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National Seminar
On
Smart Farming for Enhancing Input Use efficiency, Income and Environmental Security
(SFEIES-2017)

Indian Association of Hill Farming and ICAR Research Complex for NEH Region
Umiam, Meghalaya

National Seminar
on
Smart Farming for Enhancing Input Use efficiency, Income and Environmental Security (SFEIES-2017)

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Mobile: +919436336070, email:: anup_icar@yahoo.com

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Acid Soils and their Management for Nutrient Use Efficiency

U.C. Sharma

222-Adarsh Enclave, Trikuta Nagar Sector I Extension, Jammu-180012, J & K, India
Email: ucsharma2@rediffmail.com

Abstract

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil- and plant-water management. The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field. NUE addresses some but not all aspects of that performance. Therefore, system optimization goals necessarily include overall productivity as well as NUE. The poor fertility of acid soils is due usually to a combination of; Al, Mn and Fe toxicity, and P, Ca, Mg and K deficiency. In addition to nutritional factors, the productivity of many acid soils is affected by physical factors that include low water holding capacity (Oxisols, Spodosols, Psamments) and susceptibility to crusting (Oxisols, Ultisols). With increase in the world's population and associated increase in food demand, the acid soils are one of agriculture's last frontiers to meet this demand. Acid soils, widespread in the humid and savanna regions of the world and predominant in the tropics have been considered less suitable for highly productive agriculture. Agriculture on these soils has long been a challenge for both soil and plant scientists. Judicious management of acid soils with existing and newly generated technologies, combining the indigenous knowledge of the farmers, is necessary to enhance productivity on these soils. Socio-economic aspects and perceptions of the farmers need to be considered for success of any programme undertaken for the development of acid soils.

Keywords: *Acid soils, management, nutrient use efficiency*

Introduction

Acid soils have resisted permanent settlement and agricultural use. Sanchez (1976) mentioned that throughout civilization man has tended to settle on high base status soils. Poor crop growth in acid soils can be correlated directly with Al saturation (Coleman and Thomas, 1976). Except for extreme situations, pH *per se* rarely has a direct effect on plant growth. At very low pH of 4.2, however, the hydrogen ion concentration may hinder, or even reverse cation uptake by plant roots (Jackson, 1967). Aluminium phytotoxicity is a major cause of acid soil infertility (Bell & Edwards, 1987). The extent of phytotoxicity is related to the activity of monomeric inorganic Al species in the soil solution (Adam & Lund, 1966, Pavan et al. 1982, Cary et al. 1989). Organically complexed species are less toxic (Hue et al, 1986). Deficiencies of Ca, Mg, P and other plant nutrients are also significant on acid soils. Less than adequate soil and crop management practices have often contributed to aggravate the typical problems of acid soils, by encouraging losses of bases, thus decreasing the pH and increasing Al saturation. India has more than 36% of cultivated acid soils. These soils, considered of low fertility, need proper development and management for enhancing food production in the country. Though many technologies exist to ameliorate these soils to make them productive, but still, much remains to be done on the fronts of research, extension and farmer's awareness. Solutions are not readily available to meet this challenge. Changes in attitude and direction will be necessary at the level of the government policy, of institutions, of farmers, and of the society. Earlier, the farmers had the option of abandoning their land; population pressure now dictates that farmers must manage soil acidity in order to maintain productivity and livelihood. Strategies have to be variable, suited to local situations with minimum environmental damage. Meeting societal demand for food is a global challenge as recent estimates indicate that global crop demand will increase by

100 to 110% from 2005 to 2050 (Tilman *et al.*, 2011). Others have estimated that the world will need 60% more cereal production between 2000 and 2050 (FAO, 2009). Improving NUE and improving water use efficiency (WUE) have been listed among todays most critical and daunting research issues (Thompson, 2012).

Extent of acid soils

World

Of the total food production in the world, about 99% is produced on land and only about 1% comes from oceans and inland waters. With climate change, it is predicted that plant food production would decline, especially in the tropics. Acid soil could help in overcoming the food gap. With fast increase in world population, the demand for food is bound to increase and the only alternative would be to bring acid soils under cultivation with all the supportive technologies at command. The data given in Table 1 shows the per cent cultivation of important crops on the acid soils and their area, yield and production in the world, and thus, amplifying the importance of acid soils.

The crops like tea, cassava, rubber and oil palm are totally dependent on acid soils with 100% area; followed by coffee (90%), rye (85%), sweet potatoes (80%), sugarcane and oats (70%) and other crops. This establishes the significance of acid soils in satisfying the needs of the ever growing population. Uexkull and Mutert (1995) mentioned that forests growing on acid soils provide the bulk of the world’s timber. Palm oil, tea, coffee, pineapple and other tropical fruits, many tuber crops as well as rubber and some other medicinal crops are mainly grown on acid soils. The global extent of acid soils by main soil orders has been summarised by Uexkull and Mutert (1995) (Table 2).

Table-1: Arable and permanent crops on acid soils in the world (FAO, 1991)

Crop	Per cent on acid soil	Area (000’ ha)	Yield (kg ha^{-1})	Production (000 t)
Tea	100	2710	930	2522
Coffee	90	10126	530	5367
Cocoa	60	3344	430	1438
Rubber	100	9850	519	5108
Oil palm	100	5271	3622*	12039
Sugarcane	70	11815	5300@	62617
Coconut	20	1887	395*	706
Groundnut	70	13978	354*	4948
Soybean	35	20227	550	11125
Castor beans	90	1550	661	1024
Cassava	100	15635	8000	125080
Sweet potatoes	80	9528	11058	105360
Potatoes	60	10613	15098	67397
Rice	13	18600	1100	20460
Maize	20	25823	1800	46481
Rye	85	14000	2235	25910
Oats	70	14534	1999	26196
Wheat	5	6968	2581	18054
Barley	20	14565	2498	36338

*Oil, @sugar

Table-2: Global extent of acid soils by soil taxonomy order (000' ha)

Order	Area	
	(million ha)	%
Entisols	824	20.9
Inceptisols	561	14.2
Andisols	34	0.9
Spodosols	415	10.5
Alfisols	255	6.5
Ultisols	864	21.8
Oxisols	727	18.4
Histosols	270	6.8
Total	3950	100.0

India

Acid soils in India have been found due to drastic weathering associated to hot humid climate and heavy rainfall. Laterization, podsolization and accumulation of undecomposed organic matter under marshy conditions contribute to soil acidity. Roughly about 12% of acid soils are strongly acidic (pH<5.0), 48% moderately acidic (pH 5.0-5.5) and 40% mildly acidic (pH 5.5-6.5). Nearly 40 percent of the cultivated soils in India are acidic in nature and contain pH in the range of 4.5 to 6.5. The acid soils of India cover a large portion of the country (Table 3).

Table-3: Distribution of acid soil in India

Soil order	pH range	Area (million ha)	States
Ultisols	4.8 – 6.5	12.65	Karnataka, MP, Eastern Ghats, WB, South Maharashtra, Kerala, NE states, Jharkhand
Alfisols	5.0 – 6.7	26.90	Parts of Kerala, Odisha, WB, Andhra Pradesh, Goa, Bihar, NE states, Parts of Tamil Nadu, Karnataka, Maharashtra, Parts of J & K, Andaman Islands
Inceptisols	5.5 – 6.5	23.66	Parts of Karnataka, Bihar, UP, NE states,
Spodosols	4.4 – 6.5	22.47	Parts of J & K, UP, NE states, WB, Odisha, MP, HP, Andaman Islands
Molisols	4.5 – 6.5	8.00	Parts of J & K, NE states
Histisols	3.5 – 4.5	0.02	Kerala

North-eastern Region

More than 92.99 % of soils of north-eastern region are acidic in reaction and have a high aluminium content (Prasad et al. 1981, Sharma & Prasad 1995). The highest per cent of acid soils (98.5% is found in Tripura state, while minimum of 77.2% in Nagaland state of the region (Table 4). Maximum per cent of acid soils (30.9%) have been found in pH category of 5.6 to 6.0% (Table 5). About 4.3% of acid soils were below pH 4.5.

Table-4: Per cent of acid soil in cultivated land of the north-eastern region of India

State	Cropped area ('000 ha)	Cropped area under acid soils ('000 ha)	Acid soils (%)
Arunachal Pradesh	205	197	96.1
Assam	2780	2552	91.8
Manipur	145	132	91.0
Meghalaya	208	198	95.2
Mizoram	109	105	96.3
Nagaland	220	170	77.2
Tripura	277	273	98.5
Total	3944	3627	91.9

Table-5: Distribution of area under different soil pH groups in NE region (000' ha)

pH	<4.5	4.6-5.0	5.1-5.5	5.6-6.0	6.1-6.5	6.6-7.0	Total
Area	1022	5230	3665	7343	3949	2513	23722
Per cent	4.3	22.1	15.5	30.9	16.6	10.6	100.0

Acid soil management

The forms of Al in soils and in surface waters have been reviewed in detail, but the interactions between the forms of Al are not so well established (Ritchie 1995). The mineral forms of Al which exists in soils include hydrous oxides (gibbsite), Alumino-silicates (feldspars, kaolinite, imogolite), sulphates (jurbanite) and phosphates such as variscite (Dixen and Weed, 1989). The major factors that influence the rate of dissolution of minerals in soils appear to be pH (Ritchie 1995). The release of Al by the dissolution of Al oxides and kaolinite is a function of of pH in the range where H+ ions are adsorbed by the clay surface and reaches a maximum when no more H+ ions can be adsorbed at pH < 3.5. However, Furrer et al. (1991), found that the dissolution of montmorillonite increased almost linearly as pH decreased from 4.0 to 2.0. The amount of variation of Al^{3+} with pH in soils cannot always be explained by mineral solubility or exchange onto inorganic surfaces (Bloom et al. 1979, Cronan et al. 1986) and hence it has been hypothesised that Al bound by organic matter controlled soluble Al^{3+}. Soluble Al is generated from a sequence of events that involves the stepwise loss of free energy, where the smallest loss occurs first and may be kinetic or thermodynamic in nature (Ritchie 1995). Helyer et al. (1993) suggested that the decreased solubility of Al may be due to complete dissolution of the more soluble fractions and the binding of the dissolved Al organically. They found that main KCl-exchangeable cations in the two soils were Ca^{2+}, Mg^{2+} and Al^{3}. The per cent Al saturation of the exchange surface decreased at higher pH values and when humic acid was applied. The activities of Al $^{3+}$ and its hydrated monomers in the soil solution depend on the soil pH and the solubility of the relevent Soil Al. In highly weathered soils, the activity of Al^{3+} can be predicted from the solubility relationship of natural gibbsite, but in some soils, this overestimtes the activity (Cronan et al 1986). The soil organic matter could contribute to the undersaturation because of its strong affinity for Al (Bloom et al. 1979). In acid soils, in which Al toxicity limit plant growth, both the humic and fulvic acids (Barlett & Riego 1972) and low relative molecular mass (RMM) acids (Hue et al. 1986), form soluble comlexes with Al rendering it less toxic to plant roots.

North-eastern region of India

The soils of entire northeastern region of India have been classified broadly under Alfisols, Entisols, Mollisols, Oxisols, Inceptisols and Ultisols (Govinda Rajan & Gopal Rao 1978). These soils have also been classified into red loamy soils, red and yellow soils, lateritic soils, brown hill soils and, old and new alluvium soils (Digar et al. 1977). Entisols occur in entire valley of Assam and Manipur and narrow valleys in the hills (Anonymous (1982). Acidity in the soils of northeastern region is attributed to the presence of exchangeable Al^{3+} in soils. It varied from 0.13 to 0.63 me (%) in Nagaland (Datta et al. 1983a), 0.15 to 0.55 me (%) in Tripura, 0.04 to 3.53me (%) in Meghalaya (Prasad et al. 1985) and 0.75 to 3.0 me (%) in Brahamaputra valley of Assam (Roy Choudhary et al.1963). Datta and Sharma (2006) have documented the causes of soil acidity in the north east India. In these soils, intense leaching due to heavy rainfall causes removal of soluble salts, readily soluble soil minerals and bases resulting in soil acidity (Sharma 1988, 1989, 1990). Soil acidity is a major problem in crop production in the northeastern region, particularly in areas where low input agriculture is practised and there are few opportunities to counteract the yield depressing factors. Acidity of soils results in low availability of P to plants. In the soils of East Khasi Hills of Meghalaya, the per cent saturation of Al^{3+} varied on an average from 11.00 to 19.40 of the CEC (Ram et al. 1987). The soils of higher altitude contain higher percentage of Al^{3+} than that of lower elevations. Exchangeable Al^{3+} was correlated negatively with pH in the soils of Sikkim (r = 0.75), Nagaland (r = 0.88) and Meghalaya (r = 0.81). There is considerable amount of Al in soils having pH below 5.0. Pati Ram and Prasad (1985) reported that the organic matter contributed 45% of the total CEC of soils of East Khasi Hills and the valley soils as against only 35% of that of the uplands. About 90% of the soils in Tripura have pH below 5.6. Exchangeable Al^{3+} did not exceed 0.5 c mole (p+) kg^{-1} in 95% of soils but Fe^{3+} and H^+ seemed to have their contribution in soil acidity. In the soils of Nagaland, the pH varied from 4.3 to 6.6. Exchangeable H^+ and Al^{3+} were present in substantial quantities with mean values of 1.08 and 0.43 c mole (p+) kg^{-1}, respectively. Investigation on five land use systems viz. natural fallow, horticulture, horticulture with intercropping agro-forestry and mixed cropping in Meghalaya state of the region showed that exchangeable Al decreased from 117.8 (mg kg^{-1}) in natural fallow to 32.4, 59.2, 48.1 and 52.3 mg kg^{-1} in other systems, respectively (Singh & Das 1991). In another study, it was reported that seven years of continuous cropping increased soil pH from 4.8 to 5.5 and exchangeable Al decreased from 79.5 ppm to traces in in the region. Dutta et al. (1983b) have reported high values of lime requirement (3.2 to 27.3 t ha^{-1}) for the soils of Nagaland. Besides lime, pressmud, a waste product of sugar industry, was found to be highly suitable in ameliorating soil acidity. Application of 2.5 and 1.0 t ha^{-1} of lime produced 93.5% and 66.9% increase in crop production over no lime. There was enhanced uptake of P and Ca by wheat, soybean and maize with the application of lime. A decline in the concentration of exchangeable Mn from 12.1 to 7.1 ppm was found with lime application. Screening of groundnut germplasm by Datta et al. (1983a) showed that some strains had high tolerance to soil acidity.

Productivity constraints on acid soils

Gerloff (1977) and Blair (1993) have grouped plants into four classes, based on resonse to nutrients on acid soils. Acid soil problems are: high H+ and Al^{+3} activities in soil solution, low cation exchange capacity, high capacity of solid phase to adsorb anions, especially phosphate ions, increase in solubility of micronutrients such as Zn, Cu, Fe, B and Mn which may reach toxic level, reduced availability of soluble cations like Ca and Mg, low water holding capacity, low available organic matter/carbo, decrease in soil microbial population, inhibiting biological nitrogen fixation and mineralization of organic matter, poor nutrient supply power, decline in fertilizer use efficiency and, low activities of organic and biological soil fraction. Sustainable production systems are generally understood as those that are biologically, economically and politically sound and that do not appreciably decline the capacity of the soil to deliver its production, filtering and biological function to future generations (Sanchez 1997). Soil acidity is a problem for sustainable crop production. Oxisols, Ultisols and many Alfisols in their natural state are acidic and have a large proportion of their active cation exchange sites occupied by Al^{3+}. Without liming to neutralize Al and supply Ca and Mg, efficient and economic crop production is not possible. Since acid soils with pH values less than 5.5 generally contain exchangeable Al, it has been suggested that the lime requirement be based on exchangeable Al (Kamprath 1977). Excess Mn inhibits Ca transport into the leaves of plants and induces typical Ca deficiency symptoms. Excess Mn increase the activity of IAA oxidase, decreasing auxin level and cell wall expansion. This in turn is associated with the formation of new, negative sites which result in decreased Ca translocation into the tissue. Manganese toxicity generally occurs in soils containing sufficient total Mn. Baligar and Fageria (1997) reported that the efficiency of added fertilisers is very low in acid soils and integrated plant nutrient management system is important to improve crop yield potential.

Traditional techniques

Traditional techniques of acid soils management are related to shifting cultivation (slash and burn) (Table 6). These rely on the role of fire to reincorporate rapidly the nutrients from the natural vegetation to the soil. The ash act both as fertiliser and as an amendment. All the slash and burn techniques offer only a short duration for crop growth due to enhanced soil fertility. This may be for about 2 years. This method is acceptable only in the regions where the land is not a limiting factor. Farmers are generally averse to growing crops which occupy the land for the whole or major part of the growing season which gives no direct return (Webster & Wilson 1980).

Table-7: Traditional fire based techniques of soil fertility enhancement and toxicity alleviation (Ruthenberg 1980)

Type	Operation	Description
Slash and burn	Burn and plant	Thick and dry secondary vegetation burnt off. Immediately a crop is planted and matures before the secondary vegetation has recovered from the burning sufficiently to produce brushwood and leaves.
Slash and burn	Burn, hoe and cut, plant	In savanna areas where fire effectively eliminates most vegetation. Cutting is limited to remaining trees and bushes. It is much like the cut, burn plant system.
Slash and burn	Cut, burn, plant	The most common method. The vegetation is cut towards the end of dry season, allowed to dry, the burnt as rainy season approaches, then soil prepared for planting.
Slash and burn	Cut, plant, burn	Vegetation residue left in the fields is burnt after crops (banana, cassava) are growing –only done in forest areas. Clearing done over a long period. Crops planted as soon as smaller vegetation has been cut. After felling of trees, burning apparently inflicts little damage to established crops.
Slash and burn	Cut, add extra wood, burn, plant, hoe	Chitamene system in Zambia. Bush is cut from a larger area than is to be planted in order to obtain hotter fire and more ash on the cropped area.
Ecobuyage	Cut, bury, burn, plant	Grassy and herbaceous vegetation is cut and piled, covered with earth under a slow combustion process.

Northeastern region of India

On farm social constraints

The main problem of facing the harmonious development and management of acid soils in the northeastern region of India, apart from social and economic constraints, is the paucity of reliable data and lack of human and institutional capacity necessary for confronting the complex interactions of the social issues with acid soils management. The shifting cultivation prevailing in the region was a good land use system when the population was less and the shifting cycle used to be 25 to 30 years but, with increase in demographic pressure this cycle has come down to 2 to 10 years and the land does not get enough time for vegetation rejuvenation. The practice involves the whole nexus of tribal belief, self-image, attitude and identity. Since, the vegetation is the main component for *in-situ* burning to add nutrients for higher crop productivity, the production is now declining. This has caused environmental and soil degradation in the region. The farmers have no permanent proprietary ownership rights over the land they cultivate, but they do have usufructuary rights as recognized by tradition or clan (Sharma & Prasad 1995). The major practice of shifting cultivation is uneconomical and the farmers consider modification of soil acidity with correctives as additional burden. Lack of proper land use pattern restricts the options to replace shifting cultivation with settled one. However, farmers in some areas of Nagaland state of the region, have developed excellent methods of soil and water management due to their ingenuity and skill ((Sharma 1998). The states of the region are predominantly agricultural areas and their current status is largely a product of socio-economic restrictions and under-development of their agriculture (Sharma 1988), (Sharma & Prasad 1995). It has been said that agriculture is that sector of human activity in which there is greatest interaction between the environment and the culture that has grown in and from it (Schlippe 1976).

Off-farm constraints

Lack of knowledge and awareness of farmers about acid soils and soil acidity management is a major constraint in acid soil management in the region. Although technologies are available for amelioration of acid soils, the lack of proper communication and transport system due to rugged topography, is another constraint. This restricts the transport of inputs like amendments for higher productivity as it is precluded by high costs (Sharma & Prasad 1995). Similarly, marketing facilities and availability of appropriate tools, like heavy machinery available in the plains, are severe constraints to the development and higher productivity on acid soils. The loss of nutrients from the region is closely associated with soil erosion and runoff water (Sharma, 1989, 1990). The population of the north-eastern region has increases at a higher rate than the country as a whole.

Strategies in managing soil acidity

About five decades ago, the management solutions to soil acidity were not to use the land for agriculture. The population was low and it worked very well. Vast areas of land, particularly in the tropics, were left untouched. Other areas were used episodically, long fallows being occasionally interrupted for short periods of crop production (Myers & Pauw 1995). Fast increase in population throughout the world, particularly in the third world countries, has forced man to use the less productive lands for agriculture, and much of this less produtive land has soils that are acidic. In temperate regions, population pressure exist, but more important is the development of soil acidity due to side effects of management (Bolan et al. 1991). Techniques that aim at modifying the plants or the soil should rely on correct diagnoses of the major limitations since yields on different acid soils are low for different reasons (Myers & Pauw 1995).

The objective of nutrient use and nutrient use efficiency

The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field and supporting agricultural system sustainability through contributions to soil fertility or other soil quality components. The most valuable NUE improvements are those contributing most to overall cropping system performance. Therefore, management practices that improve NUE without reducing productivity or the potential for future productivity increases are likely to be most valuable. If the pursuit of improved NUE impairs current or future productivity, the need for cropping fragile lands will likely increase. Fragile lands usually support systems with lower NUE that also use water less efficiently. At the same time, as nutrient rates increase towards an optimum, productivity continues to increase but at a decreasing rate, and NUE typically declines (Barbieri *et al.*, 2008). The extent of the decline will be determined by source, time, and place factors, other cultural practices, as well as soil and climatic conditions.

Measures of NUE

An excellent review of NUE measurements and calculations was written by Dobermann (2007). Table 7 is a summary of common NUE terms, as defined by Dobermann, along with their applications and limitations. The primary question addressed by each term and the most typical use of the term are also listed.

Partial factor productivity (PFP) is a simple production efficiency expression, calculated in units of crop yield per unit of nutrient applied. It is easily calculated for any farm that keeps records of inputs and yields. It can also be calculated at the regional and national level, provided reliable statistics on input use and crop yields are available. However, partial factor productivity values vary among crops in different cropping systems, because crops differ in their nutrient and water needs.

Table -7: Common NUE terms and their application (after Dobermann, 2007)

Term	Calculation	Question addressed
Partial factor productivity	PFP = Y/F	How productive is this cropping system in comparison to its nutrient input?
Agronomic efficiency**	AE = (Y-Y0)/F	How much productivity improvement was gained by use of nutrient input?
Partial nutrient balance	PNB = UH/F	How much nutrient is being taken out of the system in relation to how much is applied?
Apparent recovery efficiency bydifference**	RE = (U-U0)/F	How much of the nutrient applied did the plant take up?
Internal utilization efficiency	IE = Y/U	What is the ability of the plant to transform nutrients acquired from all sources into economic yield (grain, etc.)?
Physiological efficiency**	PE = (Y-Y0)/ (U-U0)	What is the ability of the plant to transform nutrients acquired from the source applied into economic yield?

* Y = yield of harvested portion of crop with nutrient applied; Y0 = yield with not nutrient applied; F = amount of nutrient applied; UH = nutrient content of harvested portion of the crop; U = total nutrient uptake in aboveground crop biomass with nutrient applied; U0 = nutrient uptake in aboveground crop biomass with no nutrient applied.

Agronomic efficiency (AE) is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return. The calculation of AE requires knowledge of yield without nutrient input, so is only known when research plots with zero nutrient input have been implemented on the farm. If it is calculated using data from annual trials rather than long-term trials, NUE of the applied fertilizer is often underestimated because of residual effects of the application on future crops. Estimating long-term contribution of fertilizer to crop yield requires long-term trials.

Partial nutrient balance (PNB) is the simplest form of nutrient recovery efficiency, usually expressed as nutrient output per unit of nutrient input (a ratio of "removal to use"). Less frequently it is reported as "output minus input." Often the assumption is made that a PNB close to 1 suggests that soil fertility will be sustained at a steady state. However, since the balance calculation is a partial balance and nutrient removal by processes, such as erosion and leaching are usually not included, using a PNB of 1 as an indicator of soil fertility sustainability can be misleading. Biological N fixation, recoverable manure nutrients, biosolids, irrigation water, and the atmosphere can all be nutrient sources in addition to fertilizer. Values well below 1, where nutrient inputs far exceed nutrient removal, might suggest avoidable nutrient losses and thus the need for improved NUE (Snyder and Bruulsema, 2007); attainable values, however, are cropping system and soil specific.

Apparent recovery efficiency (RE) is one of the more complex forms of NUE expressions and is most commonly defined as the difference in nutrient uptake in above-ground parts of the plant between the fertilized and unfertilized crop relative to the quantity of nutrient applied. It is often the preferred NUE expression by scientists studying the nutrient response of the crop. Like AE, it can only be measured when a plot without nutrient has been implemented on the site, but in addition requires measurement of nutrient concentrations in the crop. And, like AE, when calculated from annual response data, it will often underestimate long-term NUE.

Internal utilization efficiency (IE) is defined as the yield in relation to total nutrient uptake. It varies with genotype, environment and management. A very high IE suggests deficiency of that nutrient. Low IE suggests poor internal nutrient conversion due to other stresses (deficiencies of other nutrients, drought stress, heat stress, mineral toxicities, pests, etc.).

Physiological efficiency (PE) is defined as the yield increase in relation to the increase in crop uptake of the nutrient in above-ground parts of the plant. Like AE and RE, it needs a plot without application of the nutrient of interest to be implemented on the site. It also requires measurement of nutrient concentrations in the crop and is mainly measured and used in research.

Improving nitrogen fertilizer use efficiency

Worldwide consumption of synthetic N fertilizers has increased 20-fold since 1950 and by about 150% since 1970, to about 82 Tg N y-1 in 1996. About half of current consumption is in Asia, and much of the recent increase has occurred in this region. Animal wastes used as fertilizer supplied an estimated additional 65 Tg N y-1 in 1996, compared with 37 Tg N y-1 in 1950. The evidence points to a further major increase from agricultural sources in the future, in view of projections that point to a further doubling of N fertilizer use in developing countries by 2025 (Bouwman, 1998). Applying N fertilizer when it is most needed by plants can also help reduce N2O emissions. Placing N fertilizer close to plant roots also can reduce N2O emissions. For example, applying urea in narrow bands next to the plants rather than broadcasting across the field can reduce N2O emissions. Precision fertilizer application can also improve NUE by tailoring N application to soil spatial variability. Adding less N to those parts of a field with low yield potential, as measured by yield monitoring, will avoid wasting N on locations in the field that are not as likely to respond to N fertilizer. Right N fertilizer application rate (applied at the economically optimum rate): N fertilizer refers to both synthetic and organic fertilizers (such as manure).

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Role of Pulses in Cropping System for Enhancing Input Use Efficiency

Narendra Kumar, K.K. Hazra and C.P. Nath

ICAR–Indian Institute of Pulses Research, Kanpur – 208 024, Uttar Pradesh

Pulses have been an integral component of Indian agriculture since time immemorial. They are among the ancient food crops with evidence of their cultivation for over 8,000 years. Pulses are well known for its role in nutritional security, soil amelioration, sustainable crop production, and environment services. Besides being a rich and cheapest source of dietary protein, it has a key role in improving and sustaining soil productivity on account of inherent capacity to fix atmospheric nitrogen (N) and addition of huge amount of organic matter through roots and leaves fall. Pulses also play important role in protecting the environment from the risk associated with input intensive cereal based production systems. India has pride of being the world's largest producer of pulses contributing about 18–20 million tonnes to the global pulse basket. In India, over a dozen of pulse crops are grown, the important ones being chickpea (45.6%), pigeonpea (16%), mungbean (10%), urdbean (9.7%) and lentil (5.7%).

Currently, degradation of natural resources is a serious problem that threatens ecosystem health and production sustainability. Intensive tillage and opening of soil surface during hot summer are being practiced in conventional agriculture results in short term increase in fertility, but degrades soil in long run. Structural degradation, loss of organic matter, erosion and falling microbial biodiversity are expected outcome of intensive tillage practices. Since advent of agriculture about 10,000 years back, 16–20% of present day global carbon stock is estimated to be lost to atmosphere as CO_2 and projected to further fasten the decline under mechanized tillage practice of cereal based production system. Further in the recent years, growing deceleration in total factor productivity and deterioration of soil health under cereal based cropping system has necessitated for diversification of existing cropping system with inclusion of pulses. Endowed with unique ability for biological N–fixation, deep root system, low water requirements, capacity to withstand drought, pulses are acknowledged as an important component of crop diversification and soil health management.

Crop diversification with pulses

The development of input responsive high yielding varieties of rice and wheat during green revolution led to dominance of cereal–cereal cropping systems in the country. However, continuous conventional practice of cereal based cropping systems aggravated second generation problems in these regions. A decade or so, the rice–wheat system has started sowing of sign of stress with production decline and deterioration in soil health. Emergence of multi–nutrient deficiencies, macro– as well as micro– nutrients have been reported in many parts of rice–wheat cropping system in the country. To address the negative issues associated with continuous cereal–cereal production system, the crop diversification strategy may be followed. In the recent past, several short duration, high yielding and disease resistant varieties of various pulse crops have been developed, which have played an important role in diversifying existing cropping systems in different agro–ecological regions in the country. Pigeonpea–wheat, rice–chickpea/lentil, rice–wheat–mungbean, and maize–mustard/potato–urdbean/mungbean in North–West Plains; rice–chickpea/lentil, maize–frenchbean–mungbean/urdbean, maize/sorghum fodder–pigeonpea and rice–wheat–mungbean in North–East Plains, and rice–urdbean/mungbean in coastal peninsula are some of the glaring examples.

Soil health improvement

Pulses have long been recognized and valued as "soil building" crops. Growing Pulses improves soil quality through their beneficial effects on soil biological, chemical and physical conditions. Pulses act as soil fertility restorers in cropping system due to their ability to fix atmospheric N in symbiosis with *Rhizobium*. Pulses crops leave a substantial amount of residual N which may vary from 30–60 kg N/ha. In a long–term fertility experiment at Kanpur revealed improvement in physical (soil aggregates, pore space, bulk density), chemical (organic C, pH) and biological properties (soil biota population, efficiency and synergy, microbial biomass C) of soil recorded under pulses inclusive cropping systems. Similarly, improvement in nutrients availability in soil was also observed with inclusion of pulses in cereal–cereal systems

N–economy

The intrinsic nitrogen fixing capacity of pulse crops enables them to meet large proportion of their N requirement and also helps in economizing N in succeeding non–pulse crops. Optimum rate of N–fixation of pulses is about 1.0 kg/ha/day within a cropping season, which generally referred as potential N–fixing ability of pulses in a given environment. Pulses can fix 30–150 kg N/ha depending upon *Rhizobium* population, host crop and varieties, soil properties, management level and environmental conditions. In sequential crop involving pulses, the preceding pulse may contribute 18–70 kg N/ha to soil and thereby considerable amount of N can be saved in succeeding crops. In rice–wheat rotation growing of short duration mungbean in summer may brings N economy up to 40–60 kg N/ha in succeeding rice crop. Similar effect of *kharif* and *rabi* pulses on productivity and N–economy of succeeding cereals are well established.

Pulses under conservation agriculture

The three basic principles of conservation agriculture (CA) such as least disturbance of soil, rational retention of adequate crop residue on the soil surface and sensible crop rotation for improving livelihood and ecological security are well met while bringing pulse crops in the systems. Pulse crops are considered as hardy crops which can thrive better than many other crops under adverse conditions, thus have immense value in CA. Pulses do not require fine tilth and perform equally well under minimum or conservation tillage. In addition pulses add fairly good amount of quality organic matter into the soil through roots, leaves fall and plant biomass which improves soil carbon pool. Similarly, inclusion of short duration summer pulses can be used to reduce fallow period between two crops (rice-wheat) to reduce C–loss and enhance C–sequestration of a system. In long–term studies at ICAR–IIPR Kanpur showed improvement in overall soil health and C–sequestration due to inclusion of short duration summer mungbean in rice/maize–wheat cropping system.

Pulses in rice fallow

Extensive area (about 11.7 m ha) is available under rice–fallows in India mainly due to lack of irrigation facility. Pulses like lentil, lathyrus, chickpea, mungbean and urdbean can be grown on residual moisture of rice–fallows with manipulation in agronomic practices. Resource conservation technology which deals with soil moisture conservation, organic matter build–up and improvement in soil structure and microbial population could be an appropriate approach to address these problems. Many researchers have reported that productivity and profitability from second crops in rice fallow can be improved with suitable crop management technique even by utilizing residual soil moisture.

Environmental services

Pulses are known to fix atmospheric N of about 30–150 kg N/ha. Most of the fixed-N remains in soil for succeeding crop. The N fertiliser efficiency to succeeding crop was reported up to 40–80 kg/ha. Therefore, pulses reduce the total fertiliser requirement of succeeding cereal crops. Through biological N fixation pulses save energy up to 4800 MJ/ha. However, reduced demand of fertilisers will finally reduce the green house gas emission by fertliser industries. Ground water pollution due to leaching of nitrates is major concern in India especially in rice– wheat growing Indo–Gangetic regions. It is reported that intercropping of pulses in cereals reduces nitrate leaching. Sugarcane+ urdbean and pigeonpea+ maize resulted in low nitrate nitrogen leaching as compared to sole cropping of sugarcane.

Thus, pulses have immense benefit in soil improvement and sustainability of agricultural production system. The pulses attribute higher yield of associated cereals in combination or in rotation improved soil quality, addition of growth promoting substances, decreased disease and insect–pest pressure. Thus, inclusion of pulses in cereal based system may enhance the resource use efficiency and sustainability of agricultural production systems.

Land Productivity Improvement and Livelihood Security: Linking to Spatial Mapping of Soil Quality Index Perspective

B.U.Choudhury*, Pratibha T. Das[1], K.P. Mohapatra, S. Hazarika, T. Ramesh, Anup Das and A. Balusamy

ICAR Research Complex for NEH Region, Umiam, Meghalaya-793103
[1]Northeastern Space Applications Center, Barapani, Meghalaya-793103
**Email: burhan3i@yahoo.com*

In many occasions, multifaceted factors (mostly faulty landuse practices) led poor soil health resulted in partial to complete crop failures, sub-optimal productivity *vis-a-vis* insecurity in livelihood of socio-economically poor farmers' in Northeast India. Information regarding use of soil based on the degree of its potentials/limitations may help in overcoming some of the major shortfalls. Soil health assessment using Soil Quality Index (SQI) has been in practice to evaluate the sustainability of land uses in terms of soil resilience, environmental quality and land productivity.An intimate knowledge of soil quality and their spatial distribution using remote sensing (RS) and Geographical Information System (GIS)in integration with soil survey informationis a prerequisite in developing location specific soil suitability guide for rational use of land for agricultural practices and transfer of agro-technology.

For sustainable landuse and crop production, we made an attempt to quantify spatial variability in soil health status by estimating a composite soil quality index (SQI) values of surface and profile soils of Barak Valley, Assam, NE India. Nearly 100 master profiles, 15 mini profiles were selected (based on multi-layer analysis of land use land cover from satellite data, geology, physiography, elevation, slope etc.) using RS and GIS at 1: 50, 000 scale across 6922 sq. km area of the valley. Soil samples from the geo-referenced profiles were collected (horizon-wiseupto 225 cm) for laboratory analysis of 16 soil parameters (Physical, acidity and fertility parameters). Following standard procedure, a composite soil quality index (SQI) was developed using step-wise multi-criteria decision-making approach. From the selected indicators, minimum datasets were generated using PCA. Scoring and accordingly, boundaries and shape of the scoring functions were set. Soil parameters were transformed into unit less (0 to 1 scale) by using standardized scoring functions. Proportion of variance was estimated followed by assigning of weights for each indicator. SQI was estimated from the assembling of weight and score of each indicator and finally, spatial mapping of SQI variability in GIS environment was carried out. Based on the estimated composite SQI values observed (0.35-0.71) and with the hypothesis that more SQI value, better is soil health, four categories of rating systems namely poor (<0.4), average-low (0.4-0.5), average- high (0.5-0.6) and good (>0.6) were contrived.

Results revealed that surface soils across the valley falls under two major categories: average - high in 54.2% GA (SQI: 0.5-0.6) and average-low in 38% GA (SQI: 0.4-0.5). Areas under both extreme- poor (0.2% GA) and good(1.3% GA) category SQI values were marginal and spatially confined in the central and southwesternparts**.**Similarly, profile (weighted average of 57-225 cm depth) soils were average-low (in 43%GA) to average- high (in 47%) in SQI values.Of the total 1481.3 sq. km agricultural area (AA: 21.4% GA) in the valley, soils in nearly 55%AA had SQI value falls in average –high category (0.5-0.6) while 43.1% AA had average-low SQIvalues. Only 2% AA had SQI values of more than 0.6 (good category). In agricultural areas (AA: 57%) with average –high and good SQI values (>0.5) distributed in the central, eastern and south-eastern parts of the valley reflects better soil health status for supporting intensive cropping system practices for increasing the productivity, and livelihood security. In agricultural areas (AA: 44%) with average-low and poor SQI values (<0.5) in the northern and extreme western parts of the valleycan support less nutrient/water exhaustive crops/ cropping systems (like vegetables/oilseeds-pulses). These areas with poor soil quality needs location specific soil health restoration approaches (external nutrient supplementation / in-situ resource conservation) to increase the crop intensification and land productivity for ensuring better livelihood security.

Keywords: *Soil Quality Index, Spatial Mapping, Land productivity, Livelihood Security, NE India*

Physiological Response of Upland Rice to Water Stress in a Subtropical Hill Condition

U.S. Saikia*, R. Krishnappa, B. Goswami, A. Kumar, E. Shylla, M. Lyngdoh, D.J. Rajkhowa and S.V. Ngachan

ICAR Research Complex for NEH Region, Umroi Road, Umiam 793 103, Meghalaya
**Email: ussaikia73@gmail.com*

The present study sought to investigate the effects of water stress in few physiological factors, leaf area index (LAI) and grain yield of upland rice under rainfed subtropical hill condition of North East India. Four high yielding rice cultivars were subjected to artificially imposed water stress, of 15 days duration each, during vegetative (active tillering) and reproductive stages (grain filling) in a rainout shelter. Cell membrane stability, chlorophyll content, soil moisture, LAI and grain yield were measured. Water stress markedly increased cell electrolyte leakages in both vegetative (8.2 to 33.5%) and reproductive (12.7 to 32.7%) stages. Cell membrane stability decreased with the age of the plants and the tolerant cultivars exhibited better cell membrane stability. Total chlorophyll content of water stressed plants reduced to the tune of 6.1 to 26.6% (vegetative stage) and 7.2 to 24.5% (reproductive stage). Water stress also caused drastic reduction in LAI, which ranged from 11.1 to 20.9% (vegetative stage) and 12.2 to 20.7% (reproductive stage) over the controls. The impact of water stress on physiological and growth factors of the four cultivars were reflected through differential reduction in grain yield. These results confirm that cell membrane stability and chlorophyll retention capacity are suitable indicators of water stress tolerance capability of plants and helps in screening of resilient cultivars.

Keywords: *Cell membrane stability, Chlorophyll content, Rainout shelter, Upland rice, Water stress*

Evaluation of Heating Feasibility of Poly House Environment using Earth Air Tube Heat Exchange

B.K. Sethy, R.K. Singh, H.J. Singh, H. Dayananda Singh and S.V. Ngachan
ICAR Research Complex for NEH region, Umiam, Umroi road, Meghalaya-793103

Email: bsethy088 @gmail.com

North Eastern Hill region of the country is blessed with enormous rainfall and intense biodiversity. More than 80% area is located on hills due to its geographical location. The climate is not ambient for growing all types of crops and vegetations due to infestation of insects and pests. Poly house technology is one of the proven solutions to maintain the favorable environment for growth of crops. The minimum temperature affects growth of vegetables and cash crops during winter. The temperature inside the poly houses decreases abruptly and makes the poly house environment unsuitable for crop growth. In order to address the condition, a project was conducted under AICRP on Plasticulture Engineering and Technology during 2012-2016 with the idea to use the temperature of the soil to heat the poly house environment during winter by blowing earth air to the poly house. The earth tube air heat exchanger was designed based on the temperature inside the poly house (80 cum capacity). Normally temperature in the summer reaches above 48^0C and during the winter it lies below 5 ^{0}C. Our objective was to bring the temperature inside the poly house to 25^0C. Hence temperature profiles of both inside and outside of poly house was analyzed during the summer and winter the season. Soil is the sink whose temperature remains constant throughout the seasons. Hence soil profile temperatures were taken at 30 cm, 60 cm, 120 cm, 150cm, 180 cm and 210 cm interval to observe its characteristics. It was observed that soil temperature remains constant after the depth of 120 cm. Hence 150 cm depth was considered to be optimum depth of soil from where soil temperature can be used to heat or cool the poly house. Heat exchange was estimated and with constant speed (flow rate12.5m^3/hr) of motor and four lengths of MS pipe of 9,12, 24, 36 and 48 m with 1.5" dia were tried to maintain the temperature inside the poly house. The ground surface of the poly house was excavated up to 1.5 m depth and MS pipe was laid surrounded by iron chips for facilitating heat exchange. Outside air blow pipe was connected to the heat exchange pipe for flowing air. The flown air took heat from the soil and discharged the temperature of soil to the poly house through exhaust valve opened at the poly house. The excess air inside poly house was released through the exhaust fan attached to the wall of the poly house. The temperature was regulated and optimum temperature and relative humidity were maintained inside the poly house. The system was operated at night time during Dec-Feb to heat inside the poly house. There was an average temperature increase of 9.9°C as compared to average outside temperature of 5.6°. The behavior of humidity followed the reverse trend with respect to rise in temperature. Total heat exchange was found to be 34.85 kW-h with 36 m length of pipe. Total energy consumed by the motor of the blower is 9 kW-h in 10 hours of operation. The coefficient of performance was 3.89. It was found that poly house environment can be cost effectively heated using earth air tube heat exchange during extreme winter with 36 m length of MS pipe. Blower speed can be enhanced proportionately to have desired results for more capacity poly house.

Keywords: *Biodiversity, Earth air tube, Heat exchange, Poly house, Soil temperature*

Screening of Cellulose Degrading Microorganisms Associated with Forest Floor Litters of *Jhum* Cycles

Christy B.K. Sangma and Dwipendra Thakuria

SNRM, College of Post Graduate Studies, Central Agricultural University, Umiam, Umroi road, Meghalaya-793 103
Email: christysangma@gmail.com

Jhum cycle, otherwise called as the fallow period is the restoration phase of the *Jhum* cultivation where most of the processes like regeneration, stabilization of the nutrient cycling and natural biodegradation of the biomass (litter fall) takes place. Among these natural biodegradation is one of the most important processes as it sustains all other processes. In the present study litter fall from 4 type of fallow periods *viz*. 2 years, 5 years, 10 years and 20 years were collected from *Jhum* fields of Mizoram. Since cellulose is the most important component of plant biomass and a source of carbon, the cellulose degrading microorganisms were isolated from the collected litters and screened their decomposition efficiency in agar plates containing carboxy-methyl-cellulose (CMC) as substrate. Based on the halo formation in the CMC plates the number of decomposers population was found to be more in 20 years≥10 years>2 years>5 years fallow. The viable population count in cellulose agar media (CAM) ranges from $4X10^5$ CFU g^{-1} to $91X10^5$ CFU g^{-1} of litter material showing lowest in the 5 years fallow and highest in the 2 years fallow. The carbohydrate content in the liquid broth cultures ranges from 4.21 µg ml^{-1} to 24.30 µg ml^{-1} and the cellulase activity ranges from 2.40 to 227.7 µg $ml^{-1}hr^{-1}$. Overall, from this study it can be concluded that when the *Jhum* fields were left fallow in the first 2 years the population of microbes was high which subsides in 5 years and upsurge again at 10 to 20 years, further, as the age of the fallow increases the activity of the decomposer community becomes more prominent.

Keywords: *Cellulose, Fallow, Forest, Jhum, Litter*

Long Term Effect of Herbicides and Nutrient Management Practices on Soil Microbes, Enzyme Activity and Herbicide Residue Build up in Rice – Rice System

Kaberi Mahanta, P. Dutta, D. J. Nath and J. Deka

Assam Agricultural University, Jorhat- 785013, Assam, India
Email: kaberi.jorhat@gmail.com

Soil quality improvement vis-à-vis productivity enhancement is important consideration in the effort to achieve food and nutritional security. Appropriate nutrient and weed management practices are important for improving soil health, nutrient use efficiency and ultimately crop productivity. A Long term study was therefore, initiated during 2000 with different nutrient and weed management practices at Instructional-cum-Research Farm, Assam Agricultural University, Jorhat-13. The soil of the experimental field was sandy clay loam, acidic (pH- 5.4) having CEC - 6.28 c $mol(p^+)kg^{-1}$,Organic carbon content 6.2g kg^{-1}. Key soil enzymes, microbial biomass carbon (MBC) and bacterial population were assessed to understand the effects of integrated weed and nutrient management (INM) in rice–rice sequence on soil microbial population, soil enzymes, and MBC as well as crop productivity during 2014 and 2015. Vermicompost (2 t/ha) as organic inputs and butachlor (1000g/ha) and pretilachlor (750g/ha) as the pre – emergence herbicide were used during autumn and winter rice respectively. Significantly high *Azotobacter* and phosphate solubilising bacteria population was recorded in farmers practice over the of integrated weed and nutrient management practices in rice–rice sequence .Similar trend was observed with enzyme activities viz.

acid phosphatase , dehydrogenase , respiration and microbial biomass carbon except the urease activity . Urease being a urea degrading enzyme, does not mediate the degrading pathway of the herbicides and probably therefore remained unaffected by the herbicide. Inhibitory effects of butachlor, pretilachlor and 2,4-D on population of nitrogen fixing bacteria and on the enzymes studied in rice rhizosphere had been reported up to 14 days after application of herbicides followed by gradual recovery afterwards .The conjoint application of herbicide and integrated nutrient management significantly increased the population of *Azotobacter* and phosphate solubilising bacteria, activity of the enzymes, respiration and microbial biomass carbon as compared to application of fertilizer alone. Results of the study showed temporary decline in *Azotobacter* and phosphate solubilising bacteria population, enzymatic activities, respiration and microbial biomass carbon due to butachlor, pretilachlor and 2,4-D application. All the herbicides exhibited detrimental influence up to 15 days after application which was recovered later on in case of bacterial population, enzymatic activities, respiration and microbial biomass carbon. The decline in inhibition at later stages can be attributed to decrease in herbicide activity in soil is due to adsorption, microbial degradation and microbial adaptation to the herbicide. Substitution of 25% N-fertilizer through organic source significantly enhanced the bacterial population and enzyme activities as compared to sole application of fertilizers. Further, significantly higher soil bacterial population and enzyme activities were resulted in rotational use of butachlor and pretilachlor as well as in autumn rice over the winter rice. Significantly higher yield of rice in the system was obtained with rotational use of butachlor and pretilachlor along with 25% substitution of N through organic source to both autumn and winter season rice. Mean half life of butachlor 5 days and pretilachlor 7days was recorded during autumn and winter season respectively. The herbicide residue recorded at 30 days after application was below detectable limit in soil, grain and straw of rice.

Keywords: *Herbicide Residues, Microbial Biomass Carbon, Soil Enzymes, Soil Respiration*

Effect of Weed Control and Sowing Methods on Weed Dynamics and Yield of Little Millet (*Panicum Sumatrense*) under Rainfed Condition

Gaurav Mahajan, Bhavna Dhurvey, Shiv Kumara and R.K.Tiwari

College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidalaya, Rewa, Madhya Pardesh

Cultivation of millets in rainfed areas is totally dependent on the rainfall and production of little millet is very vulnerable to climatic variability. Weeds are major impediment to millet production through their ability to compete for resources and their impact on product quality. Weeds may cause losses in millet yield ranging from 20-82% depending upon the density, species of weed, duration of infestation and competing ability with crop plants under different agro-ecological condition. Keeping the above facts in view, present investigation was conducted at Agricultural Farm, College of Agriculture, Rewa, Madhya Pradesh to find out the effect of different methods of crop and weed control measures on weeds, crop growth, yield attributes and yield of little millet (*Panicum sumatrense*).The results showed that sowing of little millet crop by providing wider row to row and plant to plant spacing and sowing of sunnhemp in between little millet rows which was later harvested at 20 DAS and used as mulch proved significantly superior over other methods of sowing. Among the options of controlling weed, integrated weed control (Herbicide + one hand weeding at 30 DAS) was found most effective in controlling weed. The percentage decrease in the weed population of major weeds like *Cyperus irria*, *Cynodon dactylon* and *Echinochloa crusgalli* was 91.64 %, 92.65 % and 95.34%, respectively up to 45 DAS stage.

Development of a Low Cost Automatic Runoff Sampling Setup for Small Hilly Catchments

Gopal Kumar, Dipaka Ranjan Sena, Batu Krishna Rao* and P. K. Mishra

ICAR-Indian Institute of Soil and Water Conservation, Dehradun,
**ICAR-Central Research Institute on Dryland Agriculture, Hyderabad*

Email: gkcswcrti@gmail.com

Quantification of sediment loss is essential for planning best management practices and prioritizing treatment areas. The most common method of runoff sampling is to collect moment sample during runoff events, or to collect composite samples using tanks, bucket in combination with traditional samplers. Sample collected by this method is neither time integrated nor time distributed over the period of events; hence do not represent real situation. Automatic samplers available in market are either costly for large scale monitoring in developing world, or grossly fails to provide representative sample/data. Poor sampling method is one of the major reasons of poor interpretation of sediment data as compared to runoff data in general.

An attempt has been made to develop a low cost device for automatic runoff sampling using simple physical, mechanical and hydraulic concepts. The new sampler does not require extra source of energy as it works on gravity. There is essential need of about 1 meter drop/fall to accommodate sampling setup. Water tight trench is made to accommodate sampling setup. Triangular section interceptor(s) with 30° top angle and 1.5 mm slot is used to intercept runoff from the nape portion of the runoff measuring structure (Weirs). Sample volume is reduced to a size less than or equal to 10 lit/hour by means of series of diamond/circular sectioned interceptor cum channel fitted in series below one another. Arm of mechanical or electrical clock is manipulated to deliver samples in 96 funnel shaped notches mounted on a circular frame, each to receive samples for 15 minute duration. A set of 96 bottles/cylinders each of 2.5 lit. capacity, properly numbered and placed in circular/rectangular fashion collects runoff samples from separate funnel, each for 15 minute intervals. The installation is customized according to the runoff measuring structures in order to collect a minimum samples of 60 ml in case of minimum 1 mm flow over weir for 15 m and maximum of 2.5 liter in case of full flow for 15 min. Extensive lab testing with very limited flow (50-60 lit per hour) with sediment concentration of 1.2 to 4.5g/lit for 5 min, 10 min and 20 min sample collection with single interceptor show very close agreement between sediment concentrating from samples collected through the new sediment sampler and sample from bulk composite, as all scatter points lie between 10% deviation from 1:1 line on scatter plot. The new runoff samplers have been tested and used in field condition at two locations at ICAR-IISWC, RC- Vasad and being presently tested at ICAR-IISWC, Dehradun. A close agreement between samples collected through the new sampler and sample from bulk composite, low cost and easy maintenance and applicability for remote watersheds are major advantages of the new runoff sampling setup.

Keywords: *Interceptor, Runoff Sampler, Sediment Concentration, Watershed*

Quantification of Throughfall in Different Tree Species at College of Agricultural Engineering and Post Harvest Technology Campus of Sikkim

H. Marbaniang, B. K. Sethy, S. R. Yadav[1] and H. Lalmalsawma[1]

Division of Agricultural Engineering, ICAR Research Complex for NEH Region, Umiam, Meghalaya, [1]*College of Agricultural Engineering and Post Harvest Technology (Central Agricultural University, Imphal), Ranipool– 737135, Sikkim*

Email: hamedari@gmail.com

Study of on-site water balance is very important, to understand the ecosystem response to global hydrological change, Measurements or estimates of various hydrological component processes are necessary for this. Throughfall is considered as one of the important hydrological input parameter instead of direct rainfall with the presence of tree canopies in vegetated watersheds. Rain that falls on a forest canopy is distributed into throughfall, stemflow and interception losses as it moves towards the forest floor. Throughfall is that amount of rainfall passing through the tree canopy and reaches the ground. In this study, throughfall was measured and their variation over four species located in the College of Agricultural Engineering and Post-Harvest Technology Campus, Ranipool, Sikkim, India between 27° 05' to 27° 09' North and 87° 59' to 88° 56' East and an altitude of 867.77 m above mean sea level. The different species include *Albizza procera*, *Schima wallichii*, *Duabanga grandiflora* and *Citrus maxima*. Efforts were also made in identifying the threshold/critical rainfall depth at which throughfall generation starts. Throughfall amount was measured by taking average of the throughfall amounts measured through number of plastic containers placed beneath each tree canopy. The rainfall amount was measured by using a non-recording raingauge (Symon's raingauge) at each storm interval. The mean value of throughfall as a percent of gross rainfall (of 380.11 mm) for species mentioned above were 83.84 % , 71.18 %, 84.14 %, 60.15 % respectively. The measured threshold/critical rainfall depths at which throughfall generation starts were 0.5 mm for *Duabanga grandiflora* species and 0.7 mm for the rest of the species. It was observed that the highest throughfall capture was found in the *Duabanga grandiflora* species which could be attributed because of its canopy traits such as the crown length, canopy openness, leaf shape and orientation, leaf size, branch angle and vertical layering of the canopies.

Keywords: *Critical Rainfall Depth, Gross Rainfall Depth, Throughfall, Tree Species*

Sustainable Development of Chandel District of Manipur by Means of Assured Water Availability through Rain Water Harvesting Unit- *Jal Kund*

Kangjam Sonamani Singh[1] and Deepak Singh[2]

[1]*Assistant Chief Technical Officer (SWCE) and* [2]*Senior Scientist & Head, Krishi Vigyan Kendra, ICAR Research Complex for NEH Region, Chandel*

Email: sonamanisingh@gmail.com

Water is an inherent need and global climate change has put this finite resource in jeopardy. The hills of Chandel are characterized by varying topology that is largely affected by high seepage flow and flash runoff. Dual effect of water in the form of heavy rainfall during monsoon and water scarcity during post monsoon is severe in this region. Existing undulated terrain and dual effects of water are the main limiting constraint in storing/ concentration of runoff water and its later use for irrigation purposes in the district. Water scarcity is a serious problem affecting the district of Chandel, where agriculture is rainfed. Any cultivated crop needs water for survival. And lack of water supply

for crops is the main reason why fields in the district remain fallow and farmers remain idle right after paddy season. The question of water harvesting is more critical in places/sites along the hill slopes due to high seepage/infiltration losses. The issue is more serious with small land holdings along the mild hill slopes due to presence of more undulated areas and unavailability of site for bigger pond construction. Water harvesting has become one of the most important practices and pre-requisite for any successful enterprise of agriculture and allied sectors under such erratic rainfall pattern. During winter months when there is no rainfall, water conserved in poly-lined ponds (*Jalkund*) above 30,000 litres act as a lifeline for the seasonal crops. Life-saving irrigation can be provided from these *Jalkund* and make the farmers earn an additional income through double cropping. *Jalkund* came as a boon for the farmers of Chandel who could cultivate varieties of vegetable crops in the integrated farming model. The beneficiary farmer altogether got a net return of Rs 3,96,000/- from his field of 3 ha out of which Rs 2,00,000/- was from the yield of tomato (12 tonnes/ha) alone over 0.5 ha area irrigated with water from the *Jalkund*.

Energy Auditing of Conventional Irrigation method in East Khasi Hills District of Meghalaya

L. Kharjana, B. K. Sethy, A. Sherring*, D. M. Denis*, A. R. Mishra* and A.Thomas*

Division of Agricultural Engineering, ICAR Research Complex for NEH region, Umiam, Umroi road, Meghalaya-793103

**Department of Soil, Water, Land Engineering & Management, Vaugh School of Agriculture Engineering & Technology, Sam Higginbottom Institute of Agriculture, Technology & Sciences,*

Email: larijana12@gmail.com

The energy input is the key point for agricultural production and economic growth of the country. Among all the agricultural operations, irrigation is one of the most energy consuming sector and it requires both human and machine work. Lift irrigation from stream/river and irrigation by gravity flow are the main source of irrigation and adopted by most farmers. Pumps are used to lift the water from stream/river. The sources of energy for using pump areeither electricity or diesel or both. The energy is generally being wasted due to over irrigation of crops. This energy can be saved in greater extent, if proper audit of energy is done for production of crops. Keeping this in views, three blocks of East Khasi Hills District, Meghalaya was selected for the study. A survey was conducted to collect input data onland-preparation, tillage, bund-making, nursery-raising, planting/transplanting/sowing, application of fertilizers/pesticides, irrigation, weeding, harvesting and threshing. Apart from these inputs, seeds and fertilizers requirement are also collected. A questionnaire was prepared and farmers were interviewed personally.To convert the various operations in form of energy (MJ/ha), standard the energy conversion factor was used. The output energy was calculated based on crop production and output-input ratio was estimated. The irrigation requirement based on crop water requirement approach was also estimated and converted into energy requirement for irrigation. The result of the study reveals that the total energy utilized in Mylliem block for production of paddy, maize and cauliflower were 22331.56MJ/ha, 14786.98MJ/ha and 16987.52MJ/ha respectively, while percentage energy utilization in irrigation was 33.67%, 20.36% and 25.25% respectively and the output-input energy ratio was estimated at 1.93, 1.88 and 1.49 respectively. In Mawryngknengblock, the total energy utilized for paddy, maize and cauliflower was 19929.12MJ/ha, 16803.64MJ/ha and 15785.34MJ/ha respectively and the output-input energy ratio was 1.21, 1.62 and 1.09 respectively and the excess energy in irrigation was 3118.77MJ/ha, 1361.4MJ/ha and 685.68MJ/ha respectively. In Mawsynram block, the total energy utilization for paddy, maize, mustard and cauliflower was 19437.92MJ/ha, 15189.72MJ/ha, 12069.16MJ/ha and

16627.48MJ/ha respectively and output-input ratio was 1.16, 2.12, 1.41 and 1.14 respectively. The percentage energy utilization in irrigation for paddy, maize, mustard and cauliflower was 28.98%, 24.04%, 36.59% and 22.38% respectively while the excess energy in irrigation was 2198.67MJ/ha, 724.88MJ/ha, 1400.6MJ/ha and 1356.58MJ/ha respectively. The result of the study also reveals that the excess energy can be reduced, by adopting scientific approaches of irrigation scheduling and water application. These practiceswill help to increase the yield significantly, better output-input ratio and economy to the farmers.

Keywords: *Crop production, Crop water requirement, Energy, Irrigation*

Performance of Winter Potato under Varied Dates of Planting: A Case Study under Mid Hills of Meghalaya

M. Gogoi, Lala I.P. Ray

School of Natural Resource Management, College of Postgraduate Studies, (CAU, Imphal), Barapani-793103, Meghalaya
Email: meghna.gogoi91@gmail.com

The performance of Potato (*Solanum tuberosum L.*) was assessed under four different dates of planting under mid hills of Meghalaya during winter season of 2016-17. An agronomical trial was laid out with four different dates of planting *viz*., D_1- 1st November, D_2- 11th November, D_3- 21st November and D_4- 1st December and replicated thrice. Irrigation was provided with a micro irrigation system at the respective scheduled date. Tubers planted on D_2 date of sowing showed higher results for number of leaves per plant, leaf area index (LAI), dry matter accumulation per plant (g), number of tubers per plant, weight of tubers per plant (g), tuber yield (t ha^{-1}) and Benefit Cost Ratio (BCR) over D_1, D_3 and D_4. The highest recorded tuber yield was 15.30 t ha^{-1} for D_2 over other three planting dates. Similarly the maximum field water use efficiency (WUE) was recorded for D_2 (56.09 kg ha^{-1}mm^{-1}) and the value of WUE for D_1, D_3 and D_4 are 50.37 kg ha^{-1}mm^{-1}, 49.71 kg ha^{-1}mm^{-1} and 44.23 kg ha^{-1}mm^{-1}, respectively.

Keywords: *Date of Planting, Micro-Sprinkler, North East India, Potato, WUE*

Productivity and Profitability Enhancement in Lowland Rice through Nutrient Management Practices under Longleng District of Nagaland

[1]Manoj Kumar, [3]D.J. Rajkhowa, [1]K. L. Meena, [2]Patu K. Zeliang, [1]E.Lireni Kikon, [1]K. Lily Rangnamei and [1]A. Namei

[1]Krishi Vigyan Kendra, Longleng, Nagaland, [2]Krishi Vigyan Kendra, Peren, Nagaland
[3] ICAR RC for NEH Region, Nagaland centre, Jharnapani, Nagaland,
Email: mkumar_cprs@yahoo.co.in

Rice is the major food crop of North East India and occupying an area of 3.5 m ha, which account ~7% of the area and 6.5% of the country rice production. Productivity of rice in north east states is ~1.5 t/ha is much below than e average national a productivity of rice 2.26 t/ha. In context to the Nagaland, rice is primary food and cultivated in an area of 18.3 thousand ha and producing 38.1 thousand tonnes with a productivity of ~ 2.1 t/ha. The Longleng district in the states fall under most backward as per classified by planning commission of India. The livelihood of the people largely depends on agriculture. Rice is the stable food in the region and cultivated an area of ~7.4 thousand ha

with production of 13.62thousand tonnes and productivity ~1.83 t/ha. The area and production of rice were 6780 ha and 13389.9 t respectively under Longleng District of Nagaland. The tribal people of the region are not even able to meet their food requirement due to the lowest productivity of rice. The main problem associated with low productivity of rice is lack of knowledge about the improved agricultural practices. Therefore Krishi Vigyan Kendra (KVK), Longleng took initiative to conduct On Farm Testing (OFT) during 2014-15 and 2015-16 to compare the different nutrient management practices along with farmers practices in lowland rice (*cv.* Teiphekyouh) for higher production and productivity and also fullfill the demand of the district. Treatments comprised of recommended doses of fertilizers (RDF) 80:60:40 Kg NPK per ha, locally available weed biomass (Eupatorium) @ 10 t/ha and farmer's practice. The experiment was laid out in Complete Randomized Block Design. The observation on different growth and yield parameters were pooled (2 year) and statistically analysed. The result revealed that the growth and yield parameters were recorded maximum under RDF and followed by Eupatorium @ 10 t/ha as compared to farmers practice. Maximum grain yield was recorded 3590 kg/ha, 3270 kg/ha and 2730 kg/ha with RDF, weed biomass@10t/ha and farmers practices respectively. Grain yield was increased by 31.5 % in RDF and 11.8 % in Eupatorium @ 10 t/ha as compared to farmers practice. Production efficiency was recorded highest with RDF (28.0 kg/ha/day), Eupatorium @10 t/ha (25.5 kg/ha/day) and farmers practice (21.3 kg/ha/day). Maximum net return and benefit cost ratio were recorded Rs.18850/ha, 1.91 with RDF treatment as compared to other treatments. Economic efficiency was found highest under RDF (Rs.147.27/ha/day) followed by Eupatorium @10 t/ha (Rs.128.36/ha/day) and farmers practices (85.70/ha/day).Hence, the farmer's practices can be replaced with the adoption of RDF or locally available weed biomass (Eupatorium) for higher productivity and income of the district.

Evaluation of Hybrid Maize for Higher Productivity and Profitability in Peren District of Nagaland

Patu K.Zeliang[1], James Kikon[1], Harendra Verma[2], DJ Rajkowa[2] A.Pattanayak[3]

[1]Krishi Vigyan Kendra, Peren, Nagaland, [2]ICAR Res Complex for NER, Medziphema, Nagaland, [3]VPKAS Almora
Email: patukhate@gmail.com

Maize is one of the most important cereal crops of Nagaland. The people use it for dietary purpose as well as for animal and livestock feed. The productivity of maize in the state is 1.96 t/ha (2012-2013) which falls far short of the national average of 2.5 t/ha. Therefore, introduction of superior hybrid maize varieties can be used as means of increasing maize productivity and production in the state of Nagaland towards achieving the goal of doubling farmers' income. In this context, KrishiVigyan Kendra, Peren district took up varietal evaluation of hybrid maize under OFT programme for the year 2017-18 at Jalukiekam village. The topography of the maize cultivation site in the Nagaland varied from hillock to gentle slope and flat land. Three different hybrid maize were taken up to be compared with the local variety' Lingta'. Vivek hybrid maize 45 and Vivek hybrid maize 53 were obtained from VPKAS Almora. Variety 'All rounder" was obtained from authorised dealer at Dimapur. In the present study, it was found that the Cob weight of 181 gm was recorded highest in All rounder followed by 177.5 gm in VHM-43 and 170 gm in VHM-53. Cob length was recorded highest in VHM-53 (17.5 cm) followed by VHM-45 (17.1cm), All rounder (17.0cm) and Local lingta (12.5 cm). Cob diameter of 5.17 cm was recorded highest in All rounder followed by 5.09 cm in VHM-43, 4.73 cm in VHM-53 and 4.34 cm in Local Lingta. Lines / cob was highest in Local Lingta (15.6) followed by VHM-53 (14.8) and All rounder (14.5), Seeds/ line was highest in All rounder (32.25) followed by VHM-43 (30.11), VHM-53 (28.05) and last Local Lingta (21.52).

Yield was found highest in All rounder (29.07qt/ha) followed by VHM-45 (28.31qt/ha), VHM-53 (25.48 qt/ha) and least in Local Lingta (17.4qt/ha). The seed of VHM-45 were found to be best in size and cobs size was also found to be uniform. Variety VHM-45 and 53 matured earliest at 110-120 days, All rounder took 125-130 days and Local Lingta at 140-145 days. Yield per day was highest in VHM-45 (2.4 Kg) followed by All rounder (2.2 Kg). Thus variety VHM 45 is found to be promising for large scale cultivation. In addition, VHM-45 being a stay green type has the added advantage of fodder from stalk. The experiment will be repeated next year for validation of the study.

Cope With Seasonal Drought in *Sali* Rice Grown with Increasing Rainfall Variability in North Bank Plain Zone of Assam, India

[1]Prasanta Neog, [1]P.K. Sarma, D. Saikia, [1]M.K. Sharma, [1]P. Borah, [1]D. Sarma, [2]G.N. Hazarika[1],

[3]G. Ravindra Chary, [4]Ch. Srinivasa Rao[3]

[1]All India Coordinated Research Project for Dryland Agriculture, BN College of Agriculture, Biswanath Chariali
[2]Assam Agricultural University, Assam, India, PIN -784176
[3]All India Coordinated Research Project for Dryland Agriculture, CRIDA, Hyderabad, Telangana
[4] ICAR- National Academy of Agricultural Research Management, Hyderabad, Telangana, India
Email: neogprasanta@rediffmail.com

The intermittent dry spells during growing season of winter or *Sali*rice, cultivated in the North Bank Plain Zone (NBPZ) of Assam, India, is the major weather risk causing widespread damage tocrop. Yield reduction in *Sali*rice was observed up to 100% due to seasonal drought, particularly when cultivated on uplands and medium lands of the zone.In the present study, the trend and variability of rainfall of Lakhimpur district of Assam was studied to understand the observed abnormalities in distribution of rainfall and increasing the frequency of extreme events like dry spells, flash flood etc which has been impacting and going to be impacted the *Sali* rice, the major crop of the area. The seasonal and annual rainfall was verified with Mann-Kendall trend test and Sen.'s slope estimator for the period of 1984 to 2016 and a significant decreasing trend of annual and seasonal rainfall with slope magnitude of -15.09 mm/yr and -29.03 mm/yr was identified in monsoon season and annual rainfall as a whole, respectively. A significant and positive trend of coefficient variation of monthly rainfall for a 10 year moving period was observed in the month June, September and October with higher R^2 values of 0.63, 0.59 and 0.50, respectively. Decrease in rainfall during monsoon season and increase in variability of rainfall explaining the recent rainfall fluctuations with large amplitudes and increasing frequency of intermittent dry spells and flash floods which are likely to aggravate in future. In the study, a parallel on-farm study was also undertaken in Chamua village (27°02'18'' N, 93°52'46''E and 83 to 90 m) in NBPZ, covering 132 ha involving 120 farmers, with an aim to identify climate resilient technologies to cope with seasonal drought in *Sali*rice by introduction of short and medium-duration varieties of *Sali* rice and manipulation of sowing time using rainwater harvested during pre-monsoon season. Except in 2012, *Sali* rice in all other years wasaffected due to delayed onset of monsoon, and/or mid-season/terminal drought coinciding with tillering, panicle initiation andgrain-filling stages of crop. Improved short-duration varieties such as *Dishang, Luit, Lachit and Kolong* and medium-duration varieties such as *Mahsuri, Basundhra and Moniram* when evaluated under upland and medium land situations, performedconsistently better than the traditional or long-durationimproved varieties. As against the average rice grain yield of 1500 kg/ha and 2250 kg/ha of the traditional varieties, improved short and medium gave 3195 kg/ha and 3947.4 kg/ha underupland and medium land situation, respectively. Though intermittent dry spells did not affect

long duration varieties of rice cultivated in clay loam textured soil with poor drainage under low land situation, grain yield of these cultivars reduced substantially (42.0 per cent) when sowing was delayed beyond 3rd week of June. Moreover, impact of late sowing further amplified if delayed sowing was followed by exposure of these cultivars to mid season or/and terminal dry spells. The exceptionally high reduction of grain yield of *Ranjit* (1050 Kg/ha) during 2011, when sowing was delayed beyond 3rd week June could be justified with the added impact of exposure of this varieties to mid season and terminal dry spells tillering to grain filling stages of the variety. Thus, it can be concluded that intermittent dry spell can be effectively managed by replacing long duration or traditional rice cultivars with short and medium duration improved varieties for well drained upland and moderately well drained medium land situation, respectively. Moreover, decreasing yield of long duration varieties in delayed sown condition could be ameliorate by sowing within third week of June which was possible sowing these varieties by using harvested rain water during pre-monsoon season in the region.

Productivity of Rice (*Oryza sativa*) as Influenced by Integrated Weed and Nutrient Management under Rainfed Condition of Manipur Valley

Priyanka Irungbam, L. Nabachandra Singh and Edwin Luikham

Department of Agronomy, College of Agriculture, Central Agricultural University, Manipur
Email: priyanka.irungbam@gmail.com

A field experiment was conducted at the Research Farm of College of Agriculture, Central Agricultural University, Imphal during the kharif season 2016 in order to study the effect of integrated weed and nutrient management on the productivity of rice under rainfed condition of Manipur valley. The soil of the experimental area was clayeyin texture with medium drainage facilities and having medium soil fertility. The experiment was carried out in factorial randomized block design (FRBD) with 15 treatment combinations replicated thrice. The treatments include 5 levels of weed management i.e. W_1:Pyrazosulfuron ethyl @50g a.i at 7 days after sowing; W_2: Pyrazosulfuron ethyl@30g a.i at 7 days after sowing + onehand weeding at 40 days after sowing; W_3: Pyrazosulfuron ethyl@30 g a.i at 7 days after sowing+ one mechanical weeding at 40 days after sowing; W_4: Pyrazosulfuron ethyl@30g a.i at 7 days after sowing + 2, 4-D @ 0.75kg a.i at 40 days after sowing and W_5: Control and 3 levels of nutrient management. i.e., N_1: 50% nitrogen from recommended dose of fertilizer (RDF) + 6 t FYM; N_2: 50% nitrogen from RDF + Azolla (dual crop)@10 t/ha + 3t FYM and N_3: 100% RDF.The analyzed data revealed that all the yield parameters like number of effective tillers per hill, panicle length, number of spikelet per panicle, number of filled grains per panicle and yield were significantly influenced by integrated weedand nutrient management. Number of effective tillers was found to be highest in W_2 (10.59) but was statistically at par with W_1(9.54) and W_3(9.85) whereas nutrient management was found to be non significant though highest value was observed in N_3 (9.27). Panicle length, number of spikelet and filled grains per panicle were found to be highest in W_3 (25.096 cm, 199.31 and 156.01 respectively) but statistically at par with W_2 and W_4.Regarding nutrient management, highest panicle length (24.65 cm) and number of filled grains per panicle (147.68) were observed in N_3 but was statistically at par with N_1(24.47 cm and 146.25) and highest number of spikelet per panicle (183.07) was observed in N_1 but statistically at par with N_3 (182.88). Highest grain and straw yield were observed in W_2 (29.42 q ha^{-1} and 32.62 q ha^{-1}, respectively). N_3 gave the highest grain yield (25.73 q ha^{-1}) and straw yield (28.8 q ha^{-1}) but was statistically at par with N_1.

Physico-Chemical Changes in Soil as Influenced by Drip Fertigation in Alluvial Soil

T. Basanta Singh[1], S. K. Patra[2] and P.K. Bandhyopadhyay[2]

[1]*ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal West, Manipur*
[2]*Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur, Nadia, West Bengal*
Email: basantasingh.t@gmail.com

Drip irrigation system has proved its superiority over other conventional methods of irrigation, especially in fruit and vegetable crops. When the inputs are added in the soil along with the water many physicochemical changes takes place inside the soil. An investigation was carried out at the BCKV, West Bengal during 2011 to 2013 to assess the influence of drip fertigation on soil physico-chemical properties of alluvial soil and its impact on yield of banana *cv*. Martaman (AAB, Silk). The experiment was laid out in FRBD with 3 replications taking four irrigation levels (D_1=0.6 ETo, D_2=0.8 ETo, D_3=1.0 ETofor drip and for surface irrigation, S at IW/CPE 1.0) as Factor-1 and three NPK fertilizer doses (F_1=60% RDF, F_2=80% RDF and F_3=100% RDF) as Factor-2. The post harvest soil physico-chemical properties were accessed.Soil pH decreased with increasing irrigation levels and fertilizer doses, but the differences were non-significant. The values obtained were 6.81, 6.77, 6.75 and 6.75 for irrigation level at D_1, D_2, D_3 and S, respectively. The corresponding values for fertilizer doses were 6.75, 6.76 and 6.76 for F_1, F_2 and F_3, respectively. The interaction between irrigation and fertilizer on soil pH was found to be non-significant. The highest pH value was recorded in the combination of D_1F_3 (6.76) and lowest value in SF_1 (6.19). The effect of drip irrigation on soil OC was found to be significant. Increasing fertilizer doses tended to increase the organic carbon to the extent of 0.61, 0.63 and 0.64% under F_1, F_2 and F_3, respectively. Among the interactions under study, D_3F_3 recorded the higher increase in OC (0.67%) followed by D_2F_2, D_2F_3 and D_2F_3 showing almost equal value (0.65%), the differences were non-significant. The higher fruit yield was obtained under drip fertigation system, i.e.,$D_{3,}$ F_3 level (43.5 t/ha) closely followed by the combination D_2F_3 (43.3 t/ha) and D_2F_2 (42.6 t/ha). The overall drip fertigation resulted in 11% higher fruit yield as compared to the conventional surface irrigation and soil fertilization with 100% RDF (SF_3).

Effect of Seed Coating Treatments on field Performance of Soybean *(Glycine max (*L.) Merrill)

T.S. Kamdi, N.S. Bhagat, Priti Sonkamble and S.K. Burghate

Seed Technology Research Unit, Dr.PDKV, Akola (MS)
Email: nilu.gpb@gmail.com

A field experiment was carried out during *kharif* season of 2011-2012 at experimental field of Seed Technology Research Unit, Dr. PDKV, Akola (MS) to study the effect of seed coating treatments viz. polymer coating @ 3ml/kg of seed, flowablethiram @ 2.4/kg seed, polymer + flowablethirum, vitavax 200*@ 2g/kg, polymer + vitavax 200*@ 2wg/kg of seed and Control stored in two packaging materials i. e. Gunny bag and HDPE bag upto 8 month with or without combination at ambient conditionon field performance of soybeanThe results revealed that the polymer @ 3ml/kg + vitavax 200* 2g/kg of seed stored in HDPE bag were higher initial plant stand (284.33), early flowering (43 days) and more plant height (57.60 cm) which matured early (69.33 days). However, the maximum no. of pods per plant (58.50), no. of seeds per plant (8.53g), hundred seed weight (10.60g),yield per plant (20.39 g), were found due to application of polymer @3ml/kg + vitavax @ 2g/kg seed treatment. Hence polymer @3ml + vitavax 200* @ 2g/kg of seed treatment stored in HDPE bag was most beneficial for enhancing the yield and yield attributes of soybean.

Keywords: *Soybean, Seed Coating, Polymer, Fungicide Coating*

Influence of Integrated Nitrogen Management Practices on Yield and Uptake of Nutrient by Hybrid Maize

Yumnam Sanatombi Devi, Edwin Luikham, Priyanka Irungbam and Y. Bebila Chanu

Department of Agronomy, College of Agriculture, Central Agricultural University, Imphal-795004
Email: yumnamsana123@gmail.com

A field experiment entitled "Influence of Integrated Nitrogen Management Practices on yield and uptake of nutrient by hybrid maize" was conducted during pre *kharif* season of 2015 at College of Agriculture, Central Agricultural University, Imphal. The experimental field was clay in texture having initial pH (5.6), organic carbon (1.77), medium in available nitrogen (310.0 kg/ha), available phosphorus (20.20 kg/ha) and available potassium (230.54 kg/ha). The experiment was carried out in randomized block design with 11 treatments each replicated thrice. The treatment were T_1= 100%RDN, T_2= 75%RDN, T_3= 50%RDN, T_4= 100%RDN + FYM @5t/ha, T_5= 75%RDN + FYM @5t/ha, T_6= 50%RDN + FYM @5t/ha, T_7= 100%RDN + vermicompost @5t/ha, T_8= 75%RDN + vermicompost @5t/ha, T_9= 50%RDN + vermicompost @5t/ha, T_{10}= FYM @5t/ha, T_{11}= Vermicompost @5t/ha. The results indicate that combined application of 100%RDN + vermicompost @5t/ha observed highest plant height at 30, 60, 90 and 120 DAS recording 32.58 cm, 105.20 cm, 164.71 cm and 177.57 cm, respectively which was statistically at par with the application of 100%RDN + FYM @5t/ha. Among the treatments, maximum number of cobs per plant (2.0), cobs length (19.98 cm), highest test weight (277.67g) was associated with 100% RDN + vermicompost @5t/ha which was also statistically at par with the application of 100%RDN + FYM @5t/ha. Highest grain yield of 70 q/ha was recorded with the combined application of 100%RDN + vermicompost @5t/ha, which was statistically at par with the application of 100% RDN + FYM @5t/ha but significantly superior to the rest of other treatments and lowest grain yield (19 q/ha) was observed with application of FYM @5t/ha. Various treatments showed significant difference in nutrients uptake by plant. Among treatments highest nitrogen, phosphorus and potassium uptake was observed in 100% RDN + vermicompost @5t/ha recorded 131.37 kg/ha, 25.46 kg/ha and 142.70 kg/ha respectively. Minimum was observed in treatment 50%RDN. The results obtained from the experiment concluded that the hybrid maize variety PAC 740 responded well to the application of 100%RDN + vermicompost @5t/ha to yield attributes parameter and higher nutrient uptake in plant could be obtained when organic manures are combined with chemical fertilizer.

Keywords*: Chemical Fertilizer, FYM, Organic Manure, Vermicompost*

Effect of Phosphorus and Potassium on Performance of Summer Maize in Valley Land of Manipur

Rajesh Kumar[1], Edwin Luikham[2], Subhash Babu[3], Chandrabhan Bharti[1], Alok Maurya[1]

[1]Ph.D. Scholar, College of Post-Graduate Studies, C.A.U., Umiam-793 103, Meghalaya
[2]Associate Professor, Department of Agronomy, CoA, C.A.U., Imphal-795 004, Manipur
[3]Scientist (Agronomy), ICAR Research Complex for NEH Region, Umiam, Meghalaya 793 103

Email: rajeshkumarmanohar@gmail.com

A field experiment was conducted at Central Agricultural University, Imphal, Manipur during the summer season on clay soil to assess the effect of phosphorus and potash levels on hybrid maize. The experiment was consists of four levels of P (P_1= 0, P_2= 40, P_3= 60 and P_4 = 80 kg ha^{-1}) and three levels of K (K_1= 0, K_2= 30 and K_3=60 kg ha^{-1}). The experiment was laid out in three time replicated factorial RBD. Full dose of P, K and half dose of N (120 kg ha^{-1}) was applied as basal dose. The result revealed that the application of 80 kg P_2O_5 ha^{-1} maize recorded significantly the higher of cob length

(16.0 cm), cob girth (14.4 cm), cobs plant^{-1}(1.4), grains cob^{-1}(315.6) and grain yield (4.3 t ha^{-1}). Similarly, among the different K levels, the highest cob length(17.2 cm), cob girth(14.8 cm), cobs plant^{-1}(1.5), grains cob^{-1}(355.8) and grain yield (5.5 t ha^{-1}) were recorded with 60 kg K_2O ha^{-1}.With regards to interaction effect of P and K, the highest values of yield attributes and grain yield were recorded with combined application of 80 kg P_2O_5 ha^{-1} and 60 kg K_2O ha^{-1}.Among the various levels of P and K, application of 80 kg P_2O_5 ha^{-1} resulted in maximum P uptake (16.05 kg ha^{-1}), which was significantly higher over the other.The addition of potash remarkably enhanced the K uptake (79.69 kg ha^{-1}) by maize. Significantly higher K uptake was observed with 60 kg K_2O ha^{-1} followed by 30 kg K_2O ha^{-1} and kg 0 K_2O ha^{-1}.The interaction of P and K on uptake of both phosphorus and potassium was significant and the combined application of 80 kg P_2O_5 and 60 kg K_2O ha^{-1} resulted in maximum P and K uptakeby crop. The combined application of 80 kg P_2O_5 and 60 kg K_2O ha^{-1}resulted in maximum net returns and B: C ratio. Hence it is recommended for harvesting the profitable yield of summer maize in valley land of Manipur.

Keywords: *Economics, Hybrid Maize, Nutrient Acquisition, P and K Levels, Productivity*

Assessing Crop Water Demand Using Geospatial Tools for Improved Water Management in Canal Commands

Laishram Kanta Singh[a&b*], Madan K. Jha[b] and V.M. Chowdary[c]

[a]*KVK Imphal West, ICAR Research Complex for NEH Region, Manipur Centre*
[b]*AgFE Department, Indian Institute of Technology Kharagpur, Kharagpur 721 302, West Bengal*
[c]*Regional Remote Sensing Centre-East, NRSC, Kolkata 700 156, West Bengal, India*
**Email: kanta_lai@yahoo.co.in*

Water is the most critical component of all living beings on the earth and demand for water is increasing day by day due to the fast growth of human population. Climatic conditions, soil and cropping patterns are important factors for determining agricultural water demand. In India, irrigation is the main water consumption which accounts more than 80% of the total water used. Spatially and temporal distributed crop water demands were estimated using meteorological and remote sensing data using geospatial techniques. Reference evapotranspiration (ET_o) was calculated using FAO Penman–Monteith method. The fraction of vegetation cover (FV) was derived from normalized difference vegetation index (NDVI). The maximum value of NDVI was obtained in the month of September, and the values of FV ranges from 0 to 1. Crop evapotranspiration (ET_c) was calculated as the product of reference evapotranspiration and FV. The resolution of the ET_c map was obtained at 250 m. The average monthly crop water demand was highest in the month of May at 8.08 mm/day. Among the crop seasons *Boro* season, has the maximum water demand followed by *Aus* and *Aman* seasons. The maximum annual crop water demand was estimated at 1237 mm/year. The crop evapotranspiration map will be useful in irrigation scheduling and for efficient crop water management. The use of geospatial tools could be faster and more reliable in identifying the variability of crop water demand in a canal command over the traditional methods.

Keywords: *Reference Evapotranspiration, NDVI, Fraction of Vegetation Cover, Crop Evapotranspiration, Crop Water Demand*

Effect of Weed Management Practices on Weed Biomass, Growth, Yield Attributes and Economics of Kharif Hybrid Maize in Costal Land Of Orissa

Chandrabhan Bharti[1], Anita Mohapatra[2], Rajesh Kumar[1] and G.N. Gurjar[1]

[1] Ph. D. Scholar, SNRM, CPGS, CAU, Umiam, Meghalaya- 793 103,
[2]Assistant Professor, Department of Agronomy, OUAT, Bhubaneswar, Orissa- 751 003
Email:bhartichandra015@gmail.com

A field experiment was conducted at Agronomy Main Research Farm of OUT, Bhubaneswar (Orissa) during *Kharif* 2015. The trial was fitted in RBD and replicated thrice. The experiment contained with ten treatments and dose of herbicides kg ha^{-1} [T_1 (Atrazine 1.0 as PE), T_2 (Oxyfluorfen 0.03), T_3 (Pendimethalin 1), T_4 (Atrazine 0.5 + Oxyfluorfen 0.03), T_5 (Pendimethalin 1 + Oxyflurofen 0.03), T_6 (Halosulfuron 0.06), T_7 (Pendimethalin*fb*Halosulfuron 0.06), T_8 (Oxyfluorfen 0.03 *fb*Halosulfuron 0.06), T_9 (farmers practice 2 hand hoeing) and T_{10}(un-weeded control)].The result showed significantly minimum weed biomass was recorded with $T_8$3.45 (11.4 g m^{-2}) followed by T_7 and T_5 at 40 DAS while, the higher weed biomass was found at 80 DAS as same as treatments at 40 DAS.Taller stature of (87.9 cm) were recorded with T_6 followed by T_7 and it was at pat with T_8 at 40 DAS while, at 80 DAS taller stature (198.5 cm) was obtained with T_2 which was found at par with T_7. LAI was recorded at 40 DAS indicated that highest value was recorded with T_8 (3.18) which was at par T_7 at 80 DAS significantly higher LAI was recorded with as same as treatments at 20 DAS.Cobs per plant were significantly differed among the weed management practices. The higher number of cobs per plant was found with treatment received T_8 over the others. The test weight of maize grains was varied from one treatment to other. Significantly the highest value of test weight was found with T_8 (287.8 g) closely followed by T_5 (283.07 g) which did not differ significantly. The lowest test weight was recorded with un-weeded control. Significantly higher a net return (Rs. 56665 ha^{-1}) was found with treatment received T_8 followed by T_5. So that herbicides Oxyfluorfen 0.03 kg ha^{-1}*fb*Halosulfuron 0.06 kg ha^{-1} can be recommended for farmers of the state to obtain satisfactory weed management andto fetch higher profit with hybrid maize cultivation.

Keywords: *Economics, Growth, Hybrid Maize, Weed Biomass, WMP, Yield Attributes*

Germination Behaviour of Some Major Agroforestry Plants as Influenced by Size of Seeds

Gautam Kumar, Pankaj Kumar Singh, [1]M.B. [1]Tandel, Ranjan Ambuj and [1]M.U. Kukadia

Institute of Foresty Productivity (ICFRE) ,Ranchi, Jharkhand, [1]Aspee College of Horticulture and Forestry, Navsari Agriculture University, Navsari, Gujarat
*Email**:** singhpankajkumar8@gmail.com*

The investigation entitled “Germination behaviour of Agroforestry plant like White Teak, Teak, Mahua, Indian Rose Wood and Bahera as influenced by size of seeds” was carried out at Instructional Farm, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat) during kharif season. In all twenty treatments involving five tree species *Tectona grandis* (S_1), *Gmelina arborea*(S_2), *Terminalia bellerica* (S_3), *Dalbergia latifolia*(S_4) and *Madhuca indica*(S_5) and four size of seeds (small- X_1, medium- X_2, large-X_3 and mixed- X_4) were tried with Factorial Completely Randomized Design (FCRD) with six replications. Among different five tree species *Gmelinaarborea* performed better with respect to all parameters under study and *Tectona grandis* performed poor. In case of size of seeds, large size proved to be the best among all four size of seeds with respect to all parameters under study. Degree of improvement went down with decrease in size and quality of seeds. The treatment combination or combined effect of *Gmelina arborea* and large size proved to be the best among all interactions.

DTPA-extractable Zinc and its Availability to Rice in Acidic Valley Soils of Manipur

Nivedita Oinam and R.K. Kumarjit

Central Agricultural University, Imphal, Manipur
Email: nive12oinam@gmail.com

Information on distribution soil zinc distribution is essential for understanding its chemical reactions and bioavailability in wetland rice soils for application of fertilizers and increasing rice yield. Thus, the relationship between physico-chemical properties and DTPA-extractable Zn (available Zn) content of rice soils were done, for that 36 surface soil samples (0-20cm) were collected from different paddy fields of four valley districts of Manipur namely Imphal-east, Imphal-west, Thoubal and Bishnupur district covering all the blocks using Stratified Random Sampling. . All the soil samples were acidic in reaction. pH ranged from 4.9 to 6 with mean value of 5.32. The Electrical Conductivity are of the soils varies from 0.05 dSm^{-1} to 0.26 dSm^{-1} at $25^{0}C$ with a mean value of 0.11 dSm^{-1}. The organic carbon content in the soils ranged from 0.79 to 3.51 % mean value of 2.68 %. The wide variation of organic carbon content may be due to various altitude of the state, previous soil management, in situ incorporation of rice stubbles, etc. The cation exchange capacity of the soils was ranged from 8.3 to 24[cmol (p^+) kg^{-1}] and the mean value was 15.94 [cmol (p^+) kg^{-1}]. The low CEC due to the presence of low calcium and magnesium content in the soils and low pH (acidic), presence of various functional groups in the decomposed organic matter and also due to the finer fractions of the soils etc. The clay content of soil varied from (mean 50.46%). The texture of the soils was mostly clay (20 per cent to 73.2 per cent), though some soils were clay loam, sandy clay, sandy loam, silty clay loam and silty clay.Considering 0.6 mg kg-1 as the general critical limit of available zinc (DTPA-Zn) in soils, 91.67% of the soils are sufficient in zinc (DTPA-Zn) ranging from 0.55 to 1.26 mg kg^{-1} with mean value of 0.89 mg kg^{-1} in the soils. Correlation studies were done to understand the status of available Zn and its relationship with soil in understanding the inherent capacity of soils to supply Zn in optimum amount for plant nutrition. DTPA-Zn maintained significant negative relationship with soil pH (r= -0.483**) indicating the availability of Zn decreases with increase pH. DTPA-Zn showed positive significant relationship with electrical conductivity (r= 0.415*).

Keywords: *Critical Limit, DTPA-Zn, Organic Carbon, Rice*

Nitrogen Release Pattern of Soil under Maize Cultivation as Affected by Different Manures

Rajesh Kumar Jatoliya, and Jurisandhya Barik Bordoloi

Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development (SASRD), Nagaland University: Medziphema Campus

Email: bordoloijurisandhya@yahoo.com

An experiment was conducted during the *kharif*season,2016 at the experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland University to study the pattern of nitrogen mineralization (N-mineralization) / N-release due to application of different manures *viz*. FYM, vermicompost (VC) and poultry manure (PM) at variable rates (2.5 and 5.0 t $ha^{-1)}$ to maize crop under field condition. Performance of the crop and nitrogen uptake (N-uptake) was also studied at different growth stages. Seven treatments consisting of T_1: Control, T_2: FYM @ 2.5 t ha^{-1}, T_3: FYM @5 t ha^{-1}, T_4: VC @ 2.5 t ha^{-1}, T_5: VC @ 5t ha^{-1}, T_6: PM @ 2.5 t ha^{-1}, T_7: PM @ 5 t ha^{-1} was evaluated with three replications in Randomized Block Design. Manure quality in terms of nutrient content, C: N ratio, lignin content and lignin: nitrogen ratio exhibited significant impact on N-

mineralization. N-mineralization recorded an increasing trend from different manures at different days after sowing of maize, mineralization decreased at harvest irrespective of the treatments. However, immobilization of nitrogen was recorded in case of FYM and VC at both the rates at 15 days after sowing (DAS). In fact, immobilization was more with higher rates. At 90 DAS, significant difference in N-mineralization was observed with maximum amount of mineralized N in treatment in T_7 (44.87 kg ha^{-1}) followed by T_6 (35.29 kg ha^{-1}), T_5 (18.10 kg ha^{-1}), T_4 (16.88 kg ha^{-1}), T_3(12.76 kg ha^{-1}), and T_2(12.07 kg ha^{-1}). Un-manured (Control) treatment recorded lowest amount of N-mineralized. PM at variable rates exhibited its superiority over FYM and VC in respect to total biomass yield and total N-uptake at different growth stages of maize. A highly significant correlation was observed among N-mineralization, grain yield and grain N- uptake irrespective of all the treatments. The present investigation revealed that the three different manures under study can contribute to the N-availability in soil in different growth stages differentially and hence, judicious management of manures in respect to time and rate of application can enhance maize productivity.The present investigation suggests further studies on different crops in respect to nitrogen release pattern to check the veracity of the performance of poultry manures and others.

Keywords: *FYM, Maize, N-Mineralization, N-Uptake, Vermicompost, Poultry Manure*

Effect of Lime and Phosphorus Interaction on Rhizospheric Enzyme Activities and Yield of Groundnut in Acidic Soils of Mizoram

Lungmuana, S.B. Singh, S. Saha, S.K. Dutta, V. Dayal, A.R. Singh and T. Boopathi

ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram-796 081

Email: lmsingson@gmail.com

Acidification induced landdegradation is currently threatening food security, and soil acidity is one of the most dominating factors for poor crop yield in the North Eastern Hill (NEH) region. In order to study the interaction effect of lime and phosphorus and its effect on soil health and yield of groundnut, a field experiment was carried out during the *kharif* season of 2014 and 2015 in ICAR, Mizoram Centre. Pooled data revealssignificant increase in the pH, available N and K due to lime application, while P and LxP interaction increased the available P content suggesting that lime induced increase in soil pH enhanced the mineralization of organic matter and nitrogen fixation of groundnut thereby increasing the available nutrients. Acid phosphates enzyme decreased with increasing level of lime and P which was might be due to the competitive inhibition of phosphatases by phosphate ions that resulted in decreased synthesis of phosphatase by microbes. Arylsulphatase and dehydrogenase enzyme activity increased with increasing levels of lime suggesting that lime induced mineralization of soil organic matter increase these activities responsible for the hydrolysis of sulphate esters and carbon cycle corroborating the hypothesis that activity of soil enzyme and rate of organic matter decomposition are closely related. Lime improved the pod yield due to increase soil nutrients through decomposition of OM and may also be from Ca and Mg contained in liming material. Our results suggested that lime applied @ 500 and 1000 $CaCO_3$ kg ha^{-1} plays an important role in increasing the yield of groundnut.

Requirement of Heat Units in the Cultivation of Blackgram

Yami Bei, P.K. Bora*, D. Thakuria and A.K. Singh
College of Post Graduate Studies, Central Agriculture University (Imphal), Umiam, Meghalaya
Email: pradip66@gmail.com

A field experiment was conducted in the Research Farm of CPGS (CAU-I) Umiam, Meghalaya, India during Kharif season of 2016 to estimate the requirements of thermal units in the cultivation of Blackgram. The experiment was laid out with 2-factor Randomized Block Design with three replications. Four dates of sowing (14th July, 26th July, 7th August, and 19th August, 2016) and three varieties (PU-31, SBC-40 and SBC-47) were taken up for experiment. The values of CGDD (Cumulative Growing Degree Day), CPTU (Cumulative Photo thermal Unit), CHTU (Cumulative Helio thermal Unit), and grain yields were recorded at 15 DAS, 30 DAS, 50% flowering, pod setting stage and harvest stage. It was observed that crops shown on 14th July recorded highest grain yield of 1.29 t ha^{-1} using 451.0 ^{0}C-day, 2224.5 ^{0}C day h, and 3195.4 ^{0}C day h as CGDD, CPTU and CHTU, respectively. It was also observed that with delay in sowing decline in the use of heat units occurred, which in turn affected the yield of crops. Among the varieties, higher heat units were used by variety PU-31 as compared to SBC-40 and SBC-47.

Keywords: *Blackgram, GDD, Heat Units, HTU, PTU*

Study on Integrated Weed Management under Different Sowing Methods of Rainfed Rice

Jamkhogin Lhungdim* and K. Nandini Devi
Department of Agronomy, College of Agriculture, CAU, Imphal, Manipur,
Email: ginlhungdim@rediffmail.com

A farmer participatory research was conducted at farmers' field of Lamshang and Kangchup foothills, Imphal west, Manipur during kharif 2015 to determine the efficacy of different integrated weed management system of rice under different crop establishment methods in the foothill lowlands of Manipur. The highest rice grain yield (35.83 q/ha) was recorded in two hand weeded (HW) plot which was statistically at par with pyrazosulfuron-ethyl 10% WP (Saathi) @ 30g a.i. /ha, application with one hand weeding (34.07 q/ha). Study on Crop establishment method indicated that, highest harvest index (39.92) and yield contributing characters viz, effective tillers/plant (20.00) panicle length (27.33), filled grains/panicle (175.13) and test weight (50.07 g) were recorded under transplanted rice with two HW in which better performance of transplanted conditions were observed over direct sowing methods and two manual weeding over the rest of the treatments. The result also revealed that all the treatments gave significant control of weed population. All the treatments under both crop establishment methods were found to be significantly higher in plant growth and yield attributes. Interaction effect revealed that, Weed control efficiency (WCE) of 72.42% was achieved under transplanted rice with two HW resulting in highest grain yield but comparable with DSR (sprouted seed) + pyrazosulfuron-ethyl (PE) *fb* HW (66.99%). However, in the economic aspect, this treatment was found to be unviable as it is time consuming and expensive practice, resulting in low net returns and benefit cost ratio of Rs. 33,158/- per ha and 1.67 respectively. Transplanted rice with two HW showed better plant growth and yield attributes too but was not significantly different from transplanted rice with pyrazosulfuron-ethyl as PE *fb* HW, transplanted rice with 2,4 D (Ester) as POE *fb* HW and Transplanted rice with (PE) *fb* POE. The transplanted rice outperformed the two DSRs (sprouted and dry seeding) in all respect. Further, amongst the two DSRs, sprouted seeding was comparatively better than dry seeding but with insignificant differences. Maximum weed index (73.40) was observed under transplanted rice with unweeded check. Except two HW in transplanted and DSRs, the weed index was found to be lowest under Transplanted rice with pyrazosulfuron-ethyl (PE) *fb* HW (6.16 %).

Keywords: *Economics, Sprouted Seeding, Transplanting, Integrated Weed Management, Yield, Rice*

Comparison of Different Reference Evapotranspiration (ET_0) Models and Crop Coefficients of Early Summer Potato in Mid Hill Region of Meghalaya

Moutusi Tahashildar, P.K. Bora, Lala I.P. Ray, Gagan Timsina

School of Natural Resource Management, College of Post-Graduate Studies, Central Agricultural University, Barapani, Meghalaya, India,
Email: pradip66@gmail.com, tusi.tahasildar8@gmail.com

An experiment was conducted to determine the crop-coefficients of potato in a mini UMS-GmBH Lysimeter with 30 cm cropping area and 120 cm length which was installed in the College experimental farm. Potato (*var: Kufri jyoti*) was grown in the experimental field as per standard agronomic practices within and outside the lysimeter. Daily data of soil moisture (with EC5 sensors), soil moisture tension (with T4 tensiometer) and drainage water volume (with SK20 vacuum) were noted. By using water balance equation the daily water loss due to evapo-transpiration from the Lysimeters was calculated. Real time weather data was collected from the Automatic Weather Station (AWS: Vintage Pro 2 of Davis) installed in the in the experimental site. The reference evapo-transpiration (ET_0) of Umiam region was calculated using Penman-Montieth model as given in FAO-56 (*FAO Irrigation and Drainage Paper 56)*. The calculation of ET_0 was done on daily basis for the period from planting to harvesting of potato. The total net radiation (R_n) for the crop period was found to be 844.11 MJ/m^2. Weekly total grass ET_0 was found between 18.93 mm to 27.46 mm. Similarly, the actual crop ET_c was found between 7.18 mm and 29.24 mm. The crop ET during early stage of the crop was primarily from the bare soil with seedling just initiating. From the calculation it was found that potato required nearly 2 weeks period for germination and initial growth. From 3rd week of planting, the crop set into growing stage and it continued to grow till 7th week after planting. During 10th week the crop reached the maximum vegetative stage and the ET_c surpassed the grass ET values. After reaching the maximum growth stage during 10th week the crop's vegetative growth was in declination and the ET_c entered into the end stage. Based on the k_c values and its trend during the crop period, it was found that after planting of potato the initial period is extended to 15 days. The growing period was found to be continued till about 46 days and thereafter the crop coefficient reached the plateau. The plateau of crop coefficient continued till 72 days and thereafter it entered in end stage. In the present experiment, $k_{c, ini}$ was found to be 0.38, $k_{c, mid}$ was 1.02 and $k_{c, end}$ was 0.76.

Keywords: *Potato, Crop-coefficient, Lysimeter, Penman-Monteith*

Effect of varying N Levels on Nitrogen Economy in Maize + Legume Intercropping in Acidic Soils of Mid Hills of Meghalaya

Saphina Mary Kurkalang, *A.K.Singh and Lala I.P. Ray

College of Post-Graduate Studies (CAU), Umiam, - 793103, Meghalaya, India
Email: adityakumar1972@yahoo.co.in

A field experiment was conducted during *Kharif* 2014 on research farm of the CPGS (CAU-Imphal), Umiam (Meghalaya) to study the effect of varying N levels on N economy in maize–legume intercropping. The experiment was laid out in factorial RBD with three replication where maize was intercropped with two legumes namely soybean and groundnut and both the intercropping systems were supplied with six varying levels of N to both maize and intercropped legume. The RDN for maize and intercrop was 80 kg ha^{-1} and 20 kg ha^{-1} respectively. Maize intercropped with soybean recorded significantly more stover and biological yield of maize over groundnut intercropped maize however; maize grain yield was at par in both the intercropping system. Maize+soybean also recorded

relatively higher uptake of N by maize grain, stover and their total however, the difference between both the intercrops was at par for these entire N uptake in maize. All N treated plots recorded significantly higher values of yield attributes over control and treatment 75% RDN of maize to maize+100% and their total. Grain, stover and biological yield (t ha^{-1}) was significantly higher in intercropped groundnut over intercropped soybean. Application of variable RDN to intercrop did not bring a significant difference in yield attributes and yield of intercrops except for pod weight $plant^{-1}$. The yield of legume intercrops increased only upto 50% RDN of IC to IC. N uptake in grain, stover and total by intercrop legumes also differed significantly due to variable N application. Maize+groundnut intercrop gave significantly higher maize equivalent yield, net return and B: C ratio and also left significantly more residual N in soil over maize+soybean intercrop. Statistically at par MEY at maize $_{60}$+IC $_{10}$ with maize $_{80}$+ IC_{20} opened the possibility of saving of 30 kg N ha^{-1} in maize+legume intercrop.

Keywords: *Maize-Legume Intercropping, Variable N Doses, Nutrient Uptake, Residual Soil N*

Design of Field Bunds Based on Rainfall Analysis for North Chotanagpur Region

Dange Jane S[1], Singh Pankaj Kumar[2], Rusia D.K.[3] and Kumar Anil[4]

[2]Singh Pankaj Kumar, Technical Officer Forestry, Institute of Forest Productivity (ICFRE), Ranchi

[1/4] Birsa Agriculture University, Kanke, Department of Agriculture Engineering Ranchi
Email: janemtech@gmail.com

Rain plays a major role in hydrology that finds its greatest applications in the design and operations of water resources, engineering works as well as agricultural systems**.** Detailed knowledge of rainfall pattern helps in planning crop calendar and designing of different storage structures to meet out irrigation requirement during drought period. Analysis of consecutive days return periods is a basic tools for safe and economical planning and design of structural and non-structural measures, small and medium hydraulic structure such as small dams bridges culverts, spillways, check dam, ponds, irrigation and drainage work in watershed management and command area development programs and plant protection activities in a more scientific basis through the application of climatologically information rainfall and will probably lead to even higher temperatures and lower rainfall in tropical areas.The rainfall data were obtained for selected district of Jharkhand state and the peak values were selected. The data were evaluated with various probability distribution function determine the best fitting model.The summary of statistics mean, standard deviation, skewness coefficient, coefficient of variation, maximum and minimum values of daily maximum rainfall is presented.The predicted rainfall for the desired return period using extreme value type I distribution and consequent estimated runoff can be safely used for designing the bunds.

Temporal Changes of Critical Crop-Weed Competition in Groundnut under Mid Altitudes of Meghalaya

Santosh Korav[1], Vishram Ram[1], N. Premaradhya[1], and R. Krishnappa[2]

[1]*College of Post Graduate Studies, Umiam*
[2] *ICAR Research Complex for NEH Region, Umiam*
Email: santoshkorav@gmail.com

A Field experiment was carried out during *kharif* and *rabi* seasons of 2016-17 at the experimental farm of the College of Post Graduate Studies, Umiam, Meghalaya. The experiment was conducted in a randomized block design, replicated thrice with twelve treatments *viz.*, weeds until 15, 30, 45, 60, 75 days after emergence (DAE), weedy treatment and weed free until 15, 30, 45, 60, 75, weed free treatment. Critical period for crop-weed competition under 5% and 10% relative yield loss were determined through Logistic and Gompertz equations. The results shows that weed dynamics (weed flora, weed density, dry matter) tended to decrease with increasing weeds free condition up to harvest. It was observed that the lowest weed dynamics associated with weed free check. While, weedy check resulted in the highest weed dynamics. The highest values of yield and yield attributes were higher with weed free check, and lowest with weedy treatment. The critical period for weed competition under 5% RYL at kharif was 16 to 66 and rabi was 15 to 63 DAE. The estimated critical period for groundnut at 10% RYL were 22 to 62 and 21 to 61 DAE in kharif and rabi seasons, respectively. The accumulated heat units of kharif and rabi seasons followed linear and quadratic trend might be the reasons for variations in the competitive period of seasons. The present study was concluded that early groundnut stage up to 15-16 DAE is more sensitive for crop weed competition to cause significant yield loss. And early stages Rabi groundnut was more susceptible for competition than kharif as compare to later stage.

Integrated Nutrient Management in Vegetable Pea-Maize Cropping Sequence

Samborlang K. Wanniang and A.K. Singh

College of Post Graduate Studies (CAU-Imphal), Umiam
Email: samborlang.wanniang23@gmail.com

A field experiment on integrated nutrient management in vegetable pea –maize cropping sequence was conducted for two consecutive years in 2014-15 and 2015-16 on the Experimental Farm of College of Post Graduate Studies (CAU- Imphal), Umiam, Meghalaya in RBD with three replications. The treatments having a combination of three organic sources namely farmyard manure (FYM), biofertilizers and FYM+biofertilizers, with six inorganic sources *viz*., recommended doses of fertilizers (RDF), RDF + Lime (0.5 t ha^{-1}), 75% RDF, 75 % RDF + Lime, 50 % RDF and 50 % RDF+lime. The analysis of pooled data observed significantly highest pea yield from the treatment combination of RDF + Lime with FYM. Pea yield obtained from a combine application of lime+FYM with RDF, 75% RDF and 50% RDF was at par among them but significantly superior to remaining treatment combinations. However, maximum number of pea pods per plant was observed from a treatment combination of lime+FYM with 75% RDF which was at par with lime +RDF+biofertilizers and RDF+FYM+biofertilizers. TSS (%) in tender pea seeds was highest with RDF+lime treatment which was at par with RDF but significantly higher over all inorganic treatments. Succeeeding maize yielded highest yield with combine application of RDF with lime, FYM and biofertilizers which was at par with 75% RDF with lime, FYM and biofertilizers and RDF with lime and FYM but significantly higher to remaining treatment combinations.

Growth, Yield and Economics of Hybrid Maize (*Zea mays* L.) as Influence by Bio-Fertilizer and Nitrogen under Sub Tropical Condition of Manipur

Edwin Luikham, Zothanmawii and P.S. Mariam Anal

College of Agriculture, CAU, Imphal
Email: edluikham@rediffmail.com

A field experiment was conducted in 2012 at the Agronomy Experimental Farm of the College of Agriculture, Central Agricultural University, Imphal. The experiment consisting of four nitrogen levels (0, 60, 120 and 180 kg N/ha) and three source of bio-fertilizers (control, *Azotobacter* and *Azospirillum*) was laid out in factorial randomized block design with three replication. The required quantity of nitrogen (60,120 and 180 kg/ha), phosphorus (60 kg/ha) and potash (40 kg/ha) were applied for each plot using Urea, SSP and MOP. Application of different levels of nitrogen and sources of bio-fertilizers exhibited significant differences in growth characters, yield contributing characters and yield. Tallest plant was recorded with application of 180 kg N/ha at 60 DAS but remained at par to 120 kg N/ha in the other three stages. Application of 180 kg N/ha recorded significantly highest value of fresh weight, dry weight and LAI over the others levels of N at first two stages of recording but it remained at par to 120 kg N/ha in the two succeeding stages of the crop. Application of nitrogen up to 120 kg/ha showed significant increase in yield contributing characters as well as the grain yield with an exception in test weight. Among the bio-fertilizers, *Azotobacter* resulted in significantly higher growth characters, yield contributing characters and yield than *Azospirillum* and control. The interaction effect between nitrogen and bio-fertilizer was found to be significant in all the characters considered. The treatment combination of 180 kg N/ha + *Azotobacter* or *Azospirillum* inoculation recorded the higher grain and stover yield which remained at par to 120 kg N/ha + *Azotobacter*. From the economic point of view, application of 180 kg N/ha and *Azotobacter* resulted in maximum gross return and net return. In terms of benefit: cost ratio, application of 120 kg N/ha and *Azotobacter* gave maximum value. Based on the results obtained from the experiment, it can be concluded that application of 120 kg N/ha and *Azotobacter* can be recommended for hybrid maize to get high yield and higher net profit.

Water Productivity, Water Use Efficiency and Production Efficiency of Maize-Based Cropping System as Influenced by Soil Moisture Conservation Measures in Mid-Hills of Meghalaya

[1]Bidyapati Ngangom, [2]Anup Das, [3]Ramkrushna G.I. and [2] Jayanta Layek

[1]*Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal*
[2]*ICAR Research Complex for NEH Region, Umaim, Meghalaya*
[3]*ICAR-Central Institute of Cotton Research, Nagpur, Maharashtra*
Email: bidyapati2088@gmail.com

A field experiment was conducted during *Kharif* and *rabi* season of 2012-13 and 2013-14 " to study the influence of soil moisture conservation measures on crop and water productivity and production efficiency in maize-based cropping systems"at the upland Agronomy field, ICAR Research Complex for NEH Region, Umiam (950 m above sea level), Meghalaya. Five cropping systems were assigned to main plots viz. Maize-Fallow, Maize-Rapeseed, Maize-French bean (bush type), Maize-French bean (pole type), Maize-Blackgram and four soil moisture conservation (SMC) measures to subplots viz. no mulch, *in-situ* maize stalk mulch (MSM), MSM+ *Ambrosia* sp. 10 t ha^{-1} and M_1+*Tephrosia*sp. 10 t ha^{-1} as sub plot treatments. During *kharif*, a general crop of maize was raised uniformly under recommended package of practices.In pre-*rabi*, after maize harvest, the crops were grown under zero till with as per the treatments along with recommended dose of nutrients.Results revealed that among the *rabi* crops, maximum leaf relative water content was obtained in black gram at 60 DAS under MSM+ *Tephrossia* with 78.4% and 78.6% during 2012-13 and 2013-14, respectively. Blackgram recorded the highest seed and stover yield as compared to other crops. The highest seed yield of 1.63 t/ha and 1.60 t/ha of black gram during 2012-13 and 2013-14, respectively and stover yield of 1.96 t/ha and 1.83 t/ha during 2012-13 and 2013-14, respectively. In terms of maize equivalent yield (MEY) French bean (pole) under *in-situ*MSM+ *tephrosia* mulch recoded maximum (9.50 and 9.86 t/ha in 2012-13 and 2013-14, respectively) productivity. Higher water productivity was recorded in maize-rapeseed system under *in-situ*MSM+ *tephrossia* mulch (0.31 and 0.29 kg/m^3 in 2012-13 and 2013-14, respectively) followed by *in-situ*MSM+ *Ambrosia* mulch(0.30 and 0.29 kg/ha in 2012-13 and 2013-14, respectively).Thehighest WUE was obtained in blackgram under *in-situ*MSM+ *Tephrossia* (9.29 and 8.20 kg/ha/mm in 2012-13 and 2013-14, respectively) followed by *in-situ*MSM+ *Ambrosia* (8.15 and 7.33 kg/ha/mm in 2012-13 and 2013-14, respectively). Production efficiency was the highest in blackgram as compared to other crops in both the year and it was maximum under *in-situ*MSM + *Tephrossia* (24.2 and 23.8 kg/ha in 2012-13 and 2013-14, respectively) followed by *in-situ*MSM+ *Ambrosia* (23.2 and 23.0 kg/ha in 2012-13 and 2013-14, respectively). Land use efficiency was higher in maize-blackgram system (54.79 and 58.08 % in 2012-13 and 2013-14, respectively) followed by maize-French bean (pole) system (52.33 and 55.62 % during 2012-13 and 2013-14, respectively) in both the year of experimentation. It was concluded that maize-blackgram cropping system with MSM+ *Tephrossia*/*Ambrosia* mulch is a profitable option with higher crop and water productivity in mid-altitude of North Eastern Region of India.

Keywords: *Production Efficiency, Soil Moisture Conservation Measures, Water Productivity*

Effect of Conservation Tillage and Live Much on Productivity Maize Based Cropping System in a *Tilla* Land of Tripura

G.S. Yadav, K.K. Barman and B.K. Kandpal

ICAR Research Complex for NEH Region - Tripura Centre
Lembucherra, Tripura (W) – 799210

In Tripura, maize is cultivated in about 5000 ha. Presently, several farmers of this state are showing their eagerness to cultivate maize in pre-kharif, kharif and winter seasons. As maize is mostly grown in medium to up land situations having sloppy terrain, repeated cultivation during consecutive seasons in combination with often encountered heavy and torrential rain could favour soil erosion. Water use efficiency can be improved through adoption of reduced tillage (RT) and zero tillage (ZT) systems as compared to conventional tillage (CT). An investigation was conducted to study the effect of ZT and RT practices on productivity of maize in a medium *Tilla* land and its residual effect on subsequent lentil and mustard crops. The field experiment consisted of five treatment combinations, viz. ZT, ZT + Live mulch (ZT+LM), RT, RT + live mulch (RT+LM) and conventional tillage (CT), was laid out by following RBD with 3 replications. The experiment was conducted during 2014-15 on a medium *Tilla* land in the research farm of ICARNEH Tripura Centre. The pre-kharif maize crop was sown on 8th April 2014 at 60 x 30 cm spacing. About fifty percent residues of previous crop were left on field as mulch in the ZT and RT plots. In treatments, where live mulch was used, the two rows of cowpea (cv. Kashi Kanchan) were sown in between of two rows of maize. The crop was harvested on 27th June 2014. The second maize crop was sown on 8th July 2014; the treatments as given to the preceding maize were repeated on the same plots and the crop was harvested on 23rd September 2014. Soil moisture content of the plots was recorded after harvest of second maize by following gravimetric method. During subsequent *rabi* season each plot was divided into two parts; in one part mustard (Pusa Mustard 25) and in the remaining half lentil (HUL-57) was sown. All the crops received the recommended levels of NPK application and need based crop protection measures.

The highest grain yield of maize grown during summer season was recorded under RT+LM and it was statistically similar to RT and ZT+LM treatments. During kharif, the highest yield was recorded in ZT+LM treatments and it was statistically similar to RT and RT+LM treatments. Overall thus it was observed that the performances of ZT+LM and RT+LM treatments were similar and they were superior to CT during both the seasons. The residual soil moisture content as recorded after harvest of kharif maize was also higher in the ZT+LM and RT+LM treatments over CT plots. The lentil and mustard yields as recorded during subsequent rabi season were significantly influenced by the preceding kharif season treatments. The seed yield of lentil and mustard ranged between 1249-907 kg/ha and between 1518-1877 kg/ha, respectively. The highest yield of both mustard (1877 kg/ha) and lentil (1249 kg/ha) were recorded in the plots that received ZT+LM treatment during preceding kharif. The lowest yields of these crops were recorded in ZT treatment. The study suggested that cultivation of maize under ZT condition with live mulch of cowpea is beneficial to the farmers for enhancing their productivity and provide a window for cultivation of short duration rabi crop on residual soil moisture. Besides proving higher system productivity, ZT+LM treatment saves land preparation cost and yields green fodder (cowpea) as bonus.

Theme-2: Climate Resilient Agriculture

Non-traditional Weed Management Approaches under Changing Climatic Condition

R.P. Singh[1 *] and S.K. Chongtham[2]

[1]*Former Director, Institute of Agricultural Sciences, BHU, Varanasi, U.P.- 221 005*
[2]*Assistant Research Scientist, Potato Research Station, SDAU, Deesa, Gujarat- 385535*
**Email: 158rpsingh@gmail.com*

Climate change is a globalmenace due to unchecked human activities such as over-expanded use of fossil fuels and deforestation, thus increasing atmospheric CO_2 concentration and average global surface temperature. Elevated CO_2 level may provide a competitive edge to C_3 crops over most of the notorious weeds which fall under C_4 plants. However, there are also a large number of C_3 weeds which may be benefitted by increased CO_2 level, thus making them more aggressive and difficult to control. Also, weeds are colonising species owing to their vast adaptability and tolerability to wide environmental conditions caused either by human or by natural activities. Consequently, weeds will become more competitive over crops thus posing aserious threat for agricultural productivity and negating some of the otherwise beneficial effects of "CO_2fertilization" of the major world crops. In this context, meticulously planning ofweed management is the need of the hour to mitigate the ill-effects of weeds on crop productivity.

Among several options for weed management, use of herbicides is the most economical and widely followedtraditional methodas it improves crop yields and save labour and energy, thereby reducing the cost of farming. However, focus of weed management is shifting toward integrated strategies to reduce the impact of herbicide use on the environment and the development of herbicide-resistant weeds. Moreover, elevated CO_2 and temperatures due to climate change may influence anatomical, morphological and physiological changes in weeds that could influence uptake, translocation and metabolism of herbicide and its overall efficacy.For example, increased tolerance to glyphosate under elevated CO_2 has been recorded for both agricultural and invasive weed species. Further, strategies aimed at mitigating climate change effects on crop production like water saving rice cultivation and drought-tolerant rice germplasm, will also have implications for weed management. So, due emphasis should be given on non-traditional weed management methods like cultural,mechanical, biological and allelopathicmethods for reducing weed problems in crops under climate change. Following non-traditional weed management strategies can be adopted and incorporatedin weed control under climate change:

a) Cultural methods-

- Identification of crop cultivars resilient to climate changes with competitive edge over weeds.
- Manipulation in planting time: Early planting of crops for avoiding the high temperature and early establishment for better weed competition.
- Crop rotation: To create an unstable and inhospitable environment for weed establishment and survival
- Optimum plant population and geometry: Shifting competition in favour of crop for better resource utilization
- Cover crop: Interference in weed development by inhibiting or retarding germination of weeds or preventing growth and development of weeds through niche pre-emption.
- Inter-cropping: Increasing diversity in the cropping system for efficient utilization of resources while suppressing weeds.
- Tillage: The method, depth, timing and frequency of tillage may influence the composition, density and long-term persistence of the weed population.

b) Mechanical methods: Improved weeding tools will attain more significance resulting in labour saving (about 20-40 man days per ha.), better and timely weed control.

c) Biological methods: Some biological control agents attach to roots and thereby stunt plant growth. Some bacteria live on root surfaces and release toxins that stunt root growth. Many fungi infect roots and disrupt the water transport system, which reduces leaf growth. Beneficial insects and nematodes feed directly on the weed roots causing injury which allows bacteria and fungi to penetrate.

d) Allelopathy: Allelopathy has received new attention in modern weed research. Targeted use of the allelopathic properties of plants could lead to a reduction of the use of synthetic pesticides. However, modern analytical techniques and holistic approach are needed for a thorough evaluation of exploitation strategies.

e) Transgenic approach: Genetic modification of crop plants by exploiting traits of weeds for better adaptability and performance under futuristic climate change conditions.

Although both crops and weeds mayrespond variably under changing climatic scenario, it is weeds that are anticipated to flourish more due to better adaptation strategies. Management of weeds under changing climate scenario is very distressing task and may become too expensive at times. Hence, there is urgent need to adopt an integrated or inclusive approach to cope-up with the weed problems under state of climate change scenario.

Climate Fluctuations and Strategies to Double Maize Production

Vinay Mahajan

ICAR-Indian Institute of Maize Research, PAU Campus, Ludhiana 141004, Punjab, India

Maize (*Zea mays* L.) is the third prominent cereal crop in global agricultural scenario In India maize is primarily grown in monsoon (*kharif*) season throughout the country. In winter (*rabi*) season, maize is sown in some part of the country, while the spring maize is also gaining importance in last few years. The maize area, production and productivity for 2015-16 were 8.691 million hectare, 21.806 million tons and 2.509 ton per hectare, respectively. Past data on climatic parameters as well as yield data on maize are important to look into setbacks and achievements. The monthly fluctuations in rainfall during maize cropping season are high in all the zones during maize crop season and the trend was significantly increasing in the month of August in CWZ. The seasonal rainfall decreased during the month of October in all the Zones. The yield performance of best test entry was *at par* or higher than the best check with significant and strong correlation with each other and with trial mean. There was increasing trend for maize yields from 1991 to 2012 in all the zones. The AICMIP had an important contribution in overall increase in zonal yields of the country even though the differential impact in different zones. The new maize hybrids from AICMIP are superior even under the changing climatic conditions in different agro-climatic zones, however there was a stabilization of the zonal yields (pooled over states within agro-climatic zones) of maize around year 2002 for seven to twelve years in different the zones of the country.

Even though maize is a rainfed crop but is very sensitive crop to the changes in climatic important variables such as temperature, precipitation, sunshine etc., that affects maize production. Climate change demands maize to withstand not only unpredictable biotic and abiotic stresses but also a new and up-coming pre-urban stresses. Since 1991, climatic parameters have seen to undergo noteworthy changes. The reduction in total rainfall in the *kharif* season, is coupled with a shift in peak of rainfall by nearly 20-25 days, reduction in peak of total rainfall during the rainiest months and less rainfall in the initial months of the maize growing season in north eastern region of the country. The critical assessment of different crops/zones for vulnerability to climatic stresses and extreme events, especially of intra-seasonal variation in rainfall, temperature, pest and disease severity *etc.* is *a* requisite to justify changes in the climate. Another up-coming stress is of growing peri-urban agriculture, occurs surrounding the boundaries of cities throughout the world and includes products from crop and livestock agriculture, fisheries and forestry in the peri-urban area. UNDP estimates that 15% of food worldwide is grown in cities. Peri-urban agriculture is becoming vital for the urban populations of many developing countries including India. Agriculture practices around cities which compete for resources (land, water, energy, labour) that could also serve other purposes to satisfy the requirements of the urban population. Often multiple farming and gardening systems exist in and near a single city.Peri-urban agriculture plays an important role in diversifying urban diets and providing environmental services in urban and peri-urban areas. Increases in both industrialization and urbanization has been associated with pollution threaten urban food production and its quality. Sewage water and industrial wastes has been a major concern in peri-urban agriculture and animal husbandry. The serious pollutants get recycled back in urban population with short and long term serious health hazards in the human population. A practical strategy need to be executed with the direct and indirect support from the public sector so as to use the treated sewage water and industrial wastes for agricultural purpose.

Doubling maize productivity

It is important to note that the major area of maize cultivation is in *kharif* season, while the maize productivity is higher in *rabi* season. In order to double maize production to five tonnes per hectare by 2025, the area in *rabi* season to be increased as well as develop maize hybrids with nine to ten tonnes/ha in *kharif* season in different zones. There are number of upcoming hybrids with around 10 tonnes/ha yield which will contribute significantly in achieving national production of 5 million tonnes. Based on last three years *kharif* data, there are hybrids in pipeline that yielded above 9 tonnes/ha over locations and years in different agro-climatic zones in all maturity groups, especially in specialty corn. In addition, the past years data was screened for more than 10 tonnes/ha in at least 50 percent locations in different AVTs and NIVTs of different zones and the information obtained was very encouraging. In spite of high fluctuations in rainfall, there was continuous improvement in the new genotypes developed at AICMIP especially in past two decades.

Issues and Strategies for Sustaining Agriculture in Hill Ecosystems of North East India in the Context of Climate Variability

D.J. Rajkhowa, Anup Das and S.V. Ngachan
ICAR Research Complex for NEH Region, Umiam, Meghalaya

Agriculture in the N.E. Hilly Region is mostly rainfed, subsistence type and suffers from a number of constraints. By and large, the region is characterized by fragility, inaccessibility and marginality. Floods, soil erosion, landslides etc. are common to the region causing huge loss to the agriculture and economy due to its undulating topography, geo-physical settings with faulty land use systems. The farmers of the region are mostly small and marginal with small land holdings, low investment and risk bearing capacity.Over 75% of the people of the region are directly dependent on agriculture for their livelihood, food and nutritional security. Therefore, improvement of agriculture has a direct and significant effect on the economy of the people of the region. Climate change and climatic variability is now a widely debated topic, globally. The impact of climate change on agriculture is being witnessed in different countries of the world including India. Rising temperatures and occurrence of extreme events, such as high intensity rainfall, frequent droughts and floods, variation in rainfall pattern are well witnessed in NEH Region also. Climatic aberrations will seriously affect the poorest section of the society who heavily relied on climate-sensitive sectors such as rainfed agriculture and fisheries (Samra*et al*., 2004; Prasad and Rana, 2006). Reduction in crop, livestock, and fishery productivity due to climate change /climatic variability is well predicted and there are variable perceptions about the intensity and consequences of climate change. The climate variability and low availability of resources and mitigation strategies with the farmers make the challenges further complex in North Eastern hill agriculture.

Slash and burn agriculture (*Jhum*) is still practised in almost all the hill states, except Sikkim on steep slopes, with reduced cycle of 2-3 years as against 10-15 years in the past. About 0.88 m ha area is still under shifting cultivation in the NE region. Huge amount of biomass (about 10 t/ha) burnt annually in *Jhuming* that leads to release of considerable amount of CO_2. The region, once endowed with rich genetic diversity of flora and fauna, has been denuded due to human activities and adoption of unscientific and unsustainable land use system. With rapid increase in human and livestock population and the rising demand of food, feed, fuel, fodder, fibre, timber and the other developmental activities, the farmers have been forced to exploit forestland and water resources in complete defiance of the inherent potential. This has resulted in progressive decrease in forest cover, loss of biodiversity, serious soil erosion leading to depletion of plant nutrients, water, gradual degradation and decline in land productivity and drying up of perennial steams as well as causing serious ecological imbalances. Gradual degradation of these resources is of prime concern and calls for location-specific measure to conserve, utilise and manage these resources for optimising production on sustained basis without adversely affecting its quality. The annual mean maximum temperature in the region is rising at the rate of + 1.11 ^{0}C per decade (Singh and Ngachan, 2012). The annual mean temperature is also increasing at a rate of 0.04 ^{0}C per decade in the region (Das, 2009). The decreasing trend of rainfall and number of rainy days has also been reported by (Saikia*et al*. 2012).

Climate variability and climate change are a reality now. An understanding of the impacts and vulnerably of hill agriculture sector and comprehensive understanding of adaptation options is essential. A multi-pronged strategy of using indigenous coping mechanism, wider adaptation of the existing climate counter acting technologies and concerted research and development efforts for evolving new location specific technologies are needed for adaption and mitigation. Judicious nutrient management, increased use of organic manure and biomass recycling etc. will lead to increase the SOC pool. Conservation agriculture with adoption of resource conservation technologies with no or minimum tillage, residue management, appropriate crop rotations, large scale production and use of organic manures, water harvesting and its efficient utilization etc. have the potential to enhance the use efficiency of natural resources such as water, air, fossil fuel and soil etc.Rajkhowa and Kumar (2013) reported that the huge potentiality of biomass recycling for improvement of soil health in the region.Efficient conversion of different plant biomass utilizing earthworms and cellulose decomposing microbes was also reported by Mahanta*et. al*.,(2014). Such technologies can improve the sustainability of agriculture by conserving the resource base with higher input use efficiency and also mitigating GHGs emissions. Development of climate resilient crop varieties, modifying sowing/planting dates, crop diversification, adoption of location specific integrated farming system, promotion of organic production system in potential area and crops, micro irrigation integrated pest management, crop insurance, increase nutrient use efficiency, agro-forestry intervention. improved weather –based agro-advisory, protected cultivation, intercropping/mixed cropping, use of renewable source of energy, creation of seed bank, custom hiring centre, use of indigenous technical knowledge, adoption of technology that reduces GHGs emissions like SRI, direct seeding, agro-forestry, increased use of non renewable source of energy in agriculture etc. are some of the adaptation strategies for agriculture under climate change scenario. Skill development and capacity development among farming community are also important not only to improve work efficiency but also for enhance economic activity and adaptation to climatic variability.

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Assisted Reproduction Led Smart Livestock Farming under Changing Climate Scenario

Suresh Kumar*, Mahesh Kumar, J.K. Singh S.Saha, N. Chand, Soni, Y.K , N. Prasad, M Pande and B. Prakash

**ICAR-Central Institute for Research on Cattle Meerut Cantt.U.P. 250001, India*

The livestock sector accounts for 40% of the world's agriculture Gross Domestic Product (GDP). It employs1.3 billion people, and creates livelihoods for one billion of the world's population living in poverty (FAO, 2006).Climate change is seen as a major threat to the survival of many species, ecosystems and the sustainability oflivestock production systems in many parts of the world (Moss *et al*., 2000). Global demand for livestock productsis expected to double during the first half of this century, as a result of the growing human population, and itsgrowing affluence. Over the same period, we expect big changes in the climate globally. The dramatic expansionof crop production for biofuels is already impacting on the resources available globally for food production, andhence on food supply and cost. Food security remains one of the highest priority issues in developing countries, andlivestock production has a key role in many of these countries. However, food security is re-emerging as animportant issue in many developed countries that had previously regarded it as 'solved'. Theseinterconnectedissues are creating immense pressure on the planet's resources. We need high quality animal science to helpmeet rising demand for livestock products in an environmentally and socially responsible way.Global climate change is one of the most significant environmental threats to the earth planet. Livestock are important to the food security of millions of people today and will be important to the food security of millions more in the coming decades. Livestock source food is not essential to human nutrition but it is highly beneficial. In livestock systems that primarily consume roughage and agro-industrial waste products, livestock add to the food supply beyond what can be provided by crops. Moreover, they make a very important contribution to food access and stability through the income and products they provide to small-scale mixed farmers and pastoralists, the asset value of animals and their flexibility of use. The role that livestock play in feeding the future will be shaped by three distinct human populations, each with its own particular needs, namely: urban dwellers, small-scale mixed farmers and livestock-dependent populations.

Livestock based farming system has potential for substantial income from the farmyard manure and self- sufficiency in fuel through biogas plants.Integrated farming system is based on the concept that "there is no waste" and "waste is only a misplaced resource which can become a valuable material for another product". Keeping this in mind, it was tried to design a cycle for effective utilization of off farm inputs. The farming practice where more than one component is involved and when the by-product of one component is utilized for the benefit of other component, the system is known as integrated farming. This method of farming is based on the concept of achieving maximum return from a limited farm space available. In integrated farming, when livestock is one of the components, it is known as integrated livestock farming. Its main benefit comes from the conversion of livestock waste into protein. Over the last three decades, India has made tremendous progress in food production. However, agricultural growth hardly ever exceeded 3 percent a year. Keeping in this view the pro-poor nature of agricultural growth, the National Agricultural Policy (NAP) 2000 targeted a 4 percent annual growth in agricultural sector by 2020, and emphasized livestock as an important driver of growth. The policy statement focuses on the need to (i) animals as a source of energy, (ii) generate and disseminate livestock related technologies to improve animal productivity. (iii) Improve marketing, processing and transportation facilities for value addition (iv) involve co-operatives and private sector in development efforts. Besides, the statement also emphasizes bringing up incentives for livestock production at par with crop production. With an enabling policy environment there is a considerable scope to diversify agricultural sector towards livestock activities. Increasing population, urbanization and sustained rise in per capita income are fuelling rapid growth in demand for animal food products. By 2020, demand for animal food products is likely to be double of the current demand.

Livestock –as a source of milk production, animal protein and draught power

Apart from milk, meat, manure and draught, animals also contribute sustainability in the form of production of by products like hides, meat meal, bone meal, tallow etc., which respectively are of immense utility in leather industry and compound feed industry.

Advanced Reproductive Technologies to Improve Livestock

The new technology takes advantage of procedures in cellular and molecular biology, including the ability to transfer new genes into the genome of domestic animals. Each technique assists in direct and rapid selection of a particular trait. The molecular approach complements the most of the reproductive methods and are being used in farm animals. Modern reproductive biotechnologies have revolutionized the world scenario and are being used not only as conservation and multiplication tools for elite and endangered livestock species but also for unfolding the mysteries of developmental biology as well as for therapeutic biomedical tool. The stem cell research particularly in livestock species is the area of research getting momentum day by day because of its multidimensional potential .The main objective of advance reproductive technologies in livestock reproduction is to increase reproductive efficiency and rates of genetic improvement. They also offer potential for greatly extending the multiplication and transport of genetic materials and conserving unique genetic resources in reasonably available forms for possible future use. The development and improvement of these technologies are concentrating on gamete and embryo collection, sorting and preservation, *in vitro* production of embryos, culturing, manipulation of embryos (splitting, nuclear transfer, production of chimeras, establishment of embryonic stem cells, and gene transfer) and embryo transfer. Also, the development of these novel technologies is facilitated by modern equipment for ultrasonography, microscopy, cryopreservation, endoscopy, and flow cytometry, microinjectiors, micromanipulators and centrifugation.

The advances in reproductive biotechnologies started with artificial insemination and embryo transfer technology and it continued with oocytes *in vitro* maturation (IVM) , *in vitro* fertilization (IVF), parthenogenetic activation, *in vitro* embryo culture (IVC), facilitating the increase in production through genetic improvement, the reduction in generation intervals and the control of diseases. The fourth generation of assisted reproductive technologies encompass cloning by nuclear transfer of somatic cells, embryo sexing, transgenesis, and stem cell biology, research models and xenotransplantation, preimplantation genetics diagnosis (PGD) and molecular tools that may assist in selection and understanding of physiological processes to increase fertility. These technologies are inter-dependent to each other while the molecular tools, are completely dependent upon the previous generations of technologies. For all the reproductive biotechnological, *in vitro* maturation is initial and mandatory step. *In vitro* production of embryos (IVP) is the creation of embryos outside of the female tract. It involves three separate and interdependent steps: (IVM), (IVF), and (IVC).

The common biotechnological approaches applied for augmenting the fertility are

1. Artificial Insemination (A.I.)
2. Estrus Synchronization
3. In vivo embryo collection and embryo transfer
4. In Vitro Embryo Production.
5. Cryopreservation of oocytes/ embryos
6. Sexing of embryos
7. Sperm Sorting
8. Stem cell research
9. Cloning
10. Tansgenesis

Impact of climate change on livestock

Climate change comes as an additional factor affecting a livestock sector that is already highly dynamic and facing many challenges. Important objectives of livestock genetic resource management include ensuring that animal genetic resources (AnGR) are effectively deployed to meet these challenges (i.e. are well matched to the production environments in which they are kept) and that the genetic diversity needed to adapt production systems to future changes is maintained. Climate change is likely to create a number of problems in many areas of animal husbandry (housing, feeding, health care, etc.) and threaten the sustainability of many livestock production systems and their associated AnGR. Many of the specific challenges associated with climate change (high temperatures, disruptions to feed supplies, disease outbreaks, etc,) as well as the general unpredictability it brings to the future of the livestock sector, highlight the importance of retaining diverse genetic options for the future. The influence of climatic conditions on milk production has been also observed for local cows which are more adapted to the tropical climate of India.

Effects of Heat Stress on Reproduction

When dairy cattle are subjected to heat stress, reproductive efficiency declines. Cows under heat stress have reduced duration and intensity of estrus, altered follicular development, and impaired embryonic development. However, the extent of reduction in reproductive efficiency during summer is difficult to assess unless reproductive measures are calculated monthly based on results of actual inseminations rather than as rolling annual averages. Common methods to ameliorate effects of heat stress have been to provide cooling in the form of shades, soakers, fans, or evaporative coolers. Because negative effects of heat stress have been identified from 42 d before to 40 d after insemination, continual cooling must be provided.Tools for synchronization of estrus have been developed that greatly reduce the need for detection of estrus.Pregnancy rates were more consistent over season when timed artificial insemination programs were used compared with artificial insemination after detected estrus, although negative impacts of heat stress were still observed. Recently, calving in summer has been reported to reduce the success of a timed first insemination between 60 and 66 d postpartum, although some researchers have found calving in the summer to have a positive impact on days open. Other techniques that have been investigated to reduce the negative impact of heat stress on reproduction include embryo transfer, induction of accessory corpus lutea, and crossbreeding.Each technique has potential advantages but not without limitations or costs. Comparative economic evaluations of various combinations of strategies to attenuate negative effects of heat stress on both milk production and reproduction are needed.

Summer heat stress has long been recognized as reducing both the productivity and reproductive efficiency of dairy cattle. The impacts of heat stress on reproductive efficiency have been well documented .Heat stress has been shown to alter the duration of estruscolostrum quality , conception rate,uterine function, endocrine status ,follicular growth anddevelopment), luteolytic mechanisms , early embryonic development and fetal growth. Although season alters endocrine profiles and fertility in males. The agriculture and animal husbandry particularly in north-eastern region are complementary and not competitive to each other. Dairying in particular, helps small and marginal farmers to improve their income. Farmers grow crops and animals and hence ensure economic advantages. It is an added advantage that almost all the household in the villages of the northeastern region is maintaining livestock (pig, poultry, cattle, goats, etc.) and produce sufficient quantities of organic manures, which could efficiently be used for organic crop production. As per the existing crop production scenario of the north-eastern region, there is an ample opportunity to boost organic production of crops to catch organic food market of the world. Under these emerging scenarios, the role of livestock is vital to promote organic agriculture in the region. It is obvious that large quantity of FYM, compost, vermi-compost and other biomass would be needed to compensate the fertilizers. Cattle dung is very important ingredient in the preparation of FYM, compost or vermi-compost. Thus livestock component has a very important role in the development and promotion of organic food production.

Adverse impact of heat stress on embryo production: causes and strategies for mitigation

The production of embryos by superovulation is often reduced in periods of heat stress. The associated reduction in the number of transferable embryos is due to reduced superovulatory response, lower fertilization rate, and reduced embryo quality. There are also reports that success ofin vitro fertilization procedures is reduced during warm periods of the year. Heat stress can compromise the reproductive events required for embryo production by decreasing expression oestrus behavior, altering follicular development, compromising oocyte competence, and inhibiting embryonic development. While preventing effects of heat stress can be difficult, several strategies exist to improve embryo production during heat stress. Among these strategies are changing animal housing to reduce the magnitude of heat stress, utilization of cows with increased resistance to heat stress (i.e., cows with lower milk yield or from thermally-adapted breeds), and manipulation of physiological and cellular function to overcome deleterious consequences of heat stress. Effects of heat stress on estrus behavior can be mitigated by use of estrus detection aids or utilization of ovulation synchronization treatments to allow timed embryo transfer. There is some evidence that embryonic survival can be improved by antioxidant administration and that pharmacological treatments can be developed that reduce the degree of hyperthermia experienced by cows exposed to heat stress.

Livestock adaptation strategies

Livestock producers have traditionally adapted to various environmental and climatic changes bybuilding on their in-depth knowledge of the environment in which they live. However increasedhuman population, urbanization, environmental degradation and increased consumption of animalsource foods have made some of those coping mechanisms ineffective (Sidahmed, 2008). Inaddition, changes brought by global warming will happen at such a speed as to exceed thecapacity of spontaneous adaptation by both communities and animal species.

Ways to increase adaptation in the livestock sector

- *Production adjustments*: diversification, intensification, integration, of pasture management, livestock and crop production, changing land use and irrigation, altering the timing of operations, conservation of nature and ecosystems.
- Modifying stock routings and distances;
- Introducing mixed livestock farming systems – i.e. stall-fed and pasture grazing.
- *Breeding strategies:* many local breeds are already adapted to their harsh conditions.

However, developing countries are usually characterised by a lack of technology in livestock breeding and other agriculture programmes which might help to speed adaptation. Adaptation strategies include not only their tolerance to heat, but also their ability to survive, grow and reproduce in conditions of poor nutrition, parasites and diseases (Hoffmann, 2008). Those adaptation mechanisms include:

- Identifying and strengthening local breeds which are adapted to local climatic stress and feed sources;
- Improving local genetics through cross breeding with heat and disease tolerant breeds. If climate change is faster than natural selection the risk of survival and adaptation of the new breed becomes greater (Hoffmann, 2008).
- *Market responses*: improvement of agriculture market, promotion of inter-regional trade,credit schemes.
- *Institutional and policy changes*: removal or putting in place of subsidies, insurance systems, income diversification practices as well as the introduction of Livestock Early Warning Systems.
- *Science and technology development*: better understanding of the causes and impacts of climate change on livestock, development of new breeds and genetic types, improved animal health, and improved water and soil management.
- *Capacity building livestock keepers* – increased awareness of global changes, and improved capacity of herders/livestock producers to understand and deal with climatic changes. Training in agro-ecological technologies and practices for the production and conservation of fodder is improving the supply of animal feed, reducing malnutrition and mortality in herds.
- *Livestock management system*s – efficient and affordable adaptation practices have to be developed for rural poor not able to buy expensive adaptation technologies.
- Provision of shade and water to reduce heat stress from increased temperature. Current high cost of energy, providing natural (low cost) shade instead of high cost air conditioning is more applicable to rural poor producers;
- Reduction of livestock numbers – lower number of more productive animals will cause more efficient production and lesser emission of GHG from livestock production.
- Change in livestock/herd composition (large animal versus small animal, etc.)

- Improved management of water resources through the introduction of simple techniques for localized irrigation (e.g. drip and sprinkler irrigation), accompanied with infrastructure to harvest and store rainwater, such as small superficial and underground dams, tanks connected to the roofs of houses, etc.

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Soil Organic Carbon Dynamics: Land Use Change and Climate Change Mitigation

T. Ramesh, S. Hazarika, B.U. Choudhury, Anup Das, A. Balusamy, R. Krishnappa, L. Joymati Chanu and S.V. Ngachan

ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya- 793 103

Soil organic carbon (SOC), the central element of soil quality, is the major building block of all the living organisms on the earth and thus it is the basis of the most productive and non-productive soil function. It is the basic input for crop production and is important for agriculture point of view. It improves the physical, chemical and biological properties of the soil and thus leads to the sustainable crop production. Soil contains, globally, 1500-2300 Pg C, approximately two times of the carbon present in the atmosphere and thrice of the carbon present in the vegetation (Lal, 2004). Therefore, any small change in SOC pool could have dramatic impact on atmospheric CO_2 concentration and regional or global carbon balance. There are several sectors contributing to the global greenhouse gas emissions including agriculture production and land use change accounting 24% of the global greenhouse emissions to the atmosphere (IPCC, 2014). Carbon sequestration depends on the balance between the inflow and outflow of the carbon to the soil. When the rate of carbon inflow exceeds the outflow, carbon will be sequestered and vice-versa. This would decrease the rate of atmospheric CO_2 increase, thereby mitigating the global warming (Tieszen, 2000).

Recent concerns with rising atmospheric levels of CO_2 have stimulated interest in C flow in terrestrial ecosystems and the latter's potential for increased soil carbon sequestration (Schlesinger, 1999). The SOC pool can act either as a sink or source of atmospheric CO_2 based on the land use and management practices by altering C inputs, decomposition and turnover, and thus potentially affect the carbon sequestration and loss (Lal, 2004). The land use change presently contributes a net emission of 1.4 Pg C per year though this assessment still remains unclear. Recent decades, the researchers are focusing more on the mitigating options for global warming; the current rise in atmospheric CO_2 can be mitigated in part by carbon sequestration in agricultural soils. Jensen (2006) in his study reported that conversion of pasture land for cultivation resulted in 59% SOC decrease; conversely the crop land conversion to pasture increased the SOC stocks by 19%. Application of biochar, biosolids, crop residue managements, conservation tillage are management practices practiced worldwide for sequestering organic carbon in soil. Therefore, the study integrating land use and soil management with SOC dynamics is quite important for the recommendation of sound land use and management practices to mitigate the impact of the climate change at the local to regional level. In a study, Ramesh et al. (2013) reported that soil organic carbon increased 37 percent under *Alnus nepalensis* based agroforestry system (AFS) compared to control in northeast India. Likewise, the net carbon accumulation was calculated from the soil CO_2 efflux under five agroforestry systems in northeast India. *Alnus nepalnesis* recorded the highest net carbon accumulation of 31 g kg^{-1} followed by *Michelia oblonga* (24 g kg^{-1}) than other agroforestry systems including control in a 150 days incubation experiment. Accodring to Gupta (1995), continuous cropping for seven years under *Leucaena*, *Acacia nilotica*, and *Albizzia procera* resulted in 13 to 56% increase in SOC over the open grass. Justin et al. (2013) studied the soil carbon dynamics under different land use and cropping systems in the Himalayan region; they reported highest values of all the carbon fractions in Oak forest recorded than the other land use and cropping systems, whereas barren land showed the lowest carbon fractions. In the forest soil, the annual addition of organic matter in the form of leaf litter is high, which remains in the soil due to the absence of any disturbance.

There are many indicators to estimate the impact of land use change and management practices on SOC changes. Total organic carbon is the indicator for the changes in SOC due to land use and management effect in long-term; while, the labile fractions of SOC namely particulate organic carbon, potassium permanganate oxidizable carbon, microbial biomass carbon and dissolved organic carbon. The soil MBC and positive and significant correlation with the amount of net carbon accumulated in soil (Ramesh et al. 2013). Similarly, in a study Yamala and Oke (2013) found significant influence of natural forest, crop land and natural fallow on particulate organic carbon and mineral-associated organic carbon. Agricultural management practices have strong influence on SOC fractions and CO_2 emissions. Application of NPK increased the SOC, SOC stocks and other fractions in rice-berseem agro-ecosystems (Majumdar et al., 2008). The labile fractions of carbon, viz. POC, MBC and $KMnO_4$-C under minimal tillage were 47%, 16% and 43% higher, respectively, in comparison to conventional tillage in the 0–20 cm soil layer (Prasad et al., 2016). Land conversion from barren to agroforestry, horticulture plantation and agriculture cultivation increased the cumulative CO_2 emission by 14.6%, 5.9% and 5.2%, respectively in northeast India (Ramesh et al. 2013). It has also been reported that the changes in land use might have modified the organic carbon transformation due to the changes in substrate quality, altered microbial community size and/or changes in soil porosity and water retention (Martinez and Zinck, 2004). The low values of CO_2 efflux rates recorded for soils under agriculture land use overall may reflect their low total C content due to the lower carbon input or net primary productivity, lower substrate quality, loss of soil carbon by frequent soil erosion events and poor structure (Prasad et al., 2016).

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Meteorological Drought: It's Effect on Rice Yield and Farming Community

Nivetina Laitonjam[1], S.M. Feroze[1], Ram Singh[1] and Kankabati Kalai[2]

[1]*School of Social Sciences, College of Post Graduate Studies, CAU, Umiam, Meghalaya*
[2]*Department of Agricultural Extension, College of Agriculture, IGKV, Raipur*
E-mail: nivelaitonjam@gmail.com

The paper analyzed drought intensity, its impact on rice yield and effect of socio-economic drought on farming community. Primary and secondary data were used for the present study. Secondary data on rainfall (1975-2007) were extracted from high resolution ($0.5^o \times 0.5^o$) daily gridded data obtained from India Meteorology Department (IMD) and data on yield of rice in Manipur was collected from Department of Agriculture, Government of Manipur. The study revealed that there was occurrence of mild (rainfall deficit up to -25 %) moderate (rainfall deficit from -25% to -50%), severe (-50% to -75% rainfall deficit) and extreme drought (-75 to less rainfall deficit) while mild and moderate drought was observed during monsoon months (June, July, August and September) in Manipur. Multiple regression model on effect of drought intensity (monsoon months) on yield of rice showed that both mild and moderate drought has positive and significant (at 5 % level of significance) impact on yield of rice. A unit increase in mild and moderate drought reduces the yield of rice by 0.52 unit and 0.53 unit, respectively. Majority of the farmers perceived about late as well as low rainfall during monsoon (87% and 91%) and winter (81% and 81%) seasons. A very high percentage of the respondents reported about increase in pest (95%) and disease (56%) infestations during climatic variability which may be due to climate change. About 5% of farmers reported decrease in area under rice and a loss in gross return by about 22,550. Increase in use of hybrid/HYV, irrigation, fertilizer, pesticide and weedicide were the different coping strategies used by the farmers to reduce the negative impact of drought on rice yield.

Keywords: *Rice, drought intensity, impact, socio-economic drought, Manipur*

Trend Analysis of Rainfall Variability in Relation to Climate Change in North Bank Plain Zone of Assam

D. Saikia, R.R. Changmai and P. Neog

Department of Agrometeorology, Biswanath College of Agriculture,
Assam Agricultural University, Biswanath Chariali, Assam, PIN -784176
E-mail: neogprasanta@rediffmail.com

One of the best ways of understanding how climate of place may change in future is the trend analysis of past climatological data of sufficient duration, which would reflect natural climatic variability as well as long-term impacts of climate change in that place. In present study, behaviour of annual, seasonal and monthly rainfall was studied by subjecting them to non-parametric Mann-

Kendall test to detect the plausible positive or negative trends and increasing or decreasing slope of trends in the time series was determined by using Sen's slope method for the four stations located at the different places in North Bank Plain Zone of Assam. The daily time series rainfall data for the period Lakhimpur (1984-2016), Biswanath Chariali (1971-2016), Balipara (1980-2016), Thakurbari (1986-2013) were analyzed statistically for each station separately. The results of Mann-Kendall test showed decreasing trend in annual rainfall in Lakhimpur and Biswanath Chariali, however, no trend in rainfall was observed in Balipara and Thakurbari over the respective periods. In case of Lakhimpur, decreasing trends of rainfall were observed in the monsoon and winter season with slope magnitude of -0.267 mm/yr and -2.345 mm/yr respectively. In case of Biswanath Chariali, decreasing trend of rainfall was observed in the post-monsoon with slope magnitude of -2.304 mm/yr respectively. Though not significant, coherent deceasing trends in monthly rainfall were observed in different the months in all four locations. The significant decreasing trends of annual and seasonal rainfall and coherent decrease in trends of monthly rainfall in different months reflected the shifting in rainfall behavior in the agroclimatic zone, which might be associated with increase in rainfall fluctuations with large amplitudes and increasing frequency of intermittent dry spells and flash floods in the recent years might in zone. The rising of rainfall fluctuation in terms of increasing numbers of flash flood and dry spells are becoming the major weather risk to agriculture and serious concern for the rainfed rice based cropping system of the zone.

Keywords: *Climate Change, Mann-Kendall, Rainfall, Seasonal, Trend Analysis*

Biochar: Impact on Soil Physical Properties and Carbon Dynamics

Jayanta Layek[1, 2], Rattan Lal[1], Anup Das[2], Gulab Singh Yadav[1], RS Meena[1] and Tarik Mitran[1]

[1]*Carbon Management and Sequestration Center (C-MASC), The Ohio State University, USA*
[2] *ICAR Research Complex for NEH Region, Umiam, Meghalaya, Pin-722139, Email: jayanta.icar@gmail.com*

Storing carbon in soil for sufficiently long period in form of biochar, a product of a controlled pyrolysis may be considered as an important method to mitigate CO_2 concentration in the environment. Due to its unique character, biochar has reported to positively change the physical and hydrological properties of soil. There is a need to quantify the amount of biochar for positive soil properties and crop productivity in maize-soybean rotational system. Therefore an experiment was undertaken with application of biochar at the Waterman Farm of The Ohio State University (OSU) in Columbus, OH, USA (40°00'N, 83°02'W) on a Crosby silt loam soil to study the role of biochar on productivity of maize based system and physico-chemical properties of soil including SOC content. A randomized complete block design was implemented with three biochar application rates: 0 Mg ha^{-1} (B_0), 5 Mg ha^{-1} (B_5), and 25 Mg ha^{-1} (B_{25}). Composite soil samples were also taken for studying other physical and hydrological properties of soil. The Soil bulk density (ρb) was reported to decrease by application of biochar. Under B_{25} it was recorded to be 1.35 as compared to 1.39 and 1.41 under B_5 and B_0, respectively at 0-10 cm soil depth. The gravimetric as well as volumetric water content and total porosity of soil was also recorded to be significantly higher under B_{25} as compared to no biochar application. Reduction in soil bulk density and increase in total porosity suggests biochar application to soil at 25 Mg ha^{-1} can be a more effective long-term management. The soil moisture characteristic curve for B_{25} was consistently higher across all soil moisture potentials as compared to B_0 at 0-10 cm soil depth. The B_{25} increase in volume of 1500 µm pores above B_0 suggests that incorporation of biochar enhances macro-pores related to water transmission, while also enhancing moisture retention by increasing the volume of 0.5 µm pores. Saturated HC (Ks) for soils of 0-10 cm depth as well as IR

of soil was also increased significantly under B_{25} as compared to no biochar application. However, the magnitude of difference between B_0 and B_5 for HC and IR was not statistically significant. The B_{25} and B_5 improved the maize above-ground biomass 1150 kg ha^{-1} and 370 kg ha^{-1}, respectively, while grain yield improved by 850 kg ha^{-1} and 260 kg ha^{-1} over no biochar application. The total N and SOC content was also increased under B^{25} as against no biochar application in the 0-10 cm soil layer, however the difference for 10-20 cm was found to be non-significant.

Results suggest biochar is an effective soil amendment for agricultural soils. One time biochar application at good rate (25 Mg ha^{-1}) has the potential to improve soil quality, sequester atmospheric carbon, and enhance crop yield. The acquired knowledge and skills of the candidate by undergoing this associateship will be utilized in studying the C-sequestration potential and improving fertility and productivity of crops in North Eastern Region of India.

Population Trend of Mithun with Corresponding Forest Coverage and Climatic Factors in Mithun Rearing Districts of Nagaland

Sabyasachi Mukherjee, Imsusosang Longkumer, Yanger Jamir, Pursenla I Pongen, Nazrul Haque, M. H. Khan, J. K. Chamuah and Abhijit Mitra

ICAR-NRC on Mithun, Medziphema, Nagaland-797106
Email: smup0336@gmail.com

National Mission for Sustaining the Himalayan Ecosystem (NMSHE), a component of the National Action Plan on Climate Change (NAPCC), attempts a better understanding of the coupling between the Himalayan ecosystem and the climate factors and provides inputs for sustainable Himalayan development. As a part of this programme, various data on mithun population, climatic factors, and area of forest coverage of three major mithun breeding tracts of Nagaland (Kohima, Phek and Tuensang) were collected. A data base is being prepared to evaluate the impact of changes in climatic factors as well as forest coverage on the population trend of mithun. In Kohima district, a drastic reduction in the mithun population (5689 in 2003 vs. 2826 in 2012) was observed along with an equally higher reduction in annual rainfall (1577.3 mm in 2003 to 1370 mm in 2012). At the same time, there has been a decrease in average humidity over the past decade. However, no change in the forest coverage was recorded in past decade. Mithun population was also decreased in Tuensang district (9693 in 2003 vs. 7355 in 2012) coupled with a gradual decline in forest coverage (3384 sq.km. in 2003 vs. 3232 sq.km. in 2012) and annual rainfall (1458 mm vs. 1432 mm). There was a minute increase in ambient temperature over the past decade. Interestingly, only Phek district witnessed a gradual increase in the mithun population (4416 mithuns in 2003 vs. 5732 in 2012) coupled with increased forest area (1611 sq. km in 2003 vs. 1767 sq km in 2012) and a minor reduction in average annual rainfall (1529 mm in 2003 vs. 1421 mm in 2012). From the initial data, it is difficult to correlate the changes in mithun population with the observed simultaneous changes in climatic factors and forest coverage. The present study nevertheless, indicated a declining trend in mithun population which corresponds with the decreasing trend of annual rainfall and forest coverage in the mithun rearing districts of Nagaland.

Buckwheat (*Fagoypyrum esculentum*): Climate Resilient Crop for Hill Agriculture

Letngam Touthang*, H. Kalita, Badapmain Makdoh and Anup Chandra

ICAR Research Complex for NEH Region, AP Centre, Basar
West Siang District – 791101, Arunachal Pradesh
**Email: letngam111@gmail.com*

With the ever changing climate and farming under the fragile environment, there is a need to look beyond the horizon for climate resilient crops for future food and nutritional security. Buckwheat (*Fagoypyrum esculentum*) with its adaptability to wide range of agro-ecological conditions with variant altitudes, tolerance to drought, crop sturdiness, short duration, low inputs requirement and resistance to pests and diseases constitutes one of the indispensable crops in hill agriculture. It also has a huge potential of medicinal and nutritional value. The crop is being more preferred by higher altitudes dweller with extreme climatic conditions where other crops seldom perform. Not only its grain, the leaves of buckwheat are consumed as vegetables, dried and preserved for off season by indigenous people of Arunachal Pradesh. However, the research improvement of this climate resilient crop with its value addition is somehow neglected and still at infancy. Nevertheless, it has a huge potential for future food and nutritional security in the face of climate change. Keeping in view all these facts, varietal evaluation was carried out among thirty entries of buckwheat (*Fagoypyrum esculentum*) *viz*. IC-329401, IC-341651, IC-258233, IC-329456, IC-109316, VL-7, PRB-1, IC-340879, IC-202226, Himpriya, IC-107619, IC-329195, IC-329198, IC-329592, IC-274439, IC-109728, IC-329591, IC-13191, IC-329199, IC-13144, IC-329200, IC-341577, IC-340881, Sangla B-1, IC-341592, IC-338646, IC-340876, IC-79238, IC-13410, IC-341581 and one local check Gruchung in mid hill condition of Arunachal Pradesh, Basar during *rabi* 2015 and 2016 with standard package of practices. The study materials were supplied by NBPGR, Phagli, Shimla. The study intended to identify best performing varieties or accession under local climatic conditions. Recorded days to 50% flowering ranged from 29-36 days. While highest plant height of 100.50 cm was recorded in IC-13410 and lowest in IC-341651 (25.05cm). Out of the thirty entries under trial, the yield of four accessions namely IC-13191 (10 q/ha), IC-169728 (9.10 q/ha), IC-13144 (7.8 q/ha) and IC-274439 (6 q/ha) were found to be higher than the local check Gruchung (4.87 q/ha) respectively. While the lowest average yield (1.5q/ha) was recorded in IC-341651. Therefore, introducing these promising accessions could augment the production and productivity of buckwheat in the region.

Sediment Carbon Sequestration Potential of Thane Creek Mangrove Ecosystem

S. Gojendro Singh [a,]*, A. Vennila [b], and S.K. Das [a]

[a]*Division of Fisheries, ICAR Research Complex for NEH Region, Umiam, Meghalaya*
[b]*ICAR-Sugarcane Breeding Institute, Coimbatore*
**Email: ind.goj@gmail.com*

The study quantified the sediment carbon sequestration potential of the *Avicennia marina* dominated mangrove ecosystem, Thane Creek, Maharashtra, India. The depth-wise sediment carbon fractions (Organic, Inorganic and Total carbon) were analysed using Walkley and black method and CHNS Technique). Sediment cores were collected up to a depth of 50 cm, and cut into 10 cm length for analysis. However, maximum number of uniform cores was collected from 75 different sites along the banks of Thane Creek up to 20 cm depth. The analysis of variance (ANOVA) also showed no significant difference in their carbon content in the depths of 0-10 and 10 – 20 cm, so the means of the two depths were used for carbon quantification. Other physicochemical parameters like Soil texture, Bulk density, pH and Conductivity were also analysed. The sediment mean total carbon were found to be 31.62 Mg C ha^{-1}, in which major contribution is provided by organic carbon (22.30 Mg C ha^{-1}).

Keywords: *Carbon Sequestration, Avicennia Marina, Physicochemical Parameters*

Wetness Trend Variability Analysis across the Tripura State

Saurav Saha[1], Anup Das[2], Samik Chowdhury[1], Gulab Singh Yadav[3], Debasish Chakraborty[2], Sandip Sadhu[4], P. Lalhmachhuana[1], B.U. Chowdhury[2], K.P. Mohapatra[2], D Daschaudhuri[3], M Dutta[3], S.B. Singh[1] and S.V. Ngachan[2]

[1]*ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib 796 081, India*
[2]*ICAR Research Complex for NEH Region, Umiam 793 103, India*
[3]*ICAR Research Complex for NEH Region, Tripura Centre, Lembucherra, Tripura 799210, India*
[4]*MSME Development Institute, Ministry of Micro, Small & Medium Industries, Govt. of India, Guwahati, Assam*

Email: sauravs.saha@gmail.com

Monthly rainfall observations from twelve rain gauge stations were analyzed, to study the spatiotemporal variability in seasonal wetness trend across Tripura. We expressed the periodic wetness pattern in terms of Standardized Precipitation Index (SPI) over variable time period *viz*. 1 month (1-SPI), two month (2-SPI), three months (3- SPI), six months (6- SPI), twelve months (12-SPI) and twenty four months (24- SPI). Agartala and Kailashar stations showed the significant declining trend ($p < 0.05$) for 1-SPI values, during January. The steady declining trends in 1-SPI were evident during April and November, for eleven raingauge stations of Tripura (except Lembucherra station). Belonia ($p <0.05$), A.D. Nagar ($p <0.01$) and Amarpur ($p <0.1$) station experienced a significance reduction in pre monsoon (March, April and May) wetness. The decline in monsoon wetness were significant for A.D. Nagar ($p <0.1$) and Amarpur ($p <0.01$) stations only. We also analyzed the past dry and wet spell events for all the rain gauge stations based on 12-SPI values. Agartala experienced the most intense dry spell events during early 1980s over the study period. Change point detection analysis confirmed the significant sudden hike in annual (12-SPI) and biennial wetness (24-SPI) pattern at A. D. Nagar, Amarpur, Kamalpur, Belonia, Sabroom and Sonamura. Spatial mapping confirmed a significant trend ($p <0.05$) in annual wetness pattern (12-SPI based) for all the twelve rain gauge stations. However, the decline was statistically significant ($p < 0.05$) for A.D. Nagar, Udaipur, Amarpur, Sonamura, Bilonia and Khowai stations only.

Impact of Climate Change on the Traditional Farming of Sikkim Himalayas

Shweta Singh, Chandramani Raj, R.K. Avasthe, Raghavendra Singh and Ashish Yadav

ICAR-National Organic Farming Research Institute, Tadong, Gangtok
Email: shwetabac@gmail.com

The traditional farming system of the Sikkim Himalaya manifests an ecosystem diversity based on micro-climatic and biophysical factors in a vulnerable and varying topography. Owing to the climate change experienced across the globe, Sikkim has been experiencing different levels of climatic variation over the years in the form of erratic rainfall/snowfall, prolonged dry spells, warmer winters, unpredictable monsoon, emergence of new diseases and pests in crops/fodder trees etc., and these changes are expected to persist in future. These events have become a potential threat for growing food and livelihood insecurity, increased drudgery, degradation of plantations of large

cardamom and mandarin orange, crop failure, scarcity of water for drinking and irrigation, migration of farm labor and increased workload to elderly people and women and increasing health problems etc. Information on temperature rise and untimely rainfall and its impact on agriculture have been reported by the farmers of the Sikkim Himalaya. The climate change induced pressures are resulting in progressive loss of agro-biodiversity. Land races of rice, maize, pulses, finger millet, yams and pumpkin are rapidly disappearing due to climate change impacts. The Sikkim Himalayas have lost the comparative advantage of large cardamom; the production of this commercial traditional crop has declined drastically in the last 10 years. The farmers here reported that cardamom in high altitudes is growing well with no signs of diseases, while the low altitude plantations have severely declined. They have also remarked that the sowing of maize in the sub-tropical zone has shifted by 15-20 days, while sowing at temperate zones remains the same. Similarly, the harvest of maize remains the same in the sub-tropical zone while harvest time has shortened by 15-20 days in the temperate zone. Also, Sikkim mandarin orange has declined both in terms of productivity and plantation area. The impact of climate change due to untimely precipitation is visible on the phenology of fodder species of both subtropical and temperate agro-climatic zones. Farmers have observed the colonization of invasive species such as *Chromolina adenophorum*, *Eupatorium odoratum*, *Bidens biternata*, causing problems in the farmlands, fallow lands and croplands. These invasive species are fast colonizing and have spread from sub-tropical to temperate agro-climatic region causing productivity decline. Sikkimese farmers have observed crop-environment relations and associated changes at different intensities and have evaluated potential risks and uncertainties. However, traditional farmers are building up the adaptive capacity of these ecosystems through their ecological knowledge systems. The mountain farmers are applying traditional technologies for managing the dynamic mountain agriculture systems with adaptive practices to cope up with the growing consequences of climate change. For soil fertility maintenance, farmers have introduced bio-composting, vermi-composting, production of farmyard manure, mulching and use of green manure. In the rain-shadow areas of South Sikkim, rain and roof water harvesting has been initiated. Bench terracing was a traditional practice often used by farmers practicing agriculture in the steep slopes. This has been revived recently to prevent runoff, soil stabilization from degradation, fertility maintenance and moisture retention. Development of farm-based agro-forestry has become an adaptive system for mitigating climate change impacts. Due to shortage of farm-labour, the farmers have developed farm-based agro-forestry for growing fodder and fuel-wood. The cultivation of *Swertia chirayita*, *Thysanolaena agrostis* and other multipurpose fodder species and medicinal plants under the *Alnus nepalensis* trees replacing large cardamom has been recently observed widely in several villages of Sikkim. The sustainability of “adaptive capacity” of the Sikkim Himalayan Agriculture system is essential to ensure the ecosystem as well as the livelihood and food security of the Sikkemese people.

Distribution of Soil Organic and Microbial Biomass Carbon in North Eastern Himalayan Region

Ch. Bungbungcha Meitei[1], M.A. Ansari[*2], S.S. Roy[2], T. Basanta Singh[2], S.K. Sharma[2], Nabakishor Nongmaithem[1], N. Chanu Gulleibi[1#], Anup Das[3], N. Prakash[2] and S.V. Ngachan[3]

[1]Junior Research Fellow, ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat
[1#]Project Assistant, ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat-795004
[2]Scientist, ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat-795004
[3]ICAR Research Complex for NEH Region, Umiam, Meghalaya
Email: merajiari@gmail.com

Surface and subsurface soil organic carbon (SOC) is a large but still poorly understood component of the global carbon cycle. We investigated the depth distribution of SOC and MBC in

North Eastern Region, testing the hypotheses that distribution of SOC with depth is linked with land use, soil and agro physical variation. The study area varied from 412 m to 1733 m msl (Low, medium and high altitude.) The land use selected from low attitude (low < 750 m) were Orange Orchard (3 years old); Banana plantation (3 years old); vegetable cropping system (Tomato/Brinjal- Potato/Veg. pea); Rice - Fallow (ICAR Farm); Rice - Tomato (ICAR Farm); land use from medium altitude (750-1500 m) Improved Jhum (3 years); Pine forest (>10 years) and from high altitudes (> 1500 m) Kiwi orchard (4 years old), Tree bean plantation (8 years) and Oak plantation (10 years). The soil samples were collected vertically from six different soil layers (0.0-0.15 m, 0.15-0.30 m, 0.30-0.45 m, 0.45 - 0.60 m, 0.60-0.75 m and 0.75 -0.90 m) and analyzed organic carbon and microbial biomass carbon. In our study, we found significantly higher organic carbon under Banana plantation (2.12%) in 0.0 to 0.15 m soil depth, while Rice- Tomato cropping system contained maximum organic carbon (1.53, 1.52, 1.51, 1.50, 1.49%) in 0.15-0.30 m, 0.30-0.45 m, 0.45 -0.60 m, 0.60-0.75 m and 0.75 -0.90 m soil depth, respectively. In surface soil (0.0 to 0.15 m), significantly ($p=0.05$) higher microbial biomass carbon (MBC) was recorded under Treebean plantation (564.5 µg/g) followed by kiwifruit plantation (501.8 µg/g). In sub surface soil (0.15-0.30 m, 0.30-0.45 m, 0.45 -0.60 m, 0.60-0.75 m and 0.75 -0.90 m), the maximum MBC was recorded under kiwifruit plantation (470.4, 439.0, 439.0, 407.7, 198.2 and 2456.2 µg/g), respectively followed by Treebean plantation. These results support our hypothesis regarding the drivers of SOC depth distribution in eastern states under various land uses and can be used to identify regions with the potential for additional subsurface soil carbon storage.

Mapping the Climate Suitability using Maximum Entropy Modelling Approach for a Hill Banana Cultivar (Kait Mon) Cultivation in India

Rajappa Joga[1], N. Sivaraj[2], Bappa Karmakar[1], Heiplanmi Rymbai[1], Puran Chandra[1] and K.P. Mohapatra[1]

[1] ICAR Research Complex for NEH Region, Umiam) - 793 103, Meghalaya

[2] ICAR-National Bureau of Plant Genetic Resources, Regional Station, Hyderabad, Telangana

Email: rajappajj@gmail.com

Banana is an important commercial fruit crop which is cultivated in majority of the countries around the world (over 100) in tropical and sub-tropical regions. India is acclaimed as one of the major centres of Musa origin and diversity and in particular North East Region of India endowed with rich banana genetic resources. Rapid genetic erosion in hot spots of banana diversity is a major concern in the climate change regime. In order to ensure sustainable cultivation of native landraces and to prevent genetic erosion in hot spot areas, suitable strategies are to be evolved to safeguard the existing diversity. Mapping the climate suitable regions using ecological niche modelling is one such step towards the sustainable cultivation and on-farm conservation of banana genetic resources. Kait mon banana variety had been subjected to ecological niche modelling using Maximum Entropy method. Presence points (geographical coordinates) were collected using a global positioning system during an exploration for the collection banana germplasm in December 2016. MaxEnt software version 3.3.3k downloaded from www.cs.princeton.edu/~schapire/maxent was used for Kait mon habitat modelling. DIVA-GIS software version 7.5 was used to generate grid maps. Open source Bioclimatic variables (19 variable - Annual mean temperature, mean diurnal range, isothermality, temperature seasonality, maximum temperature of warmest month, minimum temperature of coldest month, temperature annual range, mean temperature of wettest quarter, mean temperature of driest quarter, mean temperature of warmest quarter, mean temperature of coldest quarter, annual precipitation, precipitation of wettest month, precipitation of wettest month, precipitation seasonality, precipitation of wettest quarter, precipitation of driest quarter, precipitation of warmest quarter and precipitation of coldest quarter) for current and future climatic conditions were used for ecological niche modelling. The climate models generated for the present and future climates indicating that climate suitable regions and on-farm conservation sites are available in parts of Assam, Sikkim, Tripura, Manipur, Jammu and Kashmir, Maharashtra, Meghalaya, Uttarakhand, Gujarat, Kerala, Himachal Pradesh, Karnataka and West Bengal. However, a clear cut shift is anticipated in some of the states where currently Kait mon is grown. Highest probability value of 0.8 to 1.00 has been obtained for the above mentioned states in India for climate suitability. Accordingly, contingent plan for sustainable cultivation and on-farm conservation of Kait mon banana to be developed.

Keywords: *Banana, Conservation, DIVA-GIS,* Kait Mon*, MaxEnt*

Land use Model for Sustainable Production and Climate Resilience in Eastern Himalayas

Jayanta Layek*, Anup Das, Ramkrushna G.I., Krishnappa R., Subhash Babu, M. Thoithoi Devi and S. V. Ngachan

ICAR Research Complex for NEH Region, Umiam, Meghalaya, Pin-722139,

Email: jayanta.icar@gmail.com

Shifting agriculture (slash-and-burn agriculture) is prevalent among poor people living in hills of Eastern Himalayas. The productivity as well as income from this shifting cultivation is very low. Land degradation in the form of deforestation, soil erosion and soil fertility depletion is taking place at a massive scale. As the productivity as well as income from these shifting cultivation areas is very low, it leads to poverty and food insecurity among the shifting cultivators. Burning of jungles also creates huge amount of greenhouse gas emission. Hence it is inevitable to develop environmentally gracious and reasonably lucrative sustainable agricultural systems for these areas. Our aim is to develop a sustainable land use model for sloping hill to provide sufficient food, fodder to the farming community, improving soil fertility and reducing environmental pollution. Pine forest (400 tree ha^{-1}) with catch pits (1.5m x 0.5m x 0.3m) were advocated at hill top. Perennial fodder crops viz. broom grass, hybrid napier and guinea grass were grown in upper terraces. Cover crops viz. groundnut, soybean, frenchbean and cowpea in rainy season and rapeseed (*Brassica campestris var. toria*) in dry season were grown in next terraces. Hedge rows (Tephrosia sp.) are adopted in contour .Micro rain water harvesting structure (Jalkund, 30000 litre capacity) was installed for providing life saving irrigation. Intercropping of maize with groundnut, soybean and cowpea in rainy season and frenchbean in dry season were practiced in the mid terraces. In lower terraces, rice - lentil system under conservation tillage was practiced.

Rainy season crops under minimum till and dry season crops under no-till along with residue retention were adopted. The land use model gave food and nutritional security to the farming family by providing cereals (rice & maize), pulses (lentil & cowpea), oilseeds (rapeseed & groundnut), vegetables (cowpea & frenchbean) and fodder (broom, hybrid napier and guinea grass). Productivity of crops under conservation practices were significantly higher than Farmers' practice (FP). Residue retention increased soil moisture content by 10.6 % (average) than removal during dry season. The soil organic carbon (SOC) stock was significantly higher under fodder crop followed by cover crop and maize + legume intercropping as compared to mono-cropping of maize/rice. Soil loss and runoff was maximum in FP (cultivation along the slope) and minimum in fodder crops. Maximum loss of SOC, nitrogen and phosphorus was recorded in FP followed by maize + legume intercropping and cover crops. From the above study it the model can be recommended for conservation of natural resources and sustainable hill agriculture as viable alternative to shifting cultivation in changing climate

Keywords: *Land Use Model***,** *No-Till, Residue Retention, Shifting Cultivation, Soil Loss*

Spatial Analysis of Rainfall Variation in Southern Agro Climatic Zone, Tamil Nadu Using GIS

B.R. Easwari*, K. Palanivelu and A. Ramachandran

Centre for Climate Change and Adaptation Research, Anna University, Chennai – 25
Email: easwari1950@gmail.com

Rainfall Variability is one of the key factors, which affect the water resources and agricultural production. Hence, the proper understanding of rainfall pattern and its trends may help to improve the agricultural production and water resources. Southern agro climatic zone of Tamil Nadu is comes under the semi- arid region and frequently drought prone Zone. Therefore, the study focus on these issues to analysis the rainfall variation in Southern Agro Climatic Zone of Tamil Nadu, which is surrounded by coastal areas on the east, and mountains in the west. The patterns of irrigation in the study area are well, canal, dams and lakes and its major crops are Paddy, cholam, cumbu, ragi, groundnut, cotton, banana and tobacco. Indian Meteorological Department (IMD) daily gridded rainfall data was used for analysis (resolution - 0.5º× 0.5º) for the period of 1971 to 2005. For spatial analysis, 20 grid points was taken and analysed the rainfall pattern, gridded annual average, total annual rainfall average for each grids. The spatial analyses of rainfall variation were analysed using Arc GIS. The results show that Southern Agro Climatic Zone receives 1030 mm of total annual rainfall (gridded average) for the 35 years. The highest total annual rainfall received in the Tirunelveli district (1714 mm) and lowest total annual rainfall received in the Virudhunagar district (728 mm). The seasonal analysis results show that in winter (JF), summer (MAM), southwest (JJAS) and northeast monsoon (OND) receives 35.3, 165.3, 412.5, 417.1 mm respectively and its contribution is 3.43%, 16.04%, 40.04% and 40.49% respectively. The highest rainfall was received in Tirunelveli district for four seasons viz., winter (54.9 mm), summer (360.1mm), southwest monsoon (2110.7 mm) and north east monsoon (574.4 mm). In winter season lowest rainfall was received in Madurai district (16.3 mm), summer in Sivagangai district (85.1 mm), Southwest monsoon (110.1 mm) and Northeast monsoon (321.8 mm) in Thoothokudi district. The gridded average rainfall shows slight increased in Southern Agro climatic Zones for the period of 35 years (1971-2005). Due to the geographical location the Tirunelveli districts receives maximum rainfall as compared to other districts. With the help of this, study the government and NGO's can help the farmers to improve the adaptive measures for agriculture production.

Genetic Variability and Marker Mediated Genetic Diversity Analysis of Root Traits Associated with Drought Tolerance

Harendra Verma[1], Patu K.Zeliang[2], D.J. Rajkhowa[1] and R.N. Sharma[3]
[1]ICAR Research Complex for NEH Region, Medziphema,
[2]KVK, Peren, ICAR Research Complex for NEH Region, Medziphema,
[3]Assam Agricultural University, Jorhat
Email :harendraicar@gmail.com

The present investigation was conducted to study genetic variation & diversity for root traits associated to drought tolerance. Drought sensitivity leaf scoring revealed that Banglami, ARC 10372, Inglongkiri, Bizor, Bizor-2, as 38/2, Horin Kajuli are the drought tolerant geneotypes among 160 genotypes. The 114 genotypes taken for genetic divergence analysis differed significantly with regard to the 15 characters studied using PVC pipe. Genotypes differed significantly for root traits and drought tolerance and recovery. Inglongkiri, ARC 10372, Horin Kajuli, Bizor and Banglami (local drought tolerant check) genotypes exhibiting drought tolerance bearing long roots, high root volume system. Path analysis revealed that selection for root volume, fresh root weight, dry shoot weight and

root:shoot ratio traits will be effective for improvement of drought tolerance D^2, path analysis and PCA have identified five important characters viz. root volume, dry shoot weight, fresh root weight, drought tolerance and recovery. A set of 114 diverse rice germplasm lines were genotyped using 4 gene specific and 65 genome wide SSR markers to assess the molecular genetic diversity and genetic relatedness. AMOVA revealed that population is divergent. The value of PIC ranged from 0.18 (RM480) to 0.75 (RM474) with an average of 0.507 for all the genotypes under study. Population is diverse and marker mediated diversity is better than D^2 in depicting the diversity in the genotypes and selection of parents based on their performance and diversity need to be consider for divergence.

C and N Mineralization Dynamics in Different Soils Amended with Crop Residues and Contrasting Soil Moisture

Shaon Kumar Das

[1]*ICAR-National Organic Farming Research Institute, Tadong, Gangtok, Sikkim-737102*
Email: shaon.iari@gmail.com

C and N mineralization dynamics in three soils (Entisol; ens, Inceptisol; ics and Mollisol; mls) amended with black gram (bg) and vegetable pea (vp) residues (each at 10 mg g^{-1} dry soil) at two contrasting soil moisture contents (pF2.5 and pF3.8) were investigated under laboratory incubation for 90–120 days. The legume residues markedly enhanced the net cumulative CO_2–C flux and its rate throughout the incubation period. The cumulative CO_2–C fluxes and their rates were lower at pF3.8 than at pF2.5 with control soils and also relatively lower with bg-treated than vp-treated soil samples. After 90 days of incubation, 30–43% of the amended C of residues was recovered as CO_2–C. In one of the three soils (mls), the results revealed that the decomposition of the recalcitrant fraction was more inhibited by drought stress than easily degradable fraction, suggesting further studies of moisture stress and litter quality interactions. Greater net N mineralization or lower immobilization was displayed at pF 2.5 than at pF3.8 with all soil samples. N was immobilized equivocally in both NH_4^+–N and NO_3^-–N forms. The results showed that legume residues can be potential organic fertilizer sources for nutrient-depleted tropical soils. In addition, application of plant residue can help to counter the N loss caused by leaching. It can also synchronize crop N uptake and N release from soil by utilizing microbes as an ephemeral nutrient pool during the early crop growth period.

Keywords: *Labile Pool, N Mineralization, Legume Residues, Moisture Stress, CO_2-C Flux*

Performance of Some *Sali* Rice Genotypes under Delayed Sowing Condition

Priti Bandana Konwar[1*] and Prakash Kalita[2]

[1]*College of Post Graduate Studies (CAU, Imphal), Umiam, Meghalaya- 793103*
[2]*Department of Crop Physiology, Assam Agricultural University, Jorhat-785013*
**Email: pborpatragohain@gmail.com*

A study was conducted to assess the physiological and biochemical responses of some selected *sali* rice genotypes *viz.* satya, Luit, Monoharsali, Joya, Bordhan, Basundhara and Srimanta, belonging to different crop duration groups to delayed dates of sowing under Jorhat condition in the Instructional cum Research (ICR) farm, Assam Agricultural University, Jorhat, India during the year 2012-2013 in *sali* season. Thirty days old seedlings were transplanted and their physiological performance was evaluated. The *sali* crop in Assam faces recurrent floods at various stages of the crop. Transplanted *sali* rice besides being affected by the flood also faces intermittent drought during

the rainless period at various stages of crop which limits its productivity to a great extent. In view of the damage caused to the seedlings in seedbeds the farmers are compelled to sow seeds again and again resulting in delayed transplanting. Due to delayed sowing the time of onset of reproductive growth may also vary resulting in differences in vegetative biomass accumulation as well as grain yield. As a consequence of delayed sowing the reproductive phases of rice crop can be expected to face shorter photo period and cooler temperature which can be expected to have definite impact on the grain yield (Ahmed *et al*., 2014). Nitrogen being the major nutrient element which is directly involved in biomass production capacity of any plant may influence the amount of biomass produced prior to the onset of reproductive stage of plant. Genotypic variations in terms of Nitrogen use efficiency has been reported (Marschner, 1995) and based on this the ultimate yield from the crop may be varying under different dates of sowing (Safdar, 2008). Significant genotypic variation was observed in terms of leaf area index, total chlorophyll content, leaf nitrogen content, biomass production and grain yield. Genotypes were found to respond differentially towards the date of sowing. Highest biomass content was recorded from 27th of July sowing. While comparison was made between timely sowing and the deferred dates of sowing lowest reduction in the values of grain yield were recorded in genotype Manoharsali and Srimanta (35.66 % and 35.03 % under 20th July) , (42.89% and 58.57% under 27th July), (58.07% and 65.32 % under 3rd August) and (78.07% and 77.73 % under 10th August). These two genotypes recorded better performance in terms of parameters like leaf area index, total leaf chlorophyll content, nitrogen accumulation in biomass and plant biomass etc. The genotype Srimanta also showed highest accumulation of nitrogen in plant biomass. The genotype Srimanta showed higher grain yield in timely sowing situation and its percent reduction with delayed dates of sowing was lowest. Therefore the genotype Srimanta can be regarded as better genotype for delayed sowing. In terms of grain yield and biomass production the genotype Srimanta was found to be superior with delay in sowing by 14 days.

Key words: *Leaf Area, Genotype, Biomass Production, Total Chlorophyll Content, Grain Yield*

Climate Variability and Trend Analysis in Nagapattinam, Tamil nadu

S. Pavithrapriya*, K. Palanivelu and A. Ramachandran

Centre for climate change and Adaptation Research, Anna University, Chennai
**Email: pavisri.2008@gmail.com*

Climate change is intensifying the challenges faced by the agriculture sector, adversely affecting crop production. Agriculture also contributing a significant amount of the greenhouse gas (GHG) emissions that are causing climate change – 17% and 7 - 14% directly through agricultural activities and land use changes respectively. Climate change induced extreme temperature, changes in intensity, frequency of rainfall and reduction of rainy days causes direct and indirect impacts on the agricultural system. Nagapattinam district which is one of the major agricultural region in Cauvery delta of Tamil Nadu, having paddy, sugarcane, groundnut, green gram, black gram as a major crops. This study focus on analysing the climate trend of the region for the period of 1971 – 2015. The data was collected from Indian Meteorological Department, consisting of monthly mean maximum temperature (MMaxT), monthly mean minimum temperature (MMinT) and total rainfall. The trend in climate variability were analysed through Mann- Kendall and Sen’s slope test, Change point analysis and Anomalies, which revealed a positive trend in MmaxT and a negative trend in MminT. Also the MMaxT has increased up to 1.3°C and MMinT has decreased -0.36°C leading to increase in the diurnal temperature (1.6°C) of Nagapattinam district during the period of study. The study analysis which also revealed the highest annual maximum temperature of 33.7 ºC and minimum temperature

of 25.7 ºC was observed during the 2012 and 1983 respectively. The analysis of annual rainfall exposed that the district received highest rainfall of 1952 mm in 2004 and meager 661 mm in 1974, with an annual average total rainfall of 1358.8 mm. The seasonal analysis showed that the South west monsoon (JJAS) contributes about 19.09%, the North East Monsoon (OND) contributing 68.57% of rainfall while the least contributing of rainfall in during the winter (JF) 4.98% and summer (MAM) with 7.37%.

Soil Carbon Sequestration Potential of Different Cropping System Managed by Smallholder Farmers in Eroded Hilly Watershed of the Indian Himalaya

Vijay Singh Meena, S.C. Panday, Anirban Mukherjee, Kushagra Joshi, J. Stanley, Arunava Pattanayak

ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora-263601, Uttarakhand, India, E-mail: vijay.meena@icar.gov.in

Crop management practices and cropping system managed by farming community strongly influence soil carbon (C) sequestration and carbon management index (CMI) in eroded hilly regions. However, their combined effects and the underlying mechanism remain unclear. In this study, eleven cropping system and three soil depths across an eroded hilly watershed of Indian Himalaya were selected to investigate their effects on C-sequestration and CMI. A total of 327 composite soil samples [11 treatment (cropping system) 3- soil depth (0-15, 15-30 and 30-45 cm) and 9, 6, 8, 9, 18, 8, 6, 11, 13, 12 and 9 replication for finger millet-wheat, maize-wheat, rice-wheat, rice-vegetable, vegetable-vegetable, horse gram-lentil, horse gram-wheat, barnyard millet-lentil, finger millet-lentil, soybean-wheat and soybean-lentil, respectively] were collected for laboratory analyses. In addition, undisturbed soil samples were taken using core sampler from each soil depth for the determination of soil bulk density. Significantly higher (36.06 Mg ha^{-1} and ~ 44%) C-sequestration and CMI was observed in the horse gram-lentil and finger millet-wheat cropping system, respectively. Cropping system had minimum effect on non-labile carbon (NLC), lability of carbon (LC) and carbon pool index (CPI) of the ecosystem. Moreover, C-sequestration was increased in the pulses-pulses cropping system as compared to cereal-cereal cropping system. C-sequestration was positively correlated with CMI (R^2 = 0.94, $P < 0.01$) and soil carbon sequestration potential (CPS) (R^2 = 0.93, $P < 0.01$). However, CSP and CMI relationship was CSP = -0.742x + 64.08 (R^2 = 0.58). Converting cereal-cereal to pulse-pulse and pulse-cereal cropping system is an initial strategy to restore degraded ecosystems and increase soil CSP of different cropping system managed by smallholder farmers in eroded hilly watershed of the Indian Himalaya.

Theme-3: Innovations in Organic, Traditional and Integrated Farming Systems

Integrated Farming System a Viable Strategy for Efficient Utilisation of Resources and Improving Livelihood for Small and Marginal Farmers of NEH Region

N. Prakash*, Punitha, P**, S.S. Roy** and M.A. Ansari**

**Joint Director, ICAR Research Complex for NEH Region, Manipur*
****Scientist, ICAR Research Complex for NEH Region, Manipur*
Email mail: nprakashicar@gmail.com

In India, more than 58 per cent people are dependent on agriculture for their livelihood. North East India is not an exception. Contrary to land tenure system operating in other parts of India, Agriculture in hills of North Eastern Hill (NEH) region are mainly dual system in which both settled and shifting cultivation of land takes place. The land in hills is held by community members of the village and the usufructory rights to land are distributed by village council or village chiefs. The tribals who own individual land was governed by certain customary rules and regulation which varies from state to state and also within the state (Bezbaruah, 2007). Shifting cultivation is a predominant land use system carried out by farmers in NEH region and the village head man with his village council controls the whole system which shows variation between tribes to tribes. The eradication of shifting cultivation is not possible as it is the livelihood of the farmers hence, the *Jhum* improvment in recent years was advocated as an option. However, to improve the *Jhumias* and the *Jhum*, an holistic approach of livelihood improvement need to be addressed. For that, one of the promising option is to introduce Integrated Farming System (IFS) in a wider scale to improve the livelihood of the farmers. In North East India, the concept of integrated farming system helps to safeguarding the agricultural systems with biodiversity value, because the tribal farmer's livelihood depends upon the farming. Despite its importance, farming system has been declining due to lack of inputs availability, lack of awareness, gap between lab to land, acidification and afforestation in marginal farming areas, coupled with farmer's socio economic conditions in the most productive areas (Ansari et al., 2015). It is clear from the above that IFS is characterized by synergy and between crop and animal components that form the basis of the concept (Jitsanguan 2001; Radhammani et al. 2003; Ansari et al., 2013). IFS ensure that wastes from one form of agriculture become a resource for another form. Since it utilizes wastes as resources, we not only eliminate wastes but we also ensure overall increase in productivity for the whole agricultural systems (Ansari et al., 2016). The emergence of Integrated Farming Systems (IFS) has enabled us to develop a framework for an alternative development model to improve the feasibility of small sized farming operations in relation to larger ones (Ansari et al., 2014). The IFS is suitable for both the hills and valley region except in some part of the hilly areas where settled cultivation of land is completely absent. The farmers should be economically uplifted through location specific technology intervention strategies. The article is presented with the following subparts,

- SWOC of North Eastern Region
- Strategies of NEH Region
- Integrated Farming System (IFS)
- Modalities of implementing IFS
- IFS Models: Experiences from Manipur

In order to understand the North Eastern Region, it is necessary to understand the strengths, weakness, opportunities and challenges. The strengths and opportunities of the NEH region has to be converted to practical and useful result oriented changes to improve the livelihood among the farmers

SWOC of agriculture and allied activities of NEH Region

Strengths

- Varied agro-climatic condition suitable for agriculture and horticulture crops
- Biodiversity rich hotspot
- Adequate rainfall
- Medium to high educational status of the household
- Adequate land in hills
- Availability of man power (Many unemployed youths)
- Hard labouring women in both hills and valley
- Farmers clubs, SHG existing in NEH region

Weakness

- Family size is more than five members
- Infrastructure in remote areas are not developed
- Weak linkage between different stakeholders working for agri-allied activities
- Lack of irrigation facilities
- Lack of post harvest infrastructure
- No regulated markets
- Investment capacity of the farmers is poor
- Inadequate mechanisation
- Lack of value addition

Opportunities

- Suitable for growing high value low volume crops
- Varied agro-ecological conditions
- Supply of quality seed material
- Establishing small and medium scale processing unit
- Shifting cultivation land may be utilised effectively for promotion of orchards based on participatory decision making involving key stakeholders
- Potential area for crop as well as livelihood diversification for farmers
- Post harvest management and care
- Introduction of Integrated farming with allied activities based on location specificity
- Opportunities of meat export and domestic market capturing
- Opportunities to attract youth for agri-horti-animal and fish sector
- Agro-forestry intervention in unused fallow lands and waste lands
- Conservation and utilisation of bio-resources
- Rain water conservation and effective utilisation of other moisture conservation techniques
- Clustering of villages and growing crops / livestock/ fisheries based on location specificity and high scale marketing infrastructure can be created for the farmers
- Opportunities to go for organic farming in specific areas in hill region
- Vermicomposting in large scale should be encouraged in every districts

Challenges

- Socio-economic conditions of the farmers are poor
- Fragmented land holdings
- Common Property land tenure system

- Manipur is a land locked state
- Acidic soil
- Rainfall dependent Agriculture
- Different livelihood opportunities available to the people
- Expectation of farmers from government interms of input apart from scientific practices
- Higher input cost
- Overexploitation of forest for fuel, timber and fodder
- Poor soil management practices especially in hill region

ICAR-NEH (2007); Deka and Thirugnanavel (2013)

Options and Strategies for NEH Region to improve livelihood of the farmers based on cluster approach

The farmers in the hill region of North East India are governed by community land ownership. In this way the farmers are already united and the group mechanism already underpinned in the system. By utilising these strengths and opportunities, the farmers of NEH region has to be promoted through following options for agro - based entrepreneurship development.

- Bamboo based agri-business opportunities
- Horticulture based opportunities (Fruit orchard based on location specific fruits)
- Floriculture hot spots
- Orchid hot spots
- Cut flower hotspots
- Meat processing industry
- Piggery clusters
- Poultry clusters
- Fishery clusters
- Integrated farming system for small and medium scale farmers
- Mithun clusters
- Value addition of underutilised horticultural products

The above options can be carried out through following strategies,

- Farmers club already existing in the hills or valley region
- Community land tenure operated in hills (Village Headman can take initiative for improving the livelihood of the villagers by identifying suitable location specific entrepreneurship suitable for the village)
- Group of unemployed youths of nearby village
- Women Self-Help Groups
- Natural Resource Management groups (NRMg) formed through International Fund for Agricultural Development (IFAD)
- Individual farmers with an assistance from ICAR / respective KVKs of the region

Integrated Farming System (IFS) for small and medium farmers in NEH region

Hitherto in North East India, farmers are practising mixed farming. This mixed farming has to be converted to Integrated Farming System and subsequently to Intensive Integrated Farming System by the North East farmers for the sustainable utilisation of the resources and development of the region. Integrated farming system is the integration of different interdependent and integrating farm enterprises for the efficient use of land, labour and other resources of a farm family which provide year round income to the farmers to those specially located in remote areas (Prakash *et al*., 2017).

Why Integrated Farming System?

Shrinkage in area under cropping: Area under cropping is decreasing day by day to urbanization, industrialization, population, construction of buildings & highways. As a result there is sharp declining in the per capital carrying capacity of the land. The population of India is expected to increase to 137 & 166 crores, respectively, in 2030 & 2050 AD, while the cultivable land will decline to 141.3 & 131.3 million.

Small & Fragmented holding: The average holding of a farm in India has been declining & over 80% of operational holdings are below the size of 1.0 hectare.

Seasonal nature of income & employment & out-migration: Cropping activities in rain fed areas are restricted to four months in rainy season. Employment opportunities are scarce in other seasons. This leads to large-scale migration of male farmers to cities in search of work. Round the year employment opportunities should be there to check out-migration from rural areas.

Deterioration of resource base: The ultimate goal of sustainable agriculture is to conserve of human population over a longer period. This can be achieved by seeking the optimal use of internal production inputs in a way that provide acceptable levels of sustainable crop productivity & livestock production resulting in economically profitable return.

Household requirement: A country or state is said to achieve complete food & nutritional security if each & every person is able to consume a minimum quantum & quality of various food ingredients i.e., adequate & balanced diet on a regular basis, minimum education. Other requirements include timber system approach is essential for meeting all these diverse needs from limited land holdings of small & marginal farmer.

Advantages of IFS

- Productivity
- Profitability
- Sustainability
- Balanced food
- Environmental safety
- Recycling
- Adoption of new technology
- Saving energy
- Meeting fodder crisis
- Solving fuel and timber crisis
- Employment generation
- Agro-industries
- Increasing input efficiency
- Income round the year

(Prakash *et al.* 2015a)

Modalities of Implementing Integrated Farming System

Methodology to Organize Farming Systems under On-Farm Conditions

- **Farm selection:** Select the agro-ecological zone in which FSR is to be initiated. If necessary, further divide this agro-ecological zone to identify specific farming situation.
- **Selection of villages and farmers:** Select the village in each farming situation comprising marginal / small and medium / large farmers. Selection of village and farmers should be random so as to represent all farming community of the target area. The farmers selected for demonstration should have Interest, willingness to adopt and continue the IFS models. The IFS models demonstrated will be the demonstration plot for the whole village and nearby village to witness the impact of IFS system. Once the interested farmer was selected based on the above characteristics, the following survey need to be done.
- **Diagnosis of constraints in increasing farm productivity:** Carry out survey through Participatory Rural Appraisal. Prepare an inventory of farm resources and support services. Identify the production constraints. The technology gap, yield gap and inventory of the resources will help to design research, and to identify suitable technology intervention.
- Research, design , technology generation and adoption
- Technology transfer and diffusion of improved farming systems within recommended domain.
- Impact of technology of improved farming system – productivity, economic returns, energy input – output, employment, equity (gender issue) and environment.
- Showcasing to other farmers in the village and nearby villagers. This is done through organising, field day, showcasing the IFS by organising visit to demonstration plot by KVK and line departments. Farmer to farmer exchange of information is the widespread mode of transformation of technology. Hence organising such visits helps in dissemination of IFS technology. Publishing in success stories in local dailies also promote widespread adoption.

Integrating farming system models: Experiences from Manipur

Attempt has been made to conduct on-farm participatory research on integrated farmers field in five locations in Manipur. The major objectives the programme are to provide holistic growth of the farming sector through an area based strategies which include participatory technology dissemination with specific focus on integrated farming system through a seamless blend of traditional wisdom and modern scientific knowledge; enhancement in acreage, coverage and productivity through diversification from traditional cropping pattern to integrated farming system and improvement of agricultural resource use efficiencies in farming system mode. Community mobilization and integrated approach was the crux of this program. Capacity building and skill enhancement of the farmers was emphasized throughout the implementation process.

The selected areas comprise hilly slopes, narrow valleys and terraced land containing a wide range of microclimate (tropical to sub-temperate). All the locations suffer from acute water scarcity during winter months. The majority of the farmers relied on rainfed crop production and they have not yet been exposed to improved varieties, scientific production technology, natural resource management and post harvest technology. Under the programme, training and demonstration programmes have been conducted on different aspects of farming system.

Criteria followed for the interventions activities over farmers practice

Components	Criteria	Farmers practice	Interventions
Cereals	a. Variety b. Seed quality c. Techniques d. Weed management	a. Local or improved cultivars b. Old cultivars c. Conventional package and practices d. Hand weeding	a. Improved varieties b. Good in quality c. Improved package and practices d. Cono/rotatory weeder
Pulses/ Oilseeds	a. Variety b. Seed treatment	a. Local b. Lacking	a. Improved b. Seed treatment with fungicide and biological N_2 fixers
Vegetable and spice cultivation	a. Cultivars b. Seed c. Method of cultivation d. Manure & fertilizers e. Bioorganic	a. Local cultivars b. Uncertified seed c. Conventional methods d. Less than recommended dose	a. Improved cultivars b. Certified seed c. Improved methods d. Balance nutrition e. Organic management f. Protected cultivation
Fruits cultivation	a. Parental stock b. Training and pruning c. Fertilization d. Irrigation	a. Old and less production b. Not timely and regularly c. Below recommended dose d. Not properly	a. Improved and more production b. Timely and regularly c. Optimum dose d. Proper at certain interval
Livestock	a. Breed b. Feed c. Health management	a. Local b. Based on house hold waste c. Rarely	a. Cross breed and improved b. Quality feed c. Proper deworming and vaccination
Backyard poultry	a. Strain b. Feed c. Health management	a. Local b. Scavenging c. Rarely	a. Improved birds b. Quality and concentrated feed c. Proper vaccination d. Housing
Fishery	a. Fingerlings b. Pond liming c. Stocking density d. Feed e. Fertilization	a. Local b. Rarely c. Below stocking density d. Natural feed e. Raw cow dung	a. Improved b. Proper at certain interval c. Optimum stocking density d. Natural + Concentrated e. Fertilization and liming
Water management	a. Water harvesting unit b. Moisture conservation	a. Lacking	a. Jalkund/Farm pond b. Catch pit c. Contour trench d. Mulching
Land management	a. Land use practice b. Prevention of soil erosion	b. Lacking	a. SALT b. Terracing c. Half moon terracing
Income generating activities	a. Any enterprise	c. Lacking	A. Mushroom B. Value addition C. Bee-keeping

Integrated farming system has emerged as one of the important approaches of climate smart agriculture. To overcome the problems of resource poor farmers, a holistic, resource based, client oriented and interacting approach popularly known as integrated farming system (IFS) models were developed through participatory mode under different agro-ecosystems. Under the programme, all total five IFS were developed in Chandel (1), Churachandpur (1), Senapati (1) and Ukhrul (2) district. The models were developed following two approaches, first by utilizing the existing water body available with the farmers and second, by constructing water harvesting structure. The agriculture land located at the peripehery were used for crops and other components. The integrated farming systems developed at farmers' field with the adopted technology is presented in table below.

Name of the Participatory Farmers and Location	Components	Area (ha)	Water body (ha)
Shri A. S. Somi Nungshangkhong Village Ukhrul district Sub-tropical	Field crops (2 ha) + Horticultural Crops (3 ha) + Agro-forestry (2 ha) + Apiculture (10 hives) + Fish hatchery (1 unit) + Fishery (80 brooder) + Goatery (5 nos.) + Poultry (520 nos.) + Mushroom (1 unit) + Vermicomposting (1 unit) + Polyhouse (1 unit)	8	0.75
Shri R. D. Peter PurulAkutpa Village Senapati district Sub-temperate	Field crops (1 ha) + Horticultural Crops (1 ha) + Agro-forestry (10 ha) + Fishery (100 brooders) + Carp hatchery (1 unit) + Piggery (2 nos.) + Poultry (80 nos.) + Vermicomposting (3 unit) + Apiculture (2 hives) + Fruit processing (1 unit) + Polyhouse (1 unit)	13	1.00
Shri V. Tuime Lolly Kachai Village Ukhrul district Mild Sub-tropical	Field crops (2 ha) + Horticultural Crops (8 ha) + Agro-forestry (2 ha) + Fishery (100 brooder) + Piggery (10 nos.) + Dairy (5 nos.) + Poultry (80 nos.) + Sericulture (1 unit) + Vermicomposting (1 unit) + Fruit processing (1 unit) + Polyhouse (1 unit)	13	1.0
Shri Henkpao T. Champhai Village Mild tropical	Field crops (2 ha) + Horticultural Crops (1 ha) + Fishery (25 brooders) + Piggery (7 nos.) + Poultry (120 nos.) + Vermicomposting (1 unit) + Apiculture (2 hives)	4.0	0.20
Shri H. B. Starson ChandelKhullen Village Mild tropical	Field crops (1.25 ha) + Horticultural Crops (0.75 ha) + Fishery (80 brooders) + Piggery (14 nos.) + Poultry (60 nos.)	2.5	0.60

The performance of each models consisting of agri, horti, livestock, fisheries and secondary horticulture was evaluated for five consecutive years. The cropping intensity was increased up to 180 to 300% compared to 120% in traditional farming system. The farming intensity has also been increased 300 to 550%, as compared to 150-200% in traditional farming system. On an average, 380 to 550 days employment was generated as compared to 100 days in traditional farming system. The average net return of various farming systems was increased to the tune of Rs. 0.88 to 3.30 lakh per hectares over the traditional farming system (Prakash et al., 2015b).

Awards and Recognitions received by the farmers: The confidence of the farmers as well as ICAR team has increased when our beneficiary farmers were recognized at state as well as national level.

Awardee	Award	Conferred By
Shri V. Tuime Lolly Kachai Village Ukhrul	Jagjivan Ram AbhinavKisanPuraskar 2012	Indian Council of Agricultural Research, New Delhi
	Best Farmer Award 2015	Department of Horticulture & Soil Conservation, Govt. of Manipur
	Certificate of Recognition 2016	Indian Association of Soil and Water Conservationists, Uttrakhand
Shri R. D. Peter PurulAkutpa Village Senapati	Jagjivan Ram AbhinavKisanPuraskar 2016	Indian Council of Agricultural Research, New Delhi
	Innovative Farmer Award 2012	ICAR Research Complex for NEH Region, Meghalaya
	Best Farmer Award 2015	Department of Horticulture & Soil Conservation, Govt. of Manipur
	Certificate of Recognition 2016	Indian Association of Soil and Water Conservationists, Uttrakhand
Shri Henkpao T. Champhai Village Churachandpur	Best Farmer Award 2014	CAU North East Agri Fair 2014
	Best Farmer Award 2015	Department of Horticulture & Soil Conservation, Govt. of Manipur
	Certificate of Recognition 2016	Indian Association of Soil and Water Conservationists, Uttrakhand
Shri A. S. Somi Nungshangkhong Village, Ukhrul	Best Farmer Award 2014	Department of Agriculture, Govt. of Manipur
	Best Farmer Award 2015	Department of Horticulture & Soil Conservation, Govt. of Manipur
	Certificate of Recognition 2016	Indian Association of Soil and Water Conservationists, Uttrakhand

Sustainable development on our planet cannot be achieved without a major contribution from agriculture. People must be fed, and agriculture has to face the challenge of producing sufficient food for a rapidly growing world population whilst maintaining the world's fragile resources. Modern farming systems have evolved to meet this need in a way that combines the essential requirements of profitability and productivity. Sustainable development must encompass food production alongside conservation of finite resources and protection of the natural environment so that the needs of people living today can be met without compromising the ability of future generations to meet their own needs. Economic and ecological access to food could be only ensured by adopting farming system approach consisting of change from commodity-based to resource-based planning and integrated use and management of land, water and human resources to maximize income and employment. The primary goals of farming system is to maximize the yield of all component to provide study and stable income at higher level, rejuvenation of systems productivity and achieve agro-ecological equilibrium. Biotech stress management through natural cropping systems management and reducing the use of fertilizers and other harmful agro-chemicals to provide pollution free, healthy produce and environment to the society. Integrated farming system has the advantages of increasing economic yield per unit area per unit time, profitability, sustainability and provides balanced nutritious food for the farmers, pollution free environment and provide opportunity for effective recycling of one product as input to other component, money round the year and solve the energy, fodder, fuel and timber crisis, avoids degradation of forests and enhance the employment generation, increase input use efficiency and finally improve the livelihood of the farming community. Integrated farming systems have emerged as a well-accepted, single window and sound strategy for harmonizing simultaneously joint management of land, water, vegetation, livestock and human resources. A number of such illustrations can be given emphasizing the greater advantage of integrated farming system in generating technologies aimed at combating land degradation. It is this approach that can lead to a quantum jump in the productivity on a sustainable basis and ensure better livelihood securities to the people in fragile ecosystems. Hence, the future agricultural system should be reoriented from the single commodity system to integrated farming system for sustaining food and nutritional security.

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Diversified Farming Systems for Sustainable Livelihood Security of Small and Marginal Farmers for Chotanagpur Plaeatu Region of Jharkhand

M.S. Yadava, C.S. Singh*, R.P. Manjhi, Swati Sabnam, A. Adil and S.K. Singh

Department of Agronomy, Birsa Agricultural University, Kanke, Ranchi-834006 Jharkhand
Email:cssingh15@gmail.com

Introduction

Jharkhand state is a part of agro-climatic zone VII (Eastern plateau and Hill region) of the country. It occupies total geographical area of 79.72 lakh hectares. The farmers categorization based on their land holding revealed that almost 86% of the farmers of Jharkhand state belong to marginal and small category. The production level of agriculture, livestock and fisheries have remained low as the region faces multiple challenges i.e. low literacy level, low risk bearing ability due to poverty, lack of location specific production technologies, skewed distribution of operational holdings, natural calamities like floods, waterlogging and drought, imbalance nutrient use, low fertilizer consumption, poor farm mechanization, climate-change impact, non-remunerative prices and social constraints. Availability of sufficient man-power within the family, hard working ability and full time devotion for farming are considered as major strength of small farms. Eastern states have ample scope for increasing productivity by adoption of efficient secondary enterprises like animal husbandry, horticulture, apiary, mushroom cultivation, fisheries etc. to reduce risks associated with biotic and abiotic stresses. Such a change may help sustained and improved income, employment and standard of living besides providing diversified products to the market to the small and marginal farmers for chotanagpur plaeatu region of Jharkhand.

Methodology

One IFS model representing locally and eco-friendly conditions of small and marginal farmers in rain-fed situation of plateau region of Jharkhand was designed for 1 ha land holding to support a five member farm family. Selection of different enterprises in integrated farming system was based on the base line data available for Jharkhand state (Singh, *et. al.* 2005). It comprises of crops + livestock (cow) + fishery + apiary + recycling of farm wastes (vermicompost, FYM) + mushroom + boundary plantation of *Tephrosia spp.* + nutritional garden + water harvesting pond. Area allotted to different cropping sequences and different enterprises was to meet out the food and nutritional demand of the farm family as well as animals in the model. Out of 1 ha area of integrated farming system, 0.8 ha was given to crop components, under which five cropping systems viz. rice-wheat, maize+blackgram(1:2)-gram, maize+soybean (1:2)-mustard, groundnut- mustard and fodder sequence of maize+cowpea (1:1)- oat+berseem(1:1) were taken. An area of 0.059 ha was allocated for two cows (cross breeds-Holstein Frisian X Indigenous cow of Jharkhand) and 0.1 ha was assigned for water harvesting in farm pond. The harvested water (3000 cubic meter) was to be used for providing irrigation to the crops and for fish rearing. The rearing of Indian major carp fingerlings (*catla*, *rohu* and *mrigal*) was done with using cow manure in pond as fish feed. Fingerlings of 6-7 g size were stocked in the month of July as mixed farming in the ratio 4:3:3 of *catla*, *rohu* and *mrigal* @ 8000 to 10000 fingerlings/ha. Fishes were harvested in March-April every year. Mushroom unit was allotted 0.0145 ha and *Oyster* mushroom was cultivated from August to April. Vermi- compost unit was in 0.0265 ha area with earthworm species *Elusine foetida*. Five colonies of honey bee (*Apis melifera*) boxes were kept in the nutritional garden. The dykes or bunds of water harvesting pond were planted with *Tephrosia* spp., leaves of which were used as green manuring and for making vermicompost. Plants of papaya, banana, guava, and *Moringa* (drum stick) were also planted in nutritional garden and on bunds. Inorganic fertilizers were substituted by organic manures like vermi-compost and farmyard manure as per their availability from second year onwards, when their production started. Observations on the productivity and economics of individual components and the farming system as a whole, employment generation and nutrient recycling of different components in the farming system were recorded. Labourers engaged for activities in each enterprise were recorded in terms of hours everyday and then converted into man days /ha /day. Yield from all the components were converted into rice equivalent yield.

Results and discussion

Integrated Farming System model was initiated in 2011-12 with only crops and fishery components and become fully functional in 2013-14 with integration of all the agricultural enterprises i.e. crops, dairy, fishery, mushroom and apiary. Table-1 showed that addition of components in the integrated farming system enhanced the Rice Equivalent Yield (REY) of the system providing an opportunity to increase the economic yield per unit area per unit time as it facilitated better recycling of resources within the system along with reduction in the demand of external inputs used within farming system. Out of the different components of integrated farming system model, crops and livestock contributed major share to the total production. The different components of integrated farming generate continuous year round production at the farm in comparison of crop cultivation only which provides harvest produce once or twice in a year for the use of farm family.

Table 1: Production, profitability and employment generation through Integrated Farming System

Year	Production in terms of Rice Equivalent Yield *					Economics of the farm		Employment generation (mandays/year)
	Total Farm Production (t/ha)	Crop unit (t/ha)	Livestock unit (Milk + Vermi compost) (t/ha)	Fishery unit (t/ha)	Mushroom and apiary unit (t/ha)	Gross return (Rs/ha)	Net Return (Rs./ha)	
2011-12	4.99	4.63 (92.88)	-	0.36 (7.12)	-	62950	30019	112
2012-13	10.42	7.69 (73.75)	-	1.72 (16.48)	1.02 (9.78)	149299	108665	128
2013-14	19.03	7.54 (39.63)	7.15 (37.57)	2.58 (13.53)	1.76 (9.26)	324823	216717	356
2014-15	16.81	6.94 (41.30)	8.79 (52.28)	0.23 (1.36)	0.85 (5.07)	238682	82351	349
2015-16	15.97	7.14 (44.74)	6.44 (40.32)	0.71 (4.45)	1.68 (10.50)	239067	99063	379
Average	13.45	6.79 (40.68)	7.46 (44.68)	1.12 (6.70)	1.33 (7.95)	202964	107363	265

Figure in parenthesis represents the per cent contribution of enterprise in total production; *Based on price during year 2015-16.

Maximum gross as well as net return on the farm was achieved in 2013-14 when livestock component were included in the system, after that it decreased marginally which was mainly due to low milk and fish yield and collapse of apiary during 2014-15. However, the system as a whole provided opportunity to utilize the produce or waste material of one component as input for another component at no cost at the farm level. So, there is a possibility of reduction in cost of production of the enterprise with increased final return/rupee invested. In comparison of cropping system, which provides net income once or twice a year, the integrated farming system provided year round income, which enhanced farmer's capability for investment. During the initial years i.e. 2011-12 of integrated farming system the employment opportunities was quite lower as only crop and fishery enterprises were integrated in IFS. The employment generation enhanced in 2013- 2014 when all the enterprises becomes fully functional. The integration of crop with other farming system components increased the employment opportunities and generated enough scope to employ family labourers round the year (Singh and Singh, 2011).

Integrated farming system offers enough scope of resource recycling within the system and thus, lowers down the production cost of each component. The percentage share of inputs purchased from the market declined as more enterprises in the integrated farming system were added facilitating better recycling of resources and contributed a major fraction of percentage share of inputs generated and recycled within farm up to 27.38 to 39.3% (Table 2). The nutrient content of the manure increased manifolds after recycling into compost and vermin-compost. Nutrients recycled from cow manure were more in terms of rich population of planktons in the ponds for fish growth as well as nutrient rich irrigation water for crop growth and development. Integrated farming system provided an opportunity to increase the economic yield per unit time by intensification of cropping and integration of allied enterprises. Overall adoption of integrated farming system lowers down the production cost due to better recycling of resources produced within the farm which enhanced the net return and employment generation of integrated farming system. Thus, to improve the productivity, economic returns and employment generation for farm family, integrated farming system could be adopted instead of cultivating the crops alone especially by small and marginal farmers of Jharkhand state.

Table 2: Total Input cost and per cent share of the inputs purchased / generated and recycled within the system

Year	Total Input Cost (Rs.) (TIC)	Value of inputs purchased from market (Rs.) and its percent share in TIC	Value of Inputs (Rs.) generated and recycled within farm and its percent share in TIC	Number of Labourers engaged, annual expenditure on it and its percent share in TIC
2011-12	32932	17945 (54.49% of TIC)	-	112 man days amounting Rs. 14987 (45.51% of TIC)
2012-13	40634	22005 (54.15% of TIC)	-	128 man days amounting Rs. 18629 (45.85% of TIC)
2013-14	108105	48592 (44.95% of TIC)	-	356 man days amounting Rs. 59513 (55.05% of TIC)
2014-15	156676	33394 (21.3% of TIC)	61485 (39.3% of TIC)	349 man days amounting Rs. 61797 (39.5% of TIC)
2015-16	140074	30621 (21.87% of TIC)	38339 (27.38% of TIC)	379 man days amounting Rs. 71044 (50.74% of TIC)

Note: Calculation based on price of inputs during 2015-16.

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Designing Integrated Farming Systems in the Frame Work of Multi-Criteria Decision Making and Optimization Methodologies for Enhancing Resource Use Efficiency, Sustainable Development of Small and Marginal Farmers and Climate Resilient Agriculture

U.K. Behera

Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110012

Introduction

In order to meet the multiple objectives of poverty reduction, food security, competitiveness and sustainability several researchers have recommended to adopt integrated farming systems (IFS). IFS is an approach in which different land-based enterprises are integrated within the bio-physical and socio-economic situations taking farmers preference and goal in to consideration (Behera and France, 2016). This is a multi-disciplinary approach and very effective for solving the problems of small and marginal farmers (Gangwar, 1993). Under the gradual shrinking of land holding in India and other developing countries, it is necessary to go for IFS to make farming more profitable and sustainable. In agricultural research and development activities in India and other developing countries, the major emphasis is given to component and commodity based research projects. This research have proved largely inadequate in addressing the multifarious problems of small farmers (Jha, 2003). Due to this, there has been a demand for holistic approach for technology generation and dissemination. However, mechanisms are lacking to provide the whole farm picture or farming system model. Providing such a picture in the context of a farm or village or a region is a tedious process and difficult to calculate by human mind since number of factors are involved. Such problems can be overcome by the use of multi-criteria decision making and optimization methodologies approaches.

The research in IFS for the last few decades reveals that the enterprise planning and implementation needs scientific and systematic approach. In this situation, optimization techniques are useful for resource allocation and designing of IFS in a scientific basis (Mahapatra and Behera, 2004). Farming system studies involving a number of enterprises and taking the physical, socio-economic and bio-physical environments into consideration are complicated, expensive and time-consuming (Mahapatra and Behera, 2004). This is one of the reasons for slow progress of farming systems research in India and elsewhere (Jha, 2003). This problem can be overcome by construction and application of suitable whole farm models (Dent, 1990). Optimization models optimize the use of farm resources, and can analyse farm response to policy change in an effective way (Loucks et al, 1981). Among available, linear programming (LP) is one of the most applied solution methodology in agricultural planning to determine the optimal policy (Loucks et al., 1981) in single and multiple objective framework (Behera et al, 2015). In this paper different of multi-criteria decision making and optimization methodologies/techniques, which can help for optimal combination of the enterprises within the farming systems by taking farmers single and multi-objectives into consideration as well as an advanced modelling tool "MODAM" which has potentiality to integrate the environment and ecological goal with economic goal in the context of a farm/society or region are discussed briefly.

Integrated farming systems in single objective frame work

Decision making are the most important aspect of any business and industry. Farming is a business and agriculture is also an industry. Hence, decision making plays an important role with regard to the problems concerning production of commodities. The main questions before the producer or the production manager/farmer/entrepreneur are: (i) What to produce, (ii) How to produce, and (iii) How much to produce. LP is a modelling tool that can assist in the solution of many problems in agriculture with respect to above aspects. LP model are designed to "optimize" a specific objective criterion subject to a set of constraints, the quality of the resulting solution depends on the completeness of the model in representing the real system.

Integrated farming systems in multi-objectives frame work

In real world IFS situations farmers face the difficulty of considering several objectives simultaneously, which are conflicting in nature. In addition, farmers like to produce enough food for the farm family by utilizing his resources effectively. For this, compromise programming method can be effectively employed (Behera*et al*., 2008; Behera*et al*., 2014). Two multi-criteria programming techniques, goal programming and compromise programming (both variants of linear programming), were used in a study of small-scale dairy farms in central Mexico by Val-Arreola et al. (2006). Compromise Programming (CP) is used to provide more insight into the problem which caters multiobjective needs of the farmers. Linear and nonlinear programming methodologies can be employed in CP environment to draw different scenarios' for comparison. This enables in developing holistic model. Compromise Programming methodology has been demonstrated for designing integrated farming system and risk analysis (Behera*et al*., 2008; Behera*et al*., 2014).

Multi-objective decision support tool for agro-ecosystem management (MODAM)

There is a need for a modelling tool to analyse agricultural sustainability as a combination of economic and ecological objectives. This model should be able to: (i) simulate effects of political and economic conditions on decisions about agricultural land use at farm level; (ii) screen current and new production technologies in a standardised form and show their effects on defined indicators of sustainability; and (iii) allow economic and ecological evaluation of production techniques at regional scale, including trade-offs among ecological and economic goals with respect to one farm or to a group of several farm types (regional approach). Keeping above aspects in to considerations, a powerful bio-economic modelling tool was developed at ZALF, Germany (Zander and Kachele, 1999). In the bio-economic model MODAM, several farms are aggregated to regional model to evaluate the effects of different protection strategies and the methodology of developing region-farms. Model allows to draw different scenarios of agronomic and ecological and political decision making. MODAM is an interactive modelling system, generating trade-off functions between ecological and economic objectives and helpful from the points of view: (i) interactive experimentation (ii) it allows analysis of the maximum goal achievement possible under given conditions (iii) trade-off functions will show areas where a small decreases in achievement of the goal leads to much large realisation for another goal (iv) sensitivity analysis of the model will show where further research is necessary ; and (v) scenarios of different conditions will help political decision makers to identify the most efficient instruments to realise the desired goal achievement in practise. The Model shows hierarchical linkage between the economic and ecological parts of the model. Where maps in the geographical information system (GIS) are available, the result of the model in the form of crop rotations and their technical, economic, and ecological coefficients can be transferred to the GIS for the graphical presentations (Wossink et al., 1992). The model is based on the multiple goal linear programming approach. It consists of five levels of the hierarchically linked modules. The first level of the modules generates the technical coefficients, second level calculates economic coefficients of site-specific production techniques. The third evaluates the ecological effects of these production techniques, and the fourth generates the linear programming model. The fifth level starts the subprogram which solves the equation system, analyses the results and prepares the transfer of data to the Geographical Information System.

Agriculture Extension in 21st Century Agriculture and role of optimization

In extension and developmental programmes in most of the developing countries, the respective agencies generally go to farmers and give a variety of advice in disciplinary line and commodity approach in an ad hoc manner. In the context of present challenges to make small farms profitable, it is necessary to place an overall scenario with a system and holistic approach for farm income and employment generation and other associated benefits. This will motivate the farmers towards farming. Placing such pictures before farmers will aid their confidence to adopt new technologies in an integrated manner for enhancing farm income and sustainability. Research programme must acknowledge current concerns on poverty elimination, food security, environment, equity gender and sustainability.

In south Asia and other developing regions, the national agricultural research systems (NARS) are dominated by a disciplinary and commodity approach, which does not allow the desired agricultural growth and development of small and marginal farms. For the sustainable development of these farms, the whole systems approach is needed. These countries are struggling for the holistic development of their small farms and the war against poverty and hunger. Now, the question arises –

can they win the war against poverty and hunger with using old and perhaps obsolete weapons such as the transfer-of-technology model (TOTM), the farmer-back-to-farmers model (FBFM) and farmers-first-and-last model (FFLM). For development of small and marginal farmers in south Asia and other developing regions two aspects are very important : (i) optimization of enterprise/activities to achieve farmers objectives and (ii) optimization of scare resources among the competing enterprises/activities to make production/farming systems sustainable and climate resilient. Both these aspects are weak in NARS. Enterprise combination and resource allocations is based on adhoc approach and lack scientific approach. In this situations, agriculture extension in 21st century agriculture should revolves around optimization.

Entrepreneurship and role of optimization tool

Major part of economic development of a nation depends primarily on the entrepreneurs (Udyogpati). That is why, our country puts lot of emphasis to convert many subsistence farming to entrepreneurs by introducing new skill and creativity. In India, large number of people are seeking entrepreneurship (Udyog) as a career option. Large number of rural youth are getting attracted to entrepreneurship in agriculture and planning to set-up their own business ventures. Entrepreneurs make very conscious decisions regarding resource allocations for high commercial gains. He is often struck with the decision for trade-off between competing enterprises. Under the situations, optimization tools help the entrepreneur/manager to take decision for management of enterprise on scientific basis.

Conclusion

In extension and developmental programmes in most of the developing countries, the respective agencies generally go to farmers and give a variety of advice in an ad hoc manner. In the context of present challenges to make small farms profitable, it is necessary to place an overall scenario for farm income and employment generation and other associated benefits before the farmers in order to motivate them towards farming. Placing such pictures before farmers will aid their confidence to adopt new technologies in an integrated manner for enhancing farm income and sustainability, Research programme must acknowledge current concerns on poverty elimination, food security, environment, equity gender and sustainability. Bio-economic modelling and optimization methodologies can prove as a potential approach for providing the whole farm picture/model by considering economic and ecological consequences. MODAM is an instrument that can serve to mediate in conflicts among competing groups of land uses, by generating information about economic and ecological effects of the particular decisions. The modular structure permits linkage of additional economic and ecological modules and facilitates inclusion of the new scientific knowledge. This will be useful for interdisciplinary research.

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Effect of Nano-Nutrients on Plant Growth, Yield Attributes and Fruit Quality of Sikkim Mandarin

Ashish Yadav, R. K. Avasthe, Subhash Babu, Avinash, Adarsh Kumar,
Rajeni Pradhan, Sujata Rai and Zangmit Lepcha

ICAR-National Organic Farming Research Institute (formerly ICAR RC NEH Region, Sikkim Centre), Tadong, Gangtok – 737 102, Sikkim

Email: 2005ash@gmail.com

In Sikkim, mandarin is cultivated in an area of about 12,380 ha with annual production 16,798 tonnes and productivity is 1,356 kg/ha which is very less when compared with other states. Sikkim mandarin is considered as highly nutrient responsive crop and to improve the production and productivity under organic management requires large quantities of FYM and organic fertilizers which shall be very difficult to meet the complete nutrient requirements. Researchers also reported that fertilizer absorption efficiency of soil application methods is about 10% and root absorbed nutrients moves @ 01 ft/hr to the all parts of plant. Nano nutrients technology is an innovative strategy to improve the fertilizer use efficiency up to 95 per cent as compared to conventional soil application methods. Nano nutrients are cheap and required in very less quantity as 100-200 ml/acre in the form of foliar spray. Nano nutrients have unique feature like ultra-high absorption, increase of 20% to 200% in production, rise in photosynthesis by 3.5 times and a 70% expansion in the leaves surface area. Nano fertilizers are nutrient carriers of nano dimensions ranging from 30-40 nm (10^{-9} m) and capable of holding bountiful of nutrient ions due to their high surface area and release it slowly and steadily that commensurate with crop demand. Keeping this in view, the present study was conducted to evaluate the nano nutrients as alternative nutrient sources, which requires in less quantity and should be able to meet the nutrient requirements of Sikkim mandarin for improving the production and productivity. Moreover, the foliar spray of nano nutrients/fertilizers is environmentally sound due to their organic base (silica). The nano nutrient formulation, encompasses five macronutrients *viz*., phosphorus, potassium, calcium, magnesium, sulphur and seven micronutrients *viz*., iron, manganese, zinc, copper, cobalt, boron and molybdenum, loaded onto a nano silica base were sprayed on Sikkim mandarin in various concentrations at different growth stages of 05 years old Sikkim mandarin plants grafted on different rootstocks. Nano nutrient formulation @ 2 ml per litre sprayed at 45, 90 and 135 days after fruit set reduces fruit drop significantly as compared to control. Maximum fruit set (206 no.), fruit length (54.81 mm), fruit width (61.97 mm) and highest per cent fruit retention (72.02%) was recorded in Sikkim mandarin grafted on Rangpur lime (SM+RgLi) followed by Rough lemon (SM+RLe) (65.26%). The per cent fruit retention in Sikkim mandarin grafted on Grapefruit (SM+GF) (63.68%) was at par with Rough lemon. The best time of nano nutrient spray was found between 9-10 am, when most of the stomata were open. Nano nutrients formulation @ 2 ml per litre also showed significant effect on various fruit quality parameters. The SM+RgLi showed maximum (11.8 °Brix) TSS followed by SM+RLe (11.2 °Brix), however, control showed minimum (8.0 °Brix). Acidity was minimum (1.44%) in SM+RgLi and highest (2.89%) in SM+GF. Total sugar and Sugar: Acid ratio was significantly higher in SM+RgLi as compared to control. The ICP-MS analysis of fruit samples also showed that nano nutrient applications significantly influenced change in the concentration of various nutrients in Sikkim mandarin.

Rice-Fish Farming Systems in *Apatani* Plateau of Arunachal Pradesh: A Review

Deepjyoti Baruah, K. Kunal, R.S. Tandel, D. Sarma and A.K. Singh

ICAR-Directorate of Coldwater Fisheries Research, Bhimtal-263136, Uttarakhand
Email: deep_baruah@rediffmail.com

Rice-fish farming has been a heritage practice for the *Apatanis* in the Ziro valley of Arunachal Pradesh sustaining upon natural resources viz., land, water, rice varieties, fish species and indigenous knowledge. This paper is a review of the traditional expertise in the management of inimitable rice-fish farming of the valley and analyses the principles underlying the success of this system in fragile eastern Himalayan region of India. A survey conducted to collect data from randomly selected farmers of 7 villages of Ziro valley also determines the validity and reliability of the results. The rice-fish farming system as part of integrated ecosystem holds distinctive for its wet rice terraces with intrinsic fish trenches, dyke raised finger millets and finely apt bamboo plantations and pinewood thicket at the periphery to avoid soil erosion and conservation of forest together with intricately linked irrigation channels. Common carp (*Cyprinus carpio*) is the most preferred fish in the system cultivated with 16 indigenous landraces of rice varieties. The system assures improved rice and fish productivity than rice mono-crop, yielding 3-5 tons of rice and 200-500 kg fish per hectare per year. Furthermore, conserving this indigenous agro-culture has been meaningful to exploit rice-fish farming as eco-tourism resources for the mountainous farmers.

Keywords: *Rice-fish, tradition, indigenous, Apatani, Ziro valley, Arunachal Pradesh*

Organic Management of Insect Pests in Storage Maize

H. Kalita[1], R. Gopi[2], R.K. Avasthe, Subhash Babu[3] and B. Lepcha

ICAR-NOFRI, Tadong, Gangtok-737102
[1]ICAR AP Centre, Basar-791101
[2]ICAR-Sugarcane Breeding Institute, Coimbatore
[3]ICAR Research Complex for NEH Region, Umiam

Five non-edible substances *viz*., neem oil, lemongrass and petroleum based horticultural oil @ 7 ml/kg of grain, spinosad 45 SC @ 0.1% solution and parad tablet @ 1 tablet/kg were evaluated for their efficacy as seed/grain protectants against weevils and Angoumois grain moth in maize in storage. It was observed from the study that among five treatments, spinosad 45 SC @ 0.1% was found to be effective to reduce the population of insects (94.37% adult mortality 7 days after treatments) keeping germination per cent intact (92.50% after 6 months of treatment) followed by parad tablet (adult mortality 60.62% and germination 87.50%). Though the adult mortality was maximum in lemongrass oil treated seeds (95.62%) with less growth of population (3.25 adults after 6 months) but it has effect on germination per cent of seed (27.50 % after 6 months). In case of grain

moth grain damage % was recorded minimum in lemon grass oil (1.75% after 3 months and 8.25% after 6 months) and spinosad treated seeds (1.75% after 3 months and 7.25% after 6 months of storage) but lemon grass oil negatively affected the germination per cent of seeds (32.5 % after 6 months). Spinosad 45 SC @ 0.1% was found to be effective to reduce the infestation of seed/grain retaining the germination per cent (95.00 % after 6 months of treatment) followed by parad tablet (12.5% and 18.5% grain damage after 3 months and 6 months, respectively) and germination % (88.75%). Among five locally available botanicals *viz*., Angeri (*Lyonia ovalifolia)*, *Lantana camara, Artemisia vulgaris*, Karkus (Vernacular-Nepali) @ 10 g powder/kg and lemon grass @ 10g dry leaves/kg evaluated for their efficacy as seed/grain protectants against weevils in maize in storage, adult mortality was maximum in Karkus treated seeds @ 10 g/kg (31.25%) with less population growth (9.25 adults after 6 months) followed by Angeri (*Lyonia ovalifolia*) @ 10g/kg (26.25% adult mortality and 12.25 adults emerged after 6 months) retaining the germination per cent (92.50% after 6 months of treatment in case of Karkus and 95.00% after 6 months of treatment in Angeri). Similar result was observed in case of grain moth. The efficacy of the treatments was slightly lower in muslin cloth bag in comparison to container

Bioprospecting of Native Actinobacteria of Manipur for their Plant Growth Promoting and Anti-fungal Activity

Pintubala Kshetri, S.S. Roy*, S.K. Sharma, M.A. Ansari, Ch. Premabati Devi, Thangjam Surchandra Singh, N. Prakash and S V. Ngachan

ICAR Research Complex for NEH Region, Manipur Centre, Imphal

Actinobacteria constitute one of the largest phyla among *bacteria* and represent gram-positive bacteria with a high G+C content in their DNA. They also act as good decomposers through secretion of many extracellular hydrolysases. In this present study twelve actinobacterial strains were isolated from rhizospheric soil of tomato from Manipur, India. All the strains were screened for plant growth promoting (phosphate slubilization, IAA, ammonia and siderophore production) and anti-fungal traits (against three fungal pathogens namely *Fusarium oxysporum*, *Rhizoctonia solani* and *Pyricularia oryzae*). All total nine isolates exhibiting plant growth promoting (PGP) or biocontrol activity or both were identified as *Streptomyces* sp. by partial 16S rRNA gene sequencing. In the present study, eight strains viz. RCM-SSR-1, -2, -5, -6, -8, -11, -12 and -14 were found to be positive for phosphate solubilization. All the strains could produce ammonia; whereas, ten strains namely RCM-SSR-1, -2, -3, -4, -5, -6, -8, -9, -11 and -12 could produce siderophore. Maximum IAA production was observed with RCM-SSR-6 (36.3±2.1 μg mL^{-1}) followed by RCM-SSR-11 (25±0.2 μg mL^{-1}), SSR-RCM-8 (22.0±2.0 μg mL^{-1}) and RCM-SSR-5 (21.5±0.8 μg mL^{-1}). In anti-fungal screening, the strains RCM-SSR-1, -2, -5, -6, -9 and -11 showed antagonistic activity against the three fungal pathogens. Maximum colony growth inhibition (67%) of *Fusarium oxysporum* was achieved with RCM-SSR-5; followed by RCM-SSR-6 and -11 (62%). Up to 60% inhibition in colony growth of *Pyricularia oryzae* was noticed in RCM-SSR-5, -9 and -11; whereas, RCM-SSR-9 inhibited colony growth of *Rhizoctonia solani* to the tune of 61%, followed by RCM-SSR-2 (60%). Considering both plant growth promoting and anti-fungal activity, five strains namely, RCM-SSR-2, -5, -6, -9 and -11 were found to be most promising which showed an opportunity for developing a unique microbial formulation which can act as both biofertilizer or biopesticides.

Keywords: *Actinobacteria, Phosphate slubilization, IAA production, Fusarium oxysporum, Rhizoctonia solani, Pyricularia oryzae*

Influence of Substrates on Nutrient Status and Microbial Dynamic during Vermicomposting

P. Debnath*, S.K. Pattanaaik, D. Sah, P. Heisnam, B. Singh, and A.K. Pandey

College of Horticulture and Forestry, CAU, Pasighat, 791102, Arunachal Pradesh
Email: kanupran@yahoo.co.in

An experiment was carried out to study the effects of different locally available substrate on dynamics of nutrients as well as potentiality of phosphate solubilizing microorganism during the vermicomposting process. Composting of substrates resulted in the lowest organic carbon with narrow C : N ratio. The highest rate of mineralization of carbon was observed in the treatments T_3 (Rice straw + Cowdung + Soil: 9:3:1) during the vermicomposting. Process of vermicomposting causes an increased in the level of nitrogen, phosphorus and potassium. The highest level of total nitrogen (1.98%), available phosphorus (2.33 %) and available potassium (4.05%) were recorded in treatment T_5 (Banana Pseudo stem 50% and Rice Straw50% +Cowdung + Soil: 9:3:1) which is at par the treatment T_2 and T_3 at 90 days of composting. The lowest values of potassium were estimated under treatment T_2 (Mustard straw: Cowdung: Soil: 9:3:1) and available phosphorus under treatment T_7, respectively. Increased in the population of phosphate solubilizing microorganism, lignolytic and cellulolytic microorganism and phosphate solubility power also observed during vermicomposting process. The highest populations of phosphate and lignolytic microorganisms were found at the 90 days of maturation of composting in all treatments, whereas, cellulolytic microbes showed its maximum population at 60 days of composting process. Both phosphate solubilising microorganisms and phosphate solubility power showed maximum value in the treatments T_5 and lowest under treatments T_1. Admixture of banana pseudo stem, rice straw along with cowdung and soil in the ratio of 9:3:1 showed best performance in nutrients content as well as microbial population during vermicomposting. However, the lowest no. of days recorded in T_1(90 days) to obtained the maturation of composting, which is followed by $T_4<T_5<T_7<T_2<T_6$:: 95<97<101<104<106.

Keywords: *Vermicomposting, nutrients level, phosphate solubilizing microorganism, phosphate solubilizing power*

Traditional Food of Mishmi tribe of Anjaw - Arunachal Pradesh

Senpon Ngomle, Rebecca Eko and M.Kanwat

KVK Anjaw, ICAR AP Centre, Basar
Email: sngomle29@gmail.com

Many traditional belief and knowledge are in the verge of extinction; the younger generation are changing their food habit and consuming more readymade or fast food items. In the hilly and remote areas of Arunachal Pradesh, the tribal people still practice traditional foods preparations which are rich source of nutrients. Hence, a study was conducted among Mishmi tribes of Anjaw district, Arunachal Pradesh to document and conserve their food habit and the preparation of their popular traditional cuisines. The district is inhabited by two sub tribe of Mishmi clan i.e. Digaru mishmi and Miju Mishmi. The study demonstrates that Mishmi tribes prepare different types of traditional foods i.e. Chambai, Chika (Miju) or Tekka (Digaru), Bongsiyat (Miju), Nabuhua / Deuhua/Yuhua (Digaru) etc. Among all the cuisines, Chambai is the most preferred one. This food items are not only rich in nutrition but also plays a significant role in their cultural practice. It is consumed with pleasure during festive season and celebrations. The tribal people living in close proximity with nature have varied knowledge about the edible plants which they use and are also reflected in their cuisine, hence have made possible the conservation of indigenous biodiversity.

Effects of a Few Botanicals and Microbial Bio-formulations on Seed Quality of Stored Black Gram (*Vigna mungo*) seeds

Surabhi Datta*, T. Medhi[#], S. D. Deka[#] and L. C. Bora**

**Department of Plant Breeding and Genetics (Seed Science and Technology)*
*[#]National Seed Project (Crops), ** Department of Plant Pathology*
Assam Agricultural University, Jorhat- 785013
Email: surabhidatta19.sd@gmail.com

Black gram (*Vigna mungo*) is the fourth important pulse crop in India, which has been originated in the country and in cultivation from ancient times. Due to the tropical and humid climate of India, storage of black gram seeds till next sowing season is the most severe problem, with an average damage percentage of nearly 14.97 under storage conditions. Since, pre-storage seed treatment is very important to keep the seed quality good up to next season, the present investigation was intended to study the effect of a few botanicals and bio-agent formulations on the seed quality status of stored black gram seeds. The seeds were treated with three botanicals *viz*., Turmeric powder, Neem leaf powder and Black pepper powder and with two bioagent formulations *viz*., Biogreen and Biotime. Different seed quality parameters like moisture content, germination percentage, seedling vigour index and field emergence were observed initially just before the treatment and at an interval of two months up to nine months (270 days) of storage. At the end of nine months of storage, lowest moisture content was observed in Turmeric powder treated seeds (8.90 per cent). Highest germination (78.67 per cent) and seed vigour index (1517.63) were observed in the seeds treated with Black pepper powder which were at par with those of Neem leaf powder treated seeds and Turmeric powder treated seeds. Field emergence after nine months of storage, was highest in seeds treated with Neem leaf powder (75.33 per cent) followed by seeds treated with Turmeric powder (73.51 per cent) and Black pepper power (72.41 per cent). The seeds treated with bioformulations showed low germination as well as low seedling vigour throughout the storage period. The present findings revealed that the seeds treated with botanicals had good effect on the seed quality and can be used as an alternative of chemicals in pre storage seed treatment.

Economics of Fish cum Piggery and Fish cum Poultry Farming in West Siang District of Arunachal Pradesh

D. Datta [1], M.S. Baruah [2], C.S. Raghav [3], H. Kalita, [4]

[1]ICAR-KVK, West Siang District, Arunachal Pradesh
[2]ICAR-RC for NEH Region, Arunachal Pradesh Centre
Email: ddatta1988@gmail.com)

West Siang district is one of the biggest districts (8325 sq. km) of Arunachal Pradesh of India. Though agriculture is the primary livelihood of the people of this district, it is practiced in integrated manner with fish and livestocks. Fish cum poultry and fish cum piggery are common integrated farming system practices in this area and very effective for enhancing income along with water productivity per unit area. A study was conducted for three years (January, 2015 to July, 2017) in 24 nos. of randomly selected farmers' field situated under the latitude N 28^0 to longitude 94^0 to estimate the economics of fish cum poultry and fish cum piggery units. The average fish pond size was recorded 400 sq. m with 1.5 m depth. Fish varieties namely, Rohu (*Labeo rohita*), Silver carp (*Hypophthalmichthys molitrix)* and Grass carp (*Ctenopharyngodon idella*) were selected for composite fish culture which was integrated with pigs (*Hampshire*-local cross) and poultry

(*Vanaraja*). The study revealed that 400 fingerlings can produce 390±2.1 kg fish per unit water body area per year in the fish cum pig system while in the fish cum poultry system the fish production was 330±2.1 kg. Amongst the fish varieties tasted, Silver carp growth was fast (1.7±2 kg) followed by Grass carp (1.4±1 kg) and Rohu (1.2±0.5 kg). It was also found that the benefit cost ratio of fish cum poultry is higher (2.3) than that of fish cum pig system of farming (2.1).

Insecticidal Potential of Bamboo-leaf Prickly Ash (*Zanthoxylum armatum*) Extract against Army Worm, *Spodoptera litura* (Fabricius) (Lepidoptera: Noctuidae)

G. Kaleeswaran[1], D. M. Firake[2], R. Sanjukta[2], G. T. Behere[2] and S V Ngachan[2]

[1]*College of Post Graduate-Studies (Central Agricultural University), Umiam-793103, Meghalaya*
[2]*ICAR Research Complex for NEH region, Umiam-793103, Meghalaya, India*
Email: dfirake@gmail.com

Bamboo-Leaf Prickly Ash, *Zanthoxylum armatum* (Rutaceae) is a versatile and widely distributed plant species in the nature. It is an edible plant species, commonly used in daily life as condiments and for therapeutic remedies. Besides bioactive and medicinal properties, different plant parts of the *Z. armatum* are believed to have insecticidal potential, however, it has not been yet determined against many agricultural pests, including most destructive Oriental Army worm, *Spodoptera litura* (Lepidoptera: Noctuidae). In this framework, we demonstrated for the first time the insecticidal potential and sub-lethal effects (including antifeedent and ovicidal action) of various fractions of pericarp, leaf and seeds of *Z. armatum* against *S. litura*. All the experiments were conducted at Entomology section of Division of Crop Protection, ICAR Research Complex for NEH Region, Umiam, Meghalaya by standard protocols. Overall findings revealed that, the n-hexane pericarp extract of *Z. armatum* has strong antifeedent, ovicidal and larvicidal properties against *S. litura.* Sub-lethal doses of pericarp extract can negatively alter the biology of *S. litura.* The LC_{50}'s of the n- hexane fraction of pericarp was found to be 0.179% and 0.209%, respectively against 2nd and 3rd instar *S. litura* caterpillars by contact at 72 hours; which are comparatively lesser than Azadirachtin 0.15EC (positive control). When the 2nd instar larvae of *S. litura* were topically treated with sub-lethal dose viz., LC_{10}, the significant variations were observed in larval and pupal weight, their duration, % pupation and adult emergence in *S. litura.* The weight of fourth instar caterpillar and pupa was significantly reduced in the treatment (0.54±0.02g and 0.29±0.02g, respectively); whereas the duration of larval and pupal stage was considerably extended in treated larvae (25.83±1.01 days and 17.33±0.6 days, respectively) compared to untreated control. About 69.44±2.6% treated larvae were successfully pupated; from which 79.67±2.9% could produce healthy adults. Since n-hexane extract of leaves also has better larvicidal properties, it could be utilized for the *S. litura* management during period of unavailability of fruits (or pericarp). Accordingly, the *Z. armatum* pericarp and leaf extract has tremendous potential for its commercial utilization for the management of polyphagus pests like *S. litura* and other related species; which are quite difficult to manage even by chemical pesticides.

Livelihood Improvement of Tribal Farmers through adoption of Integrated Organic Farming System in Mid-hills of Sikkim

Raghavendra Singh, R.K. Avasthe, Subhash Babu, Boniface Lepcha, J. K. Singh, N. J. Singh, P.K. Pathak and Pallabi Phukan

ICAR-National Organic Farming Research Institute, Tadong, Gangtok-737 102

Sikkim a small hilly state in the Eastern Himalayas with almost no flat land, this entirely mountainous state has altitude range of 300-8598 m above mean sea level constitutes 0.22 percent of total geographical area with 0.05 percent population (6.11 lakh) of India. It is estimated that more than 70 per cent of rural population depends on agriculture and allied sectors for economic, food and nutritional security. The majority of the farmers of the district fall in small and marginal category. Nearly 27.1 per cent tribal population is living in the East Sikkim district. To improve the livelihood security of rural tribal population through Integrated Organic Farming System (IOFS) apparoch a small tribal village Timpyem of 44 farming families with total population 161 persons (male: 54.03%, female: 45.96%) was identified in East district located at 27^{o}33’94” N Latitude and 88^{o}60’29” E Longitude for implementation. The fesible technological interventions in Integrated Organic Farming System (IOFS) under Tribal Sub Plan were demonstrated in participatory mode by the ICAR-NOFRI and KVK-East Sikkim, Ranipool, East Sikkim during 2014-16 in order to enhance the cropping intensity, productivity and profitability of the villagers as well as of the state. With the assistance of Tribal Sub-Plan, technological interventions were detailed by providing training, on field demonstrations and inputs support. Various inputs/interventions were provided under the project with the purpose of reorienting their traditional farming into integrated organic farming system (IOFS) to increase the farm income. Systamatic study was done at one progressive tribal farmers in the village. The area of 0.3 ha was allocated to the rice-based cropping systems and 0.1 ha area allocated to the maize based system. While fulfilling the vegetable requirements 0.05 ha area provided to the year round vegetable cultivation in low cost poly tunnel. 50 nos. of vanaraja chicks has been given for backyard poultry. Livestock components (1+1) were their own under the IOFS modal. The two years data on the all the compnents were analysed and found that the profitability of the system was Rs. 299/day with a B:C ratio of 2.03. The net energy output was 74.4× 10^3 MJ with 236 man day employment generated fron the 0.5 ha modal under IOFS.

Integrated Farming System: an Approach for Enhancing Food and Livelihood Security of Hill Farmers

Subhash Babu*, Anup Das, M. Thoithoi Devi, Jayanta Layek, G.S. Yadav L.L. Srivastava, Moutusi Tahashildar and Lotika Kalita

ICAR Research Complex for NEH Region, Umiam
Email: subhiari@gmail.com

Majority of the rural populace of North Eastern Region of India are depends on agriculture for their livelihoods. Farmers of the region are cultivating one/ two crops in a year and mainly emphasized on their traditional ways of cultivation, it results in soil degradation, poor land and crop productivity, low employment generation and income. Though, some of the farmers are practicing farming system in their field but they have only few components with poor complimentary interaction results in under/ over utilization of natural resources with poor land and crop productivity. Therefore, the farmers are not getting consistent employment and income which forces them to leave the less/nonproductive agricultural activities. In this situation, Integrated Farming System is the only option to doubles the farmer's income and employment without affecting the natural resource base. In this connection ICAR, Umiam has developed a farming system model under AICRP-IFS for one ha area, out of which 7000 sq m area was allotted to agri/vegetable based cropping system, 2000 sq m under horticultural fruit crops and 500 sq m under water harvesting pond for fish cultivation. And rest of the area is kept for vermicompost and livestock components. Results showed that in totality, the IFS model generate a net income of Rs. 1, 66,424/- with monthly saving of Rs. 13869/- as well as 691 man days of annual employment. Among the various farm enterprises, the maximum net returns of Rs. 107746/- was recorded with cropping system followed by livestock (Rs. 51219/-), horticulture and fisheries, respectively. Besides that 8.6 t biomass was also recycled in IFS model for supplying the crops component nutrients demand. Pond dyke intensification an innovative idea also adopted in the IFS for proper utilization of space and water available in the water harvesting pond. Pond dyke intensification provides an addition income of Rs 4970/-. Finding on energy dynamics in integrated farming system showed that among the various component of IFS, cultivation of agricultural crops was found more energy efficient (39% EUE) followed by livestock. In totality, the improved IFS model is about 33% more energy efficient than the farmers practices of the region and having great potential to enhance the livelihood security of small and marginal farmers of Meghalaya. Thus, the study suggested that integration of various enterprises in IFS in complimentary mode may be recommended for enhancing the farm income for livelihood security of small and marginal farmers of North Eastern region.

***Keywords*:** Integrated Farming System, Income, Livelihoods, North East India

Impact of Long-term Organic Management Practices on Crop Productivity and Soil properties in North Eastern Hill Region, India

Utpal Dey, Jayanta Layek, Ramkrushna GI, Subhash Babu, Dauni Suting, Krishnappa R, M.Thoithoi Devi, Ramesh T and Anup Das*

Email: anup_icar@yahoo.com

Field experiments were conducted at Agronomy lowland farm (950 msl), ICAR Research Complex for NEH Region, Umiam, Meghalaya with an aim to find out the impact of long-term organic management practices on crop productivity and soil-properties under different cropping systems since 2005. A total of 4 management practices [NS1: 75% organic + innovative practice (10% vermiwash and 10% cow urine), NS2: 100% organic, NS3: Integrated management (50% inorganic + 50% organic) and NS4: 100% inorganic] and 4 cropping-sequences (CS_1: Broccoli-carrot, CS_2: Broccoli –potato, CS_3: Broccoli -French bean and CS_4: Broccoli -tomato) were tested in strip plot design under three replications. After 12 years of experimentations, the results revealed that, 100% organic (3.31%) management practice recorded maximum soil organic carbon (SOC) followed by integrated (3.20%) as compared to 100% inorganic and 75% organic. Available nitrogen (N), phosphorus (P) and potassium (K) increased under all the management practices relative to initial value. Maximum available N and P was observed under 100% organic (259.6 and 22.8 kg/ha, respectively) whereas, maximum K was observed under integrated management (292.2 kg/ha). In case of cropping systems, available N, P and K were found maximum under CS_3: Broccoli -French bean (258.7, 21.9 and 285.1 kg/ha, respectively) followed by CS4: Broccoli –Tomato. Soil microbial biomass carbon (SMBC) was maximum under 100% organic (184.7 µg/g dry soil) followed by 75% organic and integrated as compared to inorganic treatment. The highest carrot and potato yields (15.74 and 16.33 t/ha, respectively) were recorded under integrated management practice followed by 100% organic. However, in French bean and tomato, the highest yield (9.87 and 17.65 t/ha, respectively) were recorded under 100% organic management practice. Yield of carrot under 100% organic was statistically at par with integrated as well as inorganic management practices. However, yield of potato, French bean and tomato under 100% organic was significantly superior to inorganic management practices.

Key words: *Cropping Systems, Nutrient Management Practices, Yield, Organic Food Production*

Soil Organic Carbon Dynamics and Fertility in Response to Organic Nutrient Sources under Maize based Cropping System

Shaon Kumar Das, R. K. Avasthe, Ashish Yadav, R. Singh and M. Singh

ICAR-National Organic Farming Research Institute, Tadong, Gangtok, Sikkim-737102
Email: shaon.iari@gmail.com

Soil organic carbon is an important index of soil fertility because of its relationship to crop productivity. For instance, declining SOC levels often leads to decreased crop productivity. Thus, maintaining SOC level is essential for agricultural sustainability. The importance of SOC has increased interest and research on its build up in the soil–plant system with current emphasis on conservation tillage. In general, there is a positive relationship between SOC and crop productivity. High SOC usually results in high crop yield and biomass. Consequentially, high biomass would lead to more organic carbon input into soils thus enhanced carbon storage as SOC. Hence, SOC management would provide *win–win* benefits for both food security and climate mitigation. SOC levels increase under practices of balanced fertilization, organic amendments, cropping rotations, conservative tillage, and reduced fallow. In addition, improved farming practices, including the use of organic fertilizers, conservation farming practices, etc., can increase crop yields, reduce GHGs emissions, and enhance soil organic carbon (SOC) storage

Field experiment was conducted on clay loam soil during three consecutive years 2014-16 (pre-*kharif*) to evaluate SOC dynamics and fertility status in maize based cropping system. Five treatments, *viz*., T_1, control; T_2, 75% N through FYM + green manure; T_3, 50% N through FYM + 25% VC + GM ; T_4, 33% N FYM + 33% N VC + GM; T_5, 25% N FYM + 25 % N VC + 25% N poultry manure + GM were laid out in FRBD design and replicated thrice. Initially the soil had 0.79% organic carbon, 193.2, 13.3 and 403.2 kg/ha available N, P and K, respectively with pH 6.2. The three year pooled analyses showed that T_4 resulted in highest grain yield for RCM 1-3 (3.87 t/ha) and RCM 1-76 (4.21 t/ha). Application of different sources of organic nutrients reflected improvement in SOC (initial value 0.79% to final 0.86%). T_4 registered significantly higher available N, P and K content in soil as compared to other treatments. The grain and stover yield were influenced significantly due to varying fertility levels in different treatments. The varying fertility levels significantly influenced the plant height and dry matter accumulation at all the stages of crop growth. At all the fertility levels the plants were taller with more dry matter accumulation/plant as compared with the control at all growth stages. The higher available nitrogen, phosphorus and potassium in T_4 could be due to increased activity of micro-organisms leading to greater mineralization of applied and native nutrients.

*(100% FYM= 10 t/ha, 100% vermicompost= 2 t/ha, 100% poultry manure= 1 t/ha)

Evaluation of Botanicals against Mustard Aphid, *Lipaphis erysimi* (Kaltenbach) in Mid Hills of Meghalaya

Partha Debnath[1], Rachna Pande[2], Sandip Patra[3], Jayanta Layek[3], Avinash Pande[4], Dipali Majumdar[1]

[1]*College of Post Graduate Studies, CAU, Umiam, Meghalaya-793103.*
[2]*ICAR- Central Institute for Cotton Research, Nagpur, Maharashtra.*
[3]*ICAR Research Complex for NEH Region, Umiam, Meghalaya- 793103.*
[4]*Indian Institute of Agricultural Biotechnology, Namkum, Ranchi – 834010.*
Email: rachna.ento@gmail.com

The field experiment was carried out at ICAR Research Complex for NEH Region, Umiam during *rabi* season of 2015-16 to evaluate some botanicals against mustard aphid. The experiment was laid out in randomized block design (RBD) with eight treatments and three replications. The mustard seeds (variety: Varuna) was sown during third week of October. The treatments *viz.* Bakain (*Melia azedarach*) leaf extract (5% aqueous solution), Lantana (*Lantana camara*) leaf extract (5% aqueous solution),Turmeric (*Curcuma longa)* rhizome powder (5% aqueous solution), Marigold *(Tagetes erecta*) leaf extract (5% aqueous solution), Vasaka *(Adhatoda vasica)* leaf extract (5% aqueous solution), chloropyrifos 20% EC (200 g a.i./ha) and imidacloprid 17.8% SL (25 g a.i./ha) along with control were applied at fifteen days interval. Results revealed that *Melia azedarach* was best among all botanicals with 50.54 -61.92% and 50.71-57.53% reduction of aphid population during first and second spray, respectively. Next best treatment was *Adhatoda vasica* followed by *Curcuma longa, Lantana camara* and *Tagetes erecta.* Among all the treatments, chloropyrifos and imidacloprid recorded maximum reduction of aphid population after both the spray. Although all botanicals showed less toxicity towards non-target organisms whereas chlorpyriphos and imidacloprid were highly toxic to honey bees and coccinellid beetles.

Keywords: *Botanicals, Imidacloprid, Chlorpyriphos, Lipaphis erysimi, Mustard*

Integrated Rice Fish Farming System in Arunachal Pradesh: An overview

Shah M. Hussain[1], P. Debnath[2], Debashish Sen[3], M. Pathak[1], James Nabam[4], and Deepjyoti Baruah[5]

[1]*KVK, East Siang, CHF, CAU, Pasighat, Arunachal Pradesh*
[2]*College of Horticulture and Forestry CAU, Pasighat, Arunachal Pradesh*
[3] *College of Agriculture Tripura, Lembucherra, Agartala*
[4] *District Fisheries Development Office, Lower Subansiri*
[5] *ICAR- DCFR, Bhimtal*
Email: maheshpathak@rediffmail.com

Rice-fish culture (RFC) is a type of farming system in which rice is the main enterprise and fish are taken as additional means for nutritional security and extra income. This system may open a new horizon to improve farmer's socio-economic conditions enhancing land use efficiency at low inputs and by waste recycling. Integrated Rice Fish Farming System under either capture systems or culture systems is a low-cost sustainable practice to obtain high value protein food and minerals. A total of 04 villages of East Siang district and 04 village of Ziro area of Lower Subansiri district of Arunachal Pradesh were surveyed during *Kharif* and *Rabi* seasons of 2015 and 2016 cropping season to evaluate the economic viability and acceptability of Integrated Rice Fish Farming System. Evaluating the multilocational report on Integrated Rice Fish Farming System it has been observed that 90% of the farmers release fish seed in the ranged from 3.0 cm to 5.0 cm size in their rice field during the month of April and July in Lower Subanshiri and East Siang districts, respectively . It was

also found that survival rate of advanced fry was between 42 % and 47 % with an average weight of 0.075 kg to 0.110 kg at harvesting for both of the districts. The average net income in RFC was Rs. 45,876 and Rs. 43,713 in Lower Subansiri and East Siang district respectively, while in sole cropping of rice it was Rs. 29,694 and Rs. 32,904 respectively. The additional income of Rs. 16,182 and Rs.10, 809 were gained by adopting the RFC system as compared to sole cropping of rice.

Keywords: *Integrated rice fish farming system, economics, Arunachal Pradesh.*

Sustainable Bio-resources Flow in Integrated Farming System for Enhancing Resource Use Efficiency and Income

Moutusi Tahashildar, Subhash Babu*, Anup Das, M Thoithoi Devi, Jayanta Layek, G.S. Yadav and L. L. Srivastava

Division of Crop Production, ICAR Research Complex for NEH Region, Umiam, Meghalaya
Email: subhiari@gmail.com

Recycling of biological resources, wastes and by-products improves natural resources and incomes. A common observation among farmers is that soil fertility is improved when organic matter is returned to the soil. Farmers of North Eastern Region of India generally do not apply any external input for crop production, hence, recycling of in-situ/ex-situ biomass are crucial for sustaining soil health and farm productivity in Hill ecosystems. Adoption of integrated farming system is common practice among the farming community of North East India, but there is very poor complimentary interaction between the various farming components. ICAR Research Complex for NEH Region, Umiam developed an integrated framing system model under AICRP on IFS to standardize and conceptualize the bio-resource flow between various enterprises of farming for consistent farmer's income and employment. One ha area was earmarked during 2010 for developing the IFS model, out of which 7000 sq m area was allotted to agri/vegetable based cropping system, 2000 sq m under horticulture and 500 sq m under water harvesting pond for fish cultivation. Livestock component was allotted 500 sq m area where vermi-compost unit, threshing floor and miscellaneous uses were accommodated. Among the 7000 sq m area, 2300 sq m was allotted to rice-toria-frenchbean, 2500 sq m for maize based cropping system, 900 sq m under spice based cropping system, 600 sqm for groundnut based cropping system and 700 sq m under vegetable based cropping system. The results on findings on bio- resource flow revealed that bio-resource flow varied among the enterprises and the number, type and magnitude of flow of resources indicated the degree of integration in the system. The livestock and crop waste were decomposed in vermicompost unit and utilizers the nutrients sources for raising crop components. Among the various enterprises the highest recyclable biomass produced by crop based components (6938.9 kg) followed by livestocks (1500.60 kg). In totality the IFS model recycled 8,545.90 kg biomass, out of which 5725.00 kg used for vermicomposting and composting rest has been used for other farm purposes. In terms of NPK, the system as a whole generates 76 kg N, 31.0 kg P and 48 kg K per year through nutrient recycling/vermi composting. The IFS model maintained the sustainable production over the years (five years average) with a sustainable value/yield index of 0.46

Keywords: *Resource recycling, Sustainable income, Nutrients, Integrated Farming System*

Soil Quality Parameters and Yield of Green Gram as Affected by the Combined Application of Manures and Bio-fertilizers

[1]Sanbharisha Dkhar, [1]Jurisandhya Barik Bordoloi and [2]L.J. Bordoloi

[1]School of Agricultural Sciences and Rural Development (SASRD), Nagaland University: Medziphema Campus
[2]ACTO, ICAR Nagaland Centre, Jharnapani, Nagaland
Email: bordoloijurisandhya@yahoo.com

An experiment was conducted at the ICAR Research farm Jharnapani, Nagaland during the summer season of 2016 to study the effect of combined application of manures and bifertilizers on soil quality parameters and yield of green gram under field condition. Seven treatments consisting of T_1: Control, T_2: FYM @ 5 t ha^{-1}, T_3: FYM @ 5 t ha^{-1} + seed inoculation with *Rhizobium*, T_4: FYM @ 5 t ha^{-1} + seed inoculation with *Rhizobium* + PSB, T_5: vermicompost @ 5 t ha^{-1}, T_6:vermicompost @ 5 t ha^{-1}+ seed inoculation with *Rhizobium*, T_7: vermicompost @ 5 t ha^{-1} + seed inoculation with *Rhizobium* and PSB were evaluated in a Randomized Block Design with three replications. The combination of vermicompost @ 5 t ha^{-1} + co-inoculation with *Rhizobium* + PSB proved to be the best treatment as it produced the maximum number of nodules (41.33, 44, 18.67 at 30, 45, 60 DAS respectively), the highest grain yield (13.92 q ha^{-1}), total biomass yield (89.77q ha^{-1}) and nutrient (N, P, K) uptake. Bulk density and water holding capacity of the soil did not vary significantly under different treatment. However, available nitrogen and organic carbon content was significantly influenced in treatment T_7 and T_4 with vermicompost and FYM along with co-inoculation of *Rhizobium* and PSB. The treatment T_7 (vermicompost @ 5 t ha^{-1} + seed inoculation with *Rhizobium* and PSB) exhibited its superiority and led to the increase in population of *Rhizobium* and PSB (58.33×10^4 and 56 $\times10^4$ CFU g^{-1} soil respectively). Further, treatment T_7 also enhanced other soil biological properties like soil microbial biomass carbon (1603.91 μg g^{-1}soil), soil enzyme activities (dehydrogenase 32.23 μg TPF g^{-1} soil h^{-1}; phosphatase 185.28 μg *p*-nitrophenol g^{-1} soil h^{-1}) and basal soil respiration; probably due to the synergistic effects of nitrogen fixers and phosphate solubilisers. However, sole inoculation of nitrogen fixers with either of the manures as in case of treatment T_3 and T_6 failed to produce similar effects. The results of the present investigation revealed that manuring of green gram with vermicompost along with co-inoculation of *Rhizobium* and phosphate solubilising microorganisms not only enhances yield but also improves the important quality parameters of soil. Further, the study clearly demonstrated that application of vermicompost along with co-inoculation of seed with *Rhizobium* and PSB can be a nutrient management strategy for improving the productivity of green gram in phosphorus deficient acid soils of north eastern region.

Keywords: *Co-inoculation, PSB, Rhizobium, Vermicompost, FYM*

IFS Sustain the Farmer's Income and Transform the Livelihood Security of the Farmer: A Long Term Case Study

M.A. Ansari[1*], N. Prakash[1], S.S. Roy[1], S.K. Sharma[1], Blessa Sailo[1], Punitha P.[1] and Niranjan Lal[2]

[1]ICAR Research Complex for NEH Region, Manipur centre, Lamphelpat, Imphal, 795004
[2]Krishi Vigyan Kendra, Churachandpur

Integrated farming system (IFS) in North Eastern Hill Region (NEHR) helps to safeguarding sustainable production system for the better livelihood, food and nutritional security of the hill farmers with biodiversity value. We investigated under long term case study (five years) of IFS on farmer's field testing the hypothesis that sustainability and socio economic conditions transformation

of the farmers. The present work was carried out at T. Champhai village of Churachandpur district on the farmer's field of Mr. Hemkhopao Haokip. The land holding of the farmer was 4.00 ha, but more than 35% land was utilized and remaining 65% farm was utilized for paddy –vegetables cultivation. ICAR Research Complex for NEH Region, Manipur Centre was suggested for IFS implementation with the assistance of critical inputs during 1st and 2nd year and 3rd to 5th year ICAR supervised only to analyses his sustainability. The farmers adopted IFS components like Agri (Paddy- 2ha; Maize-0.50; Groundnut-0.50 ha during kharif and Green pea-0.75 ha in Rabi); Horti (Lemon intercropping with groundnut-0.25 ha; Cabbage-0.75 ha in Rabi); Agroforestry (Treebean-0.20 ha); Fishery (2 ponds-0.20 ha); Poultry (poultry birds-100 No.), Piggery (6 number) and Jalkund for rain water harvesting. We have analyzed the year wise farmer's productivity, resource use efficiency, income and socio economic conditions. Framers produced more yield due to scientific intervention and generated on an average, net income of Rs. 61714.8, 9052.5, 44925.0, 42685, 50251, 13300, 122100, 149800, 102500 and from paddy, maize, groundnut, greenpea, Lemon intercropping with groundnut, Agroforestry (Fruiting not started), Fishery, Poultry and Piggery respectively. However, farmers B: C ratio was 1.93, 1.76, 2.73, 2.28, 2.20, 2.37, 2.10, 2.43 and 2.69, respectively in said component. The family members employed (man days) in farming were 559, 559, 566, 566, 637 and 645 man days during 2012-13, 2013-14, 2014-15, 2015-16 and 2016-17 compared to base year 211 man days (2011-12). On an average of 5 years interventions, this IFS system provided significantly higher net income (Rs 596328.30) and Rs per Rs invested (2.28) than base year of 2010-11, when farmers were growing paddy as subsistence farming (Rs 50000) from a system. In our study, we have found that the Agri-Livestock-Fishery-Vegetable-Fruits-Water harvesting is profitable venture, which sustain the farmer's income, ensure the livelihood and nutritional security and transform his socio economic conditions.

Studies on the Physico-Chemical Parameters of Loktak Lake, Manipur with Reference to Suitability for Culture Based Fisheries

H. Bharati[1], Asha T. Landge[2], Ch. Basudha Devi[3], Geetanjali Deshmukhe[2], B. K. Kandpal[1] , Th. Nirupada Chanu[4], Y. Jackie Singh[5]

[1]ICAR Research Complex for NEH Region, Tripura Centre-799210
[2]Central Institute of Fisheries Education, Mumbai – 400061
[3] ICAR Research Complex for NEH Region, Manipur Centre-795004
[4]Central Inland Fisheries Research Institute, Barrackpore- 700120
[5]College of Fisheries, Lembucherra (CAU), Tripura -799210
Email: huirembharati@gmail.com

The present study focuses on the physico-chemical characteristics of Loktak lake, Manipur- a Ramsar designated wetland of international importance with an emphasis on the scope of capture and culture based fisheries in the lake. An attempt was made to study the physico-chemical parameters of the lake, during October, 2012 to March, 2013. Sixteen water parameters were assessed during the study viz., water temperature (19.3 ˚C to 26˚C), pH (6.46 to 8.46), turbidity (3.8 to 15.1 NTU), conductivity (93.33 to 360 µS/ cm), Dissolved Oxygen (2.56 mg/l to 8.85 mg/l), Biochemical Oxygen Demand (1.4 to 7.6 mg/l), Chemical Oxygen Demand (3.05 to 5.55 mg/l), free carbon dioxide (6.6 to 32.08 mg/l), hardness (35.66 to 84 mg/l), total alkalinity (60 to 330 mg/l), chloride (9.44 to 42.56 mg/l), nitrite (0.012 to 0.038 mg/l), nitrate (0.033 to 0.36 mg/l), ammonia (0.47 to 2.253 mg/l), phosphate (0.014 to 0.607 mg/l) and total phosphorus (0.766 mg/l to 1.933 mg/l). The fish diversity of the lake comprised of 35 species belonging to 23 genera, 12 families and 5 orders. The 12 different families recorded are Cyprinidae, Cobitidae, Clariidae, Channidae, Chandidae, Cichlidae, Gobiidae, Anabantidae, Belontidae, Notopteridae, Symbranchidae and Mastacembelidae. Cyprinidae comprising

54% of the total fish species of the lake was the most dominant fish family in Loktak lake. Fishes of the lake have high fishery importance as food or ornamental fish. Majority of the physico – chemical parameters of the lake were found to be in the acceptable range for fish culture. Being a large water body, pen culture and cage culture will be suitable for enhancing fish productivity and livelihood security in Loktak Lake.

Response of Organic Sources and Bio-Fertilizer in Soil Fertility and Yield of Cauliflower in the Foot Hills of Tripura

Ashima Suklabaidya[1], Biswajit Das[1], M. Datta [2] and B.K. Kandpal[1].

[1]*ICAR Research Complex for NEH. Region, Tripura Centre, Lembucherra, West-Tripura,*
[2]*College of Agriculture, Lembucherra, West Tripura*

An investigation was carried out at ICAR Research complex Tripura Centre, Lembucherra during , 2014-15 to evaluate the efficacy of organics (vermicompost and Farm yard manure) with or without *Azotobacter* on the soil fertility and yield of cauliflower. The experiment consisted of 10 treatments *i.e.*,T-1(*Azotobacte*r), T-2 (Vermicompost @ 2t ha^{-1}), T-3 (FYM @ 2t ha^{-1}), T-4 (*Azotobacter* + VC @1t ha^{-1}), T-5 (*Azotobacter* + VC @ 2t ha^{-1}), T-6 (*Azotobacter* + VC @ 3t ha^{-1}), T-7 (*Azotobacter* + FYM @ 1t ha^{-1}),T-8 (*Azotobacter* + FYM @ 2t ha^{-1}) T-9 (*Azotobacter* + FYM @ 3t ha^{-1}) T-10 (control). Vermicompost and FYM were applied @ 1,2 and 3t/ha^{-1} with or without *Azotobacter* @ 4kg ha^{-1} in Randomized Block Design with three replications using cauliflower as test crop. Results revealed that available nitrogen, phosphorus, potassium (NPK) and organic carbon content of the soil after the harvest of cauliflower was significantly enhanced as compared to that of control. Amongst the different sources of organic matter, vermicompost @3 t ha^{-1} with *Azotobacter* gave higher uptake of NPK in comparison with FYM at the level of 3t ha^{-1} with *Azotobacter*. The highest yield was recorded in treatment of vermicompost @3t ha^{-1} with *Azotobacter* which was closely followed by Vermicompost @ 2t ha^{-1} plus *Azotobacter*.

Theme-4: Horticulture for Nutrition and Assured Income

Spices for Income Enhancement in NE Region: Needs and Focus

A.K. Jha, N.A. Deshmukh, V.K. Verma, H. Rymbai, S. Ruth Assumi, M. Bilashini Devi, H.D. Talang
ICAR Research Complex for NEH Region, Umiam, Meghalaya

Introduction

The horticulture sector has emerged as a potential player in the Indian economy, contributing 30.4% to GDP in agriculture (ICAR, 2014). The horticultural crops put together cover approximately 24.38 million hectares area with an annual production of about 280.48 million tonnes (NHB, 2015). In the transitional stage of economic development, agriculture carried immense burden in the drive for economic growth. During maturing phase, the main emphasis still remains on the maintenance of balanced role for agriculture, but horticulture has become more important. This is due to commercialization of crops around the world. This is so because of the high increases in income derived by the cultivation of horticultural crops as compared to annual cereal crops. Horticultural crops also provide gainful employment for small and marginal farmers and agricultural labourers throughout the year. Indian spices exports have been able to record strident gains in volume and value. Spices exports have registered substantial growth during the last five years, registering compound annual average growth rate of 10% in rupee terms and 5% dollar terms of value and India commands a formidable position in the world spice trade. During 2016-17, a total of 9,47,790 tons of spices and spice products valued Rs.17664.61 crore (US$2633.30 Million) has been exported from the country as against 8,43,255 tons valued Rs.16238.23 crore (US$ 2482.83 Million) in 2015-16 registering an increase of 12% in volume, 9% in value (rupee terms).

Table-1: Second (2nd) Advance Estimate of Area and Production of Spices in India (2016-17)

Crops	Area			Production		
	2015-16 (Final Estimate)	2016-17 (2nd Estimate)	Diff. (%)	2015-16 (Final Estimate)	2016-17 (2nd Estimate)	Diff. (%)
Total Spices	3474	3535	2	6988	7077	1
Pepper	129	131	2	55	72	32
Ginger	164	165	1	1109	1081	-3
Chillies	811	831	2	1520	1872	23
Turmeric	186	193	4	943	1052	12
Cardamom	86	84	-2	24	27	13
Cinnamon	3	3	-	5	5	-

Area in thousand ha, Production in thousand MT (Source: NHB, 2017)

North Eastern Hill Region of India is a treasure trove of diverse flora and fauna and is considered as one of the mega biodiversity hotspots in the world. The region has diverse agro-climate due to varying altitude and has immense potential for the development of horticultural crops. However, the region of India is often characterized by marginality, fragility, inaccessibility and heterogeneity. In spite of the difficult terrain and inadequate infrastructure, there has been improvement in growth of horticulture sector in the region, in terms of increased area, production and productivity of major horticultural crops. With contribution of 18.8% in total agriculture production and 52% in total agricultural export, horticulture has emerged as a prominent sector offering wide scope for diversification in agriculture. It has a vital scope in foreign exchange earnings and employment generation. Among the various spice crops, the region is known for high quality ginger, turmeric, chillies and large cardamom.Ginger and turmeric are prominent among them and their cultivation is undertaken as a cash crop mostly in '*jhum'* fields spread over the hills and tribal areas of the entire region.India is the largest producer of large cardamom in the world with an annual production of 4000 tons, followed by Nepal (2500 tons/year) and Bhutan (1000 tons/year). More than 85% of the production within India is from Sikkim alone. Black pepper is also showing some promise in few pockets.

Spice diversity in the region

In ginger, the region can be considered as treasure house of germplasm. There are several cultivated types of ginger available in the region, which are generally named after the localities they are being grown. Certain indigenous types namely Maran, Bhola and Jorhat Local of Assam have been reported to be equally good in rhizome yield as well as in size. Dry ginger recovery of these varieties has been found to be even better than exotic type Rio-de-Janeiro. The pungency in ginger is due to gingerol, which is found highest in Meghalaya Local genotype (medium size) and very suitable for export purpose. In Mizoram, local types 'Thingpui', 'Thingaria' and 'Thinglaidum' are grown at large scale. Black ginger having rhizomes with bluish black tinge inside is reported to have medicinal properties and is grown by the inhabitants of Mizoram for commercial as well as their own use. In Sikkim, local types 'Bhainse' and 'Gorubathan' are grown commercially due to their high yield potential and big size rhizomes. The varieties with less fibre, high dry matter recovery, and high oil and oleoresin contents are having great export potential in international markets. The Indian Institute of Spices Research, Calicut has evolved Varada, a new variety of ginger, which is being multiplied at Ginger Development Station, Umsning, Meghalaya and the performance of the variety is quite encouraging.

Similarly, there are several cultivated types of turmeric available in the region, which are generally named after the localities they are being grown. Certain indigenous types namely Manipur Local, Nagaland Local, Sikkim Local and Jorhat Local of Assam have been reported to be equally good in rhizome yield. Dry matter recovery of these varieties has been found to be even equal or better than certain improved types. In Meghalaya, Lakadong is the main variety and more than 50% area is under this variety. Megha Turmeric-1 developed from clonal selection of Lakdong is gaining popularity. There are mainly six cultivars of large cardamom viz., Ramsey, Ramla, Sawney, Golsey, Varlangey (Bharlangey) and Bebo. In addition, sub-cultivars of the above ones like Ramnag, Madhusey, Mongneyare also seen in cultivation in small areas in Sikkim State. Another cultivar Seremna or Lephrakeyis also getting importance and is spreading to more areas in lower altitudes. There are distinct cultivars suited to different altitudes and diverse agro-climatic situations, hence increasing the scope of introduction and area expansion of suitable cultivars in the NE states. Cultivars suited for high altitudes (>1515 m msl) are Ramsey, Varlangey and Ramla. Sawneyis suited for mid (975 – 1515 m msl) altitudes and cultivars Golsey and Seremnaare suited for low (< 975 m msl) altitude areas.

Black pepper cultivation in the region contributes about 1.9% in area and 6.5% in production of India's share In the North East region of India, Panniyur -1 and Karimunda are found to perform well with consistently good yield. Black pepper varieties released from IISR are Sreekara (Yield: 2677 kg dry ha-1), Subhakara (2352 kg dry ha^{-1}), Pournami (2333 kg dry ha^{-1}), Panchami (2828 kg dry ha^{-1}), IISR Shakthi, (2253 kg dry ha^{-1}), IISR Thevam (2481 kg dry ha^{-1}), IISR Girimunda (2880 kg dry ha^{-1}) and IISR Malabar Excel (1440 kg dry ha^{-1}). Almost all these varieties are suited for cultivation in NE regions. However varieties bred for high altitude areas will be more ideal for these regions and it can be grown either as a monocrop or as an intercrop on coconut, arecanut or the shade trees of tea estates. Apart from cultivated black pepper other economically important species such as *P. betle*, *P. chaba*. *P. cubeba*, *P. peepuloides* and *P. longum* are also suited to North eastern states. There are two types of cinnamon *viz*. C. *zeylanicum* and C.*tamala*, grown in the region. The former is mainly grown for its bark which gives cinnamon of commerce. For leaf oil the later is preferred. Oil extracted from the bark and leaf is of great commercial value, domestic demand for which is on the increase.

Good Agricultural Practices (GAP) for organic production of commercial Spices in NEH Region

Organic production of Ginger

The most popular cultivated variety in the region is Nadia that possess low fibre (4.10 %) and has maximum demand for culinary purposes. Although it is said that Nadia is popular among the farmers on productivity aspect, the local medium sized varieties are still grown in larger area in the region.

Conversion plan

(i) For certified organic production of ginger, the crop should be under organic management at least for 18 months and only the second crop of ginger can be sold as organic, The conversion period may be relaxed if the organic farm is being established on a land where chemicals were not previously used, provided sufficient proof of history of the area is available.

(ii) In order to avoid contamination of organically cultivated plots from neighboring non-organic farms, a suitable buffer zone with definite border is to be maintained. In sloppy lands adequate precaution should be taken to avoid the entry of runoff water and chemical drift from the neighboring farms. Water stagnation has to be avoided in the low lying fields by taking deep trenches for drainage.

Management practices

(i) For organic production, traditional varieties adapted to the local soil and climatic conditions that are resistant or tolerant to diseases, pests and nematode infection should be used.

(ii) No synthetic chemical fertilizers, pesticides or fungicides are allowed under organic system. Farmyard manure may be applied @ 25-30 t/ha along with vermi compost @ 5 t/ha and mulching with green leaves @ 12-15 t/ha at 45 days intervals. Based on soil test, application of lime/ dolomite, rock phosphate and wood ash may be done to get required quantity of phosphorus and potassium supplementation. When the deficient conditions of trace elements become yield limiting, restricted use of mineral/ chemical sources of micro nutrients by soil application or foliar spray are allowed as per the limits of standard setting of certifying organizations. Further, supplementation of oil cakes like neem cake (2 t/ha), composted coir pith (5 t/ha) and suitable microbial cultures of Azospirillum and phosphate solubilizing bacteria will improve the fertility and yield.

(iii) Integrated strategy involving pruning and destroying freshly infested shoots during July-August (at fortnightly intervals) and spraying Neem gold 0.5% or neem oil 0.5% during September-October (at 21 day intervals) or Dipel (formulation of *Bacillus thuringiensis*) 0.3% during July to October is effective against the shoot borer.

(iv) Selection of healthy rhizomes, soil solarization seed treatment and soil application of biocontrol agents like *Trichoderma* or *Pseudomonas* (multiplied in suitable carrier media such as coir pith compost, well rotten cow dung or quality neem cake) may be done at the time of sowing and at regular intervals to keep the rhizome rot disease in check.

(v) To control other foliar diseases spraying of Bordeaux mixture 1% may be done restricting the quantity to 8 kg copper per hectare per annum. Application of quality neem cake mentioned earlier along with the bioagents *Pochonia chlamydosporia* will be useful to check the nematode population.

Certification

Certification and labeling is usually done by an independent body to provide a guarantee that the production standards are met. Government of India has taken steps to have indigenous certification system to help small and marginal growers and to issue valid organic certificates through certifying agencies accredited by APEDA. The inspectors appointed by the certification agencies will carry out inspection of the farm operations through records maintained and by periodic site inspections. Documentation of farm activities is must for acquiring certification especially when both conventional and organic crops are raised. Group certification programmes are also available for organized group of producers and processors with similar production systems located in geographical proximity.

Harvesting and curing

The crop is ready for harvest in about 8 months after planting when the leaves turn yellow, and start drying up gradually. The clumps are lifted carefully with a spade or digging fork and the rhizomes are separated from the dried up leaves, roots and adhering soil. For preparing vegetable ginger, the rhizomes are thoroughly washed in water and sun-dried for a day. For preparing dry ginger, the produce (harvested after 8 months) is soaked in water for 6-7 hours. The rhizomes are then rubbed well to clean the extraneous matter. After cleaning the rhizomes are removed from water and the outer skin is removed with bamboo splinters having pointed ends. Deep scraping may be avoided to prevent damage of oil cells which are just below the outer skin. The peeled rhizomes are washed and dried in sun uniformly for 1 week. The dry rhizomes are rubbed together to get rid of the last bit of skin or dirt. The yield of dry ginger is 19-25% of fresh ginger depending on the variety and location where the crop is grown. Fresh ginger (with relatively low fibre) harvested at 170-180 days after planting can be used for preparing salted ginger. Tender rhizomes with a portion of the pseudostem may be washed thoroughly and soaked in 30% salt solution containing 1% citric acid. After 14 days it is ready for use and can be stored under refrigeration.

Storage of seed rhizomes

For this purpose, healthy and disease- free clumps are marked in the field when the crop is 6-8 months old and still green. The seed rhizomes are stored in pits of convenient size in sheds. The walls of the pits may be coated with cow dung paste. The seed rhizomes are placed in pits in layers along with well dried sand/saw dust (put one layer of seed rhizomes, then put 2 cm thick layer of sand/saw dust). Sufficient gap is to be left at the top of the pits for adequate aeration. The pits can be covered with wooden planks with one or two small openings for aeration. The seed rhizomes in the pits may be checked once in about 21 days by removing the plank and shriveled and disease affected rhizome are to be removed. The seed rhizomes can also be stored in pits dug in the ground under shade. Storage in saw dust + dried leaves of *Strychnos nuxvomica* also prevents infestation of rhizome scale.

Organic Production of Turmeric

Conversion Plan and Buffer zone

High curcumin containing turmeric is available in the NER region and ICAR has already released a variety for cultivation in the NER. Rich loamy soils having good drainage are ideal for the crop. The most popular cultivated variety in the region is Lakadong (7.5 %) and Megha Turmeric-1 (6.8%) that possesses higher curcumin content and has maximum demand. Being an annual crop, the conversion period required will be two years. Turmeric can be cultivated organically as an intercrop with other crops provided organic methods of cultivation is followed for all the companion crops. In order to cultivate turmeric organically, an isolation distance of 25 m wide all around is to be left from a conventional farm. The produce from this isolation belt shall not be treated as organic.

Varieties: Lakadong, from Jaintia Hills, Meghalaya and Megha Turmeric- 1 (RCT-1) released by ICAR Research Complex for NEH, Uniam, Meghalaya are recommended.

Land Preparation and planting

While preparing the land, minimum tillage operations may be adopted. Beds of 15 cm height, 1 m width and of convenient length may be prepared, giving at least 50 cm spacing between beds. Solarisation of such beds is beneficial in checking the multiplication of pests and disease causing organisms. The polythene sheets used for soil solarisation should be kept away safely after the work is completed. Carefully preserved seed or rhizomes free from pests and diseases which are collected from organically cultivated farms should be used for planting. However, to begin with seed material from high yielding local varieties may be used in the absence of organically produced seeds. Planting in March-April with pre-monsoon shower is desirable. At the time of planting, apply 25 g powdered neem cake and mix well with the soil in each pit taken at a spacing of 20-25 cm within and between rows. Seed rhizomes may be put in shallow pits and covered with well rotten cattle manure or compost mixed with *Trichoderma* (10 gm compost inoculated with *Trichoderma).* Mulching of the turmeric beds with green leaves is an essential operation to enhance germination of seed rhizomes and to prevent washing off of soil due to heavy rain. This also helps to add organic matter to the soil and conserve moisture during the later part of the cropping season. The first mulching is to be done at the time of planting with green leaves @10-12 t/ha. It is to be repeated again @5 t/ha at 50^{th} day after planting. Cow dung slurry may be poured on the bed after each mulching to enhance microbial activity and nutrient availability. Weeding may be carried out depending on the intensity of weed growth. Such materials may be used for mulching. Proper drainage channels are to be provided in the inter rows to drain off stagnant water.

Plant Nutrition

Application of well rotten cow dung or compost @ 5-6 t/ha may be made as a basal dose while planting rhizomes in the pits. In addition, application of neem cake @ 2 tonnes /ha is also desirable. Earthing up after 60 days and weeding at 60, 120 and 150 days are desirable.

Plant Protection

No major disease is noticed in the crop. Leaf spot *(Collectrotrichum capsici)* and leaf blotch (*Taphrina maculans*) can be controlled by restricted use of 1% Bordeaux mixture. Application of *Trichoderma* at the time of planting can check the incience of rhizome rot *(Phythum graminicolum)*. Regular field surveillance and adoption of phytosanitary measures are required for pest management. If shoot borer incidence is noticed spot such shoots, cut open and pick out larvae and destroy them. Spray neem oil (0.5%) at fortnightly intervals if found necessary.

Harvest and post harvest operations

Turmeric is to be harvested at correct maturity. Depending upon the variety, crop becomes ready for harvest in 7-9 months. Usually it extends from January to March. Early varieties mature in 7-8 months, medium varieties in 8-9 months and late varieties after 9 months. Usually the land is ploughed and the rhizomes are gathered by hand picking or the clumps are carefully lifted with a spade. Harvested rhizomes are cleaned of mud and other extraneous matter adhering to them. The average yield per hectare comes to 20-25 tonnes of green turmeric. Turmeric is polished in power operated drums and yield of polished turmeric is 12-25% of raw-material. Fingers are separated from mother rhizomes. Mother rhizomes are usually kept as seed material. The fresh turmeric is cured for obtaining dry turmeric. Curing involves boiling of fresh rhizomes in water and then drying in the sun. No chemical should be used for processing. Only clean and uncontaminated water is to be taken for boiling rhizomes. The cleaned rhizomes are boiled in copper or galvanized iron or earthern vessels, with water just enough to soak them. Boiling is stopped when froth comes out and white fumes appear giving out a typical odour. The boiling lasts for 45-60 minutes when the rhizomes are soft. The stage at which boiling is stopped largely influences the colour and aroma of the final product. Over cooking spoils the colour of the final product while under cooking renders the dried product brittle. An easy method of curing large quantities of turmeric is as follows: The cleansed fingers/mother rhizomes are taken in perforated troughs made of GI or MS sheet with extended parallel handle. (A medium type trough of size 0.90 x 0.55 x 0.40 cm can hold about 50 kg of raw turmeric). The perforated troughs containing raw turmeric are then immersed in a pan with water which can hold 3-4 troughs at the same time. Boil till the fingers/mother rhizomes become soft. The cooked turmeric is taken out of the pan by lifting the troughs and draining the water into pan itself. The same hot water in the pan can be used for boiling next set of raw turmeric which is already filled in troughs. The cooking of turmeric is to be done within 2-3 days after harvest.

Rhizomes may also be cooked using baskets with perforated bottom and sides. The mother rhizomes and the fingers are cured separately. The cooked fingers/mother rhizomes are dried in the sun by spreading in 5-7 cm thick layers on bamboo mats or cement floor. A thinner layer is not desirable, as the colour of the dried product may be adversely affected. During night time the material should be heaped or covered. It may take 10-15 days for the rhizomes to become completely dry. Artificial drying using cross flow hot air at a maximum temperature of 60° C is found to give satisfactory product. In the case of sliced turmeric, artificial drying has clear advantages in giving brighter coloured product than sun drying which tends to suffer due to surface bleaching. The yield of dry product varies from 20-30% depending upon the variety and the location where the crop is grown. Rhizomes for seed purpose are generally stored after heaping under shade of tree or in well ventilated shaded room and covered with turmeric leaves. Sometimes the heap is plastered with earth mixed with cow dung. The seed rhizomes can also be stored in pits with saw dust. The pits can be covered with wooden planks with one or two hotels for aeration.

Value added products from spices

Ginger : Dried ginger, Fresh ginger juice, Ginger Paste, Ginger Oil, Ginger Oleoresin, Ginger Beer, Fresh Ginger Products, Ginger by-products etc.

Turmeric: Turmeric powder, Turmeric paste, Turmeric curcumin, Turmeric Oil and Oleoresin, Turmeric by-products etc.

Chillies: Chilli powder, Oleoresin, Capsanthin, Capsaicin etc.

Black Pepper : White pepper, Dehydrated green pepper, Green pepper in brine, Green pepper paste, Freeze dried green pepper, Dehydrated salted green pepper, Canned green pepper, Bottled green pepper, Cured green pepper, Sterilized black pepper, Black pepper crushed, Decorticated black pepper, Pepper oil, Pepper oleoresin etc.

Strategies for further growth

Ginger

Raised bed ginger production in hill slopes allows good drainage and slow burning process of the raised bed soil helps in destroying some soil borne pathogens. Bio-control agents are to be encouraged it is reported that some local isolates of Trichoderma sp. are effective against soft root disease both in Assam and Sikkim. Seed treatment before planting with such beneficial microorganisms should be made mandatory. Since ginger rhizome productivity is high in Assam (Karbi Anglong area) and Arunachal Pradesh, area expansion with low fibre varieties is to be planned. Processing support provided under HTM need to be further extended. APEDA has identified AEZ for ginger in Sikkim and this is the right time for creating infrastructure for value addition of ginger.

Turmeric

High curcumin containing varieties/ selections like Lakadong and Mega Turmeric-1 need to be mass multiplied for area expansion. Curcumin content, being a location specific phenomenon, selection of suitable sites (eg. Jowai of Jaintia hills of Meghalaya, parts of Nagaland) is to be undertaken for saturating with high curcumin containing varieties. Foot hills and mid-hills of Arunachal Pradesh, Nagaland, Meghalaya and Karbi Anglong experiencing more than 1500 mm annual rainfall and with well drained sandy to clayey loam soil are better suited for turmeric area expansion. High curcumin containing turmeric and organic turmeric are preferred for export outside India. Turmeric having more than 7% curcumin on dry weight basis is produced in NER and such produce will fit well in meeting international quality standards. Turmeric processing (drying, powdering, packaging etc.) also need organized support.

Large cardamom

Large cardamom farming as an under-storey crop in the hill slopes of Sikkim is an unique traditional production system. Cardamom is considered a high value commodity in Sikkim and generates employment for 80-100 days per ha. Spices Board, should plan to expand large cardamom area in other states as ‘forest floor farming’ under the shade of natural forests or under nitrogen fixing Alder afforestaion. Dehydration / drying and packaging of cardamom capsules need to be improved. Improved small scale cardamom dehydration plant/ machineries need to be supplied to cardamom farmers with HTM assistance.

Black pepper

Black pepper can be grown in wide range of soil with pH range 4.5 to 6.0. Eastern part of Assam and adjoining areas in Arunachal Pradesh; southern part of Assam adjoining Nagaland; Karbi Anglong District of Assam; Parts of Tripura in the rubber plantation zone are well suited for black pepper. Healthy rooted cuttings of promising varieties (Panniyur 1, Karimunda) are to be supplied, preferably after treating with biocontrol agents reported to be affective against root wilt pathogens. Under arecanut based HDMSCS, yield of areacanut, black pepper and citrus were recorded as higher at 2/3rd of the recommended fertilizer dose. Also, employment generation of 450-475 person days per ha was recorded under this mixed cropping practice, as compared to 250 – 275 person days in arecanut mono cropping practice. Black pepper farming in arecanut stands is recommended in NER experiencing 1250 to 2000 mm annual rainfall.

Chillies

In addition to common chillies, traditional 'Naga chilli' and 'Bird eye chilli' are unique to this region. Humid to sub-humid climate with 600 to 1250 mm rainfall and temperature range of 16 to 24o C during growing period are ideal for production of good quality chillies. 'Char' area of Assam, valleys between tillas in Tripura and Manipur valleys are better suited areas for chilli production. Hottest chilli is reported form certain pockets of Tezpur of Assam. Area expansion should take place in such niches. The ITC has already entered with an agreement with Nagaland government for production of organic chilli. Greater focus in needed for larger scale use of bio-fertilizers and bio-pesticides for organic production of chilli, for which the demand is growing.

Role of ICAR Research Complex for NEH Region

ICAR Research Complex for NEH Region has initiated research programmes on spice crops *viz.*, turmeric, ginger, King chilli *etc*. The emphasis is being given on evolving high yielding varieties of turmeric, collection, evaluation, maintenance and molecular characterization of turmeric, ginger and king chilli, off season production technology of king chilli and value addition in ginger. At the same time training are being imparted to the farmers on improved package of practices of these crops. Front line demonstrations on turmeric and king chilli are being conducted under Technology Mission (MM I), NAIP, TSP etc to popularize these crops. The institute is also giving consultancy to NGOs on organic turmeric cultivation. Information on these crops is being transferred to the stakeholders through leaflets and pamphlets *etc.*

Production and marketing constraints

1. Abiotic factors: Ginger and turmeric are mostly grown in sub-tropical hill zones where soil is acidic in nature. Cultivation is being practised on steep slopes under jhum/ bun (raised beds) system in rainfed conditions without adoption of soil and water conservation. Deep virgin soils of forest brought under jhum system are giving higher yields in first and second year of cultivation even under zero nutrient management conditions. But heavy rains and earthing works associated with the cultural operations and harvesting accelerate the erosion reducing the fertile soils into abandoned wasteland. In second cycle of cultivation on such fields after a gap of 3-5 years very low yields (5-8 t/ha) are obtained. Farmers apply only FYM at planting and no other nutrient application strategies are followed. These factors lead to low productivity. Research on soil water conservation technologies, sustainable production system etc is being carried out by the Institute.

2. Biotic factors: Non-availability of quality planting material is another important factor attributing to low productivity. The serious diseases of ginger are seed rhizome borne viz., soft rot (*Pythium sp, Rhizoctonia sp and Sclerotium rolfsii*), dry rot (*Fusarium oxysporum*) and bacterial wilt (*Ralstonia solanacearum*). Some of these, particularly bacterial wilt once introduced into cultivated fields it is very difficult to eradicate. The supply of quality planting material free from diseases can contribute enormously to enhance the productivity. Ginger stem borer (*Dichochrosis punctiferalis*), Shoot borer weevil (*Prodiotes halmaticus*) causes crop damage between 30-40 % during July-September.

There is a need for the establishment of seed agencies to supply certified seed rhizome in north-eastern region. Farmers / Farmers' clubs / NGOs could be trained to develop technical skill to produce home grown quality seed to meet their own seed requirements. Further, bio-organic/ botanical extracts developed by the Institute controls serious diseases and increases ginger yield. Such materials at low cost are technically feasible in slope areas and are eco-friendly substances.

3. Socio-economic factors: Cultivators in NE regions are resource poor and have low produce holding capacity. Lack of storage facilities at farm, non-existence of organised marketing system/

growers association etc force the growers to sell their produce just after harvesting through commission agents. Sale in village markets (weekly markets), city markets are very limited. Absence of adequate number of post-harvest processing units to absorb marketable surplus (which is nearly 70%) forces the cultivators to sell the produce as fresh only. Unorganised marketing system is another constraint determining the low adoption of improved production packages and enhancing the productivity system. Establishment of processing units in the region is needed to absorb the market surplus and produce value added products that have longer shelf life.

North East Consortium for Development of Spices (NECDS)

For integrated research and development of spices in North eastern India, a common platform is urgently required, where action plan for need based research and developmental activities on spices will be formulated, implemented and monitored. The objective can be achieved by constituting the North east Consortium for Development of Spices (NECDS). IISR and ICAR Complex will take the responsibility of conducting research, whereas Spices Board and line departments of State Governments will implement the developmental programmes. Indian Society for Spices will act as coordinating agent between the partner organizations. Progressive spice growers, Different funding agencies (like NABARD), NGOs, other institutes (DASD, ICRI, AAU, CAU, CIH *etc*.) and spices based industries will be the member of this consortium.

Future thrust

The following are the areas where focus is needed so that overall scenario of the spice production can be changed by increasing production and productivity in the northeastern region.

1. Post- harvest management: There is need to develop quality control measures, adequate packaging, transportation and storage techniques. Intensive research for protocol development of different value added products may be taken up. Low cost storage structure for long-term storage is the need of the hour. Sprouting inhibition after harvesting for a minimum period of 2-3 months using organic sources will increase the volume of export.

2. Introduction, evaluation and improvement: Introduction of indigenous and exotic high yielding strains suitable for the state may help in increasing the total production of the region. Breeding with local germplasms should be done for high yielding and better quality varieties with resistance to biotic and abiotic stress. DNA finger printing of the local germplasm should be done immediately to safe guard the interest of the farmers.

3. Quality planting materials: Since there is inadequate supply of quality planting materials and true to the type varieties are not maintained properly, a mechanism may be devised for regulating the production and supply of disease free planting materials to the growers. Micro propagation techniques may help in rapid multiplication of quality planting material.

4. Emphasis on organic farming: The production sytem in the northeastern region is organic by default. Bio-organics, bio-pesticides, integrated approach for pest and disease control and strategies for each farming systems has to be worked out. The need of the hour is to have a simplified and affordable organic certification system.

6. Economics and technology transfer: The cost benefit analysis of different farming systems is required. There is immense need to strengthen the extension system for transfer of technologies and to provide training to the farmers.

7. **Co-ordinated planning and efforts by government**: Coordinated planning for development of agri-export zones in Sikkim for cardamom, Meghalaya for turmeric, Manipur and Nagaland for king

chilli is warranted. Propagation of Public-Private-People Partnership in relation to organic spice production and spices based agro-industries is the need of the hour.

Conclusions

Despite the various schemes and programmes of the government for popularization of spice crops, a lot needs to be done. The cultivation technology of different spice crops has to be taken to farmers. For this purpose, the extension machinery has to be geared up. The per hectare productivity is low and the cost of cultivation is high in India especially in North Eastern Region. The gap between the potential yield and the yield obtained by the framers needs to be bridged to make cultivation of spice crops remunerative. Awareness among the growers needs to be grown regarding commercial cultivation of spices for earning more profit. Moreover, wide publicity needs to be given to the government schemes for promotion of spices through print and electronic media. Thus a concerted effort of all the agencies will help the North eastern region in finding an important place in the spice map of India.

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Standardization of Propagation Time and Methods for Quality Planting Material Production of Fruit Plants in North Western and Eastern Himalayan Region

Biswajit Das and H. Lembisana Devi

ICAR Research Complex for NEH Region, Tripura Centre, PO: Lembucherra- 799 210, Tripura
Email:biswajitsom_dr@yahoo.co.in

Introduction

North western Himalayan states of India which includes Jammu and Kashmir, Himachal Pradesh and Uttarakhand are major producer of temperate fruit crops, however, areas under temperate fruit crops are also expanding in temperate hilly tracts of north eastern states. Apart from temperate fruit crops, tropical and sub-tropical fruit crops are predominantly grown in the north eastern states. In India, productivity of apple (8.0 Mt/ha) is very less in comparison to many major apple producing countries (50-60 Mt/ha). Stone and nut fruits productivity is only 4.2 Mt/ha and 1.8 Mt/ha, respectively. In North eastern states, apple productivity is only 2.6 Mt/ha. Cumulative fruit productivity of north eastern states is only 8.0 Mt/ha with the range of 13.9 Mt/ha (Assam) to 3.6 Mt/ha (Sikkim). Apart from geographical difficulties and lack of advanced production technologies, availability of quality planting materials of improved cultivars of different fruit crops is considered as the major bottleneck for low productivity and slower rate of area expansion. As a result, farmers are dependent on traditional varieties and old propagation techniques. Over the years, major thrust has been put on quality planting material production and distribution of improved varieties of fruit crops along with the demonstration on the management technologies. The present study was conducted on temperate fruits (pome, stone and nut) propagation method and time under Uttarakhand condition and mango cv. Amrapali propagation method and time under Tripura condition.

Materials and methods

The experiment was carried out in two agro-climatic zones: 1. Propagation of temperate fruit crops was carried out in Central Institute of Temperate Horticulture, Regional Station, Mukteshwar, Nainital, situated at an altitude of 7000 ft amsl during 2009-2012 under the title: chip budding time and height as determining factors for bud take and successive plant growth of temperate fruit crops. 2. Tropical fruit mango var. Amrapali propagation was carried out in Tripura Centre, ICAR RC NEHR, Lembucherra during 2013-2015 under the title: production of quality planting materials of tropical fruit crops. Temperate fruit scion cultivars were collected from apple cv. Starkrimson, pear cv. Bartlett and peach cv. Red June, apricot cv. St. Ambroise, almond cv. Merced and walnut cv. Sulaiman. Rootstocks namely crab apple seedling rootstock '*Parhu*' (*Malus baccata* var. Himalaika) and clonal rootstock M9 for apple, '*Mahel*' (*Pyrus pashia* Kumaonii) seedling for pear, wild peach seedling '*Katero*' (*Prunus persica*) for peach, wild apricot seedling 'Chulli' (*Prunus americana*) for apricot, Bitter almond (*Prunus amygdalus*) seedlings for almond and Hard shell (*Juglan regia*) seedlings for walnut were used. During grafting season, chip budding, tongue and wedge grafting were performed in December-January and February-March at height 8-10 cm, 13-15 cm and 18-20 cm on selected rootstocks. During budding season, chip budding and T-budding were performed during July-August and September-October at the height same as in case of grafting. Bench grafting and bench chip budding was done on dormant rootstocks during dormant period (Dec.-Jan. and Feb.-Mar.), whereas, in-situ budding was performed during active growth stage during July-October. The nursery was established under polyhouse condition. Observation was recoded on grafting success, diameter at grafting union and plant height after the end of growing season. Under Tripura condition, mango cv. Amrapali was selected for propagation studied under shade net house. Stone grafting on 5 days old, 10day old, 15 days old, 20 days old, 25 day old and 30 days old rootstock (time: 1st June, 15th June, 1st July, 15th July and 1st August). Soft wood grafting was done on two stages of rootstock growth. First stage was on rootstocks which are less than one year old emerging from stones sown on 25th May and grafting was performed at intervals of 1st August, 15th August, 1st September, 15th September, 1st October, 15th October and 1st November. In the 2nd growth stage of rootstock, soft wood grafting was done on the same rootstocks in the next year at intervals starting from 1st March, 15th March, 1st April, 15th April, 1st May, 15th May, 1st June, 15th June, 1st July, 15th July, 1st August, 15th August, 1st September, 15th September, 1st October, 15th October, 1st November and 15th November. Observation was recorded on grafting successes after one month of grafting or budding operation and plant height and girth parameters were recorded after the end of growing season.

Result and discussion

An overall assessment of interaction effect of grafting methods and grafting time show that for dormant season propagation of temperate fruit crops chip budding during February-March is the best method which gave overall 79.9% (with a range of 92.7% in Apple to 74.4% in Walnut) success which was significantly higher than other two grafting methods, *i.e.* tongue (71.3%) and wedge grafting (73.1%) irrespective of budding height (8-10 cm, 13-15 cm and 18-20 cm). Whereas, comparative assessment of chip budding with T-budding revealed that chip budding again resulted in higher bud success in all the temperate fruit crops with 76.2% success during July-August and 74.9% success during September-October. T-budding gave 75.6% during July-August and only 56.9% during September-October. Apart from the grafting or budding methods, season was found to be very critical for better success. Chip budding, done with active vegetative or dormant mature buds on active vegetative or dormant stocks, respectively, extended the regular budding/grafting season, even if, bud is not slipping in the dormancy period or started stock/scion sap flow in the spring (Crasweller, 2005). Further, chip budding assures better cambial contact and more rapid healing (Skene, *et al.*, 1983; Gustafson and Morrissey, 2003). Under Tripura condition, mango cv. Amrapali stone grafted on 10 to 25 days old seedling rootstocks gave 72.4% to 86.5% grafting success during 1st June to 15th July. Stone grafting on 7 day old seedling rootstocks gave only 7.4% to 10.4% success. Softwood grafting of the mango seedlings of less than one year old age raised from the stones sown on 25th May and grafted at 15 days interval starting from 1st August to 1st September resulted in 76.4-90.6% grafting success. Soft wood grafting in the next year on the same rootstocks stone sown on 25th May in previous year resulted in 70.4 to 96.6% success when grafted at 16-22cm particularly during 15th March to 15th September. Very less success was recorded during October to November. It has been also reported in mango cv. Amrapali, scion defoliation for 6-9 days and wedge grafting method gave 85% success under Bangladesh condition (Akter *et al.*, 2016). Higher success of stone grafting on cv. Amrapali was also reported by (Ram *et al.*, 2015) in comparison to other cultivars.

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Prospects of Cocoa Cultivation in Assam

Alpana Das and Elain Apshara*

ICAR -CPCRI RC Kahikuchi, Assam, * *ICAR CPCRI RS, Vittal, Karnataka*

Cocoa (*Theobroma cocao* L.) is an important plantation crop. Cocoa, a beverage crop having high commercial potential, is mostly grown in India as a mixed crop in arecanut and coconut gardens. In the global production scenario, India is a very small player with the production share of a meagre 0.3%. It is mainly cultivated in four major southern states of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. The cocoa industry in the country has expanded to a considerable extent in recent years, with a production of 15133 tonnes of cocoa from an area of 71335 hectares and contributes about Rs.2000 million annually to the GDP of the nation. The dry bean of cocoa is an important raw material for chocolate industry. Area under this crop is estimated to be 71,370 hectare with a production of 18,100 MT. Kerala and Karnataka are the leading cocoa producing states followed by Andhra Pradesh. The demand for cocoa beans in Indian chocolate industries and confectionaries is about 30,000 MT (DCCD, 2015). However, only one third of the production is available to meet the demand of the existing processing industry. Taking into consideration the present day consumption patterns and growth of confectionery industry in India at around 15%, the demand for cocoa is likely to increase in coming years. The growth of purchasing power in emerging markets and the confirmation of the health/nutritional benefits of cocoa have led to a significant increase even in the global demand for cocoa. At the same time, the market has become more stringent in terms of quality requirements particularly with regard to pre and post harvest bean handling. As a matter of fact, cocoa for India is a high potential crop. Therefore, there is an urgent need to increase the production and productivity for sustaining the chocolate industry.

Cocoa is mainly grown as a mixed crop in arecanut and coconut plantations in India. There is a potential scope for introducing in other states where coconut and arecanut are grown. Arecanut is an important plantation crop grown in Assam. Assam has also emerged as the third largest producer of arecanut after the southern states of Karnataka and Kerala. Compared to the growers down south, growers in Assam seem to have taken interest in expanding the acreage under arecanut as more than 7,800 hectares were added since 2011-12. The area under arecanut went up from 68,700 hectares in 2011-12 to 74,000 hectares in 2014-15. Out of all the districts in Assam, 16 districts are having arecanut plantation of more than 2000 hectare. Golaghat has the maximum area under arecanut (6,186 hectare) followed by Kamrup Rural (4,264 hectare) and Cachar (4,123 hectare). Mono-cropping is normally adopted by the arecanut growers. Cocoa being a semi-shade loving plant, there is a potential scope of introducing this crop in this arecanut plantation as inter crop and also to enhance the fertility status of soil through organic recycling. Cocoa is a small tree, 6-8 m high, sometimes reaching to a height of 12-14 m. The growth pattern comprises of a single main stem or chupon. The terminal bud then breaks upto 3-5 meristems to give a fan branches, so called jorquette which grows horizontally. Then, the terminal bud ceases growth and 3-5 lateral branches (fan branches) develop at this level and grow almost horizontally. The bearing pattern of cocoa is cauliflorous - the flowers and fruits are borne on old wood of main stem and fan branches. Seeds called as beans are usually 20-60 in number per pod. Ripe fruits do not open to scatter the seeds or fall from the tree.

Cocoa requires well drained, rich soil, acidic to neutral with a minimum soil depth of 1.5 m. It is a semi-shade loving plant well suited for humid tropical region. Research findings at CPCRI, Research Centre, Kahikuchi, Guwahati, Assam, found that the crop can be grown successfully in sub-tropical climate. Cocoa is grown from sea level upto an elevation of about 800 m. It grows well in region where temperature ranges from 10 to 38°C and an optimum temperature of about 25°C with high humidity throughout the year. Well distributed rainfall and minimum of about 90- 100 mm per month is ideal for proper growth and yield. There are two major commercial types of cocoa *viz.*Criollo and Forestero are available which differ in pod colour and beans. Criollo pods possess dark red, rough surface, prominent ridges, pronounced point, thin wall with plumpy and white cotyledon when fresh and turn cinnamon colour on fermentation. While Forestero type possess green pod at immature stage and turn yellow when ripe. Fresh cotyledons are flat and purple and turn dark chocolate brown colour on fermentation. Other types include – Trinitario which is reported to be a hybrid of Criollo and Forestero. Amelonado, a Forestero type is cultivated in West Africa and Amazon types from Amazon forest possess vigorous growth and high yield. Since Forastero and Trinitario types are widely adapted in Asian continent they are suitable for Assam conditions. CPCRI developed four hybrids VTLCH-1, VTLCH-2, VTLCH-3, VTLCH-4 and three clones VTLCC-1, VTLCS-1, VTLCS-2 suitable for both arecanut and coconut shade.

Cocoa can be propagated through seed and vegetative means. Cocoa pods take 150-170 days from pollination to harvesting. Generally cocoa gives two main crops in a year (September –January and April - June) and it varies with different agro- climatic regions. Off-season flowering and fruiting may be seen almost throughout the year, especially under irrigated conditions. The maturity of pods can be identified by change in colour from green to yellow or red to orange. Only ripe pods have to be harvested without damaging the flower cushions. The harvested pods should be kept for a period of 3-4 days for enhancing pre-fermentation. The pods are broken by hitting against a hard surface and beans are removed without placenta and kept for fermentation immediately.

***In-vitro* multiplication of Dendrobium Hybrid 'Emma White'**

R. Devadas, R. Sherpa, S. Pattanayak, A. L. Meitei, & D. R. Singh

Plant Breeding, ICAR-National Research Centre on Orchids,
Pakyong-737106, Sikkim
**E-mail: ramgopal.devadas@icar.gov.in, r.devdas@gmail.com*

Flower stalks of Dendrobium hybrid 'Emma White' were used for induction experiment *in-vitro* using MS medium with sucrose (2%), BAP (1 to 3 mg/l) and NAA (0.1 mg/l). Well developed plantlets with complete root development were obtained from Plb's generated without callusing phase on Gamborg (G) medium supplemented with BAP (1 mg/l), after 196 days without activated charcoal. These *in-vitro* plantlets generated were used as explants for re-induction experiments to induce callusing phase to maximise the scope for multiplication rate. Shoot tips, leaves and roots were surface sterilized and cultured in basal MS medium supplemented with sucrose (2%) with combination of BAP (1, 2 and 3 mg/l) and NAA (0.5 mg/l) as different treatments (I_1, I_2, I_3….I_8). The best response was noted in treatment I_2 (BAP 1 mg/l) and I_5 (NAA 0.5 mg/l) giving good root and shoot growth, and comparatively moderate response in I_8 (BAP 3 mg/ l & NAA 0.5 mg/l) with multiple shoots and less developed roots at slow rate. Hence, cultures were used to generate callus/PLBs from plantlet using ½ MS medium with sucrose (2%), BAP (0.5 mg/l) and NAA (0.25 mg/l) without charcoal. Media with ½ Gamborg (G) supplemented with BAP (0.25 mg/l), NAA (0.25 mg/l) and Activated Charcoal was identified to induce callusing from PLBs. Healthy and good number of PLBs developed was sub-cultured on Gamborg (G) media supplemented with BAP (1 mg/l), NAA (0.25 mg/l) and activated charcoal (1.5 g/l) generated plantlets. Final effective hardening *in-vitro* with healthy roots and shoot were developed from smaller plantlet using Gamborg (G) media supplemented with Sucrose (2%), IBA (2 mg/l), BAP (0.25 mg/l), NAA (0.25 mg/l) and Activated charcoal (1.5 g/l), in addition to the sterilized stones/ bricks to create simulated environment in culture bottles. Grown up plants were shifted to *ex-vitro* hardening for acclimatization in smaller pots.

Strawberry (*Frageria* x *ananassa* Duch.) Cultivation in Western Ghats Region of Kerala

Ajith Kumar K., Anu Kurian, Muhammed Aslam, Reshmy Vijayaraghavan and Gavas Ragesh

College of Horticulture, Kerala Agricultural University, Thrissur – 680 656, Kerala
Email: ajithkumar.k@kau.in

In order to find the suitability of strawberry cultivation in Western Ghats region of Kerala, the present investigations was carried out at Regional Agricultural Research Station, Wayanad, Kerala during 2013-14 to 2016-17. Wayanad is located at 76.12°E latitude, 11.37°N longitude and at an altitude of 1000 m above mean sea level and enjoys mild sub-tropical climate. Studies were made on evaluation of cultivars, systems of planting, time of planting and mulch materials. Six cultivars of strawberry was evaluated for yield and quality and the results obtained revealed that the varieties Winter Dawn and Sweet Charlie suitable for commercial cultivation in this region. Maximum number of fruits (10.5) and highest yield (102.7 g) per plant were recorded when planted in the last week of September with black polyethylene mulch in open field. Incidence of diseases *viz*., leaf spot (*Colletotrichum gloeosporioides*), leaf blight (*Neopestalotiopsis clavispora*), crown rot (*Fusarium oxysporum* and *Lasiodiplodia theobromae*) leaf blight (*Phomopsis* sp.), leaf spot *(Mycospaerella* sp.) and collar rot (*Phytophthora* sp.) and pests *viz*., termite (*Odontotermes* sp*.)* and army worms (*Spodoptera litura*) were noticed. Highest cost-benefit ratio was also recorded in this region. Accordingly Sate Horticulture Mission-Kerala (SHM-K) has drawn up a project to cultivate strawberry in Western Ghats region of Kerala and the farmers were expected to earn better returns by diversifying into this high value crop.

Keywords: *Strawberry, cultivation, Western Ghats region, Kerala*

Effect of Mulching Materials on Growth, Quality and Soil Health Parameters in Acid Lime *(Citrus aurantifolia* Swingle)

Esther Lalruatsangi and B. N. Hazarika

College of Horticulture and Forestry, Central Agricultural University
Pasighat, Arunachal Pradesh- 791102, Email: estherlrs0811@gmail.com

A field experiment was conducted to study the effect of mulching materials on growth, quality and soil health parameters of acid lime during 2014-2015 at Fruit Research Farm, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. The experiment was laid out in Randomized Block Design with 9 treatments and 3 replications. The treatments were T_1 = No mulch (Control), T_2 = Dry grasses, T_3 = Banana leaves, T_4 = Paddy straw, T_5 = Rice husk, T_6 = Wood shavings, T_7 = Saw dust, T_8 = Polythene mulch with black side facing upward and T_9 = Polythene mulch with silver side facing upward. Results showed that the mulching materials had a significant influence on growth and quality parameters such as plant height, plant canopy spread in E-W and N-S direction, number of fruits per plant and branch, titratable acidity, reducing sugar, total sugar and ascorbic acid content. Polythene mulch with black side facing upward (T_8) gave the best results in terms of plant height (6.63 %), canopy spread in E-W (9.90%) and N-S (7.60 %) direction, fruits per plant (163.0), fruit weight (50.22 g), fruit yield per plant (7.81 kg), total sugar (0.40 %), reducing sugar (0.61 %) although the other treatments showed significant results. T_8 also recorded highest amount of organic carbon (3.11 %), available nitrogen (428.47 kg/ha), phosphorus (45.17 kg/ha) and potassium (575.06 kg/ha) while the treatment recorded highest microbial population of bacteria (83.45×10^5) in paddy straw mulch (T_4) and fungi (119.34×10^5) in rice husk mulch (T_5). The highest cost benefit ratio was observed in dry grasses mulch (1:2.67) while lowest was in banana leaves mulch (1:1.05).

Keywords: *Acid Lime, Mulching Material, Growth, Quality, Soil Health*

Development of Hybrids between Kinnow and Mukaku Kishu and their Detection with the Help of SSR Markers

Krishan Kumar[1], Kirandeep Kaur[1*], Kamaljeet Kaur[1], PK Arora[1] and Kuldeep Singh[2]

[1]Punjab Agricultural University- Regional Research Station, Abohar- 152116
[2]ICAR- National Bureau of Plant Genetic Resources, New Delhi
**Email: kiran.kaur4554@yahoo.com*

Kinnow, a hybrid (*Citrus nobilis* x *C. deliciosa*) mandarin, is high yielding and bears fruits with good flavor. However, the high seed content of this mandarin is a constraint in its consumption for table purpose as well as into processing industry. 'Mukaku Kishu' (*C. kinokuni*) has seedlessness of heritable nature and can be used as donor in the breeding programme for genetically improving Kinnow for this trait. However, due to the presence of nucellar embryony and absence of morphological distinguishers at seedling stage, the identification of hybrids post germination is difficult. The use of SSR markers can prove useful in distinguishing the hybrids from nucellar seedlings. In the present study, hybrids were developed between Kinnow (♀) and Mukaku Kishu (♂) and were identified with the help of polymorphic SSR markers. Of the total 138 SSR markers, 20 showed polymorphism between Kinnow and Mukaku Kishu and 4 markers (CMS04, TTA15, Ci06A05b and CiBE1500), were ideal for detection of hybrids. These 4 markers identified a total of 67, 102, 104 and 106 hybrids, respectively from the total of 697 analyzed seedlings. The hybrids are differing for leaf shape, plant height and number of spines and will be further evaluated for seedlessness.

Productivity Maximization and Quality Improvement in Peaches

N.A. Deshmukh*, H. Rymbai, A. K. Jha, P. Lyngdoh, D. Paul, Y. Lyngdoh, S.R. Assumi and H.D. Talang

ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya, India,

********Email: nadeshmukh1981@gmail.com*

Peach (*Prunus persica* (L) Batch.), a nutraceutical fruit, cultivated in north eastern region of India in an area of 460 hectare with a production 3,340 tonnes (NHB, 2015) Fruits of low chilling varieties *viz.*, Partap, Flordasun and Shan-e-Punjab matures in May-June, a lean period for other fruits availability, has an opportunity to tap market and earn higher income. But profuse bearing habit of peaches results in excessive crop load of undersized fruits with impaired quality, limb breakage and exhaustion of tree reserves. Poor productivity and unproductive old/senile orchards are the major constraints in peach production. Thus different experiments were conducted during 2011-2015 to standardize the productivity maximization and quality improvement techniques in peaches. Experiments on effect of pruning and flower/fruitlet thinning on peach cv. Flordasun revealed that reproductive pruning done during last week of October to first fortnight of November and flower/fruitlets thinning on 20 days after full bloom with fruit spaced at 20 cm apart on whole tree canopy hasten fruit maturity (12 days) increased fruit size (4.79 cm and 4.56 cm) fruit weight (58.09 g/fruit), fruit yield (28.82 kg/tree), TSS: acid ratio (20.17) and improve fruit skin colour (*L**, *a** and *b**) values. While in cv. Partap, thinning at 30 days after full bloom with fruits spaced at 15 to 20 cm apart advanced fruit maturity by 15 days with highest TSS (10.71 ^{0}B) and ascorbic acid content (6.11 mg/100 g). In other experiment on rejuvenation old/senile peaches, the protocol for rejuvenation was standardized. In which heading back of primary branches by leaving 50 cm on main trunk during November-December was found suitable. The 10 to 15 new shoots emerge 40-50 days after pruning,

3-4 new shoots/branches are kept and reproductive shoots pruning should be done every year during October-November. On an average 30-40 kg fruits/plant can be harvested from 3rd year onwards from rejuvenated tree. Among the low chilling varieties Partap responds better to rejuvenation. These production practices can be successfully used for productivity and quality enhancement of peaches under mid hills altitude.

Effect of Pruning Severity and Spray of Urea on Growth, Flowering and Fruiting of Guava (*Psidium guajava*) cv. L-49

Rebecca Eko, Barun Singh and Senpon Ngomle

College of Horticulture and Forestry,
Central Agriculture University, Pasighat, East Siang, Arunachal Pradesh, 791 102
Email: sngomle29@gmail.com

The present investigation was carried out in the year 2011, on four year old guava orchard of cv. L-49 planted in College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. The experiment was laid out in Randomized Block Design with six treatments and four replications with the objective of attaining higher productivity with better quality fruits during the winter season. The trees were treated with the treatments T_1-single spray of urea 10%, T_2-single spray of urea 15%, T_3-pruning of lateral shoots 50% of length, T_4-pruning of lateral shoot 75% of length, T_5- hand de-blossoming and T_6-Control(no treatment). Twenty shoots on each tree were tagged in all directions for recording various observations. Uniform cultural practices were given in each treatment. The treatments were imposed during the month of May 2011. All the treatments except control were effective in increasing fruit production in winter season. Maximum increase in production of winter season fruits (32.79kg/tree) was recorded in treatment T_2-single spray of urea 15% while yield was minimum (4.91 kg/tree) in control. The cost benefit ratio (1:6.28) was high in treatment T_2-single spray of urea 15%. The treatments significantly increased the fruit quality but the vegetative characters of the plant were not significantly affected.

Free Radical Scavenging and Antidiabetic Activity of Some Indigenous Agri-horticultural Crops of Manipur

S. S. Roy[1], Priyanka Khoirom[1], Thangjam Surchandra Singh[1], Yensenbam Malemnganba Meitei[2], Blessa Sailo[1], M. A. Ansari[1], S. K. Sharma[1], A. Sen[3], N. Prakash[1] and S. V. Ngachan[3]

[1]*ICAR Research Complex for NEH Region, Manipur Centre, Imphal*
[2]*Hemwati Nandan Bahuguna Garhwal University, Srinagar, Uttrakhand*
[3]*ICAR Research Complex for NEH Region, Umiam, Meghalaya*
Email: subhrasaikat@gmail.com

Oxidative stress in human body most often leads to non-communicable degenerative diseases like diabetes, cancer, cataracts, immune system decline, cardiovascular disease, brain dysfunction and atherosclerosis, etc. Diabetes mellitus is the commonest endocrine disorder that affects more than 415 million people worldwide. Currently, there is renewed interest in plant-based medicines and functional foods modulating physiological effects in the prevention or cure of degenerative diseases like diabetes, cancer, immune system decline etc., where oxidative stress plays a major role. Given this background, all total eight indigenous edible plants namely, Tree Bean (*Parkia roxburghii* G. Don), King Chilli (*Capsicum chinense* Jacq.), Kachai Lemon (*Citrus jambhiri* Lush), Wild Orange

(*Citrus macroptera* Montr.), Chinese Chive (*Allium tuberosum* Rottler ex Spreng.), Hooker Chive (*Allium hookeri* Thwaites), Pigeon Pea (*Cajanus cajan* (L.) Millsp.) and Black Rice (*Oryza sativa* L.) were screened for their free radical scavenging and antidiabetic activity (α-amylase enzyme inhibitory activity). In DPPH radical scavenging assay, methanolic extract of pod and seed mixture of tree bean shown maximum antioxidant activity (IC_{50} value of 0.069 mg); followed by acetone extract of pigeon pea leaf (IC_{50} value of 0.342 mg), acetone extract tree bean pod (IC_{50} value of 0.601 mg), methanolic extract of pigeon pea leaf (IC_{50} value of 0.630 mg), methanolic extract of tree bean pod (IC_{50} value of 0.914 mg) and acetone extract of pod and seed mixture of tree bean (IC_{50} value of 1.01 mg). In anti-diabetic assay, maximum inhibition of α-amylase enzyme was reported with methanolic extract of wild orange pulp (74.83%); followed by tree bean pod (67.39%), chinese chives leaf (57.14%), hooker chives root (56.84%), mixture of tree bean pod and seed (56.10%), tree bean seed (54.59%), acetone extract of wild orange pulp (54.50%) and methanolic extract of black rice husk (50.62%). Regular consumption of these crops would be helpful to fight against degenerative diseases caused by reactive oxygen species as well as to delay the onset of diabetes; while black rice husk which is considered as waste can be commercially utilized in pharmaceutical industry.

Keywords: *Antioxidant, Anti-Diabetic, A-Amylase, Tree Bean, Chinese chive, Black Rice*

Flowering, Yield and Quality Attributes of Assam Lemon after Application of Plant Growth Regulators

Sukanya Gogoi*, Utpal Kotoky and Kaushik Das

Assam Agricultural University, Jorhat, Assam-785013 (Assam), India
**Email: sukanyagogoi21@gmail.com*

Lemon trees cv. Assam Lemon were treated with two plant growth regulators in order to examine their effect on flowering, yield and quality. The treatments comprised of untreated control, three different concentrations of GA_3 (20, 40 and 60ppm) and three different concentrations of NAA (10, 20 and 30ppm). The growth regulators were applied as foliar spray at three growth stages- at pre flowering stage in the month of November; at flowering stage; and one month after fruit set. The plant growth regulators decreased the flowering-harvesting interval with stimulation in yield attributing characters like fruit size, pulp-peel ratio and juice content and quality attributes like titrable acidity and TSS-Acidity ratio. However, the treatments have no significant effect on total soluble solid concentrations. The plant growth regulators have also an influence on organic acid content particularly ascorbic acid and citric acid. After evaluation from economics of cultivation, it was found that GA_3 at 60ppm is the most economical plant growth regulator to improve flowering, yield and quality of Assam Lemon.

Keywords: *Assam Lemon, GA_3, NAA, Flowering, Yield*

Studies on Propagation of Citrus Rootstock – Carrizo Citrange

Tanjeet Singh Chahal

Punjab Agricultural University- Fruit Research Station, Jallowal-Lesriwla, Jalandhar

Email: tanjeetchahal@pau.edu

The availability and quality of rootstock is the key to successful citrus nursery production. Earlier studies have shown that during mass production when seed of desired citrus rootstocks is not available in sufficient quantity, it can be propagated through different means like stem cuttings and tissue culture. Limited supply of rootstock seed invited such methods of stock raising to cater large number of clonal rootstocks required to produce quality citrus nursery. However, these methods need to be evaluated for their effect on growth and quality of stock produced and success in nursery production of specific scions budded on them. Keeping this in view the present study was planned during 2014-15 at Punjab Agricultural University, Fruit Research Station – Jallowal-Lesriwal and following results were recorded. Seed sowing and tissue culture methods of propagation were more suitable in comparison to cutting, for achieving higher vegetative growth in Carrizo citrange rootstock for nursery production. Highest plant height and leaf number was observed in tissue culture plants while seedlings registered highest stem thickness. Propagation of Carrizo through cutting produced significantly slower vegetative growth with exception of secondary and tertiary shoot number. Seed sowing method of Carrizo propagation was most effective in producing longer roots with thicker diameter and higher fresh weight while cutting method resulted in production of higher number of primary roots. Plants propagated through seeds and tissue culture showed higher sap flow for longer duration and more number of buddable rootstocks in comparison to cutting. Significantly higher budding success of Daisy Tangerine scion was achieved in seedling as compared to the other two methods. The highest budding success of W. Murcott was recorded in seedling and tissue cultured plants. Success of these scion varieties on Carrizo rootstock propagated through cutting was much lower than the other two methods. So on the basis of above discussion inference can be drawn that seed sowing followed by tissue culture are more suited methods for Carrizo propagation in order to achieve good growth of plants with early buddable stage, good nursery qualities and higher budding success of Daisy Tangerine and W. Murcott scions in comparison to plants generated through cuttings.

Standardization of Maturity Indices of Kew Pineapple under Mid hill Conditions of Arunachal Pradesh

Thejangulie Angami, H. Kalita, Sikimoni Baruah, Takar Ronya

ICAR Research Complex for NEH Region, AP Centre, Basar
Email: thejaangami@yahoo.com

Pineapple is one of the important fruit commonly grown from the foothills to the mid hills in Arunachal Pradesh. Kew variety of pineapple being grown as organic by default in the state is one of the most popular and promising variety among the growers due to its splendid quality attributes. However, a substantial quantity of the fruits are damaged due to improper harvesting, rough handling, poor or absence of packaging systems, poor transportation system and rough rugged road conditions resulting in loss of fruits. Considerable quantities of the fruits are also lost due to lack of knowledge of the growers about the proper stage of harvesting. Moreover, appropriate maturity indices are not known for this variety as the maturity time differs in foothill and mid hill conditions. Therefore, standardization of maturity indices of this variety is required under mid hill conditions of Arunachal Pradesh to reduce the postharvest losses as well as to maintain quality of the harvested produce.

Experimental findings revealed that out of five different stages of maturity, pineapples of the Kew variety harvested during 151-155 DAF (50 % colour development stage) was found to be the right stage of harvesting pineapple for distant market which can be reached within a day or two exhibiting highest ascorbic acid content (43.17 mg/100 g) and better quality attributes. It was also found that the fruits harvested during 156-160 DAF (75 % colour development stage) was found to be the right stage of harvesting pineapple for local market with a moisture percentage of (84.05), TSS (13.60° Brix), acidity (0.38 %), TSS: acid ratio (35.79), ascorbic acid (38.73 mg/100 g), total sugar (21.01 %) and reducing sugar (4.33 %). Hence, days after flowering, TSS, acidity, TSS: acid ratio etc. may be considered as suggested indices for harvesting Kew pineapple at the right stage for local as well as distant markets during August-September under mid hill conditions of Arunachal Pradesh.

Under-utilized Fruit Crops of North-East India: Importance and Study on Antioxidant Activity

Sudip Kumar Dutta[a*], SB Singh[a], Vanlalhmangaiha[a], V Dayal[a] and SV Ngachan[b]

[a]*ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram 796 081, India*
[b]*ICAR Research Complex for NEH Region, Umiam, Meghalaya 793 103, India*
E-mail:sudipiari@rediffmail.com

In India, north-eastern hill (NEH) region has rich diversity of less-known, underutilized and ethno-medicinally important fruit crops. Among the major fruits crops of the country, NEH region has maximum diversity in citrus, banana and jack fruit; moreover high diversity in other temperate, tropical and subtropical fruits belonging to the genera *Pyrus, Rubus, Ribes, Prunus, Garcinia, Artocarpus, Phyllanthus, Annona, Averrhoa, Persia, Aegle, Passiflora* and *Tamarindus* etc. are also reported from the region. These fruits are ethno-medicinally and nutritionally important for local tribes of the region. Therefore, we attempted to quantify the bioactive and antioxidant compounds of some of these underutilized fruit crops. *Hlingsi* (*Sapindus mukorossi* Gaertn.), *Belthei* (*Aegle marmelos* (Correa) Linn.), *Kawrthindeng* (*Dillenia indica* L.), *Pangkai* (*Baccaurea ramiflora* Lour.), *Sunhlu* (*Emblica officinalis* Gaertn.) and *Tatkawng* (*Artocarpus chama* Buch.–Ham.) were high source of total phenolic (TP) content; *Kawrthindeng* (*Dillenia indica* L.) and *Sunhlu* (*Emblica officinalis* Gaertn.) were found to be high source of total flavonoids (TF). Diphenyl-2-picrylhydrazyl (DPPH), azinobisethylbenzothiazoline-6-sulphonic acid (ABTS) and ferric reducing antioxidant power (FRAP) activity of underutilized fruit crops were analysed. Significant positive correlation was detected among TF-FRAP, TF-ABTS, ABTS-FRAP, DPPH-FRAP and DPPH-ABTS assays. Principal component analysis (PCA) was found an effective technique in grouping the local underutilized fruits based on their antioxidant contents. The antioxidant data generated from this study will enhance the pharmaceutical, neutraceutical and processing use of these underutilised fruit crops. Results signify that, these underutilised fruits must be promoted for cultivation, processing, pharmaceutical and processing use in large scale.

Evaluation of the Physico-Chemical Characteristics of Underutilized *Allium* species (*Alllium hookeri* Thw.) in Northeast Region of India

M Bilashini Devi*[1], SR Assumi[1], HD Talang[1], W Shimray[1], Nisha Thakur[2], P Chaudhary[1] and AK Jha[1]

[1]*ICAR-Research Complex for NEH Region, Umiam-793103, Meghalaya*
[2]*ICAR-IARI Regional Station Katrain, Kullu-175129, Himachal Pradesh*
**Email: bilashini1712@gmail.com*

The present investigation was carried out at the Division of Horticulture, ICAR Research Complex for NEH Region, Umiam, Meghalaya to estimate the physico-chemical characteristics *viz.,* ascorbic acid content, total sugar, TSS, total chlorophyll and carotenoids in fifteen different samples of *Allium hookeri* Thw. collected from Manipur. The colour index *viz.*, *L**, *a** and *b** were also estimated for all the samples. The result indicates significant variations amongst the samples for all the traits estimated. The range of mean performance for the traits estimated are ascorbic acid content 13.61 to 50.00 mg/100g; total sugar 4.69 to 9.52 mg/100g; TSS 4.10 to 10.73^{o} Brix, total chlorophyll 0.23 to 0.98 mg/100g and carotenoids 0.06 to 0.27 mg/100g whereas the *L**, *a** and *b** values ranged from 35.14 to 46.06; -7.95 to -6.38 and 10.45 to 19.80, respectively.

Performance of Low Chilling Peach Cultivars at Lower Hills of Nagaland

H. Talang[1*], B. C. Deka[2], H. Rymbai[1], N. A. Deshmukh[1], M. B. Devi[1], Vandana Verma[3], T. Zhimomi[3] and A. K. Jha[1]

[1]ICAR Research Complex for NEH Region, Umiam
[2]Agriculture Technology Application and Research Institute, Umiam
[3]ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani
Email: hammylliende@gmail.com

Low chilling varieties of peach viz., TA-170, Flordasun and Shan-e-Punjab were evaluated to find out a suitable cultivar for commercial production under low hill condition of Nagaland. The experiment was laid out in a randomized block design with 3 replications at ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema during 2015-2016. The result revealed that cultivar TA-170 accounted for the maximum yield (15.58 kg/tree), fruit weight (40.27 g), fruit length (5.50 cm) and fruit diameter (4.50 cm) followed by Flordasun and lowest in Shan-e-Punjab. Maximum total sugars (13.71 %), reducing sugar (6.67 %) and TSS (17.35 °Brix) along with lowest acidity (0.27 %) content was observed in Flordasun. Maximum ascorbic acid (76.17 mg/100 g) content on the other hand was found in Shan-e-Punjab. From the present study, it may be concluded that Flordasun was the best performer followed by TA-170 and Shan-e-Punjab under low hill condition of Nagaland for commercial cultivation.

Assessment of Potential Pockets on Climate Suitability for Sustainable Cultivation of Hill Banana *Kait syieng* (AAB genome group) in India

Rajappa Joga[1], N. Sivaraj[2,] Puran Chandra[1], Bappa Karmakar[1] and K.P. Mohapatra [1]

[1] ICAR Research Complex for NEH Region, Umiam (Barapani) - 793 103, Meghalaya
[2] ICAR-National Bureau of Plant Genetic Resources, Regional Station, Hyderabad 500 030

Email: rajappajj@gmail.com

Kait syieng, a hill banana cultivar belonging to AAB genome group of *Musa* found mostly in small geographical area of Meghalaya is a distinct for its sweet taste and fresh aroma (fragrance of *Magnolia* flowers). *Kait syieng* is one of the hardiest medium tall banana cultivar with deep red brown stem when mature and new shoots show distinct red coloration. New leaves have a red tinge on the back of the leaves. Leaves are lengthy with midribs of leaves are dull red and the plants grow taller and are more robust and each inflorescence produces more hands of fruit. Inflorescence is used as vegetable by the locals. It is resistant to *Fusarium* wilt and fairly resistant to bunchy top disease with small sized fruits with many seeds, thin peel, creamy pulp and sub-acid taste. Considering its importance in the region and for planning proper conservation strategies and area expansion an ecological niche modelling using Maximum entropy species distribution method had been conducted

to assess potential pockets for the cultivation of *Kait syieng* in other parts of the country. DIVA-GIS version 7.5 used for converting the ascii file generated using maximum entropy method. Grid maps were generated for both Current and Future climates. Bioclimatic variables viz., Bio1 (annual mean temperature), Bio2 (mean diurnal range), Bio3 (isothermality), Bio4 (temperature seasonality), Bio5 (Max temperature of warmest month), Bio6 (Min temperature of coldest month), Bio7(temperature annual range), Bio8 (mean temperature of wettest quarter), Bio9 (mean temperature of driest quarter), Bio10 (mean temperature of warmest quarter),Bio11 (mean temperature of coldest quarter), Bio12(annual precipitation), Bio13 (precipitation of wettest month), Bio14 (precipitation of wettest month), Bio15(precipitation seasonality), Bio16 (precipitation of wettest quarter), Bio17 (precipitation of driest quarter),Bio18 (precipitation of warmest quarter) and Bio19(precipitation of coldest quarter) were used for modelling. Under the current climatic regime potential pockets for its sustainable cultivation exists in parts of Assam, Sikkim, Tripura, Manipur, Jammu and Kashmir, Maharashtra, Meghalaya, Uttarakhand, Gujarat, Kerala, Himachal Pradesh, Karnataka and West Bengal. The grid maps generated for future climate (year 2050) indicated that potential regions in Western Ghats would come down while increased pockets for climate suitability will increase in the states of Gujarat, Odisha and West Bengal. The paper further discusses on conservation strategies based on the Ecological niche modelling for current and future climatic regime.

Keywords: *Banana, Conservation, DIVA-GIS, Kait syieng, MaxEnt*

Dragon fruit (*Hylocereus* spp.) an Exotic Fruit Crop: its Growth and Yield Response in Mizoram

Vishambhar Dayal, S. B Singh, T. Boopathi, Vanlalhmangaiha, S. K. Dutta, Lungmuana, Saurav Saha, Pankaj Kumar Sinha, A.R.Singh and Samik Chowdhury

ICAR-Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram-796081
ICAR-Research Complex for NEH Region, Umiam, Meghalaya-793103
E-mail: vishambhar5009@gmail.com

Red dragon fruit, *Hylocereus* spp. (Cactaceae) is a native of Central and Southern America and is being cultivated in South-east Asian countries including Malaysia, Indonesia, Taiwan, Thailand, Sri Lanka, Bangladesh and Vietnam. Recently, India has also started cultivating dragon fruits in different climatic regions. Dragon fruits bear creamy white coloured flowers which are ornate with fragrant scent that blooms at night (7-10 PM). Dragon fruit is an exotic, nutritious and delicious fruit which has very high nutritional values and it's considered as 'super foods'. We have conducted nutrient trials for standardizing package of practices for dragon fruit under Mizoram climatic conditions. Dragon fruit started fruiting from 14-16 months after planting and fruits are ready for harvesting in 30-35 days after flowering. The growth of dragon fruit was observed at different nutrient treatments *viz*., T_1: Control, T_2: NPK fertilizer @ 25, 75, 75g/plant, T_3: NPK @ 25, 75, 75g/plant + FYM 2 kg/plant, T_4: NPK @ 25, 75, 75g/plant + Vermicompost 1 kg/plant , T_5: NPK @ 25, 75, 75g/plant + FYM 2 kg/ plant + Vermicompost 1 kg/plant. Treatment, T_5 showed significantly higher growth and number of branches as compared to other treatments. Apparently, plants were deficient in calcium and nitrogen and produece severe symptoms. Mealy bugs, aphids, hairy caterpillar, hopper, scale, pentatomid bug and white leafhopper were the major economically important insect pests. Soft rot and wet rot diseases typically infected the ends of dragon fruit branches or stems. For control of soft rot and wet rot disease, we removed and destroyed the infected branches or stems and lime @ 200 g per pole was applied near to rhizosphere; and lime @ 100g per litre of water was sprayed on the plant and followed by bactericymine @ 5 g per 15 litre of water, plantomycine @ 5 g per 15 litre of water and mancozeb @ 15 g per 15 litre of water were applied for the control of soft rot and wet rot

disease. Average fruit weight of 300-350g was found among different treatments. Therefore from the results of first years trial, it can be assumed that Dragon fruit is going to succeed well under Mizoram climatic conditions. Long term trials with different varieties and multilocations trials need to be taken up to expand the crop in the state.

KeyWords: *Dragon fruit, Nutrient treatment, Growth, Disease, Bacterimycine and Plantomycine*

Association between Biochemical Traits and Downy Mildew Resistance in Cauliflower (*Brassica oleracea* L. var. *botrytis*)

Arti Verma*, Yudhvir Singh, Simran Sharma, Bhallan Singh Sekhon and Surbhi Sharma

Department of Vegetable Science and Floriculture, CSK HPKV Palampur (HP), India-176 062
**Email's email: verma.arti104@gmail.com*

Downy mildew (DM), induced by the oomycete *Peronospora parasitica*, is a destructive worldwide disease of cauliflower and other *Brassica* vegetables. The present investigation was carried out at the Experimental Farm of the Department of Vegetable Science and Floriculture, CSK HPKV Palampur to gather information on the association between downy mildew resistance and biochemical traits in cauliflower. The experimental material comprising of P_1, P_2, F_1, F_2, BC_1, BC_2 generations of six crosses developed by utilizing the four diverse parents *viz*., DPCaY-3, Palam Uphar, DPCaY-8 and DPCaY-6 were evaluated in Randomized Block Design along with standard check in three replications during *rabi* 2015-2016. Data were recorded on total soluble solids (^{o}Brix), vitamin C (mg/100g), total sugars (%) and total phenols (mg/g). Genotypic correlation coefficients were higher than the phenotypic correlations which revealed that though there is a strong inherent association between different characters, the phenotypic expression of the correlation gets modified under the influence of environment. Correlation matrix revealed that plant disease index exhibited significant and positive correlation with total sugars, whereas this association was significant and negative with vitamin C and total phenols. Resistant genotypes have higher vitamin C and total phenols level than susceptible ones.

Keywords: *Cauliflower, Correlation, Downy Mildew, Biochemical*

Effect of Organic and Inorganic Sources of Nutrients in Potato under Meghalaya agro-Ecological Condition

Bapi Das[1], VK Dua[2], Clarissa Challam[1] and SK Chakrabarti[2]

[1]*ICAR-Central Potato Research Station, Shillong – 793009, Meghalaya, India*
[2]*ICAR-Central Potato Research Institute, Shimla – 171001, HP, India*
Email: bappidas24@gmail.com

Potato is one of the most important vegetable crop grown in India. India is the second largest producer of potato in the world after China. There is worldwide consensus that sole dependence on chemical input based agriculture is not suitable in long run and only integrated plant nutrient system involving a combination of chemical fertilizers, organic manures and bio-fertilizers are essential to sustain crop production, preserve soil health and bio-diversity. But most of the part of india farmers are continiously using chemical fertilizer alone which destroy the soil texture and structure as well as decrease the valuable organic matter content from the soil. Therefore a field experiment was conducted during summer season of 2016 at CPRS, Shillong to study the effect of organic and inorganic sources of nutrients in potato (Var. Kufri Jyoti) under Meghalaya Agro-ecological

condition. The experiment was laid out in randomized block design with three replications. There were nine integrated nutrient treatments viz; 100% RDF, 25% RDF + 75% RDN-FYM, 75% RDF + 25% RDN-FYM, 25% RDF + 75% RDN-FYM + Boron + Azotobacter + PSB + Potash mobilizing bacteria, 75% RDF + 25% RDN-FYM + Boron + Azotobacter + PSB + Potash mobilizing bacteria, 100% RDN-FYM, Boron, Azotobacter + PSB + Potash mobilizing bacteria and control (no application of fertilizer). Among the various treatments it was observed that highest number of tubers was obtained in the treatment of 75% RDF + 25% RDN-FYM (759259.30 Nos. of tubers /ha) followed by treatment 100% RDN-FYM (729166.70 Nos. of tubers /ha). The highest tuber yield was obtained in the treatment 75% RDF + 25% RDN-FYM + Boron + Azotobacter + PSB + Potash mobilizing bacteria (19.23 t/ha) followed by 75% RDF + 25% RDN-FYM (17.06 t/ha) and 100 % RDF (16.68 t/ha). The lowest yield was obtained in the treatment of control (5.41 t/ha).

Incidence of Various Diseases in Citrus Plantations in Manipur

Nabakishor Nongmaithem, S. K. Sharma, M.A. Ansari*, S. S. Roy, T. Basanta Singh,
Ch. Bungbungcha Meitei, N. Chanu Gulleibi , Ch. Basudha Devi, Rishikanta Singh, Blessa Sailo,
Anup Das, I.M. Singh, N. Prakash and S.V. Ngachan

*ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat 795 004, Manipur, India,
Email: merajiari@gmail.com*

Citrus, a tropical and subtropical crop belongs to the family Rutaceae of the tribe Citrae, consisting of large number of species and variety. In India, citrus fruits rank third in area and production after mango and banana with an estimated production of 37.0 Lakh tonnes and an area of 4.4 Lakh hectares and contribute 4.78% towards world’s total citrus. The North Eastern region of India stretches from 21° 57' N to 29° 28' N and from 89° 40' E to 97° 25' E is considered as one of the natural home of citrus and Citrus decline has been a major threat to citrus cultivation in North Eastern states. Various researchers have pointed out many factors responsible for decline in citrus orchard and damage caused by pests and diseases is one of the most important factors responsible for decline of citrus. In north eastern region, the prevailing high rainfall and humidity provides a congenial condition for most of the pests and diseases to grow multiply and attack citrus for a longer period. Diseases like tristeza, greening and canker causing havoc to citrus cultivation in North Eastern region. The symptom of retarded growth of tree, appearance of chlorotic leaves, sparse foliage, dieback of twigs, and in general a sickly appearance of tree is associated with decline. Survey for incidence of diseases in citrus plantations was conducted in different places of Manipur such as in Kachai area of Ukhrul district, Machi area of Chandel and Noney, Nungba area of Tamenglong district. Citrus plantations were found infected with diseases like huanglongbing (HLB), *Citrus tristeza virus* (CTV) and mixed infection of HLB and CTV were also recorded. Other biotic factors like canker, trunk borer, leaf miner, sooty mould were also observed on citrus plantations in Manipur. About 35% of citrus plantations were found infected with citrus canker, 53% with trunk borer and 15.2% with leaf miner in Noney and Nungba area of Tamenglong district. In Machi area of Chandel district 15% plants with HLB and 12% with sooty mold were infected. Incidence of 52% and 38% were recorded respectively for huanglongbing and CTV in Kachai lemon of Urkhul district. About 28% of the tested Kachai lemon plants had mixed infection of HLB and CTV in Urkhul district.

Vegetable Production for Enhancing Farm Income: A Case Study

Ingita Gohain
Ph.D Scholar, Dept.of ECM, AAU, Jorhat-13
E-mail: ingitagohain@gmail.com

Vegetables are one of the most important components of our daily diet. They are rich in vitamins and minerals. Farmers nowadays grow vegetables all throughout the year, considering the soil and season for a particular vegetable for earning regular and steady income to meet the daily expenditure. In recent years vegetables have become an important source of farm income in addition to the income from the agronomic crops. The present study was conducted in the South Tripura dist. of Tripura with a total no. of 22 farmers in the district. This state has good potential for growing and producing of horticulture crops. Most farmers residing near river banks have turned to be vegetable grower because of irrigation. They tend to produce early during seasons to catch the market and sustain against competitions. Local varieties and practices often lead to low productivity and poor yield. However, combining the traditional and modern technology of farming and improved variety can produce a good harvest of vegetables and thereby secure livelihood and bring nutritional security to the farmer as well as to his family. Knowing the importance of vegetable production and to meet the market demand of chilli, bottle gourd, brinjal okra on-farm trials were conducted under IIHR-NE component programme during 2015-16 in South Tripura District of the state Tripura.

Evaluation of Exotic Cultivars of Gerbera (*Gerbera Jamesonnii* L.) for Vegetative, Flowering and Quality Grown under Protected Condition at Longleng District, Nagaland.

[*1]K. Lily Rangnamei [1]Manoj Kumar, [1]E. Lireni Kikon, [1]K. L. Meena, [2]D.J. Rajkhowa, and [1]A. Namei

[1]*Krishi Vigyan Kendra, Longleng, Nagaland,*
[2]*ICAR RC for NEH Region, Nagaland centre, Jharnapani, Nagaland*
Email: lrangnamei@gmail.com

Gerbera (*Gerbera Jamesonnii* L.) is an herbaceous perennial flowering plant belongs to Asteraceae family. It is an important cut flower regarded as latest sensation to commercial floriculture industry on account of its remarkable form, magnificent colour variation, unsurpassed beauty and international market. The present investigation was carried out to study different hybrids varieties of Gerbera grown under protected condition at KVK Longleng, ICAR RC for NEH Region Nagaland Centre. On Farm Trail was conducted in two different villages i.e., Hukphang and YoangYimchen during the year 2016 - 2017. Four Gerbera hybrids Viz, Stanza, Silvester, Rosalin and Brilliance were evaluated for their vegetative, flowering and quality attributes. The data revealed that Rosalin recorded maximum in no. of leaf/plant (14.75 nos.), leaf length (49.68 cm), plant spread (58.06 cm), flower diameter (12.13 cm), diameter of trans floret(7.7 cm), diameter of disc floret (3.35 cm), Peduncle diameter (0.8 cm), length of ray floret(5.35 cm), and breadth of ray floret (1.15 cm), whereas Stanza recorded maximum in leaf breadth (19.76 cm), no. of suckers /plant (3 nos.), no. of ray floret (73 nos.), vase life (14.5 days) and no. of flowers/plant (2.25 nos.), same result was also found in Silvester. Silvester recorded maximum in plant height (51.48 cm), whereas Brilliance recorded maximum in Peduncle length of (72.35 cm). Cultivars Rosalin and Stanza appears to be the best cultivars under Longleng condition as compared to Silvester and Brilliance in terms of vegetative, flowering and quality attributes.

Combining Ability Studies for Yield and Yield Components in Chilli (*Capsicum annuum* L.

M. Janaki[*], J. Dilip Babu[1], L. Naram Naidu[2], C. Venkata Ramana[2], C. K. Koteswara Rao[3] and K. Uma Krishna

[*]*Scientist, HRS, Dr. Y.S.R.H.U., Peddapuram - 533 437, A.P., India.*
[1]*Director of Research, Dr. Y.S.R.H.U., V.R.Gudem - 534 101, A.P., India.*
[2]*HRS, Dr. Y.S.R.H.U., Lam Farm, Guntur - 522 034, A.P., India.*
[3]*Associate Director of Research (HQ), ANGRAU, Guntur - 522 034, A.P., India.*
[4]*Department of Statistics, COH, Dr. Y.S.R.H.U., V.R.Gudem - 534 101 (A. P.), India.*
Email: janaki.maradana@gmail.com

The present investigation was carried out at Horticultural Research Station, Lam farm, Guntur, Andhra Pradesh during *kharif*, 2013-14 and 2014-15 to estimate the combining ability effects employing the line x tester mating design with nine lines and six testers. The analysis of variance revealed that significant differences among the parents and crosses for all the 12 characters studied. Six characters *viz.* fruit yield per plant, plant spread, days to 50% flowering, days to fruit maturity, number of fruits per plant and number of seeds per fruit were exhibited higher magnitude of *sca* variances than *gca* variances which revealed that non-additive gene action was played an important role in the inheritance of these trait. According to *gca* effects, the genotypes LCA-442, LCA-654, LCA-655, LCA-703-2 and LCA-453 found to be promising general combiners for yield and yield components. The *sca* effects revealed that nine crosses *viz*., LCA 466 x LCA 705-2, LCA 607 x LCA 703-2, LCA 355 x LCA 678, LCA 504 x LCA 705-2, LCA 446 x LCA 703-2, LCA 615 x LCA 453, LCA 442 x LCA 453, LCA 607 x G4 and LCA 654 x LCA were identified as promising hybrids for fruit yield and it's component characters as they have exhibited significant *gca* and *sca* effects in desirable direction for most of the traits. The resulted promising hybrids may be further tested over locations or seasons and recommended for commercial release and identified good general combiners could be utilized in future chilli breeding programmes.

Arbuscular Mychorrizae Improved Cultivation of Capsicum under Protected Condition in Tripura

H.L. Devi*, B, Das, S.N. Bhowmick, B.K. Kandpal, R. Saha and P. Debbarma

ICAR Research Complex for NEH Region, Tripura centre, Lembucherra
**Email: lembihort@gmail.com*

Cultivation of capsicum (*Capsicum annuum* L. var. *Grossum* Sebdt.) is very limited in Tripura due to lack of its proper protected production technology. Though, climate of the state during winter is suitable for capsicum cultivation, but open field cultivation does not fulfill the quality standards and low production resulting in a gap between the supply and increasing demand of quality capsicum. Earlier experiment in the centre standardised that second fortnight of October as suitable planting time of capsicum var. Indra in Tripura under protected cultivation. In continuation, an attempt have been undertaken to maximise the yield and nutrient management of capsicum var. Indra with arbuscular mycorrhizae (AM) under naturally ventilated polyhouse in Tripura. The treatments were combinations of farm yard manure @10 tons/ha (blanket application) and 3 levels of recommended dose of fertilizer, *i e* 100, 75 and 50% of RDF with or without AM during 2016-17. Application of 50% RDF + AM recorded a yield of 48.26 t/ha. Further increase in fertlizer application upto 75% RDF enhances the yield by 42.5%. However, there was no significant increase in yield with increase in fertlizer dose upto 100% RDF. Soil application of AM signigicantly improves the yield by 74%. The highest fruit yield (52.63t/ha) was recorded with 75% RDF + AM. The result also corresponds with the yield attributes like maximum fruit weight (172.60g) and soil microbial population [2.45 MPN (AM)/g soil].The total soluble sugars remained non -significant in all treatments. Soil microbial population showed a negative correlation with increase in the recommended dose of fertilizer application. Reduction in the application of synthetic fertilizers improved the proliferation of microbial population; consequently the infectivity percent of AM had increased and improved the absorbing capacity of roots enabling the translocation of P along with vital micronutrients. Thus, application of 75% RDF + AM was found the most economically profitable and sustainable treatment.

Leaf nutrients in Declined and Non-declined Citrus Orchards at Varying Altitudes in Meghalaya

*H. Rymbai, N.A. Deshmukh, D.M. Firake, P. Baiswar, H.D. Talang, S.R. Assumi, A.R. Roy and A.K. Jha

ICAR Research Complex for NEH Region, Umiam, Ri-Bhoi, India – 793 103
**Email: rymbaihort@gmail.com*

An investigation was carried out to ascertain the effect of altitudes on leaf nutrients in declined and non-declined Khasi Mandarin orchards. Declined and non-declined orchards of *Khasi* mandarin were identified at varying altitudes *viz.*, >1000 msl (Ryngab, Pynursla, Mawryngkneng and Mawphu); 600-1000 msl (Lumsohpieng, Saitsama, Sohbar and Wahkhen); <600 msl (Pohriat, Dawki, Sohkhwai and Muktapur). It was observed that the leaf nutritional content ranged between 1.59-3.40% for N, 0.086-0201% for P, 1.52-2.05% for K, 1.553-2.41% for Ca, 0.18-0.31% for Mg, 141.32-180.36% for Fe, 61.51-66.49% for Mn, 1.97-3.51% for Cu and 12.33-13.73% for Zn. Leaf nutrients were higher at lower altitudes (<600 m) for N (3.01%), P (0.18%), K (1.82%), Ca (1.96%), Mg (0.32%) and Zn (11.21%). While micronutrients, such as Fe (160.52%) and Cu (2.75%), were higher at high altitude. Leaf Fe content (166.41 mg/kg *vs* 153.37 mg/kg), Mn (72.88 mg/kg *vs* 61.47 mg/kg), Cu (2.99 mg/kg *vs* 2.49 mg/kg) and Zn (16.33 mg/kg % *vs* 11.12 mg/kg) were significantly higher in non-declined over declined orchards. Furthermore, significant variation were observed on leaf nutrient of non-declined *vis-a-vis* declined orchards of N (2.89% *vs* 2.58%), P (0.18% *vs* 0.15%), K (1.91 *vs* 1.77%), Ca (1.95% *vs* 1.86%), Mg (0.32% *vs* 0.27%), Fe (153.37 mg/kg *vs* 166.41 mg/kg), Mn (61.47 mg/kg *vs* 72.88 mg/kg), Cu (2.49 mg/kg *vs* 2.99 mg/kg) and Zn (16.33 mg/kg % *vs* 11.12 mg/kg). The result indicated that nutrients are higher at low altitudes as compared to high altitudes. Similarly, irrespective of altitudes, nutrient content was higher in non-declined as compared to declined orchards.

Fruit Physico-biochemical Proteries of Declined and Non-declined Khasi Mandarin Orchards at varying altitudes in Meghalaya

*H. Rymbai, N.A. Deshmukh, D.M. Firake, P. Baiswar, H.D. Talang, S.R. Assumi, A.R. Roy and A.K. Jha

ICAR Research Complex for NEH Region, Umiam, Ri-Bhoi, India – 793 103
**Email: rymbaihort@gmail.com*

A study was conducted to find out the variations in physical and biochemical characteristics of *Khasi Mandarin* fruits collected from plants growing at varying altitudes of both declined and non-declined orchards. Declined and non-declined orchards of *Khasi* mandarin were identified at varying altitudes *viz.*, >1000 msl (Ryngab, Pynursla, Mawryngkneng and Mawphu); 600-1000 msl (Lumsohpieng, Saitsama, Sohbar and Wahkhen); <600 msl (Pohriat, Dawki, Sohkhwai and

Muktapur). Result showed that fruit attributes in declined orchards at varying altitudes recorded wide variation like fruit weight (76.0 – 107 g), fruit length (4.8 – 5.4 cm), seed number (19.66-21.66), fruit volume (80.0 – 106.5 mm) and number of fruit per trees (14.33 – 38.67), TSS (9.16-10.80%), acidity (0.96-1.42%), ascorbic acid (32.32-57.33 mg/100g), reducing sugar (3.17–5.87%) and total sugar (5.27-7.67%). Wide variation were also observed on ffruit characteristics of declined *vis-à-vis* non-declined orchards, fruit weight (90.5 *vs.* 113.8 g), fruit length (5.13 *vs* 5.49 cm), seed number (20.35 *vs* 19.30), fruit volume (92.97 *vs* 117.78 mm) and number of fruit per trees (36.47 *vs* 668.10), TSS (9.97 *vs* 10.58%), acidity (1.14 *vs* 0.95%), ascorbic acid (40.64 *vs* 33.40 mg/100g), reducing sugar (4.68 *vs* 5.36%) and total sugar (6.55 *vs* 7.63%). Furthermore, fruit characteristics such as fruit weight (92.9 *vs* 121.3 g), fruit length (5.2 *vs* 5.57 cm), seed number (19.35 *vs* 18.40), fruit volume (95.21 *vs* 127.33 mm) and number of fruit per trees (60.67 *vs* 725), TSS (10.16 *vs* 10.93%), reducing sugar (5.56 *vs* 5.77%) and total sugar (7.21 *vs* 8.15%) were found maximum in low altitude declined vis-à-vis non-declined orchards. While acidity (1.21 *vs* 0.99%) was highest in high altitudes and ascorbic acid (45.46 *vs* 35.00 mg/100g) in mid-altitudes declined vis-à-vis non-declined orchards. Therefore, fruit characteristics and yield were higher in non-declined orchards at low altitudes as compared to mid- and high- altitudes.

Theme-5: Crop Diversification and Conservation Agriculture

Agronomic Biofortification of Zinc in Cereals to Overcome the Zinc Malnutrition

Y.S. Shivay

Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi 110 012

Zinc (Zn) still represents an important health problem in developing countries, caused mainly by inadequate dietary intake. A large consumption of cereal-based foods with small concentrations and low bioavailability of Zn is the major reason behind this problem. Modern cultivars of cereals, especially rice and wheat have inherently very small concentrations of Zn and cannot meet the human need for Zn. Today, up to 50% of wheat-cultivated soil globally is considered poor in bioavailable Zn. Agricultural strategies that are used to improve the nutritional value of crop plants are known as biofortification strategies. They include genetic biofortification, which is based on classical plant breeding and genetic engineering for larger nutrient concentrations, and greater agronomic biofortification, which is based on optimized fertilizer applications. Agronomic biofortification with Zn, which has proved to be very effective for wheat and also other cereal crops including rice, oats etc. Molecular and genetic research into Zn uptake, transport and grain deposition in cereals are critically important for identifying ‘bottlenecks’ in the biofortification of food crops with Zn. Transgenic plants with large Zn concentrations in seeds are often tested under controlled laboratory or glasshouse conditions with sufficient available Zn in the growth medium for theentire growth period. However, they might not always show the same performance under ‘real-world’ conditions with limited chemical availability of Zn and various stress factors such as drought. What purpose can an upgraded transport and storage system serve if the amount of goods to be transported and stored is limited anyway? Given the fact that the Zn concentrations required to achieve a measurable impact on human health are well above those required to avoid any loss of yield from Zn deficiency, providing crop plants with sufficient Zn through the soil and foliar fertilizer strategy under field conditions is critically important for biofortification efforts.

Since the discovery of Zn as an essential micronutrient for plants (Sommer and Lipman, 1926), fertilization of crop plants with Zn fertilizers either through soil or foliar application has become an increasingly common practice in agricultural soil where Zn deficiency limits crop productivity. The main aim of Zn fertilization was typically to prevent or correct Zn deficiency and thus to improve the yield; however, very little or no attention was paid, from a human nutritional perspective, to the Zn concentrations of the edible parts of food crops such as seeds and grains or starchy roots. Finally, since the start of the International HarvestPlus (www.harvestplus.org) programme and its sub-project HarvestZinc (www.harvestzinc.org), there has been an increase in global interest to enhance Zn concentrations in the edible parts of food crops. In the framework of the Harvest Zinc project (www.harvestzinc.org), several field experiments have been carried out during the past 7–8 years in 12 countries on wheat, rice and maize with applications of several soil- and foliar-applied fertilizers. However, in India agronomic biofortification of Zn was initiatedon rice and wheat by Shivay and his associates (Shivay and Prasad, 2012; Shivay *et al.*, 2007, 2008a,b,c). Clearly, soil Zn applications at the time of sowing had little effect on the concentration of Zn in the grain under field conditions, whereas foliar Zn sprays were very effective in improving the grain Zn. Based on the results from field studies, it has been shown that among the cereals studied, wheat was by farthe most responsive to foliar Zn spray in terms of increases in grain Zn (up to 83%). Rice showed an intermediate response to foliar Zn applications and exhibited moderate increases in grain Zn (upto 27%), whereas maize appeared to be less responsive. Research is now going on to elucidate the physiological reasons behind the different responses of these three major cereal crops to foliar Zn applications.

It is well documented that foliar-applied Zn is phloem-mobile and can be readily translocated into developing grains in wheat (Erenoglu *et al.*, 2011). For foliar Zn applications to wheat, the options are zinc sulphate ($ZnSO_4.7H_2O$) and EDTA-chelated Zn. Zinc sulphate is at least as effective as Zn-EDTA for correcting Zn deficiency and increasing Zn concentrations in tissues, which means that it is the most cost-effective option compared with the relatively highly priced Zn-EDTA. The timing of foliar Zn fertilizer application is an important determinant of its effectiveness in terms of biofortification (Welch *et al.*, 2013). In both wheat and rice, foliar Zn applications are particularly effective in enriching the grain with Zn if they are applied at a later rather than an earlier developmental stage, preferably during grain-filling (Cakmak *et al.*, 2010; Boonchuay *et al.*, 2013; Abdoli *et al.*, 2014).The fertilizer strategy for the agronomic biofortification of wheat with Zn enhances the Zn concentrations not only at the whole-grain level but also specifically at the endosperm level, which is critical for target populations that consume large quantities of white flour(Cakmak *et al.*, 2010; Kutman *et al.*, 2011a).Based on the meta-analysis of published data, Joy *et al.* (2015) reported that foliar Zn application is a cost-effective strategy to improve grain Zn in cereal crops, and the costs associated with foliar Zn treatments seem to be similar to the cost of flour fortification with Zn. Applications of Zn to soil to ensure sufficient availability of Zn for root uptake and foliar applications of Zn to enrich vegetative tissues with Zn and thus enhance Zn remobilization into grains are key agronomic interventions for achieving successful biofortification of food crops with Zn. Agronomic biofortification of Zn in major cereals seems to be one of the pragmatic approaches to overcome the Zn malnutrition from the food chain.

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Crop Diversification and Conservation Agriculture practices in Post-flood Situation of Assam

Mukul Chandra Kalita

Livestock Research Station, Assam Agricultural University, Mondira, Kamrup-781127(Assam)

Email: mukul.kalita123@gmail.com

Diversification is the introduction of alternate crops,may give good scope to break the monotony of the traditional system of cultivation.Crop intensification is the main course of future growth of agriculture.Because the changing rainfall pattern over years,ground water depletion,hike in labour wages , the existing cropping pattern may not be economically viable.It is time to critically examine and redesign alternative cropping patterns based on agro-climatic zone and this must be demonstrated in the farmer's holding in order to effectively utilize the natural resources and also to utilize effectively the natural resources and also to stabilize the production and productivity. Crop diversification is maimly focussing on the following points:-

(1)From low value to high value crops

(2) From water loving crop to water saving crop

(3) From Single crop to multi/mixed crop

(4) From crop alone to crop with –Livestock-Fish-Apiculture

Diversification towards high value and labour intensive crops can provide adequate income and employment to the farmers. Awareness programme and proper motivation of farmers to shift to Alternative crops in water deficit areas is urgently required so as to feed larger people of this Region. As for example; where water is scarce, high value but low water requiring crops should be promoted. Hence, alternate cropping pattern is suggested by working out efficient zone from the Cultivation of crops, which has suitable soil and climatic features, to obtain productivity of a crop.

Relative Yield Index will help the Planners and Administrators to implement or to introduce new technologies or the schemes for the specified crops, normally working in a particular zone. The strip till drill and Rotary till drills have been developed by group of scientists in our country. It is used in preparation of soil and made it ready to sow the seeds of wheat/Maize etc. in one operation. This system consists of a shallow rotavator followed by a seeding system. Soil moisture was found to be critical in reduced tillage system. The tractor can also be used with a rotovator to prepare the soil quickly and incorporate the seed after second pass. This speeds up the planting and results in better stands with less cost than traditional methods. However, the strip and rotary till drills do a better job because the seeds are placed at a uniform depth in the single pass.

Farmers are adopting these technologies quickly in some places .The adoption could have been faster had there been the machines for all the poor farmers of North East India. Diversification as well as conservation practices were found in many places of Barak valley Zone and Lower Brahmaputra Valley Zone of Assam. Diversification trials were conducted in North Karimganjand Dullavchara blocks of Karimganj district. Similarly, it was also conducted in Lakhipur and katlicherra blocks of Cachar district under Barak Valley Zone of Assam in 2009-2011: As per the AAU Technology the following crops were grown in Farmer's Field and various results were shown below. All balanced fertilizers were applied in the farmers' field of karimganj&Cachar districts of Barak valley Zone of Assam together with 6-7tonnes/ha of FYM. Rice (w)-Rice (A) and Rice (w)-fallow systems were diversified in both this districts under Barak Valley Zone of Assam.Most of the farmers are growing the high value crops and the data are presented in Table-1&2. A few numbers of farmers are using Flat Bed system, Ridge bed techniques etc in their field. The labour cost is minimised to

50% and irrigation requirement are also reduced. Thus, the crop diversification and conservation agriculture practices becoming popular in many places of our state; breaking the monotony of traditional system of cultivations.The following mentioned yield and economics data were presented in Table 1&2.

Table-1: Variety in respect of crops with fertilizer dose, spacing and sowing time in cropping system

Crops	Variety	Fertilizer(NPK) Dose(Kg/ha)	Price (Rs/qtl)	Spacing	Sowing Time
Rice(W)	Suwasini	80-40-40	1200.00	20cmx15cm	15-07-09(T)
Rice(A)	Disang	40-20-20	1050.00	20cmx15cm	16-05-10 (T)
Capsicum	California Wonder	70-40-60	6500.00	45cmx45cm	11-1109 (T)
Rajmah	Uday	30-40-20	6000.00	30cmx20cm	09-11-09(S)
Brinjal	Longai	50-50-50	5000.00	50cmx45cm	10-11-09(T)
Knolkhol	winner	80-60-50	3500.00	45cmx30cm	08-11-09(T)
Tomato	Avinash	70-40-60	4200.00	50cmx30cm	06-11-09(T)
Potato	Kufrijyoti	60-50-50	1000.00	50cmx15cm	10-11-09(T)
Chilli	Pusajuwala	70-40-60	5000.00	45cmx45cm	10-11-09(T)
Pumpkin	ArkaChandan	75-80-80	700	2.5mx10m	15-11-09(S)

Table-2: Gross return, Net return, B:C ratios, REY and System Profitability of diversified Cropping System.

Cropping System	Gross return (Rs/ha)	Net return (Rs/ha)	REY(qtl/ha)	B:C ratios	System Profitability (Rs/ha/day
Rice(W)-Fallow	47,472.00	32,022.00	--------	2.07:1	87.73
Rice(w)-Rice(A)	80,547.00	51,697.00	27.77	1.79:1	141.64
Rice(W)-Capsicum	2,18,472.00	1,89,572.00	142.50	6.56:1	519.38
Rice(W)-Rajmah	2,19,472.00	1,91,442.00	143.30	6.82:1	524.50
Rice(W)-Brinjal	8,55,972.00	8,26,242.00	674.00	27.80:1	2,264.00
Rice(W)-Knolkhol	7,29,972.00	7,00,242.00	569.00	23.55:1	1,918.00
Rice(W)-Tomato	7,95,072.00	7,61,572.00	623.00	22.73:1	2,086.50
Rice(W)-Potato	1,60,522.00	1,30,922.00	94.20	5.42:1	358.70
Rice(W)-Chilli	3,84,972.00	3,56,742.00	281.25	12.64:1	977.38
Rice(W)-Pumpkin	1,58,571.00	1,35,641.00	75.27	5.92:1	371.62

At present, I am working at Livestock Research Station,Mondira, Kamrup from 2011 onwards. This area of Lower Assam suffers from Chronic flood problem every year and so they unable to grow kharifrice.Now they have started to grow *Boro Paddy* after the flood. But the Farmers of these areas are not getting *Foundation/Certified seeds* regularly. That is why, we have taken a programme of production of quality seed production of Boro paddy (cv: Joimoti &Kanaklata).Here, also Balanced dose of fertilizer together with FYM@6-7 tonnes/ha is applied at the time of final land preparation.

Foundation/Certified seeds were sold during October-November in each calendar year.Seeds were sown in Nursery bed during November and starts Transplanting in December to January.TheBoro Paddy(Summer rice) is harvested during May-June every year.The yearly production of Boro rice seed is shown below:-

Table-1: Year wise Production and Productivity of Boro Paddy at LRS,Mondira.(2011-2017)

Sl No	Years	Fertilizers(kg/ha)	Area(Ha)	Production(qt)	Productivity(q/ha)
1	2011-12	60-40-30,NPK	4.0	2o6.40	51.60
2	2012-13	60-40-30,NPK	3.5	181.30	51.80
3	2013-14	60-40-30,NPK	3.5	192.37	54.96
4	2014-15	60-40-30,NPK	3.0	125.22	41.74
5	2015-16	60-40-30,NPK	3.0	120.22	40.07
6	2016-17	60-40-30,NPK	3.0	125.00	41.67

Table-2: Gross return,Net return, B:C ratios of Foundation / Certified seeds in respect of Boro Paddy.

Sl No	Years	Fertilizers Dose(kg/ha)	Gross return (Rs)	Net return (Rs)	B:C ratios
1	2011-12	60-40-30,NPK	5,57,280.00	4,65,508.00	3.90:1
2	2012-13	60-40-30,NPK	4,89,510.00	3,75,550.00	2.91:1
3	2013-14	60-40-30,NPK	5,19,399.00	4,10,120.00	3.90:1
4	2014-15	60-40-30,NPK	3,38,094.00	2,34,065.00	3.48:1
5	2015-16	60-40-30,NPK	3,24,594.00	2,18,185.00	3.58:1
6	2016-17	60-40-30,NPK	3,37,500.00	2,25,250.00	3.40:1

In all trials, fertilizers were utilized judiciously for different types of crops. But if we go for seed production system of cereal crops, Pulses and oilseeds than Benefit: Cost ratios will be high.This is because of higher output values of crops. Farmers will be highly benefitted with such type of technology. For getting high yield of cereal crops, Pulses, and oilseed; we have to apply inorganic sources of fertilizers together with 6-7 tonnes /ha of F.Y.M. in all types of land in Assam. For producing about 12 to 15 tonnes of Foundation/Certified seeds of Boro Paddy(Summer rice),we need to purchase a fertilizers quantity of 5 quintol of Urea,10 quintol of single super phosphate and 2.5 quintol of Muriate of Potash in each year. Besides this we have to purchase 2-3 litres of Butachlor as weedicides in the crop field of Boro Paddy. The native soil contains high quantity of Potash. So, the requirement of Potash in Lower part of Assam is low. After the calculation, it is evaluated that with the cost of one Kg of Urea, SSP& Mop; we get the profit of Rs.40/-,Rs.53/- and Rs.24.30/ only respectively in certified seed production of Boro Paddy ;when sold rice grain in the market. Thus, it is a profitable business over and all. Introduction of new crops (Boro rice & vegetables), particularly in the post flood situation under lowland situation becoming helpful for many farmers of Assam.

Crop Diversification for Round the Year Vegetable Production under Protected Condition in Mid and High Hills

Raj Narayan*, D.B. Singh and Vivek Kumar Tiwari

**ICAR-Central Institute of Temperate Horticulture Regional Station, Mukteshwar, Nainital (Uttarakhand) 263138*

Email: rajnarayan882013@gmail.com

Introduction

Diversification through vegetable cultivation is an important source and has emerged as potential agriculture enterprises over the years. The role of olericulture in country's nutritional security, poverty alleviation and employment generation programme is becoming increasingly popular. It offers wide range of option for farmers because vegetable fit well in multiple cropping systems; many vegetable crops occupying field for shorter time, offer opportunity for higher cropping intensities. Vegetable cultivation offers year round employment in activities relating of crop raising, processing, value addition, quality and hybrid seed production, marketing etc. and gives higher yield and higher market demand for fresh vegetable throughout the year. The vegetable area and production of India is 9336.0 (000ha) and 162896.9 (000 tonne), respectively. The vegetable area and production of Uttarakhand is 88.3 (000 ha) and 10.16 (000 tonne), respectively (NHB Data Base 2013-2014). Diversification technologies are one of the important tools for the increasing production; enhance productivity and fighting hunger and malnutrition besides providing livelihood security. The average size of operational holding of a majority of farmers in our country is about 0.5 ha as also elsewhere in the world having major category of marginal farmers so much so that the F.A.O. has remark that most of the world food is produced on small pieces of land called farms. These small farms fail to provide enough employment to farming families and are not sufficient with a view point of their livelihood security. Therefore, there is need to utilize the natural resources, especially the scarce resource land, in efficient manner so that the population engaged in agriculture directly or indirectly could have reasonably good employment throughout the year there by ensuring a secured livelihood. Diversification technology is one of the important tools for increasing productions; enhance productivity and fighting hunger and malnutrition besides providing livelihood security. Major factor for low adoption of greenhouse technology in study area are: lack of knowledge of techniques for the greenhouse vegetable production, limited availability of technical person for greenhouse construction, farmers' ignorance about cost-benefits assessment of their investments, low risk taking ability, lack of enthusiasm for improvement, and inadequate extension services. Moreover, farmers of the region are not aware with the crop/technologies to be adopted for getting round the year production under polyhouses in mid and high hills of Uttarakhand. So far no definite crop(s) and technologies has been studied, standardized and popularized for round the year vegetable crop production under polyhouse in extensive way in the region. Hence, the various crops and their varieties/genotypes are been studied in different seasons to assess their growth and yield performance under polyhouse in mid and high hills of Kumaun region of Uttarakhand.

Materials and methods

The present investigations were conducted at two locations under polyhouseMukteshwar (High Hill) and Pokhrad (Mid Hill) located at 29^0 28'N and 29^0 33' N latitude, 79^0 39' E and 79^0 58' E longitude, respectively in two season viz., summer and winter of 2015-16 and 2016-17. Six crops namely tomato, capsicum, cucumber, broccoli, Chinese cabbage and lettuce were taken for the study. The tomato, Capsicum and Cucumber were planted during summer season of 2015-16 and broccoli, Chinese cabbage and lettuce were planted in winter season of 2016-17.

A total of 14 genotypes in tomato, 12 in capsicum, 3 in cucumber, 6 in broccoli, 13 in lettuce and one Chinese cabbage were evaluated in high hill conditions (Mukteshwar). Likewise, in mid hill conditions i.e. Pokhrad, 14 genotypes of tomato, 12 of capsicum, 4 of lettuce and one of Chinese cabbage were evaluated at each location. However, 3 genotypes of cucumber and 6 of broccoli were tested in high hill; and 4 of cucumber, 4 of broccoli were evaluated in mid hill condition. The plants of tomato were planted at 60x45cm and capsicum, broccoli, lettuce and Chinese cabbage plants were planted at 45x30cm spacing, whereas cucumber plants were planted at 100x50cm spacing under polyhouses at both the locations. Trials were conducted in RBD with three replications. Data were computed and statistically analyzed as per the method of Panse and Sukhatme (1985) to see critical difference and level of significance at 5 per cent.

Results

The analysis of variance revealed that most of genotypes of the crops viz., tomato, capsicum showed significant differences for all the traits and sufficient ranges of mean were also exhibited by all traits in various crops of present study at both the locations. Likewise broccoli genotypes exhibited significant differences for various traits at high hill, which were evident from the higher range of the characters under study, hence selection will be very effective in improving them. The genotypes of lettuce and cucumber showed sufficient range of means in various traits under study at both the locations.

The tomato, capsicum and cucumber genotypes were tested at both the location i.e. mid and high hills under polyhouse during summer season of 2016. In high hill condition (Mukteshwar), tomato cv. VL-4 recorded maximum fruit length (56.66 mm), fruit width (69.69 mm) average fruit weight (81.61 g) and highest fruit yield/plant (3.475 Kg) and CITH-M-T-5 was found second highest yielding genotypes with 3.02 Kg/plant fruit yield. However, in mid hill condition (Pokhrad), genotypes CITH-M-T-5 recorded highest fruit yield of 4.42 Kg/plant which was followed by CITH-M-T-3 and VL-4 genotypes with 4.15 and 4.08 Kg fruit yield/plant.Likewise, Capsicum hybrid namely Yamuna, Bombay and Orobelle found top ranking genotypes in terms of fruit yield/plant in high hill condition under polyhouse, which were exhibited 1.550, 1.240 and 1.040 Kg fruit yield/plant, respectively, whereas hybrids viz., Orobelle, Yamuna and Lucky Star produced fruit yield of 1.900, 1.870 and 1.830 kg/plant, respectively in mid hill. The Malini hybrid of cucumber recorded highest fruit yield of 2.80 Kg/plant followed by PusaSanyog (1.69 Kg/plant) in high hill under polyhouse, while as cv. Japanese Green Long exhibited highest fruit yield of 7.94 Kg/plant followed by PusaSanyog (6.43 Kg/plant) in mid hill under polyhouse.

Similarly, genotypes broccoli, lettuce and Chinese cabbage were evaluated in both mid and high hill under polyhouse during rabi season of 2016-17. The broccoli hybrid Lucky F1 produced highest head yield of 105.00 g/plant followed by Green Head (75.00g/plant) in high hill condition, however the Lucky F1 hybrid produced 164.44 g head yield/plant followed by Canavera 131.35 g/plant in mid hill condition. In case of lettuce, the genotype LS-2 recorded highest of leaf yield 276.43g/plant followed by LS-1 (265.88 g/plant) in high hill condition under polyhouse, whereas Revolution Red exhibited highest leaf yield of 444.44g/plant followed by LS-1 and LS-2 (357.77g/plant each) in mid hill under polyhouse. The Chinese cabbage cv. Solan Band Sarson was only grown at both the locations, and exhibited 0.520g and 0.703g leaf yield/plant, in high and mid hills under polyhouses, respectively. Thus, from the present investigations, it could be inferred that in general, genotypes exhibited significant differences for most of the attributes of all the crops under study at both the location. Highest values for fruit yield in Tomato were recorded in VL-4 at Mukteshwar (High hill), whereas CITH-M-T-5 produced highest fruit yield at Pokhrad (Mid hill) under poyhouse. In capsicum, Yamuna and Orebelle hybrids exihibited highest fruit yield under polyhouse at High and Mid hills, respectively. As far as cucumber is concerned, Malini hybrid produced highest fruit yield at Mukteshwar (High Hill) while Japanese Green Long exhibited highest fruit yield at Pokhrad (Mid hil) under polyhouse. In lettuce, genotype LS-2 and Revolution Red exhibited highest yield at High and Mid hill location, respectively. The broccoli hybrid Lucky produced maximum head yield at both the locations. Hence, tomato cv. VL-4 for high hill, CITH-M-T-5 for mid hill, capsicum hybrid Yamuna for high hill and Orobelle for mid hill, cucumber hybrid Malini for high hill and Japanese Green Long for mid hill, broccoli hybrid Lucky F1 for both high and mid hill; lettuce-genotype LS-2 for high hill and Revolution Red for mid hill, can be recommended for growing under polyhouse, but further one more year evaluation with some more genotypes at some more locations to be conducted before drawing final conclusion. Likewise, in Chinese cabbage only one cv. Solan Band Sarson was tested, hence further evaluation of the crops with some more genotype at various locations is also required to ascertain performance of Chinese cabbage varieties at various locations.

Grassland Management and Ecosystem Services

P.K. Ghosh, S.K. Mahanta and D.R. Palsaniya

ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003, India

Introduction

Grasslands comprise around 26% of the world's total land area and 80% of agricultural land, and represent a wide variety of ecosystems. Over the years grasslands have been one of the foundations of human activities and civilizations by supporting production from grazing livestock. This is still the situation, particularly for developing countries where 68% of grasslands are located. These grasslands have been utilized by livestock, particularly to produce meat and milk and to lesser extents fibre and draught power. This has arguably been at the expense of many other current and potential functions of grasslands. However, perspectives and perceptions of the most appropriate roles and functions of grasslands have been changing in recent decades. There has been recognition that there are numerous regional, national and global issues with which utilization of grasslands are linked. These include the function of grasslands to provide social and cultural needs for many rural societies, their role in reducing greenhouse gas emissions, as water catchments, and the preservation of ecosystem biodiversity.

Again the global demand is increasing for food, which must be met without unacceptable adverse effects on ecosystem. There are more than 800 million in the world with very low income, and an additional 200 million in the more marginal arid and semi-arid areas, who are highly dependent on grasslands for their livelihoods. Hence grasslands need to be better managed in order to best fulfil various functions. However, knowledge is often lacking, particularly for tropical grasslands. The knowledge that is available from the much more extensive studies of temperate grasslands often cannot be directly applied to tropical grasslands. Optimal management of tropical grasslands is challenging, especially given the diversity of agro-ecological contexts, the animal production constraints and soil–plant–animal interactions. Optimal management for defined production, environmental and social targets will generally include inventories and assessments of the grasslands and grazing animals available and knowledge of the important herbage–animal relationships. Although, the contribution of livestock to regional or national economies in developing countries like India is often underestimated by statistics which identify only saleable livestock food products. Apart from saleable livestock products, grasslands provide a variety of social and economic goods, and cultural services which constitute important components of the agricultural economy. Many of the rural poor depend on livestock primarily as a security and safety net, and this role is often more important than that of livestock as a commercial enterprise.

Status of Indian grasslands

Grasslands of India play a major role in the economy of the country as these are used as pastures/forage resources for domestic grazing animals. They are also livelihoods of thousands of people as grass is also used as fuel, shelter and various traditional activities. The estimates of grasslands and shrub lands in India vary from 3.7% to as much as 12% of the total area. Although, grasslands in India are the least understood and the most underestimated natural habitats. Indian grasslands are also most neglected and abused ecosystems in the country. According a report by the Forestry Commission, nearly 40% of these protected grassland areas suffer from livestock grazing and fodder extraction. Grassland ecosystem in India varies depending on the factors like climate, soil, rain and geographical location. The species of grasses found in these grasslands has a great effect on their ecosystem. The native and naturally occurring grass species maintain a continuum of the mechanism of ecosystem as compared to introduced ones. The functioning of the system very much depends on the biotic and abiotic components. The biotic components of the system are classified as producers (i.e. grasses, shrubs, herbs, mosses, lichens, algae, cyanobacteria etc.), consumers (cow, buffalo, goat, sheep, wild animals etc.) and decomposers (fungi, worms, bacteria etc.). The abiotic components are climate, parent material and soil, topography and natural resources which are needed for biotic components. Many improvement practices like introduction of legumes for better quality of forage, reseeding of grasses species for maintaining population or different soil and water conservation techniques need to be followed to obtained better provisioning services from these systems.

Silvipasture system is also gaining momentum recently to optimize, rather than maximize, production from the same unit of land through integrated management. In fact, silvipasture as an agroforestry practice is specifically designed and managed for the production of trees, tree products, forage and livestock and most important in semi-arid and arid regions. The benefit received from grasslands and silvipastures in term of provisioning services been well documented. Both grassland and silvipasture system are the unique system for dry land region which covers almost 60% of total area in India. Indeed, the choices we make today and how we use land and water resources will have enormous consequences on the future sustainability of earth’s ecosystems including grasslands and the services they provide. Silvipastoral systems comprised of Acacia and Azadirachta tress with *Cenchrus ciliaris* and *Cenchrus setigerus* grasses recorded better carbon sequestration in soil and biomass and helped to improve soil conditions. The silvipastoral system sequestered 36.3 to 60.0% more total soil organic carbon (SOC) stock compared to the tree system and 27.1 to 70.8% more SOC in comparison to the exclusive pasture system. Grasslands with 16 species stored 2.7 times more carbon than mono-cultures. However, a holistic approach is needed to estimate and quantify different ecosystem services of natural habitats.

Rejuvenation of grasslands

Grasslands are important but their care and management is highly neglected. Other than the organizations and agencies involved in R & D, the concerns by other users, societies and stakeholders for grassland and grazing lands are surprisingly meager in all ecosystems particularly in Indian context. Nevertheless, various institutions are engaged in restoration and improvement based studies. Concerted research efforts in various research institutions have resulted in the development of technologies for improvement of grasslands. Grassland improvement techniques for forage production are based on various ecological approaches, e.g. protection of grasslands for vegetation recovery, removal of unwanted bushes, re-seeding of grasslands with perennial and productive species of grasses and legumes, application of fertilizers for higher productivity and subsequently utilization of grassland either through cutting or grazing in a suitable manner.

Protection

Overgrazing results in degradation of grasslands leading to dominance of unpalatable and noxious vegetation. Protection from grazing through fencing leads to remarkable recovery of vegetation status. Grazing lands can be protected through barbed/ woven/ chain links supported by angle iron/ cement/ stone/ wooden poles or through fencing using unpalatable bushes. For grazing lands in hills, 5 years protection is recommended in order to improve the degraded low altitude grazing areas. Closure of these grazing lands not only improves forage quantity but also its quality. Studies conducted at the IGFRI, Jhansi revealed increase in the herbage yield from 0.1 to 3.5

tonnes/ha within 3 years of protection of degraded grazing lands with increase of plant population of desired perennial grasses.

Soil and water conservation

Soil and water conservation measures are extremely important for range and pasture management especially in dry areas and on sloppy degraded lands. Bunding is quite effective in sloppy and undulating lands. Along the contour lines and periphery, various types of bunds are made depending upon the topography of the area. In dry degraded areas, bunds are required to be stabilized with suitable grass species. In areas having better soil and rainfall, technique of graded bunds along with grassed waterway and drop structure for safe disposal of water has been found to be better than contour bunds.

Water storage/discharge structures are useful in ravines and watersheds. Structures like check-dams, anne-cuts and embankments of desired engineering specifications, are constructed for efficient conservation and utilization of already scarce water resources in dry areas. In some ravenous and hilly areas, gully plugging may also require erecting structure for various engineering specifications. Various grass and legume species are known to play an important role in soil and moisture conservation by reducing run-off and soil loss. In excessive windy areas, a combination of trees may be planted as winds/ shelter belt, in specific designs, to check wind impact.

Bush cleaning

Heavy infestation of bushes in grazing lands not only adversely affects the availability of open space for growing grasses but also forage production. The standard practice of bush cleaning includes either manual or mechanical felling or removal of stumps, or application of selective weedicides on the cut stumps to kill them and stop coppicing. Leaf fodder yielding stumps, however, should be maintained in the grazing lands as these provide fodder during lean period or drought.

Grazing management

The greatest single factor, which causes deterioration of grasslands, is overgrazing. During the course of grazing certain grasses are preferred while others are avoided. On account of this, selective grazing, desirable species tend to get depleted in grasslands much faster than undesirable species. In most perennial grasses, utilizing the reserve food material that is stored in the underground parts produces new shoots. Due to over grazing, the reserve food material is lost faster and perennial grasses are unable to re-generate due to continuous drain on food reserve. Therefore, Controlled grazing systems like deferred rotational ones are considered superior to other grazing systems in term of livestock performance as well as recovery of vegetation.

Grassland ecosystem services

Grasslands provide ecological, economic, and cultural and spiritual services to communities living in and outside these systems. Among others, they produce forage for livestock grazing; wildlife habitat that sustains the flora and fauna necessary to support human wellbeing; water storage and supply; maintenance of stable and productive soils; mineral resources and products; sequestering and storage of carbon; and natural beauty. The grassland ecosystem services provide a link between economic and ecological systems. Biodiversity habitat maintenance, carbon storage, and water regulation are considered primary ecosystem services from grasslands to human beings.

Grasslands for biodiverse ecosystems

Grasslands were used to consider home to significant concentrations of large mammals and plants with an ecological and economic value. Biodiversity provides many direct benefits to people and the economy such as food, fibre, and forage for grazing animals, medicines, fuel, building materials and industrial products, recreation, and hunting. Most grasslands/rangelands are not ‘natural’, they have developed as a result of human modification, especially where the dominant subsistence strategy is pastoralism, and this presents a paradox to conservationists. Historically, when the human population was relatively low, the human exploitation of grasslands was not problematic. But this is changing with the increase in human populations and demand for land for other uses, which are having a significant impact on the flora and fauna of the grasslands. Fragmentation, for example, represents a major threat to biodiversity in grasslands. High biodiversity is threatened by anthropogenic factors including livestock grazing, land clearance, introduction of exotic species, soil cultivation, fertilizer application and altered fire management. Livestock, as the largest user of grasslands, increases pressure on ecosystems, natural resources and biodiversity. Extensive grazing animal systems generally use a wide range of plant resources for livestock feed and impose variable pressure on habitats. Intensive grazing systems are usually based on a small number of species which are managed intensively, and have been considered responsible for the degradation of ecosystems. However, animal grazing can be a tool to maintain or restore biodiversity of open landscape and contribute to the aesthetic and leisure.

Grasslands for greenhouse gas (GHG) reduction

Global warming is a major concern and is predicted to affect all ecosystems and human livelihoods, particularly in the developing world. It is estimated that average global temperatures will be 2ºC higher than pre-industrial levels by 2035-2050. In the grasslands, this may change the length and timing of the growing season and the amount and seasonal pattern of precipitation. Although pastoral societies have made a minimal contribution to the global warming process, they are likely to be seriously affected by it. But Grasslands can potentially offset a major proportion of the global emissions of GHG due to livestock. These GHGs are derived primarily from emissions of enteric methane by ruminant animals, to a minor extent from nitrous oxide produced from excreta, indirectly from production of grain crops for animal feedstuffs and from deforestation to create new pastures. The 3.5 billion hectares of global permanent grassland are estimated to contain 182 billion tonnes of organic soil carbon (C) or 30% of total soil C. This comprises an important C pool comparable with 50% of total soil C in forest soils. If grasslands have an annual sequestration potential of up to 0.3 billion tonnes of organic soil C/year, grasslands could offset upto 4% of global GHG emissions. Tropical grasslands represent a storage pool of C almost twice that of temperate grasslands and are thus more important. Furthermore, as the C sequestered in grasslands as soil C is largely underground it is a more stable form of storage than the aerial components of forests. The net C storage in grassland soil may differ between years and between sites. It is affected by grassland type and age, changes in land use such as from cropping to grassland, and burning. It may also vary with annual rainfall, temperature and radiation. The management practices that can influence the loss of soil C sequestration and increase C includes (i) avoiding soil tillage and the conversion of grasslands to cropping, (ii) moderate intensification of nutrient-poor permanent grasslands, (iii) the use of lower stocking density, (iv) increasing the duration of grass leys and (v) converting grass leys to grass-legume mixtures or to permanent grasslands. Comprehensive assessment of soil organic C sequestration requires net C accounting which also considers the global warming potential of non-CO_2 gas fluxes associated with defined agricultural practices. Improved understanding of the animal and pasture systems and appropriate management options are essential.

Grasslands for water regulation

Ecosystem service of water regulation can be defined as influence ecosystems have on the timing and magnitude of water runoff, flooding, and aquifer recharge, particularly in terms of the water storage potential of the ecosystem. Grasslands can reduce water runoff by 20% in comparison with cropland and by 50% in comparison with urban areas. In fact, grasslands have effects on surface water as well as groundwater quality and recharge. While degraded grasslands are typically less able to hold moisture in the soil than non-degraded grasslands, and thus are more susceptible to the impacts of drought and heavy rainfall events. Productivity of grass also depends on soil moisture availability.

Grasslands for soil erosion regulation

Soil erosion is an important factor contributing to the degradation of grasslands/ agricultural lands and soil erosion imposes additional costs downstream in water reservoirs and settlements. Although, soil erosion costs is differentiated according to the location of impacts. On-site costs of erosion include loss of productivity, water and nutrients. Dominating off-site damage is the deposition of soil particles in water systems, which further reduces their ability to provide clean water, flood control or recreation bathing services. Appropriate grassland cover prevents such losses of soils due to water and air erosion.

Conclusion

Grassland degradation is causing decline in ecosystem condition and widespread biodiversity loss, leading to reduced provision of ecosystem services, and may cause the irrevocable loss of ecosystem functions such as soil and soil moisture retention, regulation of water flows, and regulation of carbon and nitrogen cycles. Ecological restoration is regarded as a major strategy for re-establishing and increasing the provision of ecosystem services as well as reversing biodiversity losses, but conflicts can arise, especially if single services are targeted in isolation, and the recovery can be slow and incomplete. In addition, a lack of scientific understanding of the factors influencing provision of ecosystem services and of their economic benefits limits their incorporation into land-use planning and decision making. However, the many ecosystem services from grasslands are valued variously by different stakeholders, in which local stakeholders may tend to value productive services and specific ecosystem services such as hydrological services, while international valuations may apply to niche products or for biodiversity conservation services. But there are usually trade-offs between the different ecosystem services targeted. Restoration of converted grasslands may improve ecosystem services functioning, in some cases to levels comparable with non-degraded grasslands, but may not be able to fully restore ecosystem service provision to that of natural grassland.

Various methods of improved grassland management can sequester carbon in soils and in below- and aboveground biomass. Compared to other mitigation options, grassland mitigation is cost-competitive. Climate change mitigation services in grasslands may provide an entry point to the valuation of grasslands for their conservation and restoration. Globally, grazing land management has been estimated to have a technical mitigation potential of 1.5 Gt CO_2 equivalents per annum to 2030. Degraded grasslands may have significant potential for carbon sequestration, through protection and restoration of grasslands. Unfortunately, data on the restoration potential of degraded grassland is not available. Systematic documentation and analysis of costs of protecting and restoring grasslands are still limited. More analysis and evidences are crucially required to provide a definite answer as to the forcing and response of grassland degradation and restoration to climate change and its potential of climate mitigation benefits.

Lentil - a Candidate Crop for Diversification of Rice based System in Lowland Rice Fallow of Tripura

*BK Kandpal, Gulab Singh Yadav and Anup Das

ICAR Research Complex for NEH Region, Tripura Centre, West Tripura
**E-mail: basantkandpal@gmail.com*

After the harvest of *kharif* rice (*Oryza sativa* L), climatic conditions of rice fallow lands in many areas are suitable for growing cool and warm season pulses profitably. In north East India more than 2 million ha area remains fallow after rice harvest due to various constraints such as moisture stress (excess an low), lack of suitable varieties, stray animals, poor mechanization, lack of irrigation facilities, poor awareness etc. The residual moisture left in the soil at the time of rice harvest is often sufficient to raise short-season crops. Further, by use of short-duration and high-yielding varieties of rice allowing vacating fields in September-October, the traditional rice fallows can be converted into productive lands. In low land areas with excessive soil moisture, lentil (*Lens culinaris*) is more suitable and assured than chickpea. Consequently, the rice-lentil system can be made more popular in the lowlands of eastern India specially West Bengal, Odisha, Bihar, Assam, Tripura and other states.

In India, where a large part of the area remains fallow after the *kharif* season rice there exists a scope for expansion of area under pulse crops like lentil in rice fallows. Lentil is the important pulse crop mainly grown on residual soil moisture and prominent source of vegetable protein. Besides fixing atmospheric N and benefitting the succeeding crop with residual nitrogen in soil. Lentil has a very good potential for increasing farm income as well as cropping intensity. Thus, introduction of lentil in rice fallows with appropriate production technologies may usher in another green revolution in the backward, poverty ridden and deprived region of the country. The soil structure is also improved by growing second crop (pulse) after rice with suitable seeding and tilling methods. Conservation tillage provides better ecosystem to crop than that of conventional tillage. Minimum tillage with crop residue management is found to reduce soil water evaporation, soil sealing and crusting. Early maturing lentil varieties may escape the terminal moisture stress in rice fallow and could convert these mono-cropped areas into double cropped areas, and thus, increase legume production and sustain productivity of the rice-based systems.

In rice fallows, yields of *rabi* crops are generally low and thus, a large area still remains uncropped. Limited R&D efforts in the past have led to development of improved production technologies which need to be refined and validated for different eco-regions. Table 1 provides the suggested interventions to improve the productivity of rice fallows:

Table-1: Major technological intervention for improving productivity of pulses in rice fallows

S.N.	Issues	Interventions
1.	Lack of suitable cultivars	Development of high-yielding varieties with appropriate maturity duration
2.	Poor crop stand and establishment	Crop establishment methods, sowing methods, seed priming, higher seed rate, timely planting, seed treatment with fungicides
3.	Diseases and pests	Development of IPM modules, tolerant varieties
5.	Nutrient management	Foliar spray of urea/DAP to supplement N and P
7.	Terminal moisture/heat stress	Residue mulching/lifesaving irrigation
8.	Non-availability of quality seeds	Participatory seed production
9.	Lack of mechanization	Light weight no-till planter
10.	Poor transfer of technology	Capacity building programme, exposure visits

Adoption of improved varieties will lead to increased crop productivity by 20-30% leading to higher incomes to resource poor farmers in the region. This will have direct impact in alleviating rural poverty. In Tripura conditions, L-112-7, RL -12-171, HUL57 has been identified as potential variety for cultivation in rice fallow areas of Tripura. Conservation tillage (CST) in lentil holds promise for improving soil health controlling evaporation, minimizing erosion losses, sequestering carbon and reducing energy needs. These effects reduce overall cost of production while improving yields and returns to farmers. The CST planters have been developed that cause minimal disturbance to the soil and previous crop residues while placing the seeds in an optimum position for germination and emergence. Timely planting of lentil under CST systems in rainfed lowland ecologies help the crop to escape negative effects of terminal water stress and rising temperatures. The CST technology has been demonstrated at farm levels, resulting in adoption by farmers in some regions of Tripura. The main advantages are cost savings, flexibility in planting times and reduced water requirements. Problems with adoption relate to weeds, crop establishment and availability of no-till seeders. Varieties suitable to CST are also needed. With awareness and knowledge of a package of practices, these issues can be overcome for widespread adoption of this cost saving and environmentally friendly technology. The no-till method of planting, however, requires one time investment to procure suitable no-till machine. In an experiment, lentil was sown under different methods of establishments viz. reduced tillage, no-till and paira cropping. The lentil varieties grown under reduced tillage recorded the highest yield however, paira cultivation of lentil produced lowest seed yield in Tripura conditions.

Lentil inoculated with the proper *rhizobium* (bacterial) strain has the potential to fix up to 80 per cent of its nitrogen requirement through nitrogen fixation, in a symbiotic relationship. Both the *rhizobium* and the plant benefit from the relationship. *Rhizobium* enters the root hairs of the plant and induces nodule formation. The plant provides energy and nutrients for the *rhizobium* living inside the nodules. The *rhizobium*, in return, converts atmospheric nitrogen from the soil air surrounding the roots into a form that can be used by the plant. Maximum nitrogen fixation occurs if the supply of available soil nitrogen is low and the soil moisture and temperature levels are good at the time of seeding. If the soil plus fertilizer nitrogen level exceeds 40 kg/ha, nodulation may be reduced. If the nitrogen level is 55 kg/ha or higher, nodulation can be dramatically delayed and fixation greatly reduced or eliminated. In addition to fixing a substantial quantity of nitrogen during the growing season, lentil makes a positive contribution to the overall soil nitrogen level over multiple years. In view of escalation in price of P fertilizer, the need for dual inoculation, i.e. *rhizobium* and phosphate-solubilising bacteria (PSB). *Bacillus polymixa* and *B. megaterium* cultures are being commercially produced for inoculation. The PSB produce organic acids which decrease soil pH and thus, accelerate dissolution of insoluble phosphates which become available to crop plant. The *rhizobium* and PSB cultures can be mixed together for seed treatment. Seed pelleting with nutrient solutions, especially micronutrient is also beneficial in areas being deficient in specific nutrient. The seed treatment with AM fungi enhances plant growth by improved mineral nutrition, particularly P and water uptake on account of the hyphal network originating from mycorrhizal roots which make close contact with the soil mass. The sequence of seed treatment should start with insecticides, followed by fungicide and culture.

Timely planting is key factor in the full realization of the yield potential of improved varieties of lentil. Middle of November is the most suitable time for sowing lentil. Delay in planting cause reduction in yield but the magnitude of reduction is large after 15th December. The reduction in yield could be minimized up to a certain extent by relatively closer spacing and use of higher seed rate. The estimated seed yield shown that the optimum time for sowing lentil crop was from 15th to 20th November which gave highest yield among all date of sowing and the crop sown on 10th December recorded lowest yield. Being leguminous crop, it plays an important role in the maintaining and improving the fertility status of the soil. Even then fertilizers play significant role in boosting up the production of pulses. The use of farmyard manures and other forms of organic matter can also change plant-available micro nutrients by changing both physical and biological characteristics of the soil. In many circumstances these changes improve soil physical structure and water holding capacity, resulting in more extensive root development and enhanced soil micro-flora and fauna activity all of which can affect available micronutrients levels in soil to plant. In general, paddy fields are deficient in zinc, therefore, it is advisable to watch the lentil crop for likely zinc deficiency. In initial stages of zinc deficiency, the leaflets start falling off. Spraying a solution of 0.5 per cent zinc sulphate and 0.25 per cent lime at the appearance of early symptoms can rectify the deficiency. On soils where zinc deficiency is well established, about 25 kg zinc sulphate per hectare before final discing of the field should be applied so that zinc sulphate is mixed well in the soil. Most of soils of Tripura are acidic in nature, therefore farmers are advised to apply 200 – 250 kg lime/ha through furrow application for good and healthy crop of lentil. An experiment conducted at ICAR Tripura centre showed very interesting results on lentil yield. The application 200 kg lime only produced higher yield as compared to recommended dose of fertilizer application. The efficiency of lime is increased when it is applied with farm yard manure. Foliar spray 2% urea or DAP solution (20 g urea or DAP litre^{-1} of water) may be applied as just before flowering more beneficial under conservation and paira cropping system. An experiment was conducted to develop a nutrient management system for enhancing the lentil production and productivity. Application 10 kg N + 40 kg P_2O_5 + 40 kg K_2O/ ha + 200 kg Lime/ha + 3 times foliar spray of Urea + $ZnSO_4$ + Boron was produced maximum number of branches/plant, number of pods/plant, number of seeds/plant, 1000 seed weight and seed yield as compared to early and late sown of lentil. The crop is mostly grown in un-irrigated areas. It does respond to irrigation particularly during dry winters. Like gram, lentil is also taken without irrigation. However, one irrigation at the time of flower initiation/pod formation stage increases the yield. It can tolerate drought condition to some extent. Comparatively, higher yields can be obtained by providing one to two irrigation, particularly when winter rains are not properly distributed. Considerable yield losses in lentil recorded to the extent of 30-100 per cent if weeds are not controlled within critical growth period of crop. Previously no herbicide was recommended for chemical weed management in lentil. Moreover, many times labour is not available for controlling weeds particularly at the critical period of crop weed competition. To keep the weeds under control, pre emergence application of Stomp immediately after sowing, spray application of Pendimethalin 30 EC @ 3-4 liters per hectare is recommended as well as one or two weeding and hoeing 25 -30 days after sowing are helpful.

Crop Diversification in Tuber-based Jhum Farming System: A Strategy towards Jhum Improvement and Food Security in Arunachal Pradesh

Badapmain Makdoh*, H. Kalita, Letngam Touthang, Thejangulie Angami, Doni Jini, Anup Chandra, Rajesh Alone and Bhoben Pait

ICAR Research Complex for NEH Region, AP centre, Basar, Arunachal Pradesh-791101
**Email: bmakdohicar@gmail.com*

Jhum cultivation is part and parcel of farming community of the tribal farmers of Arunachal Pradesh. Tuber crops are the main component after rice and maize and playing important role in their dietary habits and food security. Traditionally, mix cropping is followed where main crops along with vegetables, pulses, millets, wild herbs sown in random pattern resulting in under-utilization of land and posing challenges towards modern intercultural operations. Furthermore, due to its nature of low crop productivity, low return and soil erosion etc. has realized the importance of jhum improvement. Under this aspect, an attempt was made to develop a Tuber-based Land use System under jhum cultivation at ICAR RC, Arunachal Pradesh centre, Basar covering an area of 0.13 ha. Here, tuber crops are the main component diversified with other subsidiary crops (vegetables, pulses, and maize) taking into consideration of soil conservation notwithstanding the increase in crop yield, profit and sustainability. Contour and strip cropping, cover crops, legumes intercropping, hedge row planting, mulching etc. were part of the system. Tuber crops and subsidiary crops approximately cover an area of 810 m^2 (62%) and 490 m^2 (38%) respectively, where each component crop is systematically arranged to maximize land use, production and profit. Cereal crops like maize are kept at lower part of the slope and sweet potato as soil cover for soil conservation kept at the upper section. Tapioca and yam (dioscorea) being tall and covering more space are kept at lower portion of the slope or border. Intercropping of legumes like cowpea, soybean, mung bean, french bean in widely spaced tubers like tapioca, dioscorea and elephant foot yam was followed. Among Colocasia varieties, APTC-5 (16.5 t/ha), Muktakeshi (14.2 t/ha) and Telea (14.7 t/ha) were found suitable in jhum. Tapioca best performing varieties were H-97, H-226, Sree Prakash with average yield of 31.5t/h, 32.4 t/ha and 28.2 t/ha respectively. Similarly, sweet potato varieties Swarna, Pusa Sundari, Gouri and elephant foot yam Gajendra (25.6t/ha) and TRCP-1 (23.2 t/ha) found suitable. From the model unit, production of tuber crops and subsidiary crops were 1852 kg and 170 kg respectively. Also, net return of Rs.31, 497/- was achieved with Maize equivalent yield (MEY) of 3406 kg which was barely 360 kg MEY if sole maize is cultivated. Comparing farmers' practice of jhum with this improved unit, the net return was just over Rs.11, 800/- which is only 37% of the later one. The MEY and Gross return of Tuber-based jhum farming unit is almost double times that of traditional jhum field.

Keywords: *Crop Diversification, Tuber-Based Farming System, Jhum Improvement, Net Return*

Productivity of Food-Forage Intercropping System in Rice Fallows as Influenced by Integrated Nutrient Management

Khumlo Levish Chongloi[1] and K.K. Sharma[2]

[1]KVK Chandel, ICAR Manipur Centre
[2]Assam Agricultural University, Jorhat
Email:levischongloi@gmail.com

Food-forage based systems provide a support to small and marginal farmers by adjusting a substantial part of their lands exclusively for forage production in food crop based cropping systems. Forage crops need to be integrated in the existing food based cropping systems as crop intensification either in space (intercropping) or in time (sequential cropping) or both. Diversification and intensification of cropping system is not only able to fulfill the domestic needs and economic of the farmers, but it may also be more remunerative besides improvement in soil health. The present investigation was conducted to assess the productivity of food-forage intercropping system in rice fallows at the Instructional-Cum-Research (ICR) farm of the Assam Agricultural University, Jorhat. The treatments consist of four intercropping system viz. C_1= sole oats, C_2= sole pea, C_3= 3:2 row proportions and C_4= 3:3 row proportion of oat + pea intercropping and four integrated nutrient management viz., $F_{1=}$ RDF (inorganics), F_2= 50% N of RDF + 50% N through FYM, F_3= 50 % N of RDF + 50% N through vermicompost and F_4= 50%N through FYM + 50% N through vermicompost in split plot design with three replications allotting intercropping system in the main plots and INM in the sub-plots. The results of the pooled mean revealed that, among the intercropping systems pea equivalent yield and green forage equivalent yield were observed to be highest in 3:3 row proportions over 3:2 row proportions. The effect of integrated nutrient management on pea equivalent yield and green forage equivalent yield were significantly higher in 50% N of RDF + 50% N through

vermicompost than the other treatment combinations. Among the intercropping system the highest net return and economic efficiency was observed in 3:3 row proportions. Significant effect of INM on net return and economic efficiency were observed with addition of 50% N of RDF + 50% N through vermicompost, but the higher benefit-cost was observed in 3:3 row proportions with of 50% N of RDF + 50% N through FYM followed by 3:3 row proportions with of 50% N of RDF + 50% N through vermicompost. Introduction of food-forage intercropping systems in rice fallows has considerable positive effect on yield performance and can saved 50% of inorganic fertilizers besides giving best productivity and profitability.

Effect of Different Agro-Technique in Rice- Fallow Lands on Productivity and Profitability of Subsequent Crops and Residual Soil Fertility in Eastern Himalayan Region

L. K. Baishya and D. J. Rajkhowa

ICAR Research Complex for NEH Region, Nagaland Centre, Nagaland -797106, India
Email:lkbicar@gmail.com

The shrinkage of agricultural resources like arable land, irrigation water and energy, there is a dire need to design and develop new methods and techniques of crop production to meet the increasing demand for food, feed and forage through effective utilization of available agricultural input resources. A field experiment was conducted at the Research farm of ICAR Research complex for North Eastern Hill Region (NEHR), Manipur Centre, Langol farm during winter season of 2014 and 2015. The experiment was consisted of three diversified crops (Rapeseed & Mustard, Lentil and Pea) in rice fallow lands with three varieties of each Crop, rapeseed & mustard (M-27, TS-36 and TS-38), Lentil (PL-4, DPL-15 and HUL-57) and Pea (Rachna, Azad and Makhayatmubi) and three agro-techniques; Farms practice (FP = control), Minimum Tillage (MT), Minimum Tillage + Mulching (IM= Improved management practices). A total numbers of 9 nine treatment combination for each sequential crops was laid out in a RCBD with three replications. The fertilizer dose for Rapeseed and mustard was 50-60-30 kg N, P2O5 and K2O/ha along with 2t/ha of FYM; lentil 30-60-40 kg N, P2O5 and K2O/ha along with 2t/ha of FYM and pea 30-60-40 kg N, P2O5 and K2O/ha along with 2t/ha of FYM were maintained for each sequential crops. However, the dose of fertilizers was reduced to half in case of farmer's practices as farmers are using very less amount of fertilizers. The experimental results reveals that growing of rapeseed variety, TS-36 with minimum tillage and mulching recorded the highest yield (1145 kg/ha). The available soil fertility after harvest of the crop was found to increase by 32%, 31.7% and 13.9 % N, P2O5 and K2O respectively over farmer's practices. The pooled data over the two years experiments reveals that growing of pea variety, Makhayatmubi with minimum tillage and mulching resulted the highest green pod yield (3347.5 kg/ha). The soil fertility status after harvest of the different pea varieties were found to be improved in the agro- technique, minimum tillage and mulching. by 15.5%, 63 % and 12 % The N, P2O5 and K2O respectively over farmers practices. Growing of lentil variety, HUL-57 with minimum tillage and mulching resulted the highest yield (1037.4 kg/ha). The soil fertility status after harvest of the different lentil varieties were found to be improved in the agro- technique, minimum tillage and mulching. by 6%, 23.3% and 25.8 % N, P2O5 and K2O respectively. Among all the agro-techniques growing of different crops in rice fallow lands with minimum tillage and mulching recorded highest net return □71.28 X 10^3, □72.65 X 10^3, □29.26 X 10^3 in case of Pea, Lentil and Rapeseed & Mustard. The same treatment recorded highest return per □ invested □ 3.46, □ 2.75 and □2.27 respectively. Thus, minimum tillage and mulching is most suitable for higher crop productivity in rice fallow lands of hill terraces of NEH region. The growing of pea, Makhayatmubi, Lentil, HUL-57 and Rapeseed &Mustard, TS-36 was found to be more profitable.

Sustainable Diversification of Maize (*Zea mays* L.) based Cropping Systems for Productivity, Profitability and Resource-use Efficiency in West Garo Hills of Meghalaya, India

Mokidul Islam[1], L.K. Nath* and T. Samajdar

ICAR Research Complex for NEH Region,Umroi Road, Umiam-793103, Meghalaya
** KVK Lakhimpur, AAU, Assam,*
[1]Email: mislam01d@yahoo.co.in

A field experiment was conducted at Instructional Farm of ICAR- KVK Tura during kharif, pre-rabi and rabi season of 2011-12 to 2013-14 to find out the suitable production potential, profitability, resource use efficiency and sustainability of diversified maize based cropping system. The five cropping sequences were replicated thrice in randomized block design on sandy loam soil with low to medium fertility level and slightly acidic in reaction. The cropping system “Maize + Green gram (1:2) – Green gram + Maize (1:1) – Tomato” was found to be most remunerative and sustainable with system productivity (175.49 q/ha), net return (Rs.3,38,725/ha), profitability (Rs. 928.01 /ha/day), benefit cost ratio (4.40), sustainable yield index (1.00), production efficiency (Rs.58.30/ha/day), relative economic efficiency (134.30%), except land use efficiency(LUE) which was highest (85.75%) in “Maize + Groundnut(1:2) – Green gram + Maize (1:1) – Tomato” cropping system. The lowest system productivity, net returns, profitability, production efficiency, land use efficiency etc was found in sole cropping system of maize - green gram - tomato.

Keywords: *Sustainable Diversification, System Productivity, Production Efficiency*

Potentiality of Agro-forestry on Soil Conservation and its Economic Income for the People of North East Hilly Region-A Review

Punabati Heisnam, Asieleavio John, Abhinash Moiranthem, Dinesh Sah, P. Debnath and A.K. Pandey

College of Horticulture and Forestry, CAU, Pasighat,

Email: anuheisnam@gmail.com

This paper discusses the effects of trees on soil fertility, with a focus on agricultural systems. Although the potential of agroforestry for conservation and utilization of soil and water resources is well recognized, experimental evidence on the extent of actual benefits is limited. Relevant literature concerning the effects of trees on soil physical and chemical properties in tropical, subtropical, and temperate regions is reviewed, covering both natural ecosystems and agro ecosystems. Excessive deforestation coupled with shifting cultivation practices have resulted in tremendous soil loss and poor soil physical health in this region. Studies on soil erodibility characteristics under various land use systems depicted that shifting cultivation had the highest erosion ratio and soil loss in North-Eastern Hill (NEH) Region. Agroforestry systems like agri-horti-silvi-pastoral system performed better over shifting cultivation in terms of improvement in soil organic carbon, soil nutrients, reduced soil loss, soil erosion ratio and in-situ soil moisture conservation under the high rainfall to low rainfall areas, moderate to steep slopes conditions. This paper reviews the importance of agroforestry and discusses various agroforestry practices that are capable of enhancing the livelihood of the farmers. The adoption of agroforestry systems will ultimately depend on increased crop yields and economic benefits to farmers.

Key words: *Agroforestry, Soil Conservation, Income, Soil Erosion, North-East*

Diversification of Maize (*Zea mays* L.)–Based Cropping Sequence through *in-situ* Moisture Conservation in Rainfed Ecosystem of Sikkim Himalayas for Improving System Productivity and Use Efficiencies under Organic Management

Raghavendra Singh, Subhash Babu, RK Avasthe, R.Gopi and S.K. Das

ICAR-National Organic Farming Research Institute, Tadong, Gangtok-737102
Email: raghavenupc@gmail.com

Maize is an important food grain crop grown in Sikkim. Productivity of rainfed mono–cropping system of Sikkim is very low and is a high risk economic activity (Babu et al, 2016). Intensive natural resources mining, continuous degradation of natural resources and practice of mono–cropping under conventional agricultural practices in mountain ecosystems does not sustain the farm productivity and food security (Ghosh *et al.* 2010). Intercropping of maize with leguminous crop may improve the soil health and also maintain the system productivity by providing additional yield. *In-situ* moisture conservation practices during winter season through residue retention of previously harvested crop along with weed biomass may help in increasing soil moisture by covering the surface through minimizing the evaporative losses from soil. Similarly, the short duration drought tolerant and/or avoidance winter season crops may also help escape the drought during winter season and enhance the cropping intensity, thus, providing opportunity for additional crop in a system. Keeping this in view, the present experiment was undertaken with diversified cropping systems for higher system productivity, economic feasibility and employment generation.

Effect of Modified Urea Materials on Productivity and Resource Use-Efficiency of Pearlmillet (*Pennisetum glaucum*)–Mustard (*Brassica juncia*) Cropping System under Different Methods of Crop Establishment

R.S. Bana

Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi-110 012
Email: rsbana@gmail.com

Pearlmillet–mustard is a prominent production system in north–western semi-arid tract of India and plays a crucial role in national food security and livelihoods. For sustaining productivity of the system, use of organics like crop residue retention etc. is important. Conservation agriculture (CA) based resource conservation technologies has proved to produce more with less costs, reduce environmental threats, improve soil health and less soil moisture stress. Thus, for addressing the issues of resource fatigue and bridging *'management yield gaps',* CA based management options are cornerstone. Further, like other major production systems, nitrogen use efficiency in pearlmillet-mustard cropping system is also a cause of concern. Keeping in mind the environmental and socio-economic threats posed by high N losses and poor input use efficiency in the present production system an experiment was carried out at IARI, New Delhi to find out the effect of modified urea materials on productivity and resource use efficiency of pearlmillet-mustard system. The experiment was conducted at New Delhi and was laid out in a split-plot Design with three replications. There were two crop establishment systems viz. conventional tillage and zero tillage with residue retention for pearlmillet as well as for mustard in the main-plots. In sub-plots, five coated urea materials viz. control, prilled urea, gypsum coated urea, phosphogypsum coated urea and sulphur coated urea. In kharif the urea treatments were applied to pearlmillet in two splits. Half dose of nitrogen (30 kg N/ha) was applied as basal dose and remaining N was applied at panicle initiation stage to the pearlmillet. During *rabi* Indian mustard was raised without any nitrogen application on residual fertility to find out residual effect on mustard. 'Pusa Composite-443' cultivar of pearlmillet and 'Pusa Mustard-26' variety of Indian mustard were used in the experimentation. The results of the experiments shows that application of gypsum coated urea, phosphogypsum coated urea and sulphur coated urea resulted in higher growth, productivity and nitrogen &water use efficiency as compared to prilled urea and control treatments. However, the highest pearlmillet grain yield and system productivity was recorded with sulphur coated urea, but the other modified urea materials were at par. Zero tillage with residue retention was found superior over conventional tillage and gave slightly higher yield but did not have significant effect on protein content of pearlmillet. The system productivity and net returns were also highest under zero tillage with residue retention and under coated urea materials.

Weed Management Practices on Growth and Yield of Transplanted Kodomillet (*Paspalum scrobiculatum* L.) - CO3 variety

*Yendrembam Bebila Chanu, S. Jawahar#, Y. Sanatombi Devi and Priyanka Irungbam

Department of Agronomy, College of Agriculture C. A. U, Imphal-795004
#Department of Agronomy, Annamalai University, Tamil Nadu- 608002
**Email: bebilachanu@gmail.com*

A field experiment was carried out at the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalainagar, Tamil Nadu, India during *Kharif* season (June-October) 2014 to study the effect of weed management practices in transplanted kodo millet. Kodo (*Paspalum scrobiculatum* L.) The present investigation was carried out with the objectives to study the effect of weed management on growth and yield of transplanted kodo millet. The experiments with six treatments were laid out in randomized block design with four replications. The treatments comprised of different weed management practices *viz*., T_1 - Unweeded control, T_2 - Hand weeding twice on 20 and 40 DAT, T_3 - Butachlor 50% EC @ 1.5 kg a. i ha^{-1} on 3 DAT, T_4 - Pretilachlor 50% EC @ 0.5 kg a.i ha^{-1} on 3 DAT, T_5 - 2, 4, D – Na salt 80% WP @ 0.75 kg a.i ha^{-1} on 20 DAT, T_6 - Bispyribac sodium 10% SC @ 20 g ha^{-1} on 20 DAT. The results revealed that the hand weeding on 20 and 40 DAT significantly registered the tallest plant height of 39.29, 73.36 and 90.32 cm on 30, 60 DAT and at harvest stages, respectively and unweeded control recorded the lowest plant height of 28.15, 60.12 and 71.05 cm at 30, 60 DAT at harvest stages respectively. Highest leaf area index of 1.53 and 4.74 was recorded with the hand weeding on 20 and 40 DAT and the lowest leaf area index of 0.89 and 2.93. Highest grain yield of 2884.29 kg ha^{-1} was recorded with the hand weeding on 20 and 40 DAT which was 122.78 per cent increased over control and lowest grain yield of 1294.63 kg ha^{-1} was recorded in unweeded control treatment. Among the various treatment, hand weeding on 20 and 40 DAT recorded highest straw yield of 7881.48 kg ha^{-1} and the lowest straw yield of 2064.35 was recorded in unweeded control treatment. The results obtained from the experiment concluded that the kodomillet variety CO_3 responded well to the hand weeding on 20 and 40 DAT to growth and yield attributes parameter could be obtained.

Keywords: *Butachlor, Kodomillet, Weed Management, Pretilachlor*

Traditional Soil and Water Conservation Practices of Mizoram Farmers

Y. Ramakrishna*[1], Lungmuana, S.B. Singh, T. Boopathi, B.K. Singh, A.R. Singh, S.K. Datta and Saurav Saha

ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram-796081
[1] KVK Ukhrul, Hundung, Ukhrul Manipur 795 142
Email: ramakrishna_iari@rediffmai.com

Soil and water being an indispensable resource has been degrading in different forms possessing even a greater threat to food security especially for Mizoram state being a hilly terrain and where jhum cultivation is predominant for crop production. Over many years, *Mizo* farmers had practice different indigenous soil and water conservation measures depending upon the resource availability. These practices were collected and compiled through interviews and field observation covering the state. Villagers mostly rely on natural spring water collected in various forms for cultivation and domestic purpose in dry season. As bamboo is common, it has been used as a supplying system for water directly or as a frame for conveyance system and storage. Plant biomass such as truck and other vegetative parts are used as a barrier to collect and reduced the runoff soil and water in jhum field. Similarly, crop practices like mixed cultivation, mulching and relaying are also common in jhum field for conserving soil moisture.

Keywords: *Mizo, Indigenous, Jhum Cultivation, Soil and Water Conservation*

Production potential of maize (*Zea mays* L.)- Based Intercropping Systems under Foothill Condition of Nagaland

Lowrence Kithan and L.Tongpang Longkumer

Department of Agronomy
School of Agricultural Sciences and Rural Development
Nagaland University, Medziphema Campus- 797106, Nagaland
**Email- lowrencekithan@gmail.com*

A study was conducted on "Production potential of Maize (*Zea mays* L.)- Based Intercropping systems under foothill condition of Nagaland" at the experimental farm of School of Agricultural Sciences and Rural Development (SASRD) Nagaland University, Medziphema Campus, Nagaland under rainfed condition during 2015 and 2016. The treatments comprised of different row ratios *i.e.* (1:1), (1:2), (2:1) and (2:2) respectively of maize intercropped with perilla, sesame, ricebean and soybean along with sole crops of maize, perilla, sesame, ricebean and soybean. The experiment was laid in RBD with 3 replications and 21 treatments. Sole crops performed better than intercropping systems in respect of growth and yield attributing characters. Among the different sole crops maize performed better with respect to growth, yield and other biological efficiencies. Sole maize recorded the best with regard to growth parameters like plant height, leaf area plant^{-1} and stem thickness with its pooled at 315.25 cm, 2.23 and 2.44 cm. While in regard to yield parameters sole maize recorded superior than all other sole crops with its mean and pooled in respect to number of cobs plant^{-1} (1.87, 1.97, 1.92), cob weight (g) (143.67g, 144.67g, 144.17g), number of grains cob^{-1} (555.33, 556.00, 555.67), shelling percentage (81.00, 80.67, 80.83), grain yield (4230.00 kg ha^{-1}, 4330.12 kg ha^{-1}, 4280.06 kg ha^{-1}) and stover yield (5196.82 kg ha^{-1}, 5396.82 kg ha^{-1}, 5296.82 kg ha^{-1}). Among the different intercropping systems paired rows (2:2) ratios of maize + soybean performed significantly better in terms of yield (1564.21 kg ha^{-1}, 1567.10 kg ha^{-1}, 1565.65 kg ha^{-1}) and production efficiencies viz., LER (1.78, 1.78), RCC (53.95, 55.22), CEY (4692.63 kg ha^{-1}, 4701.3 kg ha^{-1}), ATER (1.53, 1.53), Aggressivity (0.04, 0.041) and SPI (75.36, 77.20). As for economics, paired rows (2:2) ratios of maize + soybean proved superior to all other treatments in net return (Rs. 1,42,612.6, Rs. 1,44,779.4), gross return (Rs. 1,72,612.6, Rs. 1,74,779.4) and B:C ratio (4.75 and 4.82).

Keywords: *Maize, Perilla, Sesame, Ricebean, Soybean, Intercropping, Yield, RCC, Economics*

Evaluation of Rice bean Cultivars for Adaptation to Acidic Soil under NEH Region

Manoj Chaudhary[1], K K Sharma[2], S R Kantwa[1] and Rameswar Sah[4]

[1]Indian Grassland and Fodder Research Institute, Jhansi (UP)-284003
[2] AICRP on Forage Crops, Assam Agricultural University, Jorhat (Assam)-785013
[4]ICAR- National Rice Research Institute, Cuttak (Odisha)-753006
Email: manoj310975@gmail.com

Rice bean is a nutritious crop but less known and it had been put in underutilized category, has emerged as a potential legume for grain as well as fodder purpose in higher rainfall areas. The nutritional quality of rice bean is better than as compared to many other legumes of *Vigna* family. Now, it is inviting as a leguminous fodder crop which can be used as green fodder for animal nutrition. Keeping in view the importance of rice bean as fodder crop, the present investigation was carried out in *Kharif,* 2015 to evaluate agronomic parameters of rice bean varieties for quality fodder production in acidic soil of Assam at Assam Agricultural University, Jorhat. Four varieties of rice bean namely, Bidhan-1, Bidhan-2, RBL- 6 and JRBJ-05-2 were tested in randomized block design (RBD) with five replications. The study revealed that maximum plant height (103.4 cm) was significantly observed in variety Bidhan-1 and lowest being in RBL-6 (88.20 cm). The highest number of plants/m row length (25.8) was recorded with RBL-6 and lowest in Bidhan-2 (21.20). Among the different cultivars, the higher green fodder (36.61t/ha) and dry fodder (8.36 t/ha) yields were obtained with Bidhan-2 followed by JRBJ-05-2 (35.43 t/ha & 8.2 t/ha), RBL- 6 (32.38 t/ha & 7.45 t/ha) and (31 t/ha & 7.13 t/ha). The highest crude protein content was noted 12.4% with the cultivars JRBJ-05-2 which was at par with RBL- 6 (12.4%) followed by Bidhan-2 (11.9%) and Bidhan-1(11.6%). Among different cultivars Bidhan-2 was observed superior in terms of yield and could be advocated for growing under acidic soil condition of NEH region for higher fodder productivity.

Keywords: *Rice Bean, GFY& DFY, Protein Content, NEH Region*

Performance of Green Gram and Black Gram in Maize Fallow under Different Weed Management Practices

M. Thoithoi Devi[1], S.B. Singh[2], A. Ratankumar Singh[2] and Samik Choudhary[2]

[1]ICAR-Research Complex for NEH Region, Umiam, Meghalaya
[2]ICAR-Research Complex for NEH Region, Mizoram Centre
Email: thoiagri@gmail.com

Pulses are popularly known as “Poor man’s meat” and “rich man’s vegetable”, contribute significantly to the nutritional security of the country. Considering its importance in the dietary pattern, India becomes the net importer of pulses due to its estimated demand of 23-24 million tons annually despite being the largest producer, 25% of world’s production. The production of pulses is also not uniform across the country as over the past two decades the productions of pulses has largely shifted from northern India to central and southern part and contribute 80% of total pulse production

in the country. As far as North Eastern region is concern, all the states are pulse deficient ranging from 6.4 per cent in Nagaland to 91.5 per cent in Tripura. It may be due to non-vegetarian food habit of people and following the rice and maize-fallow cropping pattern. The later is an opportunity which can be harness optimally for horizontal spread of pulses across the region. Mizoram is not an exception in the region as it is also deficit in approximately 70% of its pulse requirement and the state has only 3700 ha area under pulses with a production of 5000 tons. So, there is need to increase the pulse production of the region with concerted efforts. Pulse requirement of the region can be satisfy either by expanding the net area under cultivation or intensifying cropping over the existing area or by enhancing productivity per unit area. Raising net sown area in hilly terrain is difficult, thus raising the cropping intensity along with increasing production per unit area per unit time is the only viable option left. In Mizoram, after harvesting of maize, the field is kept fallow and this maize fallow can be effectively utilized for cultivation of pulses. One of the major obstacles in pulse cultivation in North eastern region is severe reduction in yield due to heavy infestation of weeds. Recognizing the above facts, ICAR Research Complex for NEH Region, Mizoram Centre evaluated the performance of green gram (variety Tripura Moong 1) and black gram (variety Tripura Maskolai 1) under different weed management practices during 2015 in the experimental farm, Kolasib. In case of green gram, among the different weed management practices, the tallest plants were recorded in weedy and the shortest plants were found in hand weeding at 25 days after sowing (DAS). Weed free being at par with hand weeding at 25 DAS produced significantly more number of branches per plant than hand weeding at 40 DAS and weedy. The highest number of pods per plant was found in weed free (28.4) which were followed by hand weeding at 25 DAS (26.2), hand weeding at 40 DAS (23.5) and weedy control (20.4). Weed free recorded 42.69% more yield than weedy. In case of black gram, weed free, hand weeding at 25 DAS and hand weeding at 40 DAS recorded 21.96%, 16.88% and 12.16% more yield than weedy.

Changing from Subsistence to Remunerative Cropping: A Success Story of Diversification through Legume in Jhum Land

M.A. Ansari*, P.K. Saraswat, S.K. Sharma, N. Prakash, Meitei Ch. Bungbungcha, T.S. Leenda Monsang, N. Ajitkumar Singh, L. Somendro Singh, Deepak Singh, N. Lal, Y. Ramakrishna, Anup Das, S. Hazarika and S.V. Ngachan

ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal-795004
Email: merajiari@gmail.com

In North Eastern Region of India an estimated 1.47 million hectares is under shifting cultivation and about 0.44 million tribal families are dependent on this for their livelihood. The shifting cultivation is an indigenous land use system widely distributed and practiced in Manipur, where most of the farmers growing rice, which is not productive and economical. However, the rice grown in Jhum land gave very low yield (0.5 to 0.9 t/ha). In Manipur, farmers were growing paddy in hilly jhum areas, which was not profitable than pulses and earlier farmers were getting net returns from rice only from Rs 12000 to 19000/ha due to less yield in Jhum areas. The legumes are most remunerative alternative and tolerant to intermittent moisture and soil acidity induced abiotic stresses. However, it may be a valuable alternative crop for replacing rice from upland and medium land as well as shifting cultivated areas. The technology demonstrated like Pigeonpea (UPAS-120), Ricebean (Local), Rajma (Chitra)- Potato, Ricebean (Local), Rajma (Chitra)- Potato, Rajma (Chitra)- Pea (Rachna), Ricebean (Local)-Pea (Azad pea), Groundnut (ICGS-76)-Lentil (HUL-57). Altogether 419 beneficiaries were covered from 63 villages of Chandel (23), Churachandpur (18), Imphal West (7), Tamenglong (7) and Ukhrul (12). The farmers produced 1.2 to 1.76 tonnes of pigeonpea/ha, 1.3 to 1.7

tonnes ricebean/ha, 1.4 to 1.9 tonnes Rajma/ha, 1.4 to 1.8 tonnes pea/ha and 0.85 tonne lentil/ha. They have earned net returns varied from. The beneficiaries especially from Jhum cultivated areas received net returns of Rs 56000 to 105000/ha, where, rice mixed farming is dominant with low productivity (0.5 to 0.9 ha^{-1}) and less economical. When considering economic returns, the legumes can be a valuable alternative crop for replacing rice from Jhum areas. Besides that, pulses crop fixed the atmospheric nitrogen in soil, improved the soil health, and reduced the soil loss, conserve the soil and water and suppress the weed growth through smothering effects. Pulses production in hill agriculture plays a significant role in nutritional security and used for various purposes and as well as for second cycle produce in livestock farming.

Morpho-physiological and Root Architecture Response of Pea (*Pisum sativum* L.) Cultivars for Resource Conservation Practices in Rice (*Oryza sativa* L.) Fallows of North Eastern Region, India

Krishnappa Rangappa[1], Anup Das[1*], Savita[1,2], Utpal dey[1], Jayanta Layek[1], Subhash Babu[1], M Thoithoi Devi[1], N A Deshmukh[1], Ramesh T[1] and SV Ngachan[1]

[1]ICAR Research complex for NEH Region, Umiam, Meghalaya-793103, [2]ICAR-Krishi Vigyan Kendra, UAS, Dharwad, Karnataka-586 209,
**Email: krishphysiology@gmail.com*

Adoption of modern conservation agricultural practices is viable and effective for enhancing resource use efficiency and improved soil quality of marginal soils in fragile and erosion prone areas of North Eastern Region (NER). But the role of reduced tillage and recycling of organic matter on root environment and consequent changes on crop physiological traits are not substantially understood. In the light of this, the current study primarily focussed at examining the long term residual effect of main tillage treatments and residue management practices which were applied to main crop rice on root architectural plasticity and morpho-physiology of succeeding pea (*Pisum sativum* L.) cultivars (cv. Arkel and Prakash) grown during rabi season with NT with uniform fertilization. Results revealed that root architectural attributes were significantly varied across pea cultivars as a result of residual effect of different tillage and NM practices applied to preceding rice crop. Higher values of root surface area, total root length, root volume, root length ratio (RLR) and root tissue density were observed with more shoot to root biomass diversion under CT compare to NT and MT in both pea cultivars. In addition, significantly higher values of functional root traits viz., RLR, root mass ratio and root fineness had been observed under CT and sole application of 50% NPK and 100% NPK compare to other tillage and NM practices. In contrast, increased root exudation was observed under reduced tillage (NT and MT) along with organic residue addition particularly by *cv.* Arkel. However, remarkable changes in stress responsive morpho-physiological traits like enhanced chlorophyll pigmentation and favourable leaf characteristics under NT with 50% NPK+ WB/GLM applications were observed. Leaf area expansion was noticed higher with increased leaf thickness and with optimum turgidity under NT and MT than CT in both the pea cultivars. Relative increase in quality green pod and stover yield with enhanced partition efficiency and harvest index was observed in both the Pea cultivars under reduced tillage and with 50% NPK+WB/GLM application compare CT and other NM practices. Performance of Pea cultivar, *cv.* Arkel was observed better in terms of better root architectural plasticity and root chemical environment with concurrently improved morpho-physiological response which resulted in relatively higher green pod yield under MT along with 50% NPK+WB/GLM. Thus, adoption of MT along with 50% NPK+WB/GLM in kharif rice has substantially improved the root growth and morpho-physiology of Arkel cultivar in rice fallows of NER agro-ecosystems.

Energy Use Efficiency of Rice-based Cropping System for Higher productivity and Economic returns in North Eastern Region of India

Anup Das[1]*, Savita[1,2], Krishnappa R[1], Jayanta Layek[1], M.Thoithoi Devi[1], Subhash Babu[1] and SV Ngachan[1]

[1]ICAR Research Complex for NEH Region, Umiam- 793 103, Meghalaya
[1, 2]ICAR-Krishi Vigyan Kendra, Indi- 586 209, Karnataka
**Email: anup_icar@yahoo.com*

Rice being major cereal and energy intensive crop, cost of cultivation, input and energy use efficiency of rice based cropping by resource poor farmers of North Eastern Region (NER) is cause of concern for sustainable rice production. There is urgent need for identification of resource use efficient rice cultivation technologies with low per capita energy requirement as well as assured income as compared to other part of India. In the present study, long term field experiment was conducted based on hypothesis of reduced cost of cultivation and energy requirement with retention and recycling of crop residues, weed biomass (WB) and green leaf manure (GLM) along with no or minimum tillage intensity will enhance the overall cropping system efficiency. Different tillage practices comprising of no-till (NT), minimum tillage (MT) and conventional tillage (CT) were considered as major treatments and residue management (RM) practices viz., 100% NPK (80:60:40 kg ha^{-1}), 50% NPK (40:30:20 kg ha^{-1}), 50% NPK + *in-situ* residue retention (ISRR) of rice straw @ 5 Mg ha^{-1}, 50% NPK + WB of *Ambrosia artemisiifolia* @ 10 Mg ha^{-1} on fresh weight basis and 50% NPK + GLM of *Tephrosia purpurea* @ 10 Mg ha^{-1} on fresh weight basis were included as subplot treatments. After harvest of rice (cv. Shahsarang -1), pea (cv.Prakash) was sown under NT with standing rice stubble (20 cm) and by following recommended package of practices. Recorded rice equivalent yield (REY) was significantly higher under the adoption of MT compared to both NT and CT and with application of 50% NPK+GLM which was followed by 50% NPK+WB and 50% NPK+ISRR. The cost of cultivation was observed higher under CT than NT and for application of 50% NPK+WB. The net returns were noticed higher under MT and with the application of 50% NPK+ WB (Rs.1, 51,773 ha^{-1}) followed by application of 50% NPK+ GLM (1, 48,943 ha^{-1}).However, B:C ratio of CT was starkly lower than that of NT and significantly higher B:C ratio was recorded under 50% NPK+WB (2.80) and the lowest under 50% NPK (2.22). The highest energy input footprints was under CT followed by NT and MT and in 50% NPK + ISRR among the RM practices. The energy output was recorded defiantly highest under MT than that of NT and with application of 50 % NPK+ GLM as compared to other tillage and RM practices. As result, the energy use efficiency was tacitly observed higher under MT than NT, which was almost 1.29% and 1.27% lower than CT and NT, respectively and among RM practices it was with the application of 50% NPK, lowest being observed under 50 % NPK + ISRR. Consequently adoption of NT/MT with suitable combination of RM practices (WB/GLM) emerged as worthwhile production strategy with higher energy use efficiency and economic returns for sustainable productivity of rice-pea cropping system in NER of India.

Key words: *B:C ratio, Energy Use Efficiency, Rice Equivalent Yield, Residue Management, Tillage*

Effect of Planting Pattern of Intercropped Legumes on Yield and Economic Return from Maize

Daphibanri D Lyngdoh, A.K.Singh and Lala I P Ray

College of Post-Graduate Studies (CAU), Barapani, Meghalaya, India

To study the effect of intercropped legumes and their planting pattern on growth and yield of maize, a field experiment was conducted during *kharif* 2015 on research farm of the College of Post Graduate Studies (CAU), Umiam (Meghalaya). The experiment was laid out in randomized block design with three replications having ten treatments consisted of three intercropping systems namely maize+ soybean, maize+ mungbean and maize +groundnut with three planting patterns viz., sole planting of maize, soybean, moongbean and groundnut, 1:1 intercropping of maize with soybean, moongbean and groundnut, and paired row planting of maize to accommodate two rows of intercropped legumes stated above. Yield attributes of maize varied significantly due to intercrops and their planting pattern except for cob length, no. of grain row plant^{-1}, no. of grains cob^{-1} and grain wt cob^{-1}. Grain, stover and biological yields of sole maize was at par with its intercropping with any of the three legumes at both the planting pattern however, maize intercropped with both the planting pattern and with groundnuts in between the pairs recorded relatively more grain yield over the remaining treatments. Biological yield also followed the trends of maize grain yield. All the intercropping maize treatments recorded higher uptake of N, P and K in grain and stover over sole maize. Maximum net return and B:C ratio was alsorecorded from intercropping maize treatments over sole maize in which paired row maize intercropped with groundnut recorded higher net return and B:C ratio which was at par with 1:1 intercropping of maize with groundnut.

Keywords: *Maize-legume intercropping, Planting pattern, Yield, Net return and B:C ratio*

Crop Diversification: An Adaptive Management Strategy for Building Resilience in Agriculture towards Climate Change

Priyajoy Kar[1], Neela Madhav Patnaik[2], Arjun Prasad Verma[3]

Ph.D Research Scholar, Dairy Extension Division
National Dairy Research Institute, Karnal
Email: karpriyajoy@gmail.com

Now days, climate change are having negative consequences for agricultural production systems and it has generated a desire to build resilience into agricultural systems. With greater climate variability, shifting temperature and precipitation patterns and the global change components, we expect to see a range of crop and ecosystem responses that will affect integral agricultural process. Such effects include changes in nutrient cycling and soil moisture, as well as shifts in pest occurrences and plant diseases, all of which will greatly influence food production and food security. Climate change will affect both biotic and abiotic factors in crop systems, threatening crop sustainability and production. Diverse agro ecosystems with a broader range of traits and functions will be better able to perform under changing environmental conditions. Crop diversification can improve resilience in a variety of ways; by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events. Although there are different additional benefits for adopting and promoting crop diversification, yet the adoption is very slow in current scenario. These are mainly due to the economic incentives encouraging production of selected crops, the push for biotechnology strategies like drought resistant, flood resistant crops, and

peoples stereotypic thinking that monoculture are more productive than diversified systems, which have been working as hindrances in promoting this management stratergy.Farmers and agricultural managers must consider the different ways that diversification can occur in the system. Optimizing diversification strategies at various scales, and useful stakeholder involvement and participatory research will encourage the farmers to adopt crop diversification and formulate mitigation strategies against climate change. Government should incentivize more diverse cropping systems that will maximize the production and profits of the small and marginal farmers and it should be included in the country's agricultural policy realm which will help to increase diversity in the farm systems and to adopt greater climate variability in the future.

Management of Solid Waste with the Help of Vermin-Composition and its Application in Plant Growth

Jaibir Tomar

J.V.College Baraut, C.C.S University Meerut (U.P.)-250611

Management of solid waste has become one of the biggest problems, we are facing today. Vermi-composting is the better option to tackle with his problem. Vermi-composting is the process of conversion of organic waste by earthworms to valuable humus like material, which used as a natural soil conditioner. Vermi-composting is environment friendly and cost effective technique for soil waste management. Vermi-composting is much better than chemical fertilizer because it is not associated with any kind of risk. Earthworms are potentially important creatures that are capable of transforming garbage into gold. Earthworms are an exceptionally valuable fertilizer. Vermi-composting has many applications in crop improvement such as pathogen destruction, water holding capacity of soil, improved crop growth and yield, improved soil physical, chemical and biological properties and production of plant growth regulators.

Keywords: *Vemi -composting, Management, Fertilizers*

Theme-6: Livestock and Fishery for Sustainable Livelihood

Stem Cell and Cloning Technology for Quality Animal Production

M.S. Chauhan

Director, ICAR-Central Institute for Research on Goats, Makhdoom (Mathura), UP
Email: Chauhanabtc@gmail.com

Introduction

Among all the livestock in India, buffalo holds immense promise and potential as is evident from the fact that buffaloes contribute 56% of the total milk produced in the country, though their number is only 35% of the total bovine population. Therefore, buffalo is sometimes also referred to as 'Black Gold'. Rearing buffaloes proves to be more profitable compared to rearing cattle and has the added advantage of lean-meat producing animal. The buffalo is reputed to be an efficient converter of fibrous feed, which is quite cheap, into high quality milk, which possesses many bio-protective factors and acts as pharmaceuticals. However, buffalo still continues to be confronted with inherent problems like weak estrus-symptoms, seasonal-breeding and higher age at puberty. In spite of the fact that India has more than half of the buffaloes of the world, the number of elite animals is very small. The number of elite breeding bulls is also pathetically low. Progeny testing programmes take such a long time that the bulls are culled and eliminated, even before the genetic merit of the bull is established. Therefore the need of the hour is to develop reproductive technologies which can address these problems. Once these problems are addressed to, with improved domestic production and marketing and a better access to expanding word market, India has the potential to become more competitive in the export of livestock products especially from buffalo and goats.

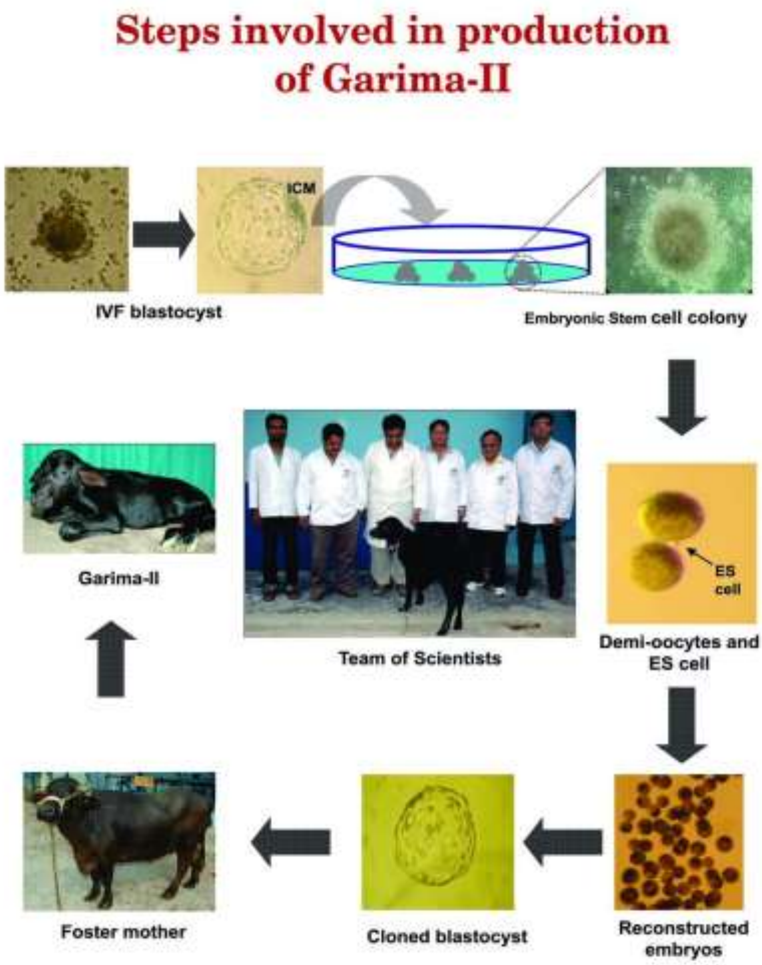
Animal cloning technology has the potential of addressing all the three problems mentioned above. It was, therefore, felt by the team that standardization of animal cloning technology was the need of the hour and needed to be exploited for harvesting the benefits in shortest possible time. Since cloning and embryonic stem cell technology are complementary, a concerted effort needed to be made involving application of a number of advanced reproductive technologies such as cloning, embryonic stem cell, transgenesis etc. to buffalo to improve its productivity. However, the lack of availability of any of these technologies was a major challenge that was to be overcome.The development of embryonic stem cell (ES) technology is a newly emerging area. ES cells are of great interest to medicine and science because of their ability to develop into virtually any other cell type made by the body. Pluripotent ES cells provide a powerful tool for the studies of early embryonic development, gene targeting, cloning, chimera formation and transgenesis. ES cells are unique.

What are Embryonic Stem Cells?

Embryonic stem (ES) cells, as the name suggests, are the cells derived from the embryo that have the property to divide infinite number of times and are pluripotent i.e. they can give rise to any cell type, including gametes. These characteristics have made them an invaluable research tool for genetic engineering, developmental biology and disease models. Due to their pluripotency or ability to develop into any cell type, these cells can be used as a source of specific, clinically important adult cells such as bone, muscle, liver or blood cells for the treatment of various ailments. The production of pluripotent ES cells from farm animals provides a platform to improve the knowledge at the molecular level and hence, facilitates effective improvement of farm animals. ES cells have very varied applications like enabling studies on the fundamental events in embryonic development, production of therapeutic delivery systems, regenerative medicine, etc. The use of ES cell technology in farm animals may overcome current limitation on efficient gene transfer by providing an abundance of stem cells to be manipulated at the genetic level. Besides these uses, ES cells provide a powerful tool for the studies of early embryonic development, gene targeting (replacing endogenous genes), cloning, formation of animal having cells from two or more different populations of genetically distinct cells (chimera) and transgenic animal production. Because of their potential use for targeted gene manipulation, ES cells could have enormous agricultural, biomedical and pharmaceutical applications through cloning and transgenesis. Transgenic animals having foreign gene, have played and are anticipated to continue to play an important role in our pursuit of knowledge for understandings the genetic basis of human disease. Transgenic farm animals have also been extensively used as bioreactors for production of commercially valuable biological products. There is an ever increasing need for animal models instead because of the complexity of biological processes that form the basis of most diseases.

How Garima –II was Produced?

Having realized the potential of embryonic stem cells, National Dairy Research Institute (I.C.A.R), Karnal has achieved successfully cloning using Embryonic Stem Cell as a donor cell and produced a female buffalo calf through ‘Hand-guided Cloning Technique’. The calf named ‘Garima-II’ was born at NDRI, Karnal on August 22, 2010.



The ES cell used for producing Garima-II was from an ES cell colony derived from buffalo blastocysts (stage of embryo when it gets preimplanted in the uterus) generated using in vitro fertilization (IVF) technique. Buffalo oocytes for the IVF procedure were obtained from slaughterhouse ovaries and the cryopreserved semen was from an elite bull from Artificial Breeding Research Centre, NDRI. The oocytes were matured and fertilized in vitro. The fertilized oocytes were cultured in vitro for another 7-8 days to enable them to develop to the blastocyst stage having inner cell mass which is the source of embryonic stem cells. Inner cell mass cells were isolated mechanically from blastocysts and were cultured on bed of somatic cells (fetal fibroblast) which provides the microenvironment for growth of ES cells under specific culture environment for producing ES cells. Following propagation, the ES cells were passaged or splitted repeatedly. The ES cells used for producing Garima-II had undergone 29 passages (117 days).

Garima II

During this period, these cells had been characterized by examining the expression of a battery of markers of pluripotency to ensure that the cells were indeed stem cells. These embryonic stem cells were then used as a donor cell for providing the genetic information in the cloned calf produced through Hand-made cloning. In this technique the immature oocytes derived from slaughterhouse ovaries were matured in vitro to a stage where the oocyte could be fertilized. But since in cloning, the donor cell provides all the genetic material so the nuclei of the oocytes were removed by cutting with “hand held fine blade” after removing the outer layer of oocyte called as zona pellucida. The enucleated oocytes were then electro-fused with single cell taken from a colony of ES cells at passage 29. The resulting embryos were cultured and grown in the laboratory for 7 days to develop them to the blastocyst stage. The blastocysts were then transferred to the recipient buffalo. Pregnancy was confirmed at day 45 by ultrasonography and Garima-II, which was delivered by a Caesarean operation, was born on August 22, 2010 having a birth weight of 32 kg.

Mahima with her mother Garima- II

We have demonstrated that the animals produced through cloning have absolutely normal physiological processes can be proved by the successful delivery of a female calf named as "Mahima" by Garima-II on January 25, 2013 after Garima-II was inseminated with frozen-thawed semen of a progeny tested bull.

Application of ES Cells in farm animals

ES cells have varied applications for farm animals as well as humans, like enabling studies on the fundamental events in embryonic development, production of therapeutic delivery systems, gene targeting, and regenerative medicine. Production of pluripotent ES cells from farm animal species might have a big influence on the genetic modification of these animal species. Availability of ES cells is expected to be especially useful in cloning technology, gamete (oocyte, sperm) formation. Also, in the context of gene targeting, use of ES cells could overcome current limitation on efficient gene transfer by providing an abundance of stem cells to be genetically manipulated by using conventional recombinant DNA techniques.

Somatic cells cloning through nuclear transfer, to produce healthy cloned animals, remains remarkable but highly inefficient and prone to epigenetic errors. The high rates of mortality throughout development create serious animal welfare issues, which limit the acceptability of somatic cloning. In animal breeding, improved genetic markers, correlated to specific livestock production traits, will provide confidence in cloning selected embryos and their derivatives, especially undifferentiated embryonic stem cells. This will enable rapid dissemination of the most recent elite genotypes to avoid the genetic lag associated with cloning adults. Furthermore, for the production of transgenic animals, embryonic stem cells might also be beneficial, because they are more amenable to precise genetic modifications and result in higher cloning efficiencies than somatic cells in the mouse. We can say that for agricultural applications, embryonic cloning will ultimately prove more useful than somatic cloning.

Embryonic stem cells can develop into the germ cell lineage, or germline, as shown by mouse blastocyst injection and by *in vitro* differentiation of mouse and human ESCs. Several reports have recently documented primordial germ cell- (PGC), sperm-, and oocyte-like cell development after mouse and human ESC differentiation, and one study observed mature and functional mouse ESC-derived sperm that were capable of producing offspring. However, functional ESC-derived oocytes have not yet been reported.

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Ornamental Fish –A Potential Aquaculture Sector in Northeast India

S.K. Das

ICAR Research Complex for NEH Region, Umium, Meghalaya- 793 103.

Email: skdas01@yahoo.com

The Northeast India is endowed with rich resource of fresh water habitats. There are innumerable streams, lakes, reservoirs and a variety of aquatic habitats in the form of flood plain and wetlands. The diversified freshwater resources harbour several important fish species of ornamental value. Goswami *et al* (2012) listed a total of 422 fish species from north east India, belonging to 133 genera and 38 families. Some of these species are rare and endemic to only northeast region. A good number of indigenous fishes of the region therefore attract many hobbyists in several parts of the world. The country exports mostly the indigenous varieties of ornamental fish to the international market and the Northeast India contributes more than 85 % of total volume. At present, the trade in the region is highly unorganized and most of these species are harvested from wild and traded to international markets through a few registered exporters of the country outside the northeast. Nearly 25 -30 fish species of ornamental value are mostly exported from the Northeastern India (Das,2004). Some of the important fish species are *Botia dario, Channa stewartii, Channa barca, Channa bleheri, Gagata cenia, Hara hara, Garra species, Mystus sp. Somileptes gongata, Nemacheilus botia, Macrognathus aculeatus, Mastacembelus pancalus, Rasbora species, Danio species* and many others. Due to remoteness of the landing centres and lack of adequate post-harvesting infrastructures & awareness, these fish species are generally utilized for local consumption and for preparation of various fish products employing traditional methods.

In recent past, many of the Northeast Fish species have become vulnerable due to over exploitation, degradation of water bodies, pollution, indiscriminate fishing activities, poisoning etc. Further, major share of ornamental fishes exported from India are the wild caught varieties from the rivers and wetlands. This is rather a great threat to the fish biodiversity of the region. There is an urgent need to review the conservation status of important ornamental fish species of the region before they are exploited for trade in order to conserve the fish germplasm of the region through better management practices, captive breeding, open ranching etc. Although the conservation efforts are still at its infancy, nevertheless, a few successful attempts have been made in the past to develop protocols for captive breeding and culture of a few important native ornamental fish species of the Northeast India under laboratory condition through research programmes funded by the National Agriculture technology project (Das and Kalita 2003,2004&2005;Das 2006 & 2007).

The ornamental fish sector is relatively new to the region. In order to promote the sector there is urgent need for concerted efforts of researchers, technologists, financial & developmental organizations and finally the entrepreneurs. While the indigenous fish species of ornamental value are mostly exported to international market, the region has ready domestic market for exotic ornamental fish species and the aquarium accessories. Therefore, the strategic roadmap should be planned in order to fulfill not only the international demand but also the domestic demands for sustainable development of the sector. A few bottlenecks in developing the sector are:

1. Information on captive breeding of indigenous ornamental fishes is very scanty,

2. Lack of suitable technologies to breed some of the important varieties of ornamental fish (that are in greater demand in the international market) under controlled conditions,

3. Inadequate proper transport and lack of quarantine facilities at the ornamental fish collection centers.

4. Dearth of well-trained and skilled entrepreneurs & technical experts and finally

5. Inadequate support from the government and financial sectors.

For sustainable development of the sector strong emphasis be given on captive-bred ornamental fish aquaculture. Both exotic fishes and indigenous fish may be prioritized for commercial seed production. Research institutes/scientific organizations should take up seed production and rearing technology development programme for important ornamental fish species (both exotic and local). Captive-bred ornamental fish could serve to reduce the current exploitation rates of wild specimens. In ornamental fish business, the segment of live fish is not much. The major segment is the aquarium and its accessories. Since most of the accessories are imported from southeast Asian countries, technical collaborations with Govt./private firms located in China, Taiwan etc be encouraged for successful ventures in the northeast India and accordingly the entrepreneurships in manufacturing of multipurpose/decorative aquarium, ornamental fish feed (live as well as dry), filters, aerators, decorative toys, aquatic plants, etc can be promoted under the “Make in India programme”.

Massive awareness programme is required to educate the people of the northeastern region on importance of ornamental fish sector and also to increase the number of aquarium hobbyists among the households of the region. Organization of exhibition or participation in major trade shows in India and abroad shall help in promoting Northeast fishes and aquarium products. In the past the MPEDA (Marine Products Export development Authority), Kochi, Kerala made a maiden effort in the Northeast India in 2004 & 2005 to promote the sector through training and demonstration programme in collaboration with the College of Fisheries, Assam Agricultural University, Raha (Das, 2004). It is to be noted that ornamental fish trade in the region can sustain only through aquaculture practices involving captive breeding and rearing. In recent years we are only beginning to learn the importance of this promising aquaculture sector in the northeast India. It is high time that entrepreneurs, technologists and financial institutions work in close partnership to go into real action and stimulate a sustainable growth.

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Integrated Artificial Insemination Delivery Models for Enhancing Pig Productivity in North Eastern Hill region of India

Kadirvel Govindasamy* and S.V. Ngachan

* *ICAR Research Complex for NEH Region, Umiam, Meghalaya – 793 103, India.*

Email: velvet.2007@rediffmail.com

Pig meat continues to be an important part of the human diet throughout the world and it represents about 40% of all red meat consumed worldwide. The improvement in efficiency of pork production is the result of swine genetic improvement through the use of artificial insemination (AI) technique. The great advantage of AI is that the genetic potential of best germplasm can be transferred to a large number of sows, leading to faster genetic improvement of large population. In India, the situation is totally different and AI in swine is still in its infancy. This particular technology has revolutionized the dairy industry in India, however, similar success could not be achieved in in pigs. Pig husbandry is important and integral component of farming system in the north eastern region of India. Pork is the most important constituent of total meat production of this region. This AI technology has major role in the region to improve the pork production and productivity in the region. Today, AI is widely applied throughout the developed world in the commercial pig farm. However, very scanty information is available on successful use of AI in small holder pig production system. Recently study clearly demonstrated the feasibility and potential benefit of AI to smallholder traditional pig production in tribal rural area. AI is better than the natural service for faster dissemination of superior germplasm and genetic improvement of non-descriptive local pig to increase productivity. Due to the multiple benefits to the small holder pig farmers (Kadirvel et al, 2012), many developing countries recently introduced the AI technique for genetic improvement of local pigs. The importance, benefit and model of AI technology transferable to backyard pig farmers for strengthening pig productivity in rural areas of Thailand was described in the recent past (Visalvethaya *et al*, 2010; Kadirvel *et al* 2012). This invited paper details the present status of artificial insemination and different AI delivery models in the smallholder backyard pig production for increasing the income and food security.

Artificial Insemination (AI) delivery models were developed in a participatory mode for dissemination of superior germplasm to smallholder traditional pig production system of north east India. The information system was designed in such a way that AI was carried out at the doorstep of the farmer upon the request in three models;1) Direct linkage with farmers and 2) Linkage with trained youth (skilled AI personals). To produce crossbred piglet and genetic improvement of non-descriptive local pigs, AI delivery mechanism were developed with participatory mode including farmers, village leaders and key persons in the selected villages (n=36). The information system was designed in such a way that AI was carried out at the doorstep of the farmer upon the request. A total of 367 oestrus sow/gilts were inseminated at farmer doorstep. The success rate, benefits and impact of AI technology in different delivery model were analyzed in term of production, productivity, profitability and sustainability. The study obtained a farrowing rate of 78.44% and 75.35% in the model-1 and model-2, respectively. The growth rate of crossbred piglets obtained following AI was significantly higher than that of natural service under the smallholder traditional production system. The tribal farmer benefited in many ways; i) timely availability of superior germplasm to produce crossbred piglets, ii) saved the mating cost of INR 1000-1200 and transport of cost (INR 300-400) of female to the boar premises and iii) controlled mating to prevent inbreeding. Skilled AI personnel produced through training of unemployed youth ensured continuity of the programme with less dependency on the government machinery for timely insemination at farm-gate level with affordable cost, thereby generated self-employment opportunities. In addition to genetic improvement, this technology can overcome the breeding constraints in the smallholder backyard pig production for increasing productivity. Further, the study assesses the success rate and benefits of estrous synchronization with fixed time AI in rural smallholder pig production system. Results revealed 85% of sows exhibited all behavioral and physical signs of estrous after synchronization with Pregnant Mare Serum Gonadotrophin (PMSG; 800 IU of) followed by 500 IU of human chorionic gonadotropin (hCG). The farrowing rate of 80.10 %) and litter size of 8.24 ±0.32) was obtained after estrous synchronization with timed insemination and it facilitated the AI by effective co-ordination, reducing shipping cost and insemination cost, besides improving heat detection and reducing weaning to estrous interval in smallholder pig production system.The study clearly demonstrates the multiple benefit of AI technique with different delivery model to smallholder traditional pig production in tribal rural area for increasing the income, food security, and livelihood. Critical issues for AI involve oestrus detection in the sow, timing of insemination and applying strict hygiene measures. Future developments will focus on new technologies to better assess semen quality in practice, to preserve semen for a longer time and to inseminate sows successfully using a lower number of spermatozoa using new AI techniques.

Poultry Production in North EasternRegion of India- Prospects and Problems

Sunil Doley[1*], Sonia Chongtham[2], Vinay Singh[3] and M.Norjit Singh[4]

[1,*]*ICAR Research Complex for NEH Region, Umiam, Meghalaya*

[2] *ICAR Research Complex for NEH- Manipur centre*

[3]*ICAR Research Complex for NEH- Tripura centre*

[4]*CAU, Imphal*

Email:doleysunil@yahoo.com

Introduction

Poultry is one of the fastest growing sectors of Indian agriculture with annual growth rates of 5.57 percent and 11.44 percent in egg and broiler production, respectively. India stands as third and fourth largest egg and chicken producer in the world. Currently the total Poultrypopulation in our country is 729.21 million with a growth rate of 12.39 per cent over the period 2007-12 (19th Livestock Census, 2012) and egg productionis around 82.93 billion with per capita availability of 66eggs per annum. Calendar year 2017 egg production is forecast at 84 billion eggs, up by five percent from last year.During 2014-15, the chicken meat production was 2.68 million tonnes (Prabhakaran, 2016) and is estimated to be 3.26 million tonnes during 2016-17. The per capita consumption of poultry meat in India is estimated at around 3.6 kg per head per year, which is low compared to the world average of around 17 kg per head per year.The sector is providing direct or indirect employment to 6.5 million peoples. About 80 percent of the employment is generated directly by poultry farms; the rest by the feed, pharmaceutical, equipment and other support services required by poultry.

North-Eastern (NE) region of India comprises of eight states (Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura and Sikkim) with 27 million ha area which occupies about eight per cent of total land area with 4.55 crores of human population. Agriculture is the major source of employment and livelihood for more than 70 per cent of population in this region. The area is known as meat consuming zone of India. Livestock is an important component of mixed farming system due to preference of meat in their diets. About 30 per cent of landless and 48 per cent of marginal households keep livestock in the NE region (NSSO, 2003).

Poultry sector in north eastern (NE) region

The total poultry population of the region is 43.53 millions (Table-1), out of which Assam accounts for 62.52 per cent followed by Tripura (9.81 %), Meghalaya (7.81%), Manipur (5.74%), Arunachal Pradesh (5.16%), Nagaland (5.00%), Mizoram (2.92%) and Sikkin (1.04%).The region contributes 5.97 per cent of total poultry populationaround 2 per cent intotal egg production of the country. Assam is the highest (55 %) producer of egg in the region, followed by Tripura (11%) and Nagaland (9%). Though the country has witnessed a huge leap in egg production during the recent years but it has been much slower in NE region.

Out of the total poultry in the region, more than 95 per cent birds located in rural area which mostly indigenous fowls (19th Livestock Census, 2012). The potentiality of these indigenous birds in terms of egg production is only 70 to 80 egs/ bird/ year and meat production is also very less.The total demand for table eggs in this region is estimated to be 819 crores per annum as per ICMR recommendation of 180 eggs per person per year. However, the per capita availability of eggs in the region ranges from 15-42 with highest availability of 42 eggs per head per annum in Manipur and lowest in Assam. All the states registered varying degree of increase in per capita egg availability except Sikkim, Mizoram and Tripura. Deshi fowls of Arunachal Pradesh and Sikkim produces more than the rest of India whereas improved fowls of Sikkim, Nagaland and Arunachal Pradesh produces more than the rest of India.

Market Sources reveals that the region imports more than 40 lakhs eggs daily from outside states like Andhra Pradesh, Punjab, West Bengal etc. (Kalita et al.,2016). As compared to the layer farming, the broiler farming has become most profitable venture for self employment among the rural youth of the region.

Table 1. Poultry population of NE states (Nos.)

State	Rural	Urban	Total
Arunachal Pradesh	2188749	55482	2244231
Assam	26837618	378551	27216169
Manipur	1920770	578746	2499516
Meghalaya	3379945	20087	3400032
Mizoram	850755	420598	1271353
Nagaland	1838703	339767	2178470
Sikkim	445734	6232	451966
Tripura	4092513	180220	4272733
Total NE	41554787	1979683	43534470
Total All India	697895256	31314064	729209320
Per cent of all India in NE	5.95	6.32	5.97

Prospects of poultry farming in NE region

Rearing of poultry in small numbers in the backyards under free range or semi-intensive system is a common practice followed in north east region. Abundant availability of natural food base such as waste, cereal, grain, pulse, grain byproducts, kitchen waste, insects, worms, green grass etc. is a boon to backyard poultry in all parts of this region. Egg and meat production in NE region is largely dependent on low yielding native chicken. Increasing the genetic potential of these native chicken varieties may help in increasing their productivity. Very recently, a new indigenous breed called Kaunayen chicken from Thoubal, Imphal West, Imphal East and Bishnupur districts of Manipur is registered. They are also found in the hill districts of Chandel, Churachandpur, Senapati, Ukhrul and Tamenglong. These birds have an elongated body with long neck and legs. Their estimated population is approximately 60,000-80,000.However, the present selection and breeding program (Natural Selection) being adopted by farmers may not be enough to considerably increase the production of the native chicken.

Practicing backyard poultry farming in rural household with improved varieties of birds can ensure the availability of eggs and meat in rural/tribal areas, which could help in alleviating the incidence of protein deficiency of the susceptible group, women, children, expectant mothers and aged besides providing supplemental income. Due to several limitations to establish the intensive poultry farming in this region, it is always convenient to encourage small-scale rural poultry in the region.Rearing method largely depend on the type of the bird reared, availability of resources and the preference of local population for meat or eggs. Specific improved varieties of birds are available for meat, eggs and both (dual purpose). In areas where plenty of natural feed resources (insects, white ants, fallen grains, green grass etc) are available, a small number of birds (10-20) can be reared for meat purpose under free-range condition. If the local demand is for meat in large quantity, the dual purpose or colored feathered broiler chicken can be reared under semi-intensive conditions by providing all the essentials inputs. Interestingly, the majority of the verities developed for the kind of farming need about 25-30% less input in the form of movement and feed.It is necessary to develop suitable chicken varieties, which thrive and survive well in backyard free-range conditions of NE region (high humidity and diversified climatic condition). Directorate of Poultry Research (DPR), Hyderabad has developed some varieties like Vanaraja,Gramapriyaand Srinidhi that are performing well all over due to their versatile adoptability in all climate conditions of our country. The acceptance and popularity of these varietieshavebeen increasing day by day in the NE region. In addition, few more chicken varieties like Giriraja, Girirani, (UAS, Bangalore), Gramalakshmi (KAU Mannuthy), Nandanam(TANUVAS, Chennai), Kalinga brown (OUAT, Bubaneswar) etc.with colored plumage and tinted eggs similar to the Desi hen and can be tried for their suitability and adoptability under free range scavenging conditions. Other multicoloured, meat type chicken varities like Krishi-bro (DPR, Hyderabad) and CARI Dhanaraj (CARI, Barielly) can be tested for their production under semi intensive farming condition using low cost feed for promotion of broiler farming in NE Region.Since all the above mentioned improved varieties of bird developed for backyard poultry farming are hatched out artificially, they essentially require initial brooding. During juvenile period chick cannot regulate its body temperature and therefore, needs artificial heat to maintain body temperature. Therefore, warmth environment should be provided for 4-5 weeks of age. Additionally, young chicks are easily prone to predator attack. Although majority of these chicken varieties possess better immune competence than commercial broiler and layer varieties, but they need to be protected from common infectious disease like Ranikhet diseases, infectious Bursal disease and fowl pox. Rearing conditions include providing artificial heat, vaccination and shelter for better survivability and performances of these birds under free-range backyard conditions. Other poultry species like duck, turkey, guinea fowl etc. can also be reared under low input backyard and semi-intensive systems.

Problemsof poultry farming in NE region

Feed is the main cost which constitutes 65-70 percent of total production cost of bird. Cost of poultry feed in north eastern region is higher than mainland India due to many factors like non-availability of large quantity of feed ingredient,transportation charge, non-availability of big commercial feed mill, etc. Formulation of balanced feed with the locally available cheaper raw material is a major challenge to cut down cost of rearing.The improved quality chicks are one of the major critical inputs for the backyard poultry production. However, availability of quality chicks is a major constraint in villages which are mostly located in remote places. Moreover, lack of effective technological intervention and also lack of knowledge among the farmers about scientific feeding, health care and other practices are the main impediments for low productivity of birds.

Controlling the incidence of disease in the free range and backyard chicken is a challenging task as they are exposed to adverse environmental conditions such as weather changes, poor quality feed, contaminated water and air, predatorsetc.Ranikhet disease (RD), Infectious Bursal disease (IBD) and fowl pox are most important viral diseases commonly occurring in this region. Moreover, scavenging nature of birds exposes them to several internal and external parasites, which affects their growth and production performance. Regular monitoring and de-worming of birds for parasites is very important. Rearing of multiple age groups at the same place under free range and backyard farming makes disease control most difficult. Besides, different species of poultry like chicken, ducks, turkeys, guinea fowls, etc. are reared in the same premises, thereby transmitting many diseases among them and could jeopardize the vaccination programme.In addition, the carcasses of birds that died of infectious disease also pose serious health hazard to the backyard chicken. Besides, the north eastern states are boundary and exposed to neighboring countries like Bangladesh, Bhutan, Myanmar and China. Therefore, trans-boundary diseases and emerging and re-emerging zoonotic diseases should be strictly monitored and controlled. Pandemic disease like Avian Influenza outbreaks are frequently reported from this region of India, so a strict quarantine unit should be set up at the international borders connecting to neighboring countries to check the import and export of poultry birds and its products to this region. Moreover, the veterinary infrastructure in the region is inadequate in terms of both quantity as well as quality. Lack of scientific processing and organized marketing of poultry and poultry products, inadequate credit availability etc. are other important challenges in the region.

Strategies for development of poultry sector on the region

A comprehensive poultry sector development strategy encompassing effective technological intervention for increasing the productivity of the birds and also to boost the rural economyand employment through rural poultry farming should be initiated.Therefore,the following strategies may be followed for overall development of the poultry sector in the region.

- Development of zone specific chicken varieties utilising local germplasm of this region.
- There is a need to develop cheaper balance ration using locally available ingredients for feeding to improved backyard poultry.
- Production of major feed ingredients like maize and soybean through bringing more area under cultivation through availability of quality seeds.
- Supply of improved variety chicks on regular basis to the farmers of the region.
- Training to the farmers on scientific management of the poultry. It will help in increasing egg production and reducing the poultry diseases.
- Intensive epidemiological studies and timely disease control.
- Incentives to commercial poultry farming through enhanced and easy credit arability.
- Establishment of scientific poultry processing units.
- Organized marketing of poultry meat and eggs in the region remains relatively insignificant despite efforts in the past to develop and promote collective market mechanisms. It is thus apparent that developments in the traditional market will be very important.

Conclusion

Poultry sector has immense importance in agrarian economy of North-EasternRegion of India for employment and income generation and ensuring food and nutritional security. However, the region has to go a long distance to realize the full potential of this sector. A proper policy initiative encompassing improved technological intervention, breed improvement, quality feed availability, proper disease control,proper processing and organised marketing approach, increased credit availabilityand encouragement for entrepreneurship development will help to a great extent in realising the maximum potential of poultry sector in the region. In order to meet the deficiency gap in poultry meat and egg sectors, adequate and sustained efforts will have to be made to improve the production efficiency of the rural poultry. In the prevailing condition of the region, the improved rural poultry production has great potential to fulfil the nutritional requirement as well as to help in the generation of rural employment and poverty alleviation.

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Climate-Smart Aqua-based 'IFS' Model: A Key to Sustainable Prosperity

Ratan Kumar Saha

College of Fisheries, Central Agricultural University (Imphal), Lembucherra, West Tripura, Tripura, Email: ratankumarsaha123@rediffmail.com; ratankumarsaha123@gmail.com

At present agriculture sector as a whole facing hardship challenges to meet the food security and livelihood improvement of poor small holding farmers. Agriculture and fisheries sector is largest consumer of water, is highly vulnerable due to its direct dependence on climate parameters. Fisheries and aquaculture support the incomes and livelihoods of about 10-12 percent of the world's population. The sector has an important role to play in gender equality, poverty and food security. Aquatic systems are also associated with rich biological diversity in a wide variety of ecosystems. The global population is expected to increase to 9-10 billion by 2050. Expanding populations will create greater demand for aquatic foods, and the importance of aquatic resources and production systems will increase. To meet this demand, the aquaculture sector may need to increase production by 70-100 percent over current levels in the next two decades. However, aquaculture also faces increasing constraints as competition for land, water, energy and feed resources becomes more acute related to the north east India. These factors combined with the impacts of the accumulation of green house gases (GHGs) in the atmosphere and water relate to a number of physical phenomena including gradual changes in water temperature, high evaporation rates leads to reduce of water levels, lowers water quality, irregular/ unpredictable rainfalland frequency(changes in precipitation and water availability), sudden flooding of water bodies, acidification of water bodies, disruption of river flow, change in thermal structure/ stratification, storm severity and frequency. These physical changes affect ecological functions within aquatic systems such as species composition, ecosystem, biodiversity, productivity, production and yield, feeding activity, growth, reproduction, survival in culture, nursery and hatchery level, dry season mortality, distribution and seasonality, changing the abundance of natural food available to culture species, eutrophication, algal bloom, more diseases and disruption, bringing new predators and pathogens, fishing, culture practices, water and other resources, post harvest operations, and so on. Eventually these affect the socio-cultural, socio-economical, communities, livelihoods, and market of a particular area.

To combat these problems, the successful and continued delivery of benefits from fisheries and aquaculture will require the development of clearly targeted policies, sound management, technical changes and investments. Aquaculture is not practised evenly across the country and this write-up addresses the potential impacts of climatic change on the freshwater aquaculture sector with possible adaptations and mitigations to overcome these impacts. Development of climate-smart aqua-based "IFS' model is thus a need of the hour to achieving future food security and climate change goals. The college of Fisheries, CAU (I), Tripura developed 3-tier aqua-based "IFS' model which includes four (4) A i.e., Aquaculture + Agriculture + Animal Husbandry + Apiculture. This model was replicated at different locations of Tripura by the College with various location specific interventions such as (i) Fish-vegetable-fruit farming(ii) Fish-vegetable farming, (iii) Fish-fruit farming, (iv) Fish-pig farming, (v) Fish-vegetable-pig farming, (vi) Fish-fruit-pig farming, (vii) Fish-fruit-vegetable-pig farming, (viii) Fish spawn rearing–vegetable farming, (ix) Fish-medicinal plant farming, (x) Fish-rice-vegetable-fruit farming, (x) Fish-fruit-goat farming, (xi) Fish-agriculture-mushroom, (xii) Fish-duck-farming, xiii) Fish-fruit-beekeeping and xiv) Fish-cow farming. These interventions were done by adopting an ecosystem approach to aquaculture (EAA) management by following most effective thematic adaptation measure. Adaptations include changing to less carnivorous species, diversification of culture species including mollusc, crabs and aquatic plants wherever possible, domestication of wild (locally available/ endemic/ indigenous) species to minimize impacts on biodiversity, use non-reproducing stock in farming systems, organic farming (cow based farming), backward aquaculture (Aquaponics), family–based climate smart aquaculture,selective breeding, genetic improvements, feed source diversification, immunostimulant feed, medicated feed, new forms of feed management, efficient use of resources, good management practices (GMPs), aquatic animal disease surveillance (establishment of regular monitoring and emergency procedures), stress reducing management; biosecurity measures, use of fallow land/ unproductive land/ waste land, adjustment of harvest and market schedules, quality control and management.

Functional Enhancement of Pork Sausage through Addition of Blood Fruit (*Haematocarpus validus*) an Underutilized Fruit in Northeast India

B.B. Banerjee, L.S. Meitei, G. Kadirvel and S. Doley

Division of Livestock Production, ICAR-RC for NEH Region, Umiam, Meghalaya
Email:velvet.2007@rediffmail.com

Traditional sausage is one of the most popular meat products in Northeast India especially with pork. Percentage of pork consumption is around 68.75% in Northeast region which is highest amongst all other forms of meat. An attempt has been made to enhance the functional property of pork sausage by addition of blood fruit *(Haematocarpus validus)* which is an underutilized fruit of Northeast India. Functional food in simple terms can be defined as “processed foods having disease-preventing and/or health – promoting benefits in addition to their nutritive value”. Blood fruit is analysed to have high levels of beta carotene (14 mg/100gm) and anthocyanin (200 mg/100gm) which act as antioxidants. It is also found to be rich in iron content (6 ppm). The fruit was also analysed for its minerals like Mn (1.82 ppm), Cu (0.912 ppm), Zn (1.146 ppm) and K (0.321 ppm). 10% of the fruit was added in the pork sausage emulsion which was processed through subsequent stages of sausage making as per standard protocol. The pork sausage with blood fruit, on organoleptic evaluation was found to score 7 in Hedonic scale for overall acceptability which was at par with plain pork sausage. It was further analysed to estimate beta carotene and anthocyanin content which recorded a value of 4.48 mg/100 gm and 6.14 mg/100gm respectively and compared against plain pork sausage where beta carotene and anthocyanin was below the detectable range. The other parameters analysed and compared were crude protein, crude fibre, ether extract, nitrogen free extract, ash and calorie. The results proved the functional upgradation of pork sausage with blood fruit. Such an initiative will not only provide a healthier variety product but also help to utilize blood fruit during its peak season when there is surplus production which is otherwise thrown out.

Productive and Reproductive Performance of Lumsniang Pig Variety

G. Kadirvel, L. Anandakumar Singh* S. Doley, Ashok Kumar, G. Khargharia, K. K. Baruah and S.V. Ngachan

Division of Livestock Production, ICAR-RC for NEH Region, Umiam, Meghalaya
Email:vetvet.2007@rediffmail.com

Pig husbandry is important and integral component of farming system and important role in improving socio-economic status of the farmers in the North East Hill region of India. For improvement the pig productivity in the region, ICAR Research Complex for NEH region has successfully developed crossbred pig variety with Niang Megha (Indigenous pigs of Meghalaya) as indigenous germplasm and Hampshire pig as exotic blood by crossbreeding and maintained by *inter se* mating of 75% crossbred for last six year in the ICAR pig farm. The result reveals that Lumsniang pig variety attains the body weight of 77.5-90.7 kg at the age of 12 months. The post weaning growth rate was 300-367g/day with average feed conversion efficiency of 1:4.30. It has excellent reproductive traits including age at puberty (273.66±21.19 day), age at first conception (318.00±31.41day) and age at first farrowing (432.17±31.52 day). The good mothering ability is one of the important feature viz. litter size at birth (9.52±0.55), litter size at weaning (8.12±0.81), average individual weight at birth (0.85±0.16 kg) and average individual weight at weaning (9.46±1.14 day). The life time productivity traits of the Lumsniang pig variety for average of 6 farrowing/ sow viz., total litter size at birth (51.83±2.70), average litter size at birth (9.13±0.17), total litter weight at birth (44.07±2.29 kg), average litter weight at birth (7.75±0.14 kg), total litter size at weaning (47.17±2.69), average litter size at weaning (8.29±0.20), total litter weight at weaning (446.19±25.43 kg) and average litter weight at weaning (78.46±1.91kg) are promising. The variety has excellent carcass quality with an average dressing percentage of 72.33 and back fat thickness was 2.30 cm. The study concluded that Lumsniang pig variety has better adaptability in hill ecosystem, climatic resilient traits including the body physiology suitable to hill ecosystem, promising growth rate and feed conservation efficiency, good mothering ability with higher litter size and litter weight at birth as well as weaning, excellent carcass quality and better disease resistance capacity.

Keywords: *Lumsniang Pig, Productivity, Reproductivity, Life Time Productivity Traits*

Effect of type of Birth and Sex on Growth Pattern and Kleiber Ratio in Assam Hill Goat

G. Khargharia*, G. Kadirvel, S. Doley, L. Anandakumar Singh, Prakash R. Dutta, K. K. Baruah and Ashok Kumar

Livestock Production Division, ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya -793103
Email: gautkhar74@gmail.com

A total of 289 data were collected from Livestock Farm, Livestock Production Division, ICAR Research Complex for NEH Region, Meghalaya to evaluate the effect of type of birth and sex on the growth pattern and Kleiber ratio (KR) of Assam Hill goat. Body weight at birth (BWB), 3 months (BW3)and 6 months (BW6); average daily gain from birth to 3 months (ADG1), 3 months to 6 months (ADG2) and birth to 6 months (ADG3); and KR from birth to 3 months (KR1), 3 months to 6 months (KR2) and birth to 6 months (KR3) were estimated. The mean BWB, BW3, BW6, ADG1, ADG2, ADG3, KR1, KR2 and KR3 were found to be 1.440 ± 0.348 kg, 6.571 ± 0.004 kg, 11.036 ±

0.104 kg, 0.057± 0.001, 0.050 ± 0.001, 0.053 ± 0.001, 0.014 ± 0.001, 0.008 ± 0.001 and 0.009 ± 0.001 respectively. Weight of single birth (1.587 ± 0.031 kg, 6.927 ± 0.104 kg and 11.289 ± 0.124 kg) kids were significantly higher ($p<0.05$) than twin (1.383 ± 0.027kg, 6.396 ± 0.091 kg, 10.823 ± 0.108 kg)and triplet birth (1.243 ± 0.052kg, 6.225 ± 0.173 kg, 11.111 ± 0.206kg) at birth, 3 months as well as 6 months of age. Significantly higher ($p<0.05$) body weight was found for the male kids compared to the female in all the three age groups. ADG1 and ADG3 were significantly higher ($p<0.05$) in male kids. The study also revealed that ADG1 was significantly higher ($p<0.05$) in single birth compared to twin and triplet and ADG2 was significantly higher ($p<0.05$) in single and twin birth compared to triplet birth. Type of birth had no significant difference in case of KR1 and KR2 but KR3 was significantly higher ($p<0.05$) in single and twin birth compared to triplet. Selection on the basis of growth traits can be carried out to improve the performance of Assam Hill goat.

Keywords: *Assam Hill Goat, Growth, Sex, Kleiber Ratio*

Effect of Supplementation of Silkworm Pupa Meal on Growth and Nutrient Utilization in Crossbred (HS X GH) Grower Pigs

Keshab Barman*, S. Banik, Girish Patil, S.R. Pegu, Sunil Kumar, Anil Kumar Das, Karabee Dutta, D.K. Sarma and Lalitha N[1]

ICAR-National Research Centre on Pig, Rani, Guwahati, Assam, India, PIN: 781131
[1]Eri Silworm Seed Production Centre, Central Silk Board, Guwahati-781017
[*]Email: barman74@rediffmail.com

Eighteen crossbred (HS x GH) castrated grower pigs (3 months old, body wt. ranged from 13-14 kg) were divided into three groups of six each in a randomized block design to see the effect of supplementation of silk worm pupa meal on feed intake, growth, nutrient utilization and nitrogen balance. Three different diets were prepared for feeding of experimental animals. These were namely - T_1: standard grower ration without silkworm pupa meal and designated as control diet, T_2: standard grower ration supplemented with 1.5% silkworm pupa meal by replacing 9.4 % protein supplements which include mixture of groundnut cake and soyabean meal and standard grower ration supplemented with 3% silkworm pupa meal by replacing 18.9 % protein supplements. The pigs were fed on the experimental grower rations twice daily in the morning and evening. The crude protein content (% DM) of the grower ration was ranged from 18.01±0.51 to 18.06±0.17 while that of silkworm pupa meal was 73.13±0.21, while CP content of silkworm pupa meal was 59.88±0.96. The average dry matter intake was (g/d) 804.60±1.54, 804.17±0.18 and 805.91±1.03 respectively in T_1, T_2 and T_3 groups which were found similar across all the groups. Digestibility coefficients (%) of dry matter, crude protein, ether extract and crude fiber was increased ($P<0.05$) in silkworm pupa meal supplemented groups. Nitrogen balance (g/d) was found positive across all the groups and values were 13.74±0.44, 16.55±0.07 and 17.07±0.05 in groups T_1, T_2 and T_3 respectively and was increased ($P<0.01$) in supplemented groups in comparison to control. The average body weight gain (g/day) was found higher ($P>0.05$) in silkworm pupa supplemented groups. The cost (Rs/kg gain) was reduced ($P>0.05$) in T_2 and T_3 groups in comparison to T_1 group. The feed conversion efficiency (FCR) was higher ($P>0.05$) T_2 and T_3 groups than control group. From this study, it is concluded that silkworm pupa meal can be supplemented @ 3 % level by replacing 18.9 % protein supplements in grower crossbred pigs to improve growth, nutrient utilization, feed conversion efficiency and also to reduce the feed cost.

Keywords: *Silkworm Pupa Meal, Supplementation, Growth, Nutrient Utilization, Crossbred Pigs*

Enhancement of Reproductive Efficiency through Estrus Synchronization and Timed AI In Mithun (*Bos frontalis*) Cows under Semi-intensive System

M. H. Khan*, S. B. Hazarika, P. Perumal, S. Mukherjee and Abhijit Mitra

Animal Physiology & Reproduction Laboratory, ICAR-NRC on Mithun, Medziphema, Nagaland

Email: haidermeraj@rediffmail.com

Mithun (*Bos frontalis*), the ceremonial animal of North-East India, is a shy breeder. Females often exhibit poor expression of estrus whereas males show poor mounting behavior under confinement. Due to poor expression of estrus, it is difficult to identify the females in heat which may result into longer calving to conception and inter-calving interval. Aim of the present study was to reduce calving to conception interval (days open) in mithun cows, reared under semi-intensive system, through estrus synchronization and timed AI. Study was carried at Medziphema Mithun Farm of NRC on Mithun, Nagaland. A total of 29 post-partum mithun cows, age between 4-7 years, were selected and divided randomly in two groups viz., treatment (n=23) and control (n=6). Before starting the experiment, all the animals were examined through rectal palpation and ultrasonography to ascertain non pregnant status and reproductive soundness. Synchronization treatment was started at day 60 after calving. Animals in group A (treatment) were injected with GnRH (buserelin acetate 0.02 µg, im) at day 0 followed by PGF2α (cloprostenol Sodium 526 µg, im) at day 7. Estrus was detected at day 9 and AI with frozen mithun semen was done. Simultaneously, second GnRH injection was given on the same day. Second AI was done next day morning. While in group B (control), normal saline was injected as placebo and estrus detection was done daily in the morning by parading of intact mithun bull. Date of estrus was recorded and AI was done. Result showed that, out of 23 animals synchronized, 19 (82.60%) exhibited estrus and all the animals were inseminated with frozen thawed Mithun semen. Pregnancy was confirmed by non return rate and rectal palpation method. 14 (73.68%) animals were found pregnant. Control group exhibited estrus 86.56±14.66 (range 51 – 182 days) days after initiation of the treatment while treatment group exhibited estrus just after 9 days of initiation of treatment. Conception rate was found to be 50% in control group which is significantly lower than in treatment group. It may be concluded that reproductive efficiency of Mithun cows may be increased through estrus synchronization and timed AI under semi-intensive system.

Effect of Melatonin and Buck Exposure Treatment on the Reproductive Performance of Singharey Goats in Agro-Climatic Conditions of Sikkim

Rafiqul Islam*, Mahak Singh, Brijesh Kumar, R. K. Avasthe and Priya Chettri

ICAR-National Organic Farming Research Institute
Tadong, Gangtok -737102, Sikkim

Email: rafiqvet@gmail.com

Singharey is a typical native goat of Sikkim which constitutes the major part of the state's goat population. Goat farming is a popular and traditional way of livelihood system associated with poor and marginal farmers with a sustainable source of income in rural Sikkim. The present study was aimed to increase the reproductive performance of Singharey goats using melatonin and buck exposure treatment. Singharey goats that had kidded at least once at ICAR-NOFRI goat farm were selected and included in the experiment. Effect of melatonin on reproductive performance has been studied using three different dose rates *i.e.* Control (Group I: no melatonin), 10 mg (Group II), 20 mg (Group III) and 40 mg (Group IV). Estrus induction rate was 100% in melatonin treated groups

(Group II, III and IV) and 42.85% in Group I (Control). Kidding rate was 42.85%, 150%, 150% and 166% in Group I, II, III and IV, respectively. Kidding percentage could be increased with melatonin treatment with more twins and triplets births. Effect of buck exposure on the reproductive performance of Singharey goats was also studied. Buck exposed does showed higher estrus induction rate (94.11%) than the non-exposed control does (66.67%). The birth weight of kids of buck exposed group (1.98±0.10) was significantly ($P<0.05$) higher than the kids of melatonin treated group (1.58±0.07). It is concluded that both melatonin and buck exposure treatment is effective in inducing estrus in Singharey goats in Sikkim. Melatonin treatment yielded higher estrus induction and kidding rates in Singharey goats, whereas birth weight of kids was recorded to be significantly higher in buck exposed group.

Comparative Performance of Vanaraja and Srinidhi Birds under Intensive and Backyard Systems of Rearing in Meghalaya

S. Doley[1], M. Das, G. Khargharia, G. Kadirvel, K. Puro, A. Kumar, R. K. Dewry, H. Sharma and M. K. Kalita

ICAR Research Complex for NEH Region, Umiam, Meghalaya – 793103
E-mail: doleysunil@yahoo.com

An experiment was conducted to study the comparative performance of Vanaraja and Srinidhi chicken varieties under intensive and backyard systems of rearing in Meghalaya. Different productive and reproductive traits were recorded to compare their performance under intensive system in the Institute Poultry Farm and under backyard system of rearing in the farmers' fields. The average body weight of Vanaraja at 40 weeks of age was found to be 3.85 and 2.74 kg for male and female birds respectively under intesive system of rearing and the correspoding values were 2.69 and 1.83 kg under farmers' field. The average body weight of Srinidhi birds at 40 weeks of age was 4.31 and 1.86 kg for male and female respectively under intesive system of rearing and 2.81 and 1.53 kg for male and female birds respectively in farmers' field. The average age at first egg and egg production upto 40 weeks under intensive system were 126 and 130 days; and 59 and 63 numbers for Vanaraja and Srinidhi respectively and the corresponding values in farmers' field were 154 and 161 days; and 40 and 42 numbers . The fertility and hatchability were found to be 86 and 71 per cent in Vanaraja and 82 and 69 per cent in Srinidhi under intensive system of rearing. The results showed overall better performance of Srinidhi compared to Vanaraja birds both in the intensive and farmers' field in the agroclimatic condition of Meghalaya.

Expression of Heat Shock Protein in Indigenous Naked Neck, Normal Feathered and Vanaraja Grower Birds during Winter Season in Meghalaya

S. Doley[1], M. Das, G. Khargharia, G. Kadirvel, K. Puro, A. Kumar, R. K. Dewry, H. Sharma and M. K. Kalita

ICAR Research Complex for NEH Region, Umiam, Meghalaya – 793103
E-mail: doleysunil@yahoo.com

The aim of the experiment was to study the expression levels of different Heat Shock Protein (HSP) in indigenous Naked Neck, Normal Feathered and Vanaraja grower birds during peak winter months in Meghalaya. The experimental birds were reared on deep litter system under standard management condition during peak winter. Total 36 numbers of grower birds at the age of 12th week, comprising 12 birds from each group were selected randomly for collection of blood samples and estimated their HSP expression levels by using ELISA kit. The expression levels in Indigenous Naked Neck, Normal Feathered and Vanaraja were found to be 1.62 ± 0.78, 2.26 ± 0.68 and 1.2 ± 0.35ng/ml for HSP20; 2.03 ± 0.28, 1.7 ± 0.29 and 1.4 ± 0.15ng/ml for HSP40; 21 ± 5.89, 18.67 ± 8.84 and 8 ± 1.32ng/ml for HSP70 and 2.03 ± 0.34, 1.83 ± 0.57 and 1.17 ± 0.21ng/ml for HSP90 respectively. The results revealed higher expression of different HSP levels in Indigenous Naked Neck and Normal Feathered compared to Vanaraja grower birds during winter indicating higher tolerance of indigenous birds to cold stress.

Chungrung, A Mithun Cross Cattle an Interspecies Hybridize Animal Boon for Mishmi Tribes of Arunachal Pradesh

Tilling Tayo[1]*, Doni Jini[2], Manish Kanwat[1], Neeta Longjam[3] and Prasanta Mahanta

[1]*KVK–Anjaw, ICAR A.P center Basar for NEH region*
[2]*ICAR, A.P center Basar for NEH region*
[3]*KVK-East Siang, CHF Pasighat, Central* Agricultural University (CAU), Arunachal Pradesh.
Email: tilling.tayo@gmail.com

Species hybridization between Mithun and cattle is a form of out-breeding, to produce new offspring called locally *Chungrung* by Digaru Mishmi, is a natural paradigmatic shift towards positive development of new breeds (Chungrung), thereby improving the low face value animal (cattle) to high face value animal (Chungrung), without much human manipulation against the desire of Animal. However, there is a dilution in pure germplasm of both the species. Nevertheless, Species hybridization is a boon for Mishmi society, because as per traditionally and customary law and practices, Chungrung worth and value are used at par with Mithun in Mishmi society, like two different facet of same coin, thereby improving the socio-economic status of person. Where Mithun price is sky, rocking costing around Rs 60,000 – 80,000 per adult Mithun, in counterpart adult cattle cost around 15,000 – 20,000 only. Consequently Mithun and Chungrung is consider as most blessed animal for livelihood sustenance in many different dimension be it in social, culture or religious aspect of Mishmi society in Arunachal Pradesh.

Keywords: *Chungrung, Mithun, Cattle, Interspecies Hybridize, Mishmi Tribes*

Growth Performance of Hampshire Pigs in Winter and Summer Season under Feeding with Different Dietary Energy Diets

P.K. Pathak, R. Roychoudhury, J. Saharia, M.C. Borah, D.J. Dutta, R. Bhuyan and D. Kalita

Department of Livestock Production and Management, College of Veterinary Science, Assam Agricultural University, Khanapara-781022
Email: drpkp19@gmail.com

An experiment was carried out at 30-sow Teaching Unit, College of Veterinary Science, AAU, Khanapara for a period of one year (October, 2014 to September, 2015) to find out the effect of seasonal thermal stress on growth performance of Hampshire pigs under different dietary energy diets. Eighteen weaned piglets (at 56 days) of Hampshire pigs irrespective of sex were selected and randomly divided into three dietary groups viz. Gr.I, Gr.II and Gr.III consisting of 6 animals of almost similar body weight in each experimental group for winter months in 1st phase and summer months in the 2nd phase. A total of 3 rations were prepared for grower and finisher stage as per the NRC feeding

standard for pig (NRC, 1998). The ration having 110, 100 and 90 per cent energy of NRC (1998) designated as high energy (HE), medium energy (ME) and low energy (LE), respectively. The ME, LE and HE treatment were represented three dietary groups of pigs *viz.*, Gr.I, Gr.II and Gr.III, respectively for both winter and summer, where Gr.I (ME) was considered as control group. The average initial body weights of weaned experimental piglets were almost similar with the average value of 10.55 kg. Analysis of variance showed that during winter season Hampshire pigs attained significantly higher ($P<0.01$) body weight as compared to summer season. Statistical analysis of data also revealed that energy level of diet had highly significant ($P<0.01$) influence on the body weight of pigs and significantly ($P<0.01$) higher body weight was recorded in high energy incorporated group. Analysis of variance showed that during winter season Hampshire pigs attained significantly higher ($P<0.01$) average daily body weight gain than summer season. Statistical analysis of data also revealed that energy level of diet had highly significant ($P<0.01$) influence on the average daily body weight gain of pigs. It was also recorded that high energy incorporated diet minimizes the production losses in terms of body weight gain during summer.

Keywords: *Hampshire Pigs, Season, Growth Performance, Dietary Energy Levels*

Effects of Feeding Brewer's Spent Grains on Milk Production of Dairy Cows under Traditional System of Rearing in Sikkim

P.K. Pathak, R.K. Avasthe, N.J. Singh, B.Lepcha, P. Phukan, J. K. Singh and R. Singh
ICAR-Krishi Vigyan Kendra, East Sikkim, Ranipool-737135
Email: drpkp19@gmail.com

In Sikkim, pasture quality and availability varies markedly throughout the season and therefore, can hardly meet the dairy cow's needs especially from December to March. When grass is in short supply or is of poor quality (low energy and protein contents) the body condition is quickly lost, particularly in fresh calvers, resulting drastically reduced milk yield. Brewer's in Sikkim, generate extensive by-products in the form of spent grain. Brewer's spent grain is a valuable source of energy and protein and it is a safe feed when it is used fresh and/or properly stored. The fresh brewer's spent grain feeding to the animals contains 27.66% dry matter, 6.98% protein, 10.54% crude fibre, 3.33% ether extract and 3.2% ash (Ramesh Chandra *et. al.* 2010).The experiments were carried out in the dairy farms of selected farmers located at Saramsa and Nandok area of East district of Sikkim. The present study was conducted to find out the effects of feeding brewer's spent grains as a non-conventional feed resource on milk production of Jersey crossbred cows during winter season (December to March) and its economic viability in Sikkim. Twenty crossbred cows calving in the month of November were selected, consisting 10 milking cows of almost similar body weight and milk yield and randomly divided into two dietary groups *viz.*, Gr. I and Gr. II, where Gr. I considered as control and Gr. II considered as treatment group. During the experimental period, the animals were reared under standard management practices. In the Gr. I, the experimental animals were given 5 kg computed balanced ration along with 10 kg green grasses daily, whereas in the Gr. II, animals were fed 2.5 kg of computed balanced feed mixture along with 9 kg of fresh spent grains daily in two equal halves in the morning and evening. The experiment showed that the milk yield increased by 18% in animals of Gr. II supplemented with brewer's spent grains, where the cost of concentrate feed was also reduced to half as compared to Gr. I. The B:C ratio was recorded as 1.66 and 2.39 in the Gr. I and Gr. II, respectively. Therefore, brewer's spent grain can provide an economical alternative to traditional grains and forages used in dairy farming operation in Sikkim.

Keywords: *Brewer's Grains, Dairy Cows, Sikkim, Economics of Feeding, Winter Season*

Temperature Manipulation as a Safe and Smart Technology for Production of Monosex Stocks of *Macrobrachium rosenbergii*

Rekha Das*[1], Himanshu Priyadarshi[2], Basant Kumar Kandpal[1], Lopamudra Sahoo[1], Chandan Debnath[1] Kouberi Nath[1], Huirem Bharati[1], Abhijit Singha[1] and Sourav Debnath[1]

[1]*ICAR Research Complex for NEH Region, Tripura Regional Centre, Lembucherra-799210*
[2]*College of Fisheries, Under CAU (Imphal), Lembucherra-799210*
Email: rekhakalidas84@gmail.com

Macrobrachium rosenbergii (scampi) is a decapod crustacean of high market value inhabiting freshwater bodies of the Indian subcontinent and Australia. The males of the species grow faster and attain larger sizes than females and hence monosex male culture is preferred over mixed culture. The current method of monosex stock production by manual segregation is labour intensive, tedious and error prone and hence effective alternatives are sought. Presence of a sex labile early development phase when environment can override genetic sex determination system is reported in several species of aquatic animals. This study aimed to examine the possibility of employing temperature manipulations during a potential sex labile phase in *M. rosenbergii* to influence its sex differentiation. Accordingly, sexually undifferentiated freshly metamorphosed *M. rosenbergii* post larvae were reared at three sub lethal temperatures (24±2 ^{o}C, 28±2 ^{o}C and 30±2 ^{o}C) in circular plastic tubs of 50L capacity with constant aeration. The tubs were maintained in triplicates with 75 animals per tank, fed on plankton *ad libitum*. The water temperature in the tubs was maintained using submersible thermostats. At PL 10 stage, the animals were observed under the microscope for external sexual structures and the sex of each individual noted. The sex ratios of each treatment were compared to the control by chi square test. No significant difference ($P<0.05$) in the sex ratio was observed between the treatments. The low male to female sex ratio (1:3) observed in the species was consistent with reported literature. Thus, deviation from 1:1 ratio in post larval sex could be due to the higher cannibalism among males due to HIG reported in the species. It also remains to be verified if temperature manipulations during egg incubation phase can influence sex differentiation in *M. rosenbergii.*

Reproduction Management in Bovines under Field Conditions using Technological Interventions

Suresh Kumar, S. Saha, Y.K. Soni, M. Pande, A. Bhargava[*], Keshav Kumar[**], B.B.S. Yadav[**], A.S. Sirohi, Nemi Chand, Naresh Prasad, Jitendra Kumar Singh and B. Prakash
ICAR-Central Institute for Research on Cattle
Post Box No.17, Grass Farm Road, Meerut Cantt.-250001, U.P.
**MSD pharma, ** UPLDB*

The present strategy was planned to evaluate the fertility status of bovines in field conditions around Merrut, U.P. and to address the infertility problems in field and also to device a practical approach for reproduction management and augmentation of fertility in cattle and buffaloes in collaboration with UPLDB covering villages of Meerut, Baghpat and Muzaffarnagar districts of U.P. During 27 infertility camps a total of 1178 animals were treated for various ailments. Out of them 26.54% were anestrus, 11% were repeat breeders and 62.46% animals had general health related problems. A total of 495 were found to have various reproductive disorders. Almost 55% sub-fertile animals responded after receiving dewormer, mineral mixture and other non hormonal supplements whereas 36.98 % of infertile animals needed hormonal interventions followed by A.I. and /or needed treatments with 65.45% success rate for conception.

Circadian rhythm in Endocrinological and Biochemical and Haematological Profiles in Mithun (*Bos frontalis*) Bulls during Summer and Autumn Season

Tsarila Z.T Sangtam[1], N.Savino[1] and P. Perumal[2]

[1]*Department of Livestock Production and Management, Nagaland University, Medziphema-797106.*
[2]*ICAR-National Research Centre on Mithun, Medziphema-797106. India*
Email:neilhouvotso@yahoo.com

The present research was carried out on 30 mithun males of different age groups. The mithun males were distributed equally into five different groups based on their age and consisted of six animals per g roup and the groups were such as Gr A (0.1-1.0 year), Gr B (1.1-2.0 years), Gr C (2.1-3.0 years), Gr D (3.1-5.0 years) and Gr E (5.1-6.0 years). The blood samples were collected from each animals by venipuncture of jugular vein in heparin tubes (20 IU of heparin/mL of blood) from the experimental mithun bulls at 0400 hrs interval throughout the day during the different seasons. The samples were tested for different parameters including hormone profiles - Follicle stimulating hormone (FSH) , Luteinizing hormone (LH) , Testosterone (T) , Cortisol (CORT) , Thyroxine (T4) , Insulin like growth factor -1 (IGF-1) , melatonin , blood profiles - red blood cells (RBC), white blood cells (WBC), erythrocyte sedimentation rate (ESR), haemoglobin (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC)), antioxidant profiles - glutathione (GSH), glutathione reductase (GSHRx), superoxide dismutase (SOD) , catlase (CAT) and total antioxidant capacity (TAC), malondialdehyde (MDA) and biochemical profiles - Total protein, Albumin, Glucose & Cholesterol. The hormone profile, FSH, LH/ICSH, testosterone, melatonin and thyroxine were significantly ($P<0.05$) higher and cortisol, prolactin and IGF-1 were significantly ($P<0.05$) lower in autumn than in summer season. The haematological parameters such as TRBC, Hb, ESR, PCV and WBC were significantly ($P<0.05$) higher in autumn than in summer season whereas MCV and MCH were significantly ($P<0.05$) lower in summer than in autumn season. The biochemical profiles such as total protein, albumin, globulin, glucose and total cholesterol in mithun blood plasma revealed that there was significant ($P<0.05$) difference between the autumn and summer seasons. MDA was significantly ($P<0.05$) higher in Gr E than in Gr A and as age advances the concentration of MDA was increased. There was significantly ($P<0.05$) higher MDA in Gr C, D and E and non-significantly higher in Gr A and B was observed in summer than in autumn season. In case of TAC and CAT, it was significantly ($P<0.05$) increased from Gr A to Gr B and then decreased gradually to Gr E. GSH concentration in blood serum revealed that there was significant ($P<0.05$) difference between the age groups and was increased from Gr A to Gr C and then decreased to Gr E in the mithun male animals whereas in Gr A, D & E, significant ($P<0.05$) difference was found between the summer and autumn seasons and non-significant difference was observed in other experimental groups. GSHRx in blood serum of mithun male revealed that there was significant ($P<0.05$) difference between the age groups and was significantly ($P<0.05$) increased from Gr A to Gr B and then decreased to Gr E whereas significantly ($P<0.05$) higher value was obtained in autumn than in summer in Gr A, B and D and non-significantly in Gr C and E. Effect of age groups on SOD of blood serum in mithun male animals revealed that there was significant ($P<0.05$) difference between age groups being highest in Gr A and then decreased to Gr E whereas non-significantly higher value was obtained in autumn than in summer season. The present study indicated that autumn season was more preferable to the mithuns as it is a cold loving animal. In summer season, mithun has to spent higher energy for performing daily activity. The study also suggested that there should be a suitable feeding and grazing policy to counteract the stress caused by heat and to reduce the thermal stress in mithun.

Keywords: *Mithun, Hormones, Biochemical, Antioxidants, Haematological, Nagaland*

Theme-7: Frontiers in Plant and Animal Health Management Including One Health Concept

Transboundary Viral Diseases- Threats and Control Strategies Revisited

Arnab Sen*, I Shakuntala, R.Laha, S.Ghatak, K.Puro, Sanjukta.R, Meena Das, Samir Das, Raj Kumar Pegu, Samprithy Baruah, Surmani. H, A. Karam, Amit Chakraborty, Priyanka Mukherjee

ICAR Research Complex for NEH, Barapani, Meghalaya

Email: arnabsen123@gmail.com

Abstract

Viruses are thus adapted to extremely diverse niches. Zoonotic viruses are spectacular examples of emergence and re-emergence resulting from innocent environmental manipulation or natural environmental change. Important aspects of ecological change and their relation to emerging viral life cycles are: 1) Population movements and the intrusion of humans and domestic animals into new arthropod habitats, particularly tropical forests; 2) Deforestation, with development of new forest-farmland margins and exposure of farmers and domestic animals to new arthropods; 3) Irrigation, especially primitive irrigation systems, which are oblivious to arthropod control; 4) Uncontrolled urbanization, with vector populations breeding in accumulations of water (tin cans, old tires etc.) and sewage; 5) Increased long distance air travel, with potential for transport of arthropod vectors; 6) Increased long-distance livestock transportations, with potential for carriage of viruses and arthropods (especially ticks); and 7) New routing of long-distance bird migration brought about by new man-made water resources. Rapid globalization leading to increased trade and thus continuous movement of humans and animals, climate change, increased concentration of animals and humans pose an ever increasing threat of infectious diseases crossing the borders and leading to huge outbreaks. Outbreaks of exotic viral and bacterial diseases have become a real threat to animal populations worldwide in recent years. Outbreaks of FMD in UK in 2001 and 2007, Blue tongue in 2007, equine influenza in Australia in 2007 and India in 2008-09, highly pathogenic avian influenza (H5N1) are some of the glaring examples of the amount of devastation they can cause in terms of economic losses and damage to the industry. The scars from these outbreaks are stark reminders which make us sit and probe our capabilities to work towards creating technologies and garner our scientific knowledge in pursuit to overcome these infections. Theoretically, sealing our borders and stopping the movement of all human and animals can help us achieve the task but its sheer magnitude and enormity certainly make us ponder upon some better scientific means to find a sensible solution to this enigmatic problem of transboundary diseases.

Disease

Infectious diseases have shaped human history. They are dynamic, and will continue to influence where and how humans live—and human activities will alter the paths and expressions of infectious diseases. A broad range of societal, biological, and physicochemical factors influence the distribution, incidence, and burden from infectious diseases. In recent years, patterns of infectious disease have changed. These changes include the description of diseases caused by pathogens long present but not previously identified, recognition of seemingly new microbes, changes in old pathogens (for example, changes in distribution, incidence, virulence, resistance to drugs), new disease—disease interactions, and the spread to humans of organisms never previously known to be human pathogens. Although much media attention has focused on tropical, remote locations and on exotic viral infections such as Ebola, the changing pattern of infections involves all geographic regions and all classes of pathogen (such as viruses, bacteria, fungi, helminths [parasitic worms], and protozoa). Most of the major global causes of death from infectious disease are common, widely distributed infections, such as tuberculosis, measles, HIV, influenza, pneumococcus, and rotavirus.

Infections: Chronic vs acute

Infections kill and disable through many mechanisms. Many pathogens cause acute disease, but infectious diseases also impose a burden through chronic diseases, including cancer. Chronic diseases may be a consequence of persistent infection (for example, hepatitis B virus) or may result from tissue damage caused by past infection. Many cancers have been linked to infections. The World Health Organization (WHO) estimates that more than 1.5 million cancers each year, or about 15 percent of the total, are related to microbes. The three that lead the list are gastric (Helicobacter pylori), cervical (papillomaviruses), and liver (hepatitis B and C viruses) cancers.

Microbes

It is useful to take a broad view of microbial life before focusing on microbes that harm humans. Only a tiny fraction of microbes that exist on Earth have been identified and characterized. Of those identified, most do not infect humans; some are essential for shaping and sustaining life as we know it. Microbes are old, diverse, abundant, and resilient. They live in communities, send signals to communicate with each other, and change in response to changes in the environment. Microbial communities living deep in the Earth metabolize organic materials bound to rocks and sediments and shape the physical environment. Some microbes have short generation times (for example, twenty to thirty minutes for an organism like staphylococcus, compared with twenty to thirty years for a human), and hence can undergo rapid change. Such organisms change via mutation, but also by a variety of molecular maneuvers that involve acquisition and exchange of genetic information (for example, transfer, reassortment, recombination, conjugation, and so forth). These can alter microbial traits relevant to human health—virulence, resistance to drugs, and even transmissibility.

Source of microbe

The source of microbes causing infections in humans is typically another human, an animal or arthropod, or soil or water. Globally, about 65 percent of infections that lead to death are spread from person to person (such as respiratory tract infections, tuberculosis, HIV, and measles); almost a quarter are carried in food, water, or soil (for example, infections such as cholera and hookworm); and about 13 percent are vector-borne (namely, malaria and leishmaniasis) as per World Health Organization, 1997.

To cause disease, a microbe must find a way to enter the human host and reach appropriate cells or tissues where it can attach and replicate. Microbes typically enter the body via ingestion, inhalation, or through the skin or mucous membranes. Many important pathogens, including the malaria parasite, are carried to the human host by a mosquito and inoculated through the skin. Some pathogens have complicated cycles that involve one or more intermediate hosts, typically animals that support one stage of development of the pathogen.

Diseases in Pre-historic times

Many infectious diseases of human and veterinary importance have pre-existed since pre-historic times *i.e.* early human colonization of the globe and have been of evolutionary significance. Human and wildlife animals have been responsible for dissemination of many diseases new areas. The Spanish conquistadors introduced smallpox and measles in the Americas and, similarly, movement of domestic and wild animals during colonization introduced their own suite of pathogens (Daszak et al., 2000).

The first influenza pandemic for which more than one descriptive reports exist was that of 1889. Retrospective research has partially identified the virus responsible by testing for influenza antibodies in the serum of people who were alive at that time (Tumova, 1980). However, despite the importance of influenza as a disease of humans, the earliest recognition of influenza virus in animals related to infections of poultry. A disease capable of causing extremely high mortality in infected domestic fowl was first defined in 1878 and became known as fowl plague. As early as 1901, the causative organism of this disease was shown to be an ultra-filterable agent (*i.e.* a 'virus') Alexander D.J (2000). Isolation of influenza virus as the causative organism of a disease of pigs with clinical signs similar to those in humans first described at the time of the 1918 human pandemic (Dorset *et al.*, 1922). This swine influenza virus preceded isolation of human influenza virus. The African rinderpest panzootic of the late 1880s and 1890s is a paradigm for the introduction, spread, and impact of virulent exotic pathogens of wildlife populations. This highly pathogenic morbillivirus disease, enzootic to Asia, was introduced into Africa in 1889. The panzootic front travelled 5000 km in 10 years, reaching the Cape of Good Hope by 1897, extirpating more than 90% of Kenya's buffalo population and causing secondary effects on predator populations and local extinctions of tsetse fly. Populations of some species remain depleted and the persistence of rinderpest in eastern Africa continues to threaten biodiversity. Pandemics of cholera, influenza, plague and other diseases have also occurred in the past.

Influenza has been one of the notable viral affections in the past. The Spanish influenza of 1918-1919 was responsible for death of more than 18 million humans world over (Fields, 2001). The causative agent, not characterized at molecular level earlier due to non-availability of sophisticated molecular techniques, has now been identified as H5N1 influenza virus. Now it is also known that waterfowls are the reservoir hosts while pigs act as mixing vessels.

Changing patterns of infectious diseases

Infectious diseases have shaped the evolution and history of animal kingdom especially human and animals. Infectious diseases are dynamic and will always continue to influence the overall activities of human being in all the spheres of their lifestyle. It is very obvious by now that human activity will alter the paths and lexis of infectious diseases. The distribution, incidence, and burden due to infectious diseases are influenced by a range of societal, biological, and physicochemical factors. The pattern of infectious disease has been changing continuously which has been responsible for sustained microbial evolution. These changes include the description of diseases caused by pathogens long present but not previously identified, recognition of apparently new microbes, changes in epidemiology (e.g., changes in distribution, disease incidence, virulence of microbial strains, microbial resistance to drugs) of old pathogens, new disease—disease interactions, and the spread (to human/animals) of organisms never previously known to be human/animal pathogens.

The understanding of how these factors influence the emergence, re-emergence and spread of infections is of paramount importance in control and eradication of infectious diseases. The changing pattern of infectious disease is typically affected by interaction of multiple factors. The emergence/re-emergence of a disease could be an unintended consequence of many developmental activities which is perceived as progress. Various developmental activities which can be attributed to many ecological changes include: (i) building of a dam; (ii) clearing of lands; (iii) change in landscape, (iv) mass processing and wide distribution of foods and water; (v) medical/veterinary interventions (transfusions of blood/blood products; vaccines; animal feed containing livestock/fish/poultry offal); (vi) mass immunization; (vii) use of drugs and chemotherapeutics; (viii) use of antimicrobial agents; (ix) inland/national/international travel and trade; (x) changing pattern due to land use (intensive cropping, animal husbandry); (xi) indiscriminate use of fertilizers, insecticides, pesticides, hormones in agricultural operations, (xii) use of probiotics and unconventional feed additives in animal feeds and use of hormone injections (oxytocin) for realizing over production; (xiii) extensive mechanization of agricultural operations; (xiv) practice of extensive undefined livestock husbandry systems inappropriate to a particular region, state or a nation; (xv) international/inter-continental movement of migratory birds.

Factors contributing to change in disease pattern

Many factors are contributing to the changing patterns of infectious disease. Those commonly identified are microbial adaptation and change, human demographics and behavior, environmental changes, technology and economic development, breakdown in public health measures and surveillance, and international travel and commerce (Lederberg et al., 1992). How these influence the appearance, reappearance, and spread of infections will become apparent in the discussion of specific disease examples. Typically, multiple factors interact, leading to changes in a disease. The emergence of a disease may be an unintended consequence of what is viewed as progress: the building of a dam, clearing of lands, mass processing and wide distribution of foods and water, medical interventions (namely, transfusions of blood and blood products, tissue and organ transplantation, cancer chemotherapy), and use of antimicrobial agents.

The burden of disease in humans can increase through (i) increased contact between a pathogen (disease-causing agent) and host, (ii) increase in virulence or resistance of the pathogen, (iii) increase in the vulnerability of the host, or (iv) limited access to effective prevention or therapy. A human or a population can be completely or relatively invulnerable to some infections because of (i) immunity (past infection or immunization), (ii) genetic factors, or (iii) a whole range of barriers (such as shoes, screens, good housing) or (iv) interventions (for example, provision of clean water and adequate waste disposal, control of organisms responsible for transferring pathogens between hosts) that prevent contact between human and pathogen. Good nutrition, including adequate intake of micronutrients, can lead to an improved outcome in at least some infections.

Reservoir animals

The source of microbes causing infections in humans is typically another human, an animal or arthropod, or soil or water. Similarly, the source of microbes causing infections in animals could be another animal, a human, or arthropod, or soil or water. Globally, about 65 percent of human infections that lead to death are spread from person-to-person (such as respiratory tract infections, tuberculosis, HIV, and measles); almost a quarter are carried in food, water, or soil (for example, infections such as cholera and hookworm); and about 13 percent are vector-borne (viz., malaria and leishmaniasis) as per World Health Organization (1997).

Zoonotic pool

Perusal of the emergence of viral diseases to date indicates that many of these viruses already existed in nature and they gained access to new host population due to change in ecological or environmental conditions. Many pathogens of human and animals, which may include agents currently in an isolated population, may make the best source for microbes causing future epidemics. Such pathogens need careful scrutiny if they are highly transmissible (Ewald, 1993; Mims, 1991), particularly through the respiratory route. However, many historical examples of infectious zoonoses (Fiennes, 1978; McNeil, 1976) suggest that the "zoonotic Pool"– introductions of viruses from other species– is an important and potentially rich source of emerging diseases and some of these pathogens might become successful in causing the disease in new host under conducive environments. The appearance of HIV, SIV, Hantavirus and co-evolution of some other primate lentiviruses, as described below, constitute the best examples of zoonotic introductions. The human immunodeficiency virus (HIV) is one of the many examples of zoonotic introductions. The origin of HIV-1 is still uncertain and hence no argument can be put forth regarding its zoonotic introduction.

However, (a) identification of an infected man in a rural are of Liberia whose HIV-2 strain resembled more closely to viruses from the sooty mangabey, a presumed reservoir of virus closely ancestral to HIV-2 than it did HIV-2 strains circulating in the city (Gao et al., 1992), and (b) recent identification of a new subtype of HIV-1 from Africa (represented by strain Ant70 and MVP-5180), which seems to have branched off fairly early in the HIV lineage and is closely related to a virus isolated from chimpanzees can be interpreted as separate , possibly, earlier zoonotic introduction (Meyers and Korber, 1994).

Similarly, there is a large pool of simian immunodeficiency viruses (SIV) in African green monkey populations (Allan et al., 1991; Meyers et al., 1992), including the probable ancestor of sooty mangabey virus. Many of the primate lentiviruses may not have been identified yet. Which virus from the pool of SIVs and other primate lentiviruses may emerge in future cannot be predicted.Identification of the virus responsible for the recent "Four Corners" disease (now called Hantavirus pulmonary syndrome; the original virus is known as Sin Nombre) in the western United States is another example for zoonotic introduction of emerging infectious disease. In the beginning of May 1993, patients with clinical symptoms like fever and acute respiratory distress were presented in hospitals and serology and detection of genetic sequences by PCR provided evidence for a previously unrecognized Hantavirus as the cause of the outbreak (Nichol et al., 1993). The isolation and identification of the virus with the same genetic sequences in local rodents, primarily the common species *Peromyscus manuculatus* (deer mouse), which were also the rodent mostly trapped near homes confirmed these rodents to be the reservoirs of hantavirus. Over 20% of the captured Peromyscus were positive for Hantavirus. It was probable that the virus had existed for long in mouse populations but that unusual climatic conditions led to increased adult survival over the winter and increased rodent population in the spring and summer providing greater opportunities for people especially agricultural workers to come closer with infected rodents (and hence with the virus).

The realization of the potential threat due to wildlife EIDs for wildlife itself, for human and domesticated animals, and biodiversity conservation; is due to (i) the increased incidence of disease outbreaks in endangered species and in humans due to wildlife EIDs, (ii) advancements in veterinary diagnostics and care, (iii) advances in host-pathogen biology including host-pathogen interface, and (iv) the understanding of the important role of wildlife in biodiversity conservation. The adversity in agriculture has also helped in realization of the importance of wildlife EIDs in the evolution and sustenance of the ecosystem.

Spill- Over and Spill-Back

Spill-over is the transmission of infectious agents from reservoir animal populations (often domesticated species) to sympatric wildlife. Spill-over underpins the emergence of a range of wildlife EIDs and is a particular threat to endangered species since presence of infected reservoir hosts can lower the threshold density of pathogen and lead to local (population) extinction . African wild dog population has been continuously declining since 1960s and has now become endangered species with fragmented population of < 5000 animals. This population is now susceptible to various diseases. Wild dog became extinct in Serengeti in 1991 which coincided with epizootic canine distemper in sympatric domestic dog. Similarly, rabies has also resulted in heavy mortality of wild dogs and a viral variant common in sympatric dogs has been identified from one such incident. The Hendra virus (HeV) affects horses and humans and the bats of genus *Pteropus* found in Australia act as reservoirs as they have sub-clinical infection naturally as well as experimentally. The HeV has been isolated from fetuses of experimentally infected pregnant bats. Similarly, specific immuno-staining was seen in the placenta. It is now believed that HeV does not induce disease in bats, at least experimentally, but is responsible for a sub-clinical infection, except perhaps in pregnant animals where the virus might induce congenital disease following transplacental transmission (Westbury, 2000). Isolation of HeV from uterine discharges of a bat that had miscarried twin fetuses, and from three other bats has been reported (Halpin *et al*., 1996). How the 'spill-over' of HeV occurs is not yet clear, although it is sporadic and uncommon. Current data also suggest that additional natural hosts of HeV are unlikely to exist in Australia leading to believe that spillover of the virus must occur from bats to horses, although whether it is direct or through intermediates, requires further investigation (Westbury, 2000).

The "Spill-back" can be defined as reverse "spill-over" i.e. transmission of diseases to sympatric populations of susceptible domesticated animals. Introduction of brucellosis in America was due to introduction of cattle and presence of brucellosis in elk and bison in Yellowstone National Park (USA) is a threat to animals grazing at the park boundary. Other examples of spill-over infection include sarcoptic mange in foxes (in Europe) and wombats (Australia) and bovine tuberculosis (global). Tuberculosis threatens to "spill-back" to domestic livestock and ultimately to humans.

Surveillance

Surveillance is basically keeping a vigilant eye on the animal health status in a given country (or region). It can be defined as all regular activities aimed at ascertaining the health status of a given population with the aim of early detection and control of animal disease of importance to national economies, food security, and trade. In routine national disease management, surveillance is used as tool to keep record of disease occurrences, and analyses of the secular trends assist authorities in detecting major shifts in disease that could lead to epidemics. In specific disease control programmes, surveillance is used to evaluate the effectiveness of control strategies, and to detect needs for mid-course adjustments in the programme. In the last stages of a disease eradication programme, surveillance becomes most important as a tool first for finding the last cases of the disease to be eradicated, and then for keeping a watchful eye for re-entry of the disease agent in the disease-free population. Regardless of the basic objective, the tools and components of a surveillance system are essentially the same, although there may be variations in the amount of emphasis put on the different components.

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Parasitic Infections in Pigs of North Eastern Hill Region of India

R. Laha

Division of Animal Health, ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya-793 103

Email: rglaha@gmail.com

Rearing of pigs is one of the ways of livelihood of tribal population of north eastern region of India. But one of the major constraints of rearing of pigs is the infections and infestations of these pigs by different types of parasites. Pigs may be infected with internal parasites or infested with external parasites. Internal parasitic infections in pigs may be caused by helminths i.e. nematodes, trematodes and cestodes or may be caused by protozoa. Infection with internal parasites inhibits weight gain and decreases feed conversion and thus the time require to reach market weight goes longer. Internal parasitic infections in pigs particularly by gastrointestinal (GI) parasitic infections by helminths and protozoa affects pigs performance in terms of poor growth rate, reduced weight gain, reduced feed conversion and condemnation of affected organs (Nsoso *et al.* 2000) and pigs of north eastern region have been found to be infected with high percentage of various GI parasites (Yadav and Tandon, 1989), Ebibeni *et al.*, 2013). The major helminth species in temperate pig production include *Ascaris suum* (the large roundworm), *Trichuris suis* (whipworm), and *Oesophagostomum* spp. (nodular worm) (Roepstorff et al., 2011).Pigs that are infected with one or more species of such parasites reduced food utilisation and growth rate (Hale and Stewart, 1979; Hale *et al.*, 1981, 1985) as well as a changed body composition, while migration of *A. suum* larvae results in substantial liver condemnations (Roepstorff, 2003). Young animals may die from anaemia due to massive worm infections and causes increase susceptibility to secondary infections with ensuing mortality, reduce milk yield in lactating sow and reduce piglets growth (Adebisi, 2007). Economic losses due to parasitism in pigs not only caused by the internal parasitic infections, external parasitic infestations are also responsible for economic losses. But pig producers are generally concerned with internal parasitic infections of their pigs and ignored the external parasitic infestations. Here, both internal and external parasitic diseases of pigs will be discussed. Parasitic diseases of pigs not only causes harmful effect to pigs, some of the parasitic diseases are transmissible between human and pigs and that will also be discussed here.

Internal parasitic infections: Pigs may be infected with round worms, cestodes, trematodes and protozoa. Important round worms of pigs are *Ascaris suum*, *Oesophagostomum* spp., *Metastrongylus apri*, *Stephanurus dentatus*, *Ascarops strongylina*, *Macracanthorhynchus hirudenaceus*, *Strongyloides* sp. and *Trichuris* sp. *Fasciolopsis buski* is the important trematode of pig. Hydatid cyst and *Cysticercus cellulosae*are the important cestode or tape worm of pigs. Among protozoa, coccidia i.e. *Eimeria* spp. infection has been found to be commonly occurring protozoa in pigs. Besides coccidia, pigs may be infected with Balantidium *coli*, a GI protozoa infections which has zoonotic significance. The reported prevalence of various internal parasitic infection in Meghalaya are- *Ascaris suum* (44%), *Oesophagostomum* spp. (11.0%), *Metastrongylus apri* (13.3%), *Stephanurus dentatus* (10.59%), *Ascarops strongylina* (5.96%), *Macracanthorhynchus hirudenaceus* (3.74%), *Fasciolopsis buski* (3.32%), Hydatid cyst (3.32%) and coccidian oocyst (37.03%) (Rajkhowa, C.). In a study of this area, eleven species recovered and in descending order the prevalence are as follows: *Ascaris suum, Oesophagostomum dentatum, Bourgelatia diducta, Stephanurus dentatus, Globocephalus connorfilii, Physocephalus sexalutus, Ascarops dentata, A. strongylina, Pseudocruzia orientalis, Setaria bernardi and Gnathostoma hispidum.A. Suum* has been found to be the most prevalent species (51.67%) in the pigs of this region. The overall infection rate was considerably higher (76.42%) in the low-altitude region rather than in the high-altitude one (62.50%). The highest level of infection (73.2%) was observed during autumn and the lowest (63.0%) in winter (Yadav and Tandon, 1989). In another study of this area, overall 47.98% pigs have been reported as positive for GI parasitic infections and eight species recovered like *Ascaris suum* (50.00%), *Oesophagostomum spp.* (40.59%),*Strongyloides spp.* (38.12%), *Trichuris suis* (9.90%), *Metastrongylus spp.*(9.40%), *Macracanthorhynchus spp.*(5.44%), *Fasciolopsis buski* (2.47%) and oocysts of coccidia (17.33%)(Rajkhowa, 1996).

In a recent study, Laha *et al.* (2014a) reported over all prevalence of GI parasitic infections in pigs of four north eastern states like Meghalaya, Nagaland, Mizoram and Manipur as 37.77%.Amongst helminthes, over all, *Ascaris suum* infections (65.46%) were predominant in these four states followed by Strongyle spp.(45.96%), *Trichuris* spp.(16.66%) and *Strongyloides* spp. (13.06%). Amongst protozoa *Eimeria* spp.(34.00%) and *Isospora* spp.(3.50%) was recorded. State wise 36.34%, 47.31%, 34.45% and 60.95% GI parasitic infections in pigs have been recorded in Meghalaya, Nagaland, Mizoram and Manipur, respectively. The mean faecal egg counts in terms of eggs per gram of faeces (EPG) of pigs of Meghalaya, Nagaland, Mizoram and Manipur, were 1289.13, 2038.44, 475.19 and 897.26, respectively. Except Mizoram, *Strongyloides* spp. was recorded in other three states. Among protozoa *Eimeria* spp. was recorded in all these four states and *Isospora* spp. was recorded in three states,except Meghalaya. *T*he pigs of Manipur reported to suffer from higher percentage (52.34%) of infection with *Isospora* spp.In earlier studies in Meghalaya, 68.38% pigs (Yadav and Tandon 1989) and 47.85% pigs (Chandra and Ghosh 1989) were found infected with one or more species of GI nematodes. A lower percentage of GI parasitic infections (22%) in pigs of Mizoram has been reported earlier (Deka *et al.*, 2005). The prevalence of GI parasitic infections in Meghalaya found to be more in unorganized pig farms as compared to organized pig farms which were recorded as 36.18% and 28.65% with mean EPG 1345.98 and 1056.12, respectively (Laha *et al.*, 2014b). The GI parasitic infection in pigs of Meghalaya recorded as higher in rainy (45.79%) and cool season (42.02%) as compared to cold (29.80%) and warm/hot (34.25%) seasons.

The coproculture of positive faecal samples revealed the presence of larvae of *Oesophagostomum dentatum* **(**80.62%) and *Strongyloides ransomi* **(**19.37 %) (Laha *et al.*, 2014c). In a study the prevalence of gastrointestinal parasitic infection in pigs was recorded as 22.58% and 55.95 % in organized and traditionally managed pig farms, respectively. The pattern of infection was either single (81.25%) or mixed (18.75%) infection with a faecal egg count range of 50-1400 egg per gram (EPG) of faeces. Among the helminthes Strongyle spp. were predominant (33.33%) followed by *Ascaris* spp. (9.37%), *Strongyloides* spp. (3.13%) and *Trichuris* spp. (2.08%). Besides helminth, *Eimeria* spp. infection was recorded in 33.33% animals (Das *et al.*, 2010a).

Ebibeni *et al*. (2013) reported a high prevalence of GI parasitic infections in piglets (81.6%) and in adult pigs (61.7%) of Dimapur district of Nagaland.In piglets, they observed mixed infections with different nematodes in 32.6% piglets and single infection in 48.9% piglets. They showed highest percentage of strongyle infection (38.7%), followed by *Eimeria* sp (34.7%), *Strongyloides ransomi* (28.5%), *Ascaris suum* (18.3%) and A*scarops* sp. (2.04%). In adult they observed mixed infection in 20.5% pigs and single infection in 41.1% pigs .The strongyles were the most prevalent GI parasites (35.3%), followed by *Eimeria* spp.(19.1%), *A. suum (* 5.8%), *S. ransomi (*4.4%) and *Ascarops* spp. (2.9%). Village wise parasite distribution showed a maximum parasitic infection in Dizephe (92.0 %), followed by Bade (75.0%), Dhansiripar (71.4%), Molvom (64.7%), Jharnapani (55.5%) and Seithekima village (54.1%). From four villages of Phek district of Nagaland, Borkotoky *et al.* (2014) recorded the prevalence of *Ascaris suum* (28.75%) followed by *Eimerian* spp. (16.25%), *Strongyloides ransomi* (10.00%), Strongyles (6.25%), *Trichuris suis* (6.25%), and *Capillaria* spp. (1.25%) among indigenous local pigs. Among the three age groups of pigs considered, there were significant differences ($p<0.05$) between these groups as well as among different species of parasites. Among the three age groups, incidence is more in younger animals than adult pigs. They have also reported that, in comparison to sex, there was no significant difference in occurrence between male and female pigs.

***Ascaris suum*:** *A. suum* is the largest nematode of pig. The female is upto 40 cm. long and there is no possibility of confusion with any other pig parasite. The egg is ovoid, yellowish with a thick shell, the outer layer of which is irregularly mammillated. *A. Suum* has been found to be the most prevalent species in pigs of this region (Deka *et al.* 2005 ;Laha *et al.* 2014.). In pigs of Meghalaya, *A. suum* infection has been reported as highest prevalent (69.30%) upto 3 months of age and 8.91% in pigs above 6 months of age (Rajkhowa, 1996). Yadav and Tandon (1989) reported *A. suum* as the most prevalent species (51.67%) in the pigs of this region is presumably of zoonotic importance.Each female worm is capable of producing more than 2,00,000 eggs per day. The migrating larvae in large numbers may cause pneumonia. In the liver the migrating larvae can cause 'milk spot' which appears as cloudy whitish spots up to 1.0 cm. in diameter (Urquhart *et al.*, 1988). The adult worm in the intestine may cause damage to the mucosa and may be obstruction. The adult worms cause production loss in terms of decrease weight gain. In piglets which become heavily infected, may show signs of pneumonia, especially a cough and exudates into the lungs. Heavy infection with adult cause diarrhoea. Examination of faecal samples, examination of sputum and post mortem examination are the different ways of diagnosis of *A. suum* infections in pigs.

Nodular worm /*Oesophagostomum* spp.: Strongylid nematodes, *Oesophagostomum* spp. infect the caecum and large intestine. *O. dentatum* is probably the most common parasite of adult pigs. In the intestine they forms nodule. Piglets as young as two to three week of age can be infected leading to a grayish-yellow diarrhea. It has been observed that the pigs' diet can have a significant influence on establishment and fecundity of *Oesophagostomum* spp. Thus, diets with high levels of insoluble dietary fibres provide favour- able conditions for the establishment and egg production of *O.*

dentatum, whereas diets rich in digestable proteins and carbohydrates significantly reduce worm burdens and fecundity (Nansen and Allan, 1999). The parasite is responsible for poor productivity and due to this infection pregnant sows become thin, inappetance and following farrowing, there is decreased milk production (Urquhart *et al.,* 1988).

Whip worm/*Trichuris suis:* The adult worm is about two inches long and lives in the caecum where it burrows into the caecal and intestinal wall disrupting nutrient absorption and allowing secondary bacterial and viral infections to infect the host. The females lay eggs that are passing in the feces and can become infective in approx. three weeks. These eggs are also very hardy and can last in the environment up to ten years. Often moderate numbers of adult *T. suis* are present in the caecum and colon, but the worm burdens may occasionally be high and cause unthriftiness and death (Nansen and Allan, 1999). Diagnosis can be done by examination of faecal samples.

Metastrongylus apri: Swine are the exclusive hosts for *Metastrongylus*. The adult metastrongylid lungworm lives in the bronchi and bronchioles. The parasite has an indirect life cycle in which most earthworm species can serve as intermediate hosts. Larvae develop within earthworms. Pigs less than 6 months of age may cough and dyspneic. Infected pigs may also have a history of loss of appetite, poor feed conversion, unthriftiness and weight loss.

Stephanurus dentatus:*S. dentatus* is the 'kidney worm of pig'- a stout worm up to 4.5 cm long with transparent cuticle through which the internal organs may be seen. Though the favourable site is perirenal fat, some worms occur in the kidney itself. The main pathogenic effect is due to the larvae which damage the liver and other organs.In heavy infection there may be cirrhosis, in rare cases liver failure and death. The ureter become thickened and in chronic cases may be almost occluded.

Hydatid cyst: Here human, pigs acts as intermediate host and dog, fox etc. acts as definitive host. Dog harbors the adult parasite *Echinococcus granulosus* in the intestine and they lay eggs. Eggs come outside the body of the dog through faeces. Intermediate hosts like cattle, sheep, goat, pigs and human through contaminated pasture or contaminated food or drinking water ingest these eggs. The embryo penetrates the intestinal wall of these intermediate hosts and enters in blood circulation and reaches various organs like liver, lungs etc. Embryo settles these organs and formed hydatid cyst. From Meghalaya, 3.32% pigs reported as positive for hydatid cyst infections (Rajkhowa, C.). Deka *et al.* (2008) reported 0.43% and 0.34% infections in pigs of Assam and Meghalaya, respectively with persistence of dog-pig cycle.

Protozoan parasitic infections of swine

Gastrointestinal (GI) protozoan infections has been reported to cause reduced body weight gain and decreased haemoglobin conc. in infected pigs ((Bauri *et al.,* 2012) that have generally received little attention. Coccidiosis in pigs causes diarrhea (may be bloody), dehydration, loss of appetite, poor growth and occasional mortality in piglets and has been reported to have negative impact on growth rate of pigs. Some of the GI protozoan parasites of pigs like *Balantidium coli* and *Cryptosporidium* spp. have zoonotic significance also. Ebibeni *et al.* (2013) reported 34.7% *Eimeria* spp. infections in pigs maintained in village condition in Dimapur district of Nagaland. Borkotoky *et al.* (2014) reported 16.25% *Eimeria* spp. infections among indigenous local pigs in Phek District of Nagaland. Laha *et al.* (2015) reported over all42.95% pigs of Dimapur District of Nagaland found to be positive for *Eimeria* spp. infections. The overall prevalence of gastrointestinal protozoan parasitic infections in swine of Meghalaya recorded as 29.77%. *Balantidium coli* (9.83%), *Eimeria* spp. (11.56%), *Cryptosporidium* spp. (2.32%), *Entamoeba polecki* (1.74%), *Giardia intestinalis* (1.45%) and *Isospora suis* (2.89%) were detected in infectedanimals. Morphological identification of swine coccidia revealed presence of different species of*Eimeria viz., Eimeria debliecki, E. porci, E. suis,* *E.perminuta*, *E. cerdonis*, *E. spinosa* and *Isospora suis* (Anonymus, 2015). In a recent study, Das *et al.* (2017a) reported overall 11.7% pigs of Meghalaya as positive for coccidial infections. Age-wise, 32.8%, 42.4% and 24.8% infections were recorded in pig of <6 months, 6-12 months and >12 months, respectively.

Parasitic Zoonoses: Zoonoses are the diseases which are naturally transmissible between vertebrate animals and man. When the infective agents are parasites, it is known as parasitic zoonoses. Helminths and protozoa are mainly involved to cause such diseases. Contaminated food and water are main sources for transmission of parasitic zoonotic diseases. Food and water borne zoonoses are important component of parasitic zoonoses (Chhabra and Singla, 2009). GI protozoan parasites of pigs like *Balantidium coli* and *Cryptosporidium* spp. and larval stages of adult *Taenia solium* i.e. *Cysticercus cellulosae*have zoonotic significance.

Balantidium coli**:** *B. coli* are ciliate protozoan parasite responsible for causing Balantidiosis in animals and human. Balantidiosis is a zoonotic disease and is acquired by humans via the fecal-oral route from the normal host, the pig. It is generally harmless for pigs, but sometimes it may produce clinical symptoms and fatal disease. The infected pigs may show moderate to severe diarrhea or may not show any clinical sign. Most human infections are asymptomatic or limited to mild diarrhea and abdominal discomfort. However, in rare instances, the protozoa may lead to hemorrhagic lesions in the intestine, perforation, secondary bacterial infection and generalized peritonitis. Earlier from this region, Rajkhowa *et al.* (2012) recorded 16.16% *B.coli* infections in an organized pig farm of Assam and Laha *et al.* (2013) reported that 41.3% pigs of this region are infected with *B. coli*. Laha *et al.* (2015) reported over all58.45% pigs of Dimapur District of Nagaland found to be positive for *Balantidium coli* infections. So, the high percentage of *B. coli* infections in pigs of this region may be a caution for human being, as the infection has zoonotic significance.

Cryptosporidiosis is a protozoan disease caused by obligate intestinal parasite belonging to the genus *Cryptosporidium* that infects more than 150 hosts including human beings. It causes severe diarrhea, anorexia and weight loss, especially in neonatal and immunocompromised animals. The sporulated oocyst of *Cryptosporidium* sp. can be transmitted from an infected host to a susceptible host by the fecal-oral route. Overall 6.71% fecal samples of pigs of Meghalaya found as positive for *Cryptosporidium* spp. (Das *et al.*, 2017b).

Cysticercus cellulosae:Human beings are infected when they eat undercooked pork containing cysticerci (*Cysticercus cellulosae*), the larval stage of *Taenia solium*, developed in the muscles of pig. Adult worm in the intestine of human causes vague abdominal discomfort, intestinal disorders like diarrhoea/ constipation, chronic indigestion and anaemia. Plain (1991) reported 18.63% pigs of Assam and Meghalaya found to be positive for cysticercosis. Barkataki *et al.* (2012) reported overall 9.5% pigs of Nagaon, Morigaon and Karbi Anglong Distt. of Assam as positive for cysticercosis. Porcine cysticercosis in Sivsagar Distt.of Assam reported as 1.72% (Kakoty and Islam, 2014).Few reports on taeniasis i.e. *Taenia solium* infections in human of north eastern states are also available. Plain (1991) found 3.83% infections in Guwahati and Meghalaya. Barkataki *et al.* (2012) recorded 11.48% infections in Assam (Nagaon, Morigaon and Karbi Anglong Dists.) and Kakoty and Islam (2014) found 0.53% human taeniasis in Sivsagar Dist. of Assam.

Gastrodiscoidosis: In the north eastern state like Assam, the infection is prevalent (Roy and Tandon, 1992). This is caused by *Gastrodiscoidis hominis*, pigs and human being are infected. If untreated, it may cause death, particularly in children.Pig is common reservoir host and source of infection for man.

Fasciolosis : Caused by *Fasciola hepatica* and *F. gigantica*. Although reports of human infections are rare, but hepatobiliary symptoms with obstructive jaundice due to *Fasciola* spp. in children have been reported from Uttar Pradesh (Elhence *et al.*, 2001). A child with adult fluke in the gall bladder detected by ultrasonography in Assam (Narain *et al.*, 1997).

Ascaris suum and may be *T. suis* are zoonoses and closely related to *A. lumbricoides* and *T. trichiura*, which infect millions of people worldwide, respectively (de Silva *et al.,* 2003). As mentioned earlier, Yadav and Tandon (1989) reported *A. suum*is presumably of zoonotic importance. There are two valid species of *Ascaris* for human and pigs-A. suum for pigs and *A. lumbricoides* for human. There are several hypothesis regarding the origin of thse two species of *Ascaris*. As per one one hypothesis, *Ascaris suum* is derived directly from *A. lumbricoides* with the persistent ancestor being *A. lumbricoides* and *A. suum* being the newly derived species, and vice versa. As per another hypothesis, *Ascaris lumbricoides* and *A. suum* are the same species, this hypothesis being supported by studies showing both low morphological and low genetic divergence at several genes (Leles *et al.*, 2012).They concluded that *Ascaris lumbricoides* and *A. suum* are a single species and that the name A. lumbricoides Linnaeus 1758 has taxonomic priority; therefore A. suum Goeze 1782 should be considered a synonym of *A. lumbricoides*.

Some of the parasitic zoonotic diseases should be taken into consideration although not reported from this region as per knowledge of author concerned.

Trichinellosis: Caused by *Trichinella spiralis.* The primary host is pig which act as reservoir host for man. Infection of man occurs when they eat pork containing the larval form of trichinellae. Mortality rate is 5%. Sometimes thrombosis may occur in man. Demonstration of trichinella larvae after biopsy is the method of diagnosis.

Sarcocystosis: Human became infected after consumpsion of undercooked or raw meat containing *Sarcocystis suihominis* (in pork). Pigs are intermediate hosts of*S. suihominis* where man acts as definitive host. *S. suihominis* has been reported from Pantnagar in stool samples of children (Banerjee *et al.*,1994).

Fasciolopsiosis: This is the infection of human being caused by *Fasciolopsis buski*. This is the largest trematode parasitising man (Chatterjee, 2009). The adult parasite remains in the small intestine of man and pig. Pigs are the normal host and serves as reservoir of infection for man. Eggs are liberared from the pig through the faeces which developed in the water, formed ciliated miracidium. Miracidium enters into the snail and comes out as Cercariae. Cercariae swims in the water, attach to grass blades or vegetables and form metacercariae. Definitive hosts (man, pig) infected after ingestion of contaminated vegetables containing metaceceria.

Toxoplasmosis: Toxoplasmosis is caused by *Toxoplasma gondi*. Man and other warm blooded animals are its host and distributed worldwide. Cats including wild Felidae are the definitive host and man acts as intermediate host. Transmission of the disease takes place by three ways- ingestion of uncooked meat containing tissue cysts, ingestion of food and water contaminated with infected faeces and congenitally. Congenitally acquired Toxoplasmosis is more severe than postnatally acquired infection. In AIDS patients and other immunocompromised patients, Toxoplasmosis may be life threatening. Mental retardation, hydrocephalus, chorioretinitis, intracerebral calcification, loss of hearing and death may occur. The most common sequlae in congenitally infected children is the loss of vision.

The pigs of north eastern region found to be suffer from high percentage of nematode parasites that may be due to both unhygienic management practices and favourable environment for survival and development of pre infective stages of nematode larvae (Yadav and Tandon, 1989). The climatic condition of north eastern region is hot and humid followed by heavy rainfall which are much conducive for growth and propagation of helminth parasites (Borkotoky *et al.,* 2014). Besides, the prevalence of worm burden, spectrum of helminth species largely depends on the types of swine production systems (Nganga *et al.*, 2008) and most of the rearing system is of backyard condition, where animals were reared with minimum input of scientific management (Borkotoky *et al.,* 2014) may be the reason of high prevalence of nematode infections in this area. The feeding habits of animals also influence the occurrence of nematode particularly of *A. suum* infections in pigs (Yadav and Tandon, 1989). Among climatic factors, rainfall directly influences the pathogenicity of the parasitic infection level (Chattopadhyay and Bandyopadhyay, 2013).

External parasitic infestations

Sarcoptic mange infestation in pigs

Pig owners are generally concerned with internal parasitic infections of their pigs and ignored the external parasitic infestations. Amongst various parasitic infestations of pigs, infestation with mites which causes a disease known as 'mange' is very much important. Sarcoptic mange in pigs caused by the mite *Sarcoptes scabies* var. *suis* is one of the external parasitic infestation of pigs which pig owners generally ignored. It isthe most common mange infestation of pigs. *Sarcoptes scabies* var. *suis* infestation in pigs has economic importance (Damriyasa *et al.*, 2004). There are three ways by which this mange causes economic losses to the pig owners. Firstly, this parasite has negative effect on growth rate and efficiency of feed conversion particularly in growing and finishing pigs. Because, this parasite penetrates deep into the skin, produce itching sensation, cause stress and resulted loss of body weight. In this way they cause loss of production. Secondly, the damaged skin may be invaded by secondary bacterial infection, which aggravates the condition. Thirdly, sarcoptic mange infestation may cause decrease fertility of sows, responsible for economic losses to the pig owners. In addition to morbidity and mortality, another important aspect of this infestation is that it may cause damage to pig handlers which cause severe itching as it has been reported that 65.2% pig handlers out of 46 studied had symptoms of itching and diagnosis of *S. scabiei* mite in 20 persons have been done (Chakrabarti, 1990). Hence, mange infestation in pig is very much important. *Sarcoptes scabies* var. *suis* infest only pigs and cannot survive on other livestock or man. In length, these mites are upto 0.5 mm long and from dorsal aspect, only two pairs of anterior legs can be seen. They can be observed only under microscope.Eggs are laid by the female parasites at the rate of 1 to 3 eggs per day. After a period of 5 days, the eggs hatched to form larvae. Larvae moult to form nymph and further moulting of nymph form adult. It takes about 10-15 days to complete the life cycle of this parasite. These parasites are not reproduce outside the host, but the mite may survive outside the pig for upto 12 days at a temperature of 7^0C to 18^0C and a relative humidity of 65 to 75%.

The spread of infestation among pigs mainly occurred by close skin contact between infected pigs and healthy pigs. Besides, infested pigs when rub their skin in the wall or any surfaces, they contaminate the surfaces and by contact of healthy pigs with recently contaminated surfaces, the infestation may spread to the healthy pigs. This mite infestation produce lesions in ears, head, neck, shoulders, legs and back region. Reddening of the infested area, formation of crusts, hyperkeratosis, and fall of hairs from the area characterize these lesions. Wrinkled, thickened, rough, raised skin and thick asbestos-like skin lesions can be observed in infested pigs. The infested pig shows the symptoms of pruritis, as a result affected pig rub the skin against the wall of the pen. It is better to purchase pigs from mange free farms to stop the entry of infestation in a healthy farm. One can suspect in infestation in a pig by observing the clinical symptoms exhibited by the suspected pigs like pruritis and rubbing of the skin in the wall of the pen. Identification of mite from the infested pig is the confirmative diagnosis. For this deep skin scrapings should be taken from the suspected lesions and should be examined under microscope after digestion in 10% potassium hydroxide and centrifugation. Now-a-days immunodiagnostic techniques are being used for diagnosis of this infestation. The parasite was first reported in 1857 and now it is distributed worldwide (http://www.uaex.edu/Other_Areas/publications/PDF/FSA-3077.pdf). The reports of occurrence of *S. scabiei* var. *suis* infestation in pigs from abroad and India are available (Chellapandian et al. 2004; Rueda-Lopez 2006; Lowenstein et al. 2006a). The infestation is restricted not only in sporadic forms but it may occur as an outbreak also. Subramanian et al. (2001) reported about an outbreak of scabies in a piggery. In North-Eastern region of India, where population of pigs are more and in general maintained in an unorganized way in villages as well as in organized farms, reports of *S. scabiei* var. *suis* infestation in pigs are also available from that part of the country. Report of *S. scabiei* var. *suis* infestation in pigs maintained in a remote village of Ri-Bhoi District of Meghalaya are available (Anonymous, 2009). In one organized farm of Meghalaya, presence of *S. scabiei* var. *suis* infestation were detected in five pigs out of 15 suspected pigs which were suffered from skin lesions (Das *et al.,* 2010b). In another study of Meghalaya, among suspected skin lesions of pigs maintained in both organized and unorganized way, overall 11.11% pigs were found positive for *S. scabiei* var. *suis* infestation (Anonymous, 2010). In a recent study, Rajkhowa *et al.* (2012) from Assam reported over all 23.61% pigs are infested with *S. scabiei* var. *suis* in an organized pig farm of Assam.Out of 196 numbers of suspected pigs of both organized and unorganized pig farms as well as pigs brought for slaughter to pig slaughter houses of Meghalaya, 21 (10.71%) numbers of pigs were found infested with *Sarcoptes scabiei* var. *suis* after microscopical examination of skin scrapings (Laha *et al.* 2014d).Among suspected skin lesions of pigs from Chattishgarh, Maiti *et al.* (2004) found 37.50% pigs were affected with sarcoptic mange.The infestation has been found to be more in winter than rainy season (Galhotra *et al.,* 1980)with younger animals suffered more (44.53%) than adult animals (24.37%) (Rajkhowa *et al.,* 2012).

The lesions are characterized by reddening of the infested area, formation of crusts, hyperkeratosis, and fall of hairs from the area with wrinkled, thickened, rough, raised and thick asbestos-like skin. The main clinical symptoms observed in the naturally infested pigs were pruritis as a result affected pigs showed rubbing of the skin against the wall of the pen (Das et al. 2010).Pigs naturally infested with *S. scabiei* var. *suis* showed significant decreased value of haemoglobin (Hb), packed cell volume (PCV), total erythrocytic counts (TEC), serum copper, serum zinc and serum glucose with increased level of Alanine aminotransferase (Sinha *et al.,* 2004). Reduced haematological values like Hb, PCV and TEC along with decreased level of biochemical constituents of serum such as Ca, P, Zn, Cu , total serum protein and albumin have been observed in naturally gastrointestinal nematode infected and sarcoptic mange infested indigenous pigs (Kumar *et al.,* 2007). The economic impact of *S. scabiei* var.*suis* infestation in pigs may be due to decreased growth rate, decreased fertility and lower feed conversion ratio due to the infestation. *S. scabiei* var. *suis* infestation have been found as detrimental for the production performance in pigs (Arends *et al.,* 1990; Davies, 1995; Elbers *et al.,* 2000). In experimental *S. scabiei* var. *suis* infestations in growing pigs, a depressed mean growth rates from 9.2% to 12.5% has been observed (Cargill and Dobson, 1979). The economic losses due to sarcoptic mange infestation are also caused by decreased fertility of sows and lower feed conversion ratio (Zimmermann and Kircher 1998). In a study, growth performance of piglets from *S. scabiei* var. *suis* infested and treated sows showed significantly higher (541.5 g per day) than piglets from *S. scabiei* var. *suis* infested and untreated sows (518.4 g per day), because naturally infested untreated sows transmit the infestation to piglets and thereby showed less growth performance (Mercier *et al.,* 2002). The growth performance (average daily gain in gram per day) of naturally contact-infected *S. scabiei* var. *suis* pigs, in comparison to non-infected pigs has been found to be differ according to the period of infestations (Elbers *et al.,* 2000). They recorded a decreased growth performance of 35gm per day, 50 gram per day and 41 gram per day during 0 to 35 days, 35 to 112 days and 0 to 112 days of infections, respectively.

Treatment of pigs infected parasites

Piperazine salts – These compounds are efficacious in the removal of ascarids and nodular worms. Up to 100% of the lumen dwelling stage may be eliminated with a single treatment. But mature worms are more susceptible. A second treatment is recommended 2 months later to remove emerging larval stages. The recommended dosage is 275 – 440 mg/kg b.wt.

Imidazothiazoles- Levamisole has a broad range of activity in the removal of gastrointestinal, respiratory and urinary tract nematodes. It removes 90-100% of *Ascaris, Strongyloides* and *Metastrongylus* and 72-90% of *Oesophagostomum, Trichuris* and mature *Stephanurus.* Only the hydrochloride form is approved for use in swine and is administered in the feed or water at 8 mg/kg b.wt. Powdered form is highly soluble in water and is rapidly absorbed from the GI tract, with 40% excreted in urine in 12 hours and 41% in the faeces over 8 days. It should not be administered within 72 hours of slaughter.

Benzimidazole Carbamates- There are several efficacious compounds among the benzimidazole carbamates. The progenitor of this class of anthelmintics is thiabendazole (TBZ). TBZ has a more than 95% efficacy against *Strongyloides* and *Oesophagostomum* but much less effective against ascarids and whipworms. Mebendazole, cambendazole, albendazole, fenbendazole and oxfendazole are substituted benzimidazole carbamates. They are known to be effective against the major GI parasites of swine, with the latter two compounds active against kidney worms and whipworms.

Ivermectin @ 300ug/kg. B.wt. S/C is effective against GI parasites of pig.

Trichinellosis : Thiabendazole @25 mg/kg twice daily for one week or Albendazole 400 mg twice daily for 8-15 days are effective for treatment.

Fasciolopsiosis: Praziquantel @ 75mg/kg/day in three divided doses for one day is effective.

***B.coli* and Coccidiosis:** A combination of Metronidazole (@20 mg/kg. b.wt.) and Furazolidone (@10 mg/kg. b.wt.) or single Oxytetracycline @10 mg/kg. b.wt. orally consecutive for 4 days were found 100% effective for the treatment of *B. coli* infections in pigs. Amprolium (@ 45 mg/kg b.wt.) orally were found 100% effective for the treatment of *Eimeria* spp. infections in pigs (Laha *et al.,* 2015).

Sarcoptic mange: Doramectin or Ivermectin at a single dose rate of 200-300 µg/ kg body weight subcutaneously is effective for treatment of *Sarcoptes scabiei* var *suis* infestation in pigs. Das (2010b) successfully used Ivermectin subcutaneously @ 200 µg /kg body weight in treatment of *S. scabiei* var. *suis* infestation in crosbred pigs. Ivermectin @ 300 µg /kg body weight was used for treatment of *S. scabiei* var. *suis* in pigs with a repeated treatment after two weeks and the medicine was found to have 90% efficacy within two weeks.In a comparative study of three medicines i.e., Doramectin (1%) @ 300 µg /kg body weight single intramuscular injection, Diazonin liquid (20%) 3 ml in one litre water dipping for 3 occasions at weekly intervals and deltamethrin 4 ml in one litre water dipping for 3 occasions at weekly intervals found 100% efficacy of doramectin, 86.67% efficacy of diazinon and 76.67% efficacy of deltamethrin in treatment of natural *S. scabiei* infestation in pigs (Baishya *et al*., 2003).Treatment of affected pigs along with monitoring of infestation is very much needed for the control of *S. scabiei* var. *suis* infestation in pigs. Repeated treatment is essential, as most of the acaridecides are not able to destroy the eggs. So, it is necessary to repeat the treatment after 14 days of first treatment, as per life cycle of the parasite..Ivermectin @ 300µg/kg b.wt subcutaneously found to be effective for the treatment of *S. scabiei* var. *suis*infestations in pigs of Meghalaya (Laha *et al.*, 2014).

Control of parasitic infections /infestations in pig

- Treatment of infected pigs with proper chemotherapeutic agents.
- Parasite control could be done by good sanitation.
- Pig shed and premises should ne clean and movement of persons should be minimized.
- Good nutrition to the pig's is essential.
- Avoidance of eating raw vegetable
- Sterilization of night-soil before its use as a fertilizer and
- Destruction of molluscan hosts are some of the preventive measures against trematode infections in man.

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One Health Program: Its Implications and Opportunities

I Shakuntala* , S. Das, A. Karam, R.K. Sanjukta, S. Ghatak, K. Puro & A. Sen

Division of Animal Health, ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya
**Email: ishakuntala92@gmail.com*

One Health is a collaborative, international, cross-sectoral, multidisciplinary mechanism to address threats and reduce risks of detrimental infectious diseases at the animal-human-ecosystem interface (1). It is for the integration of professionals with expertise in biosecurity,law enforcement and intelligence to join the veterinary,agricultural,environment and human health experts essential to One Health. The connectedness of humans,animals, plants and the environment was highlighted at the 2014 launch of the Global Health Security Agenda (GHSA) the 5 year commitment by the White House,partner nations and international organizations to significantly accelerate activities to address biological threats. Many emerging health issues are linked to increasing contact between humans and animals, intensification and integration of food production, and the expansion of international travel. Approximately 75% of recently emerging infectious diseases affecting humans are diseases of animal origin; approximately 60% of all human pathogens are zoonotic (2). Besides these emerging zoonotic diseases, food-borne diseases and other diseases associated with agriculture have great impact on the health and livelihoods of people in different parts of the world. South Asia, and in particular India, face a high challenge of agriculture associated diseases (AAD) owing to the huge number of agriculture-dependent people, along with a large livestock population (3). Intense interactions between humans and animals, fragile food safety standards and rapid intensification of agriculture across the country, further exacerbate the issue. India is a hotspot of several neglected zoonoses like zoonotic tuberculosis and brucellosis, besides various food-borne diseases (4).

The problem of AADs and emerging zoonoses should be addressed by specific preventive interventions, in particular, by an early and accurate detection of new outbreaks of epidemic diseases, including emerging zoonoses. The ability to understand the underlying causes of the emergence of diseases and the ecology of the agents and their hosts is urgently needed. Fulfilling these needs is the only way to support an effective prevention or a rapid containment of possible emerging events. The only promising approach to adequately tackle the problem is the creation of adequate systems for early detection warnings, to interpret them and to prepare adequate control measures. Since health risks in agriculture and animal breeding affects animals, workers and consumers, and prevention involves several different disciplines, it is evident that a holistic approach is needed, in which all the factors of prevention in agriculture are involved. In this light, the concept defined as the "One Medicine" by Schwabe has seen an unprecedented revival in the last decade and has evolved towards "One Health" conceptual thinking, emphasizing epidemiology and public health. Food and Agricultural organization (FAO) of the United Nations is one of the agricultural organizations that embrace one health across its various areas of expertise:

- Managing animal health,natural resources, fisheries and forestry;
- Promoting access of safe,nourishing food
- Adapting to climate change and mitigating its effect
- Formulating policies of sustainable agriculture production and
- Advocating for gender equality

FAO’s priorities in one health are

- Leverage the lessons learned in combating H5N1 highly pathogenic avian influenza virus to tackle a host of animal diseases that threatens human health and livelihood at the disease source
- Strengthen surveillance system at the regional, national and local levels to prevent and detect disease emergence
- Understanding disease risk factors, including the socioeconomic context, to prevent and manage disease outbreak
- Develop capacities at regional, national and local levels and
- Reinforce safe animal production practices and veterinary infrastructure in the long term to defend against high impact diseases (5).

FAO is taking a lead role in One Health through the organization international status and neutrality, its expertise in hundreds of disciplines, its vast network and ability to developed and implement high level policies as well as village level strategies where communication outreach and involvement are most needed.

Highlighting the scope of improvement of existing strategies to counter problems of AADs, greater thrust must be laid on the 'what to' and 'how to' of One Health operationalization in the context of India. The One Health movement is endorsed by World Health Organization (WHO), the World Animal Health Organizations (OIE) and the Food and Agriculture Organization of the United Nations (FAO). In India, the One Health approach is now coming centre stage with efforts of senior leadership from Ministries of Health and Agriculture. In moving forward, the guidance of senior leaders will be needed to chalk out concrete plans to further operationalize it. One Health case studies from across the region would help identify knowledge and consolidate these experiences as one progress towards One Health.

One health security in practice

On January 31, 2014, a One Health Security workshop that are directly related to the Global Health Security Agenda was held in US to discuss recent examples of projects that successfully combined the One Health concept and security, as well as gaps in the knowledge and preparedness in One Health Security. This workshop planned to enhance awareness, preparedness, and training in response to a range of diseases including foot-and-mouth disease, botulism, and anthrax.

Anibiothreat

Another example of One Health Security presented at the January workshop was the 3-year AniBioThreat project. AniBioThreat, grounded in science and practical experience, aimed to improve the European Union's (EU) capacity to counter deliberate biological threats to agriculture by raising awareness and implementing prevention and response policies and practices. The €7 million pilot project was initiated in 2010 in response to a 2009 European Union Chemical, Biological, Radiological and Nuclear action plan. In addition to the range of countries that participated in the AniBioThreat project, there was great diversity of expert participation in the fields of veterinary medicine, security, forensics, animal and public health, food safety, and academia ,superintendents, sergeants and police officers, fingerprint experts, lawyers, communicators, DNA specialists, veterinarians, medical doctors, bacteriologists, virologists, molecular biologists, agronomists, pharmacists, and modelers. In total, a staff of 170 people contributed to AniBioThreat from the law enforcement and animal and public health communities, aiming to bridge gaps in multisectoral capability.

The results of the AniBioThreat project were published in a supplement to the journal *Biosecurity and Bioterrorism* in September 2013. The special issue contains 29 articles about bioterrorism threats to animals, feed, and food and the AniBioThreat experience.

Next steps for one health security

The One Health Security workshop highlighted some additional areas where attention is needed to counter emerging threats, such as feed and food-chain resilience and emerging diseases in wildlife. There is also a great need to assess how surveillance is occurring in wildlife and whether there are appropriate response policies in place to address wildlife health. Multidisciplinary approaches are needed at the local, national, and global levels to prevent and mitigate crises at the interfaces between humans, animals, and the environment (7,8).To ensure sustainability, the One Health Security approach to wildlife disease should be based, to the maximum extent possible, in already existing structures to conserve financial resources and avoid duplication of effort (9).

Even though the connectedness of humans with their environment is now generally acknowledged, the veterinary, human, and environmental health disciplines have in large part remained separate in their work and professional training. The past decade has seen great strides in changing this, including integrated surveillance initiatives, new education and training programs focused on One Healthand research to study how diseases in animals become threats to human health and how changes in the environment affect animal, human, and plant health.

The importance of a global "one health" strategy

One Health has experienced a renaissance during the past decade, fueled in part by zoonotic diseases that have the potential to become pandemics, such as HPAI H5N1, better known as bird flu, and SARS (Severe Acute Respiratory Syndrome), as well as increasing antimicrobial resistance. This has fostered projects like the U.S. Department of Health and Human Services Global One Health initiative. Climate change is considered perhaps the biggest global health threat of the 21st century, which makes a Global One Health strategy highly relevant. Animal agriculture is considered the biggest contributor to human-caused greenhouse gas emission according to the World Watch Institute and the Food and Agriculture Organization of the United Nations. Global health policies responding to climate change, land and soil degradation, biodiversity loss, and more will thus need to consider the impact of the world's livestock sector on human health.

The demarcation of one health

According to the symbolic One Health umbrella, One Health is a wide encompassing field where several disciplines could contribute. Some authors consider the terms 'One Medicine', 'One Health' and 'One World, One Health, One Medicine' to be entirely synonymous. They argue for a 'new fusion of veterinary, human and evolutionary medicine'. Furthermore, they claim: 'We can treat the shared diseases of all animals, including humans, by taking a multispecies – that is, zoobiquitous – approach in our daily practices'.

The concept of health

The concept of health could be defined on at least three different levels: the individual level, the group or population level, or the ecosystem level. There is an ongoing discussion both in animal ethics and in philosophy of medicine on how to look at animals. A similar discussion has been present in the conflict between animal ethics and environmental ethics when it comes to ascribing values. Animal ethicists claim that inherent value only can be ascribed to individuals (humans and some animals) but not to ecosystems. This is a central distinction between the now common terms biocentrism and ecocentrism.

According to Jakobsson (10), ecosystem health is a combined concept of ecosystem and health.' 'Ecosystem health is a comprehensive and integrated approach, which reflects the health of the living and non-living components of the land and marine world'. Jakobsson recognizes that this way of looking at health is far wider than the traditional one, and it shows links between human activity, ecological change, and health. 'Health ultimately depends upon ecosystem services i.e. availability of fresh water, food, fuel, pollination etc.' Not at all mentioned above, but nevertheless important, is plant health, which could be defined both at an individual and at population level (11). Plant health, or more specifically the fact that contaminated plants can act as vectors for diseases that affect humans, has been identified as important within One Health (12). This analysis gives us at hand that only health at the individual level is a true concept of health, and that health at the other levels are more a tool for the surveillance of processes or states among aggregated individuals. Furthermore, a One Health approach may create a scientific environment where not only laboratory equipment or office space is shared by, for example, physicians, veterinarians, and microbiologists but where access to samples is shared more generously within the scientific community. In this way, biological samples (be it tissue, blood, fecal samples, effluent water, or anything else possibly relevant), which can be quite difficult, expensive, or ethically complicated to collect, can be used by several different research groups who may be interested in the same – or different – pathogens or toxins, but from different angles.

Practical consequences for education

The One Health approach can also be applied in a teaching context. Initially, the focus of the One Health discussion appears to have been mainly on food-producing animals, but there is now an increasing interest in illuminating the importance of zoonoses also from a pet ownership perspective, where it is crucial that veterinarians, physicians, and other health care professionals recognize each other's expertise, a view that is reflected also in higher education.

One health economics for healthy people, agriculture and environment

The One Health approach can enhance understanding amongst sectors, identify risk mitigation options, and provide a more complete picture of how human health is linked to other species and the environment. A One Health approach is also good for the economy. Economic losses associated with zoonotic disease are enormous. The total direct costs of H5N1 'bird flu' outbreaks have exceeded US$20 billion since 2003. SARS in East Asia and Canada led to losses estimated at US$41.5 billion. And current estimates suggest that antimicrobial resistance (AMR) may reduce world GDP by upwards of 3.5% annually by 2050. Best estimates indicate that US$ 3 billion per year is required to build and operate One Health systems for effective disease control in developing countries. This would yield as much as $37bn in savings from reduced epidemics and pandemics – a net win of $34bn annually

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Natural Suppression of an Outbreak of Armyworm, *Mythimna separata* (Walker) in jhum rice of West Siang district, Arunachal Pradesh

Anup Chandra[*1], Homeswar Kalita[1] and Debjani Dey[2]

[1]*ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar 791 101*
[2]*Division of Entomology, Indian Agricultural Research Institute, New Delhi 110 012*
**E mail: anup.ento@gmail.com; anup.chandra@icar.gov.in*

Rice is the most important food crop of Arunachal Pradesh and Jhum rice constitutes a major traditional cultivation system in Arunachal Pradesh. Infestation of armyworm, *Mythimna separata* (Walker) occurs occasionally but heavily in the form of outbreaks. An outbreak was reported from several places *viz. Sago, Ngomdir, Doje Jelly, Doje-Jeku, Bagra,* and *Angu* villages of West Siang district of Arunachal Pradesh in the first week of July 2017. A study was conducted to record the level of infestation of *M. separata* in Jhum rice along with their natural enemies, if any. Surveys at intervals of 10 days were done to record the infestation in the field and also parasitisation, if any, in the laboratory. Observations were recorded on the number of larvae per plant and number of plants infested. Large number of larvae were collected, brought to the laboratory and reared for recording the presence of natural enemies, if any. The collected larvae were kept singly in glass tubes and reared on their natural diet for emergence of natural enemies.

On 1st July 2017, the level of infestation was recorded as 89.67±0.03 per cent with 6.37±0.61 larvae per plant. After 10 days, the infestation reduced to 78.7±0.03 per cent with 5.34±0.23 larvae per plant. Further, the infestation of armyworm drastically dropped down to 14.7±0.05 per cent with 0.17±0.06 larvae per plant on 20th July and only to 6.3±0.025 per cent with 0.07±0.03 larvae per plant on 30th July. It would be worthwhile to also mention here that large numbers of cocoon clusters were also observed on the rice plants in early July. Braconid, *Cotesia ruficrus* emerged in large numbers from the cocoons. Number of clusters of cocoons per 100 plants was observed as 18.67±10.60 on 1st July, 31.33±11.59 on 10th July, 7.33±4.04 on 20th July and 6.67±1.53 on 30th July. There were 8 to 25 cocoons observed in one cluster whereas number of cluster varied from 1 to 4 on a single plant. However, Dipteran parasitoids emerged from the larvae of *M. separata* reared in the laboratory. The dipteran maggots which emerged from the larvae of *M. separata* in the laboratory were dirty white coloured. The maggots were 10.27±1.87 mm in length and took 3.33±2.97 days to pupate after emergence from the host larvae. Initially, the pupae were light brown coloured which later turned to dark-brown. The dark-brown coloured pupa measured 6.13±0.74 mm and 3.02±0.13 mm in length and breadth, respectively whereas the pupal period was recorded as 10.2±1.42 days. The parasitisation per cent of this dipteran recorded from the larvae collected from the field on 1st July was 11.48±2.80 which increased to 72.20±7.09 per cent by the 10th of July. The drastic reduction in the level of infestation of armyworm may be attributed to the parasitisation of *C. ruficrus* initially and later by the yet to be identified dipteran parasitoid. Both these parasitoids might have considerable potential in managing the outbreak and bringing down the infestation of armyworm. Taxonomic identification, mass multiplication in laboratory and practical utilization of these parasitoids for the purpose of biological control of *M. separata* are the prospects ahead.

Keywords: *Armyworm, Mythimna separata, Outbreak, Natural enemies, Cotesia ruficrus*

Estimations of Serum Minerals and Glucose Following Subcutaneous Melatonin Treatment for Restoration of Ovarian Cyclicity in Summer Anestrus Buffaloes (*Bubalisbubalis*)

Ashok Kumar*, S Mehrotra, G Singh, Amit Khati, G Kadirvel, A Chopra, A S Mahla and AK Patel

ICAR CSWRI ARC, Bikaner

Email: drashokkumar39@gmail.com

The study was designed to uncover the effect of melatonin on serum calcium, phosphorus and glucose concentration in summer anestrus buffalo. The investigation was conducted on 28 healthy postpartum Murrah buffalo cows of age 5.11± 0.62 years and body weight 539± 17.48kg maintained under isomanagerial conditions with intensive system at the Cattle and Buffalo Farm, IVRI, Izatnagar. Buffaloes diagnosed as summer anestrus (n = 28) on basis of absence of overt signs of estrus 3 months postpartum, concurrent rectal examination and radioimmunoassay for serum progesterone at 10 days interval, were grouped as untreated (Group I, sterilized corn oil, n = 8) and treated (Group II, single S/C injection of MLT @18 mg/ 50 kg bwt in sterilized corn oil, n = 20). Estrus detection was carried out twice daily using teaser bull parading along with observation of behavioural estrus signs till days 28 post-treatment. Blood samples were collected at 4-day intervals starting from days 8 pretreatment to days 28 post-treatment and for the entire cycle length in responded animals at 4 days interval till day 24 post-estrus. Serum was separated by centrifugation at 187 X g for 10 min and stored at 20^{o} C until analysis. Serum calcium, phosphorus and glucose were estimated by Span diagnostic kits (Surat, India). Statistical analysis was done using repeated measures ANOVA by PROC Mixed of SAS 9.2. Serum Ca, P and glucose concentrations in MLT treated and control buffaloes did not differ significantly within and between both groups. Serum Ca, P and glucose concentrations did not alter significantly between days of MLT induced estrous cycle, although it was non significantly higher on day of estrus. However, the group and period effect as well as interaction effect of group and period in serum calcium and phosphorous were not significant. Whereas, the group and period effect was significant but interaction effect of group and period were not significant in serum glucose concentration. Authors have got encouraging finding using S/C MLT with estrus induction rate of 90% and overall conception rate of 32.4% in summer anestrus buffaloes. Therefore it can be concluded that MLT supplementation restored cyclicity resulting in improvement in conception rate without altering serum calcium, phosphorous and glucose concentration in summer anestrus buffaloes.

Alternate Plant Protection Technologies for the Management of Weevil Pests of Banana

Gavas Ragesh*, Lekha M., Ajith Kumar K. and Pushpalatha P.B.

Banana Research Station, Kerala Agricultural University, Kannara, Thrissur-680 652, Kerala
**Email: gavas.ragesh@kau.in*

Banana and plantains are considered to be the pristine sources of food which is rich in carbohydrates, minerals and vitamins. Though India is the largest producer of banana in the world, production of banana and plantain in India is hindered by several biotic factors especially pests. Banana stem weevil, *Odoiporus longicollis* Oliver and banana rhizome weevil, *Cosmopolites sordidus* Germar are the most important pests of banana causing an economic loss of 10-30% or death of the plants in severe cases. Multi location trails were conducted under RKVY project from 2013-2017, for developing alternate pest management technologies with higher environment safety, target specificity and least pesticide residues in the products. For the management of pseudostem weevil (*Odoiporus longicollis*) infestation in banana, application of Fipronil 5% SC at 0.015% (3 ml/l) or Carbosulfan

25EC at 0.038% (1.5 ml/l) at 5, 6 and 7 months after planting (MAP) and for organic management spraying of Entomopathogenic Fungus, *Beauvaria bassiana* @ 20 g/l at 5, 6 and 7 months after planting were effective. For the management of rhizome weevil of banana, application of Thiamethoxam 25 WG (0.2g/l or 1g/5l) or Fipronil (0.3 G @ 10 g formulation/ plant) thrice at planting, 2 and 5 MAP or sucker treatment with *Pseudomonas fluorescens* @ 20 g/l+ application of Entomopathogenic Nematode, *Heterorhabditis bacteriophora* thrice @ 4 infected wax moth larvae/plant, at planting, followed by 2 and 5 months after planting were effective for the biological control of rhizome weevil of banana. The above management options resulted in least infestation and an increased yield of 10-30%, and a monetary benefit of 1.25 to 1.75 lakhs/ha. Due to their target specific mode of action with pesticide residues below detectable levels, these plant protection chemicals are viable components in Integrated Pest Management (IPM).

Keywords: *Banana, Weevil Pests, Alternate Technologies, IPM*

Entomopathogenic Nematodes (EPNs): A Novel Technology for the Management of Weevil Pests of Banana

Gavas Ragesh*, Ajith Kumar K.[1] and Pushpalatha P.B.

Banana Research Station, Kerala Agricultural University, Kannara, Thrissur-680 652, Kerala
[1]College of Horticulture, Kerala Agricultural University, Thrissur- 680 656, Kerala
**Email: gavas.ragesh@kau.in*

Entomopathogenic Nematodes (EPNs) are beneficial nematodes that have the ability to parasitize and kill insects. These are microscopic, non-segmented, elongated round worms that are colourless and lack appendages. Two genera of EPN *viz.,Steinernema* and *Heterorhabditis* have proven track record as excellent biocontrol agents against insect pests belonging to orders *viz.,* Coleoptera, Lepidoptera, Hemiptera, Orthoptera etc. Banana stem weevil, *Odoiporus longicollis* Oliver and banana rhizome weevil, *Cosmopolites sordidus* Germar are the most important pests of banana causing an economic loss of 10-30% or death of the plants in severe cases. Biological control of banana stem weevil can be successfully achieved by leaf axil application of EPN infected Galleria cadavers and use of stem trap swabbed with *Heterorhabditis* sp. @ $1x10^6$ IJs/ml at 5th, 6th and 7th month after planting as a prophylactic control measure. If holes along with frass material or jelly like exudation are observed on pseudostem, inject 20 ml of active infective juveniles (IJs) @1000 IJs/ml into the holes as a curative control measure. For the management of banana rhizome weevil, sucker treatment with *Pseudomonas fluorescens* @20 g/l+ soil placement of cadaver infected with EPN, *Heterorhabditis bacteriophora* @ 4 infected wax moth larvae/plant at planting, followed by two applications at 2nd and 5th months after planting is effective. The above prophylactic and curative management options lead to an increased yield of 10-30% and a monetary benefit of 0.85 to 1.25 lakhs/ha. Easiness in mass production and application coupled with high survival rate and compatibility with most insecticides made EPNs, a viable component in Integrated Pest Management (IPM).

Keywords: *Banana, Weevil Pests, EPN, IPM*

Seroprevalance of Bluetongue Virus Antibodies in Goats of Meghalaya

Amarjit Karam, Koushik Kakoty, R K Sanjukta, Samir Das, K Puro, S Ghatak, Arnab Sen and *I. Shakuntala

ICAR Research Complex for NEH Region Umiam, Meghalaya
**Email: ishakuntala92@gmail.com*

Bluetongue (BT) disease is an economically important, non-contagious, insect-borne, viral disease of ruminants in the semi-tropic and tropic region worldwide. In the Northeastern state of Assam the prevalence of anti-BT antibodies in different agro climatic zones ranged between 31-50%. The present study was conducted to ascertain the seroprevalence of bluetongue in goats of Meghalaya, India. A total of 252 serum samples were collected during March 2015 to April 2017 from caprine belonging 5 districts viz. West Garo Hills (n=73), Ri-Bhoi (n=132), West Khasi Hills (n=14), Jaintia Hills (n=4) and East Khasi Hills (n=29) of Meghalaya. This serum samples were subjected to AB ELISA test for the detection of anti-bluetongue antibodies. This is the first report of bluetongue antibody detected from goats of Meghalaya, however clinical report on bluetongue in small and large ruminants has not been detected so far. Overall, out of a total of 252 caprine serum samples screened for BTV anitibodies by AB ELISA kit, 65 animals (25.8%) were found positive for BTV antibodies. The seroprevalence in these 5 districts were 41.09 % (30/73) in West Garo Hills; 24.2 % (32/132) in Ri-Bhoi, 7.1% (1/14) in West Khasi hills and only two samples out of four screened were positive in Jaintia Hills. None of the samples were positive in East Khasi Hills. The present seroprevalence status of bluetongue indicates presence of sub-clinical infection for the first time in the state of Meghalaya. In the entire Northeastern India, bluetongue was never detected earlier, off late since 2013 the incidence is reported (Assam). Again, in Meghalaya seropositivity of bluetongue might be attributed to the import of goats from the prevalent zone, thus it calls for a strict quarantine measures in animal trading.

Detection of Bovine Brucellosis by Serological and PCR Techniques in North Eastern Hill States of India

R.K. Sanjukta, I Shakuntala*, S. Ghatak, K. Puro, S. Das, A. Karam, K. Kakoty, A. Dutta & A. Sen

ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya
Email: ishakuntala92@gmail.com

Brucellosis is a zoonotic, chronic and infectious disease, which is caused by the intracellular pathogens of the genus *Brucella.* Serological tests are crucial for laboratory diagnosis of brucellosis since most of the control and eradication programs rely on these methods. Inactivated whole bacteria or purified fractions are used as antigens for detecting antibodies generated by the host during the infection. Rose Bengal Plate Test (RBPT) can be classified as a screening test, whereas Enzyme Linked Immunosorbant Assay (ELISA), as a complementary or confirmatory test. Polymerase Chain Reaction (PCR) technique, using primers B4 and B5 are used for detection of *Brucella* genus which encodes a protein of *Brucella abortus* 31 kDa, BCSP31. A study on brucellosis in North-eastern hill states of India was carried out from October 2012 to July 2017, employing the techniques of ELISA (IDEXX Brucellosis Serum X2 kit, Netherlands), RBPT (Pourquier Rose Bengal Antigen, IDEXX Netherlands) and PCR. The objective of this study was to detect and analyze the presence of bovine brucellosis based on serological and PCR techniques. A total of 832 bovine serum samples were collected and screened using ELISA and RBPT test. ELISA positive samples were screened for detection of BCSP31 gene by PCR. ELISA and RBPT revealed the presence of Brucella agglutinins in 14.79% (123/832) and 10.94% (91/832) serum samples respectively. It was interesting to note that all the samples found positive by RBPT were also positive by ELISA. Besides, 32 more samples were exclusively positive by ELISA. Employing PCR assays, 72.3 % (89/123) samples were detected to be BCSP31 gene positive. All of these 89 samples found positive by PCR were also ELISA positive and 80 were RBPT positive. Again, 9 samples were detected to be ELISA and PCR positive but RBPT negative. Hence, ELISA detected a higher number of bovine brucellosis as compared to RBPT and PCR techniques. Thus our results also suggest that ELISA method could be used as a complementary test or confirmatory for detection of brucellosis in live cattle with lowest risk of infection for laboratory workers.

Host Plant Resistance against *Rhizoctonia solani* AG 1-IB Causing Foliar Blight of Soybean in Meghalaya

R. Laloo[1], P. Baiswar[1*], D. Majumder[2] and DM Firake[1]

[1]*ICAR Research Complex for NEH Region, Umiam 793 103, Meghalaya, India*
[2]*College of Post Graduate Studies, CAU, Umiam 793 103, Meghalaya, India*
**Email: pbaiswar@yahoo.com*

The present investigation was carried out to determine the host plant resistance against *Rhizoctonia solani* causing foliar blight of soybean in Meghalaya. Twelve isolates were used for molecular characterization using specific primers to determine anastomosis groups and sub-groups. The isolates RL1, Rim_1, RL2, RL4, RL5, RL6, RL7, RL8, RLR, RL9 and RL10 belong to AG 1-IB. Only one isolate RL3 (product size ~ 265 bp) belonged to AG 1-IA. In Advanced varietal trial (AVT) 1, varieties/lines KDS 780 and DSb 28-3 had low natural incidence (2.5 & 7.5%, respectively) and low disease severity (25 & 23.3%, respectively) while varieties/lines JS 20-98 and JS 97-52 had high natural incidence (35 & 52.5%, respectively) and high disease severity (62.7 & 80.9%, respectively). In AVT 2, varieties/lines SL 955 and SL 983 had low natural incidence (2.5 & 5%, respectively) and low disease severity (5 &15%, respectively) while varieties/lines Himso 1685 and JS 97-52 had high natural incidence (35 & 47.5%, respectively) and high disease severity (63.6 & 65.1%, respectively). Twenty varieties/lines from AVT 1 and twelve varieties/lines from AVT 2 were used for in vitro screening against *R. solani*. In AVT 1 (leaves) varieties/lines JS 20-96 and DSb 28-3 were less susceptible (Area under disease progress curve AUDPC = 53.6 for both). In AVT 2 (leaves) varieties/lines DSb 25 and VLS 86 were less susceptible (AUDPC = 37.0 & 49.6, respectively). In AVT 2 (pods) varieties/lines VLS 86 and DSb 23-2 were less susceptible (AUDPC = 119.3 & 101.1, respectively).

Keywords: *Foliar blight, Glycine max, AG 1-IB, Rhizoctonia solani*

Acaricidal Efficacy of Certain Herbal and Chemical Ectoparasiticides against *Rhipicephalus microplus* Infestation in Mithun (*Bos frontalis*)

P.R Dutta, J.K. Chamuah, D. Borkotoky, R. Dowerah, M.H Khan, and A. Mitra

ICAR-NRC on Mithun, Jharnapani, Nagaland-797106
**College of Veterinary Science, Khanapara, Ghy-22*

Email: drjayantavet@gmail.com

Ticks are important ectoparasites which results in economic loss in livestock industry by causing anaemia, tick injury, entomophobia, tick paralysis besides transmitting pathogenic microorganisms to the host animals**.** Therefore, the present study was taken to compare the efficacy of some herbal extracts i.e. oil of Lemon grass *(Cymbopogon citratus)* and leachia grass and three synthetic acaricides viz. Deltrin (deltamethrin emulsifiable concentrate-12.5% W/V, Arians Biopharma), Nayflee (Fipronil 0.25% W/V, Intas Pharmaceutical Ltd., Ahmedabad), Extick (Amritraz dip concentrate liquid 12.5% W/V Vet Mankind, New Delhi), and against the *R. microplus* tick infestation in mithun. Among the chemical drugs, Nayflee showed cent percent efficacy followed by Extick (98.38%) and Deltrin (93.28%), respectively. In case of the herbal extracts, lemon grass oil showed an efficacy of 98% against *R. microplus*. However, a less efficacy leachia oil (35.08%) was recorded. From the present study, it is concluded that lemon grass oil can be recommended for periodic used as an acaricidal drug against nymphal stages of tick infestation considering its herbal nature and safety point of view.

Diagnosis of Cryptosporidiosis in Pigs

M. Das[1*], R. Laha[1], A. Kumar[2], G. Kharguria[2] and A. Sen[1]

[1]*Division of Animal Health, ICAR Research Complex for NEH Region, Umiam, Meghalaya*
[2]*Division of Livestock Production, ICAR Research Complex for NEH Region, Umiam, Meghalaya*
[*]*Email: meenad3@gmail.com*

Cryptosporidiosis is a protozoan disease caused by obligate intestinal parasite belonging to the genus *Cryptosporidium* that infects more than 150 hosts including human beings. It causes severe diarrhea, anorexia and weight loss, especially in neonatal and immunocompromised animals. It can parasitize a wide range of animals including humans and have zoonotic significance. It is a unicellular protozoon, parasitizes the microvillus border of the gastrointestinal epithelium. This monoxenous parasite completes its entire life cycle within a single host. The common feature in this species is the presence of four naked sporozoites, which are contained within a thick walled oocyst without sporocysts. The sporulated oocyst of *Cryptosporidium* sp. can be transmitted from an infected host to a susceptible host by the fecal-oral route. Oocyst of *Cryptosporidium* sp. is not detected by normal fecal examination techniques. The present study was designed to compare different diagnostic methods for diagnosis of Cryptosporidiosis in pigs. A total of 1068 numbers of fecal samples of pigs were collected randomly from different regions of Meghalaya and examined by Sheather's sugar flotation, modified Ziehl-Neelsen, negative staining i.e. malachite green (0.2%) staining and molecular method i.e. Nested Polymerase Chain Reaction (PCR) for detection of *Cryptosporidium* oocysts. Overall 28 (6.71%) samples were found positive for Cryptosporidiosis. Diagnostic sensitivity for detection of *Cryptosporidium* sp. in fecal samples of pigs varies with different techniques. Malachite green stain, Sheather's sugar solution, modified Ziehl Neelsen stain and Nested PCR detected *Cryptosporidium* sp. with 100%, 100%, 92.85% and 96.42% sensitivity, respectively.

Keywords: *Diagnosis, Cryptosporidiosis, Pigs*

Coccidiosis in Pigs of Hilly region of Meghalaya

M. Das[1*], R. Laha[1], A. Kumar[2], G. Kharguria[2] and A. Sen[1]

[1]*Division of Animal Health, ICAR Research Complex for NEH Region, Umiam, Meghalaya*
[2]*Division of Livestock Production, ICAR Research Complex for NEH Region, Umiam, Meghalaya*
[*]*Email: meenad3@gmail.com*

Coccidiosis is one of the most pathogenic intestinal diseases caused by different species of Phylum-Apicomplexa. The disease is particularly a problem of confined animals kept under intensive husbandry practices. The disease is characterized by scours, dehydration, rough hair coat, reduced growth rate, weakness, weight loss, variable mortality and morbidity and is not responsive to most antibacterial therapy. To know the prevalence of coccidiosis in pigs of hilly region of Meghalaya, fecal samples were collected randomly from the pigs maintained in both organized and unorganized farms and examined for detection of coccidia oocysts by flotation techniques. Sporulation of the oocyst was done in 2.5% potassium dichromate solution for identification of the species. Oocyst count per gram (OPG) of feces was determined by the modified McMaster technique. Overall 11.7% pigs were found to be infected with coccidial infections. Age-wise, 32.8%, 42.4% and 24.8% infections were recorded in pig of <6 months, 6-12 months and >12 months, respectively. Different species of *Eimeria* were identified and species wise *E. debliecki* (42.99%) infection was highest followed by *E. suis* (27.10%), *E. porci* (15.89%), *Isospora suis* (14.4%), *E. perminuta* (10.28%), *E. spinosa* (2.80%) and *E. cerdonis* (0.93%). The oocyst per gram of feces ranges from 50-1450. In piglets of <6 months age, *E. suis* (37.93%) was highest followed by *E. debliecki* (36.96%), *E. porci* (23.53%), *E. perminuta* (18.18%) and *I. suis* (1.68%). However in pigs of 6-12 months age, *E. porci* (47.05%) was recorded highest followed by *E. suis* (44.83%), *E. debliecki* (34.78%), *E. perminuta* (18.18%), *I. suis* (2.85%), *E. spinosa* (2.80%) and *E. cerdonis* (0.93%). In adult pigs of >12 months age, *E. perminuta* (63.63%) was highest followed by *E. porci* (29.41%), *E. debliecki* (28.26%), *E. suis* (17.24%) and *I. suis*. Both *Eimeria* sp. and *Isospora* sp. are found to be responsible for coccidiosis in pigs of Meghalaya.

Keywords: *Pigs, Coccidia, Species, Meghalaya*

Pathogenicity of *Rhizoctonia solani* AG 1-IB on Common Weeds in Meghalaya

Pamala Princejayasimha[1,2], Pankaj Baiswar[1*], Rajesh Kumar[1], Dipali Majumder[2] and Sandip Patra[1]

[1]*ICAR Research Complex for NEH Region, Umiam 793 103, Meghalaya, India*
[2]*College of Post Graduate Studies, CAU, Umiam 793 103, Meghalaya, India*
**Email: pbaiswar@yahoo.com*

Rhizoctonia solani Kuhn is a soil borne fungal plant pathogen, infecting several crops. Many weeds act as collateral hosts of this pathogen and help in spreading this pathogen. Pathogenicity of *R. solani* AG 1-IB isolate was tested on 47 common weeds of Meghalaya. Incubation period on all the common weeds was 2-3 days except 6 days on *Cyperus iria* with *R. solani* AG 1-IB isolate. Minimum day for sclerotia formation was 4 days on *Crassocephalum crepidioides, Galinsoga parviflora* and *Tridax procembens*. Maximum sclerotia production (16 nos.) was observed on *Lantana camara*. The weed *Emilia sonchifolia* was most susceptible to isolate *R. solani* AG 1-IB based on area under disease progress curve criteria. Highly susceptible weeds identified in this study should be avoided for mulching purpose since this will increase the inoculum load of this pathogen.

Keywords: *Rhizoctonia solani*, *AG 1-IB, Weeds, Pathogenicity*

Gastrointestinal Parasitism in Poultry of North Eastern Region of India

R. Laha, M. Das, S. Doley, B. Sailo, Doni Jini, V. Singh, Brijesh Kumar, M.Singh, Puro, K., D. Bhattacharjee and A. Sen

ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya-793 103

Among various animal husbandry practices, poultry farming is considered as one of the least cost farming. In recent years, poultry farming has developed tremendously. But frequent outbreak of diseases is a constraint for poultry farming. Both back yard and commercial poultry farming are in practice in north eastern region of India. Among diseases, gastrointestinal (GI) parasitic infections in poultry causes heavy economic losses to the poultry industry due to weight loss, decreased feed conversion ratio, retarded growth, decreased egg production and mortality in young birds. Keeping in view of the importance of GI parasitic infections in poultry, a study on prevalence of GI parasitic infections in poultry in six states of north eastern region of India was undertaken. For this, pooled faecal samples of poultry maintained in different organized poultry farms and poultry maintained in different households in unorganized ways were collected from the states Meghalaya, Manipur, Arunachal Pradesh, Tripura, Sikkim and Nagaland. Besides, intestinal tracts of slaughtered poultry birds were collected from local butcher shop of Meghalaya and examined to detect GI parasitic infections. A total of 920 numbers of faecal samples of poultry were collected from these six states for a period of two years and examined under microscope to detect the eggs or oocysts of GI parasites. Overall 42.28% faecal samples were found positive for eggs or oocysts of different GI parasites. Statewise 40.23%, 45.56%, 54.28%, 47.05%, 42.85% and 32.65% GI parasitic infections were diagnosed in Meghalaya, Manipur, Arunachal Pradesh, Tripura, Sikkim and Nagaland, respectively. Eggs of *Ascaridia galli*, *Capillaria* spp., *Strongyloides* spp. and oocysts of different *Eimeria* spp. were detected. A total of 300 numbers of intestinal tracts were examined and out of these 20.66% intestinal tracts were found positive for parasitic infections. *Ascaridia galli, Raillietina* spp. and *Eimeria* spp. were recovered from intestinal tracts. Different species of *Eimeria, viz. E. tenella, E. acervulina* and *E. praecox were* identified by molecular technique using PCR.

Parasitic Infections in Livestock of Meghalaya and Sikkim

R. Laha, A. Sen, Brijesh Kumar[1], Ashok Kumar[2], M. Das, D. Bhattacharjee and Amarjit

ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya-793 103
[1]ICAR-NOFRI, Tadong, Gangtok, Sikkim-737 102
[2]ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya-793 103
Email: rglaha@gmail.com

Parasitic infections in livestock are responsible for considerable economic losses as a consequence of mortality in infected animals, decreased milk yield and reduced weight gain. To diagnose the parasitic infections in livestock in Meghalaya and Sikkim, faecal samples of pigs, cattle, goats , buffaloes and blood samples of cattle were collected from the state Meghalaya and faecal samples of yak and sheep were collected from the state Sikkim. A total of 113 numbers of faecal samples of pigs, 77 numbers of faecal samples of cattle, 46 numbers of faecal samples of goats, 11 numbers of faecal samples of buffaloes and 22 numbers of blood samples of cattle were collected from the state Meghalaya and a total of 270 numbers of faecal samples of yak and 106 numbers of faecal samples of sheep were collected from the state Sikkim. These faecal samples and blood samples were examined under microscope after processing by standard method to detect parasitic infections. Out of these, 64.60% pigs, 28.57% cattle, 28.26% goats, 22.64% sheep and 35.55% yaks were found infected with gastrointestinal (GI) parasites. In pigs, among GI parasites, infections with *Balantidium coli* found as predominant infections where 26.54% pigs showed the presence of cysts of *B.coli*. The eggs of *Ascaris suum* (21.23%), Strongyle spp. (20.35%) and oocysts of Coccidia (*Eimeria* spp.) (12.38%) were detected. The ocysts of *Eimeria* spp. (12.93%), eggs of Strongyle spp. (11.68%) and Amphistome (3.89%) were detected in faecal samples of cattle. Infections with Strongyle spp. (15.21%) found as predominant infections in goats followed by *Eimeria* spp. (10.86%), *Moniezia* spp. (8.69%), *Strongyloides* spp. (6.52%) and *Trichuris* spp. (4.34%). The Oocysts of *Eimeria* spp. (16.98%), eggs of Strongyle spp. (4.71%) and *Trichuris* spp. (0.94%%) were detected in faecal samples of sheep. Different GI parasites, like ocysts of *Eimeria* spp. (19.25%), eggs of *Neoascaris* spp. (11.92%), Strongyle spp. (5.92%), *Trichuris* spp. (1.85%) and *Strongyloides* spp. (0.74%) were detected in faecal samples of yaks. Faecal samples of a buffalo calf which was suffering from diarrhea and ematiation, was diagnosed as infected with *Eimeria* spp. Blood samples of a cattle of Meghalaya which was suffering from high rise of temperature and coffee coloured urine was found positive for *Babesia bigemina* infection after examination of Giemsa stained blood smears. It can be concluded that parasitic infections are very much prevalent in these two states and in some animals it is in moderate form and in some animals like pigs, the percentage of infection is high. Mostly these parasitic infections remained in subclical forms but sometimes clinical forms of parasitic infections also noticed. Monitoring of parasitic infections and its control in these states are essential to increase the production of livestock.

Development and Evaluation of a Multiplex PCR Assay for Rapid Detection of Methicillin-Resistant *S. aureus* (MRSA) from Pigs

S. Rajkhowa*, D. K. Sarma, S. R. Pegu, M. Choudhury, P. Thakuria and K. Saikia

ICAR-National Research Centre on Pig, Rani, Guwahati, Assam
** Email: swaraj.rajkhowa@gmail.com*

Staphylococcus aureus is a common bacterium found on the skin and nasal passages of healthy people. It is commonly associated with skin and soft tissue infections and sometimes it causes pneumonia, bacteremia, meningitis, sepsis and pericarditis. *S. aureus* bacteria harboring the *mecA* gene are resistant to methicillin and other β-lactam antimicrobials and are referred to as methicillin-resistant *S. aureus* (MRSA). MRSA has become a pathogen of increasing importance in hospitals (healthcare-associated MRSA), the community (community associated MRSA) and livestock operations (livestock associated MRSA). To date, livestock-associated MRSA (LA-MRSA) has been found worldwide, particularly among people who are involved with livestock farming. Livestock, especially pigs can serve as reservoirs for LA-MRSA. A novel multiplex PCR assay was developed and evaluated for rapid detection of MRSA from pigs. The detection limit of the m-PCR assay was 10^2cfu/mL for the simultaneous detection of all the target genes. The diagnostic sensitivity of the assay was evaluated by using 42 MRSA strains isolated from samples of pigs. The assay was highly specific for detection of target genes and can be used for routine screening of pig herd / pork for the presence of MRSA.

Non-tuberculous Mycobacteria Circulating In Human, Animal and Environment; a Look at our Northeastern Region

Esther Vise[1,2], Akshay Garg[2], Ingudam Shakuntala[1], Arnab Sen[1], Michael Mawlong[3], Sandeep Ghatak[1], Amrajit Karam[1], Rajkumari Sanjukta[1], K Puro[1], Samir Das[1, *]

[1]*ICAR Research Complex for North Eastern Hill Region, Umiam,*
[2]*School of Bio-Engineering and Bio-Sciences, LPU, Phagwara, Punjab, India*
[3]*Department of Microbiology and Mycobacteriology, Nazareth Hospital, Shillong, Meghalaya,*
[*]*Email: drsamirvph@yahoo.com*

The nontuberculous mycobacteria (NTM) are ubiquitous opportunistic pathogens with isolations from water, air, soil, vegetables, hospital equipment, amoeba, human, animal, fish etc. NTM belongs to the genus *Mycobacterium* and consists of around 180 species of which 70 are opportunistic pathogen causing infections in different host including human. In the genus *Mycobacterium*, the well known and dominant pathogens are *M.tuberculosis* responsible for human tuberculosis, *M.leprae* for leprosy in human and *M.bovis* for bovine tuberculosis. Earlier, the NTMs are usually not considered as a potential threat to human but globally, human NTM clinical cases are increasing and in developed countries they even surpassed the infections by *M.tuberculosis*. Cases of NTM are increasingly being reported during the last one decade from the country, with few reports from North East India also. Opportunistic infections by NTM frequently remain underdiagnosed or misdiagnosed as tuberculosis, mainly due to its similar clinical presentation in human as that by *M.tuberculosis* and zoonotic *M.bovis* and because of lack of access to affordable identification techniques in resource constrained set-ups. Hence, the study was targeted for assessing the presence of NTM and its transmission dynamics in man, animal and environmental sources from representative areas of North East, to assess the gravity of the situation and to understand the underlying depth of the burden of NTM in North East. Human samples were collected from probable tuberculosis patients under strict biosafety measures. Animal samples were collected by trained veterinary practitioners and environmental samples collected alongside. Samples were transported in cold chain, whenever required, and processed within 24 hours. An overall total of 555 samples were processed for mycobacterial isolation from animal (220), human (121) and environmental sources (214). Samples inoculated in egg-based Lowenstein Jensen media and Middlebrook 7H11 agar media. Slants and plates were incubated at 37°C upto 3 months with regular interval check. Primary identification was done by ZN staining followed by molecular identification.

A sum of 63 (11.35%) isolates was positive for *Mycobacterium* genus identified by genus specific *hsp65* PCR followed by speciation through sequencing. Out of the 63 isolates sequenced, 39 (7.02%) were NTM, 24 (4.32%) belonged to MTBC. It is noteworthy to mention two NTMs were isolated from human with *M.tuberculosis* here also being the dominant pathogen and a significant number of NTM isolation were from milk dominated by *M.chelonae*. The other species being isolated were *M.lentiflavum, M.peregrinum, M.fortuitum, M.immunogenum, M.saopaulense, M.goodii, M.novocastrense, M.pyrenivorans,* while 03 species could be identified as mycobacteria, their species could not be identified due to their novel nature. Timely detection, species identification or classifying at least up to the complex level is necessary for successful therapy of NTM cases. Awareness among clinicians, especially those handling tuberculosis cases is important to differentially diagnose such infections. Significant isolation of opportunistic pathogen like *M.chelonae* from a widely consumed dietary nutriment like milk is notable. Improved diagnostics, a one health approach is required in identifying the risk factors and possible transmission mechanisms for combating the public and animal health threat posed by these agents.

Bio-efficacy, Persistence and Safety Evaluation of Indoxacrb in Tomato

Sandip Patra[1] and Arunava Samanta[2]

[1]*ICAR Research Complex for NEH Region, Umiam, Meghalaya-793 103.*
[2]*Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal, India-741252.*
**Email: sandippatra47@gmail.com*

Indoxacarb, an oxadiazine group of insecticide which is highly effective, nonsystemic and synthetic organophosphate replacement insecticide registered for the use on vegetables to control lepidopteran pests. It acts by blocking the sodium channel in insect neurons and designated a ‘reduced risk’ product by Environment Protection Agency. Therefore, present experiments were conducted to study the residue dynamics of this insecticide in tomato and calculated the safety index for this insecticide in an Indian context besides bio-efficacy. The experiments were conducted at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, W. B., during *rabi* season of 2012-2014. Foliar application of indoxacarb @ 75 g a.i./ha (recommended dose) and indoxacarb @ 150 g a.i./ha (double the recommended dose) were applied twice at 15 days interval to evaluate the bio-efficacy and persistence when pest infestation was started. The larval population of *Spodoptera litura* and *Helicoverpa armigera* were recorded from randomly selected 5 tagged plants/plot for bioefficacy study. Both tomato and soil samples were collected at 0 (2hr), 1, 3,7,10 and14 days after final application of insecticide from treated and untreated control plots for estimation of residue dynamics in/on tomato and soil in the laboratory. Indoxacarb treated plots recorded 2.25 to 1.16 larvae/5plants with 66.11 to 82.46% reduction over untreated control plots (6.64larvae/5plants). No residue was detected on 10 days of application irrespective of doses. Residual half-life ($T_{1/2}$) was 1.65 and 1.70 days for single and double doses, respectively. Pre-harvest interval (PHI) of indoxacarb in tomato was calculated at 1.43 to 2.85 days based on MRL value of indoxacarb in tomato (0.50 ppm) fixed by European Union (EU).

Keywords: *Indoxacarb, Bio-efficacy, Persistence, Tomato, Soil, GC-ECD*

In vitro Evaluation of Fungicides against *Alternaria* spp. causing Core Rot of Citrus

Sandeep Raheja, Harish Siag and Anil Kumar

Punjab Agricultural University, Regional Research Station, Abohar 152116, Punjab, India
Email: harishsiag-coapp@pau.edu

Fifteen fungicides of different type were evaluated against core rot pathogen (*Alternaria* spp.) of citrus, the most important fruit crop of Fazilka district in Punjab. Culture were isolated from diseased fruits, identified by cultural characteristics and microscopic studies and mass multiplied on PDA. Each fungicide had four treatments of different concentrations such as for contact 1000, 1500, 2000 & 3000 ppm, for systemic 50, 100, 250 & 500 ppm and for combination of contact & systemic 250, 500, 1000 & 1500 ppm and replicated four times. Results revealed that three systemic fungicides viz. Tilt, Folicur & Nativo cause 100% inhibition of pathogen growth and sporulation at lowest concentration (*i.e.* 50 ppm) followed by Luna experience & Amistar top on which pathogen show a little growth. While Copper oxychloride among contact type and Avancer among combination type of fungicides show promising result for inhibition of growth and sporulation of pathogen even at the concentration of 1000 ppm. So it is concluded that the core rot disease of citrus can be controlled effectively by using above mentioned fungicides. Further studies of these fungicides as preventive and curative application are under experiment. These studies give an alternative option of application for better results and to prevent the resistance break down against the fungicides by the pathogen.

Keywords: *Fungicide, Pathogen, Concentration, Citrus, Core Rot*

Toxicity Effect of Some Insecticides on Spiders and Coccinellids in Brinjal and Cabbage Ecosystem

S. Dhamala[1], S. Patra[2], D. Thakuria[1], P. Baiswar[2], M. P. Devi[2] and K. Ningthoujam[1]

[1]*College of Post-Graduate Studies, Central Agricultural University, Umiam, Meghalaya, India.*
[2]*ICAR Research Complex for NEH Region, Umiam, Meghalaya, India.*
Email: sakil.dhamala@gmail.com

To determine the effects of insecticides on natural enemies namely spiders and coccinellids in crop ecosystems, two field experiments were conducted at Entomology Research Farm, ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya during *kharif*- 2016 on brinjal and *rabi*-2017 on cabbage. The experiments were laid out in randomized block design (RBD) with three replications for each treatment. Brinjal and cabbage seedlings (30days old) were transplanted in the plot size of 3m x 4m. Three insecticides *viz.* indoxacarb 14.5SC (75 and 150 g a.i./ha), chlorfenapyr 10SC (100 and 200 g a.i./ha) and chlorpyrifos 20EC (200 and 400 g a.i./ha) were applied with initiation of pest infestation along with control check. Spiders and coccinellids population were recorded from randomly selected 5 tagged plants/ plot before spray and subsequently 7 and 14 days after each spray for both the crops. Results revealed that there was a negative impact of chlorfenapyr and chlorpyrifos on spider population in brinjal and cabbage ecosystems. In brinjal, the lowest mean spider population was recorded in chlorpyrifos at higher doses (400 g a.i./ha) with 2.51 spiders/5plants followed by same insecticide at recommended dose (200 g a.i./ha) with 2.74 spiders/5plants and chlorfenapyr @200 ga.i./ha (2.94 spiders/5plants) and chlorfenapyr @100 g a.i./ha (5.02spiders/5plants). The highest percentage reduction of coccinellids was also found in higher dose of chlorpyrifos (78.65%) followed by chlorpyrifos at recommended dose (75.44%), higher dose of chlorfenapyr (32.74%) in brinjal. In cabbage, the similar trend of impact of insecticides on both spiders and coccinellids were observed.

Keywords: *Brinjal, Cabbage, Spiders, Coccinellids, Indoxacarb, Chlorfenapyr, Chlorpyrifos*

Evaluation of Certain Novel Insecticides against Gram Pod Borer, *Helicoverpa armigera* (Hubner) Infesting Field Pea, *Pisum sativum* (L.)

Ardhendu Chakraborty[1]*, Dipak Nath[2], Subhra Shil[2], Dipankar Dey[2] and Rahul Ghosh[2]

[1]*Palli Siksha Bhavana, Visva-Bharati University, Sriniketan, West Bengal-731236*
[2]*Krishi Vigyan Kendra-Khowai, Chebri, Tripura- 799207*
E-mail: imardhendu@gmail.com

A supervised field experiment was conducted in randomized block design with three replications of seven treatments during Rabi season 2015-16 at Krishi Vigyan Kendra, Khowai, Tripura to evaluate the effect of some novel insecticides against the *H. armigera* in field pea. Efficacy of six insecticides *viz.*, Indoxacarb 14.5 SC @ 500 ml/ha, Cypermethrin 25 EC @ 1000 ml/ha, Lambda cyhalothrin 5 EC @ 500 ml/ha, Thiodicarb 75 WP @ 625 gm/ha, Spinosad 45 SC @ 200 ml/ha and Carbosulfan 25 EC @ 1000 ml/ha tested against *H. armigera* larvae. The treatment with Indoxacarb 14.5 SC @ 500 ml/ha was found best with minimum population of *H. armigera* at first spray 1.23 (3 DAS) and 2.00 larvae/five plants (9 DAS), and the minimum larval population at second spray 1.57 (3 DAS) and 3.33 larvae/ five plants (9 DAS). The Cypermethrin 25 EC @1000 ml/ha was recorded less effective among all the treatments, though it was statistically superior to the untreated control. Highest yield was recorded in Indoxacarb 14.5 SC @ 500 ml/ha treated plots (6.5 q/ha),

followed by Spinosad 45 SC @ 200 ml/ha (6.0 q/ha). The result revealed that Indoxacarb 14.5 SC @ 500 ml/ha was found best to minimize the larval population.

Keywords: *Helicoverpa armigera, Field pea, Insecticide*

Management of Late Blight of Potato in West Siang District of Arunachal Pradesh

Kangabam Suraj Singh[1], H. Kalita* and C.S. Raghav[1]

*[1]ICAR-KVK West Siang, ICAR RC Basar and *ICAR RC for NEH Region A.P Centre, Basar-79110*
Email: ksurajsingh@gmail.com

Late blight caused by Oomycetes pathogen *Phytophthora infestans* (Mont.) de Bary is one of the devastating diseases in this region and recently it has become a serious threat to potato growers of West Siang. In Basar circle of West Siang district, sometimes crop losses due to this disease go to extent of 95-100 per cent in susceptible variety if the crop is not protected. Therefore, an experiment was conducted to evaluate the efficacy of spray schedule of fungicides Mancozeb 75% WP @ 0.2% and Cymoxanil 8% + Mancozeb 64% @ 0.2% in comparison to untreated control. Susceptible variety Kufri Jyoti was grown in KVK instructional Farm, Bam during 2015-16 and recommended package of practices was followed. It was observed from the study that spraying of one prophylactic spray of Mancozeb 75% WP @ 0.2% and more 4 spray of Cymoxanil 8% + Mancozeb 64% @ 0.2 at 7 days interval was found to be the best for the effective management of late blight (83.2 % reduction in disease incidence over control) in the winter grown crop and significantly increased the yield (21.42 t/ha) over control (9.31t/ha).

Keywords: *Kufri Jyoti, Phytophthora Infestans, Prophylactic, Late Blight*

Incidence of Methicillin-resistant *Staphylococcus aureus* (MRSA) in Animals and Humans

Dharitree Sonowal[1], Sandeep Ghatak[1]*, Acheenta Gohain Barua[2], A. Sen[1], I. Shakuntala[1], K. Puro[1], RK Sanjukta[1], RA Hazarika[2], Poznur Hussain[2], Simanjita Phukan[3], Rajeev Sharma[2], Shantanu Tamuly[2], Sarat Sonowal[2], Dyuti Purkait[1], Surmani Huidrom[1], Koushik Kakati[1]

[1]Division of Animal Health, ICAR Research Complex for NEH Region, Umiam, Meghalaya
[2]College of Veterinary Science, AAU, Khanapara, Guwahati
[3]Guwahati Medical College and Hospital, Assam
Email: ghataksnd@rediffmail.com

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a significant pathogen of animals and humans. MRSA is defined as a strain of *Staphylococcus aureus* that is resistant to a large group of β-lactams antibiotics which includes penicillins and cephalosporins. The resistance in MRSA is conferred by the presence of *mec*A gene. MRSA has become a serious nosocomial infection worldwide and due to its zoonotic potential, MRSA pose considerable threat for people in contact with the animals. This study aims to investigate the incidence of MRSA in animals and humans. A number of samples were collected from various cases of clinical and sub clinical mastitis from different farms of cattle in and around Guwahati city. Goat samples were also collected from clinical and sub clinical mastitis cases and from wound infections from Goat Research Station Byrnihat. Canine samples were collected from the outpatient department of Teaching Veterinary Clinical Complex, College of Veterinary Science Khanapara. On the other hand human samples like nasal and hand swabs were collected from the people associated with various animals and some clinical samples were also collected from the patients of Guwahati Medical College and Hospital, Assam. Samples

were processed for isolation of *Staphylococcus aureus* employing standard bacteriological procedures. Presumptive isolates of *S. aureus* were confirmed by polymerase Chain Reaction (PCR). Results indicated 14.41% (31/215), 42% (21/50), 13.54% (21/155), 5.88% (3/51) and 19.5% (46/235) incidence of *S. aureus* in cattle, goat, dog, people associated with animals and human patients from hospital respectively. Disk Diffusion Test was done with cefoxitin and methicillin antibiotics for the phenotypic detection of MRSA. MRSA were confirmed by detection of *mec*A gene through PCR. Sixteen of 215 cattle samples (7.44%), 2 of 50 goat samples (4%), 14 of 155 dog samples (9.03%), 16 0f 285 human samples were positive for MRSA. Among human samples 1 of 51(1.96%) samples collected from people associated with animals and 15 of 234 (6.41%) samples from hospitalised patients were positive for MRSA. Overall the results indicated considerable incidence of MRSA among dogs and humans. Further investigation on the potential of zoonotic transfer among various hosts is underway.

DNA Barcoding on Insect Pests of Orchids

Rumki H. Ch. Sangma, D.M. Firake and G.T. Behere

ICAR Research Complex for NEH Region, Umiam-Meghalaya-793103
Email: rumkisangma@gmail.com

DNA Barcoding was done on insect pests of orchids. Different specimens of insects like shootborer larvae (*Peridaedala* sp.), thrips, aphids, scales like biosduval scale (*Diaspis biosduvali*), ti scale (*Pinnaspi buxi*), lecanium scale, soft brown scale (*Coccus hesperidum*), two new scale species and one species of mite (*Tetranychus urticae*) were collected from infested orchid plants from NRC Orchids located at Pakyong, Sikkim and its Sub-campus at Darjeeling, West Bengal. The DNA was successfully extracted from all the specimens. PCR amplification using different universal primers targeting different regions of mitochondrial Cytochrome oxidase I gene revealed that, out of twenty samples, only six samples belonging to three different insect species were amplified. It is interesting to note that none of the primer combination worked for scale insects and mites, but at the same time all primers combinations worked for Shoot borer and amplified the targeted region of COI gene. Two or more primer combinations also worked for Thrips and Aphids. The sequenced samples were analysed using Molecular Biology Software, Staden Package. All the sequenced samples produced good quality reads and had good confidence level. After trimming the messy 5' and 3' ends, a final 704bp, 500bp, 492bp and 498bp good quality sequenced were obtained for Shootborer, Aphid sp., Thrips85 sp. and Thrips86 sp., respectively. The species identity of shoot borer, Aphid sp. and Thrips could not be established at molecular level due to the unavailability of nucleotide sequences information for the COI gene studied in the present investigation in the NCBI GenBank. The DNA barcodes for shoot borer has been submitted to NCBI vide Accession Numbers Peridaedala_sp_GB80_329415 Peridaedala KY628008, Peridaedala_sp_Samp19_1265 Peridaedala KY628009 and Peridaedala_sp_Samp22_1268 Peridaedala KY628010. Given the difficulties in identification of insect pests and natural enemies of orchid, there is an urgent need to generate a molecular data and development of taxonomic expertise in insect pests and natural enemies of orchid for better designing of management practices for insect pests of orchid.

Establishment of the Fungal Entomopathogenic Fungi *Beauveria bassiana* as an Endophyte in Tomato

Lipa Deb[1], Dipali Majumdar[1], T. Rajesh[1], R.K. Tombisana Devi[1], D.M. Firake[2] and L. Hemochandra[3]
[1]*College of Post Graduate Studies, Central Agricultural University, Umiam, Meghalaya – 793103*
Email:Lipa178deb@gmail.com

Beauveria bassiana is the most widely studied entomopathogenic fungi which have drawn attention worldwide not only as an insect-pest control but also as management of plant pathogenic fungi and bacteria along with their plant growth promotion activities. Evidence has accumulated that *B. bassiana* can endophytically colonize a wide array of plant species, both monocots and dicots. The endophytic behaviour of *B. bassiana* isolates in tomato plants were studied by performing gnobiotic assay for duration of three weeks. Plant colonization by different isolates of *B. bassiana* was determined three weeks after inoculation till optimum growth was obtained in control by re-isolating the fungus through culture based technique. All *Beauveria* isolates were able to successfully colonize tomato plants which were confirmed due to the formation of white mycelial growth emerging from the leaf discs obtained from inoculated plants plated on selective media. The highest percentage of colonisation of *Beauveria* in tomato plants were observed in BP1.3 (80.24 %) followed by BP1.1 (72.22 %), whereas, the least percentage of colonisation was observed in BP2.1 (21.67 %) and BP2.2 (35.56 %). These results indicate that this entomopathogenic fungus can be established as an endophyte in tomato following seed inoculation and foliar spray method. These findings suggest that tomato plants are conducive for endophytic fungal growth of both inoculated *B. bassiana* isolates, and could possibly lead to an innovative methodology to manage insect pests and diseases in biocontrol programs.

Keywords: *Beauveria bassiana*, Entomopathogen, Endophyte, Mycelial Growth, Biocontrol

Spinosad - A bio-pesticide for the Control of Insect Pests under Field and Stored Condition

N. J. Singh[1], R.K. Avasthe[2], Raghavendra Singh[1], P.K. Pathak[1], B. Lepcha[1], P. Phukan[1], and J. K. Singh[1]

[1]*Krishi Vigyan Kendra, Ranipool-737135, Sikkim, India.*
[2]*ICAR-National Organic Research Farming Institute, Tadong-737102, Sikkim, India,*
Email: johnson.singh1@gmail.com

In India, the crop losses have declined from 23.3% in post-green revolution era to 15.7% at present. In terms of monetary value, Indian agriculture currently suffers an annual loss of about US$ 36 billion (Dhaliwal *et al*., 2015). Many farmers use prophylactic and curative microbial insecticides to minimise damage caused by insect pests. Hence, the biopesticide strategies should be utilized in integrated pest management programs to reduce crop losses without affecting the quality of environment. Spinosad, a bacterial based bio pesticide which is highly active, by both contact and ingestion, in numerous insect species was evaluated during 2015-16 and 2016-17 at KVK Farm, East Sikkim to determine its efficacy in different insect pests under field and stored condition. The results revealed that consistent with low infestation, damage in Spinosad treated cabbage, tomato and maize significantly reduced the mean larval population of *Plutella xylostella*, *Pieris brassicae*, *Spodoptera litura* and *Mythimna separate* respectively against the farmers' practice. The biological insecticide spinosad was also evaluated in laboratory bioassays as a surface treatment for maize to control adult *Sitophilus zeamais*. Spinosad was applied @ 1 ppm to 100 g of maize and placed in a vial. When *S. zeamais* were introduced into the vials, 100% mortality was recorded. The results of this laboratory study showed the efficacy of spinosad against *S. zeamais* under stored condition.

Keyword: *Efficacy, Field and Stored, Insect Pests Condition, Spinosad*

Molecular Marker Based Detection of *Aspergillus flavus* (Link ex Fries**) in Maize Kernels and Poultry Feeds**

Shweta Singh[1,2], V. Paranidharan[2] and R. Velazhahan[2]

[1]*ICAR National Organic Farming Research Institute, Tadong, Gangtok*
[2]*Department of Plant Pathology, Centre for Plant Protection Studies,*
Tamil Nadu Agricultural University,Coimbatore- 641 003, Tamil Nadu
Email: shwetabac@gmail.com

Aflatoxins, a group of mycotoxins that are secondary metabolites mainly produced by *Aspergillus flavus*, *A. parasiticus*and*A.nomius*during infection of susceptible crops, such as maize, groundnut, cotton and chillies. These are carcinogenic, mutagenic and teratogenic thus posing adverse health effects on humans and livestock. Aflatoxin contamination is considered one of the most serious food safety issues worldwide for which regular monitoring of the levels of aflatoxins is necessary. An alternative could be detection of the aflatoxin-producing fungi in foods and feeds. PCR methodsusing markers designed from genes coding for key enzymes in aflatoxin biosynthesis have been employed for screening of food and feed commodities for the presence of *A. flavus*. *A. flavus*-specific primers based on the O-methyltransferase gene (omt-A) that is involved in the aflatoxin B1 biosynthesis, were designed and used to detect the fungus by PCR. *Omt-A* encodes for methyltransferase which converts sterigmatocystin (ST) to o-methyl-sterigmatocystin (o-ST) (Shweta *et al*., 2013). This study was undertaken to detect *Aflavus* strains in artificially inoculated maize kernels and poultry feeds collected from different parts of India.The maize kernelscollected from farmer's fieldwere surface sterilized with 0.1% $HgCl_2$ solution for 2 minutes and washed in two changes of sterile distilled water. Seeds were dipped in spore suspension of *A. flavus*($1x10^6$ spores/ml) and placed on sterile petridishes lined with wet blotters. The plates were incubated at 25°C in the dark for 3 days. The inoculated maize kernels were ground with liquid nitrogen and total DNA was extracted by using the CTAB extraction method (Doyle and Doyle, 1987). The isolated DNA was conditioned to both conventional and real time PCR using *omt*-A primers. For real time PCR, the plasmid DNA containing the 260-bp insert was diluted to obtain 10^7 to 10^{11} copies of the target DNA. These target DNA standards were amplified with *omt*-A primers in real-time PCR to enable estimation of copy numbers of the target DNA in unknown samples. A 260 bp PCR amplification product obtained in all the samples of inoculated maize kernels confirmed the presence of A. flavus in these samples. Further, to quantify the target DNA present in these samples, the positive detected samples were subjected to real time PCR. The samples that showed positive for *A. flavus*infection by conventional PCR assay also showed positive by real-time PCR. In the maize samples, Ct values ranged from 20 to 22 for the infected maize kernels. The standard curve obtained showed a linear correlation between copy number of the cloned target DNA sequence of *A. flavus* and Cycle threshold (Ct) values, with R^2 of 0.98. Such PCR-based assays for detection of *A. flavus*in food and feed industries and quarantine laboratories will prove to be beneficial in monitoring the levels of A.flavus in commodities being imported or exported.

Effect of Biocontrol Agents on Bacterial Blight, Vegetative Growth and Flowering of Anthurium cv. Tropical under Shade House Conditions in Mizoram

A. Ratankumar Singh, S.K. Dutta, T. Boopathi, S. B. Singh, Lungmuana, Saurav Saha, Vishambhar Dayal and N. Hemanta Singh

ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib-796 081, Mizoram, India
Email: ratanplantpatho@gmail.com

The present study was designed to estimate the long term effect of biocontrol agents, plant extract and bactericides on bacterial blight incidence, vegetative growth and flowering quality of *Anthurium andreanum* L. (cv. *Tropical*) under shade house conditions in Mizoram. Seven treatments were evaluated. The experiment was designed in completely randomized block design (CRBD) with 4 replications. Test plant *cv. Tropical* was planted with spacing of (50×50) cm and 40 test plants per treatments were maintained. The treatment was carried out by root dipping before planting and foliar sprayed at 30 days interval for three consecutive years (July, 2014-June, 2017). The results indicated that the maximum disease control was recorded in *Trichoderma viride* @ 1% (89.59%) and *P. fluorescens* @ 1.5% (80.35%) treated plants, followed by *T. harzianum* @ 1% (76.25%), Streptocycline (0.05%)+Copper hydroxide (0.2%) (75.31%) and strobulurin @ 0.01% (70.15%). Neem solution @ 2% was found to be the least (65.15%) effective for minimizing the blight. The highest blight incidence (94.35%) was recorded in control plots. The growth and flower yield attributes results indicated that anthurium plants applied with *T. viride* and *T. harzianum* at monthly interval, showed the maximum average of plant height (38.23-42.15 cm), stem length (35.23-39.21cm), number of flower per plant per year (10-15), spathe size (17.5-22.5 cm x 13.5-15.6 cm) spadix length (6.1-7.12 cm), flower stalk length (31.6-40.1 cm), number of suckers per plants (5.25-7.01) and least number of days (105-133 days) taken for flowering as compared to control plant showed poor plant health and flower quality. These finding can be used for improving Anthurium plant health management programs for higher productivity and good economic return.

Dropping Behaviour of *Myzuspersicae* (Sulzer) (Hemiptera: Aphididae) on Response to Predatory Mirid *Macrolophus pygmaeus* Rambur (Miridae: Hemiptera) on Tomato Plants

N. Sarmah[1,2] A. Devee[1,2] and D. Perdikis[1]

[1]*Laboratory of Agricultural Zoology and Entomology, Agricultural University of Athens, Iera Odos 75, 118 55, Athens, Greece*
[2]*Laboratory of Entomology, Department of Entomology, Assam Agricultural University, Jorhat-785013, Assam, India*

A laboratory experiment was carried out in the Laboratory of Agricultural Zoology and Entomology, Agricultural University of Athens, Greece during 2015-17 to study the dropping behavior of *Myzuspersicae* (Sulzer) (Hemiptera: Aphididae) by exposing to *Macrolophuspygmaeus* Rambur (Hemiptera: Miridae). The prey was observed for 2 hours continuously by placing 30 no. of *M.persicae* on the different leaves of a tomato plant. Firstly one and secondly two *Macrolophus pygmaeus* were released. The incidence of dropping was recorded in apex, middle, lower and top leaves. Significantly higher dropping incident was observed when two *M.pygmaeus* were released together in apex leaves (12.90±1.06). When one no of *M.pygmaeus* was released highest dropping incident was found in apex leaves (7.70±0.69). When observed the mean surface area of the different leaves from different position of tomato plants, lower leaves showed significantly highest surface area (104.482 cm^2) followed by Middle leaves (52.84 cm^2). The trichome density was dependent on the

factors “leaf position” and the “leaf surface”, whereas their interaction was not significant (F=19.81, df=3, 24, P<0.0001, F=346.56, df=1,24, P<0.0001, F=2.04, df=3, 24, P>0.13). Although the most efficacious way to dodge the antagonists is dropping, it also introduce them to alternate mortality risks viz ground predators, high temperature or inability to find another host plant. This may be indicated that *M.pygmaeus* effects *M.persicae*not only directly by consumption but also indirectly by bringing some change in the behaviour of prey.

Keywords: *Macrolophus pygmaeus, Trichome, Antagonist*

Genetically Divergent Virus and Virus-like Pathogens Infecting Horticultural Crops in North East Region of India: an Emerging Concern

Susheel K. Sharma[1], S.S. Roy[1], Th. Surjit Singh[1], T. Chanu Ng[1], S. Rakesh Singh[1], Y. Rupert Anand[1], SapamMonteshori[1], Y. Herojit Singh[1], Sumitra Phurailatpam[1], Arati Ningombam[1],M.A. Ansari[1],N. Prakash[1] and S.V. Ngachan[2]

[1]ICAR-Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal-795004
[2]ICAR Research Complex for NEH Region, Umroi Road, Umiam, Meghalaya-793103

Email: susheelsharma19@gmail.com

Virus and virus-like pathogens still remains to be most devastating factors in cultivation of agri-horticultural crops. North East (NE) Region of India encompassing large biodiversity coupled with congenial environmental conditions suitable for multiplication of insect vectors makes virus diseases even more widespread. Systematic surveys were conducted in different pockets of North East India to record the prevalence of virus and virus-like diseases on different horticultural crops. A genetically distinct recombinant potyvirus associated with yellow mottle and fruit deformation disease of passion fruit was identified. This potyvirus did not show any serological cross-reactivity with the other potyviruses belonging to bean common mosaic virus genetic cluster. Citrus plantations in NE region were found infected with citrus tristeza virus (CTV) and huanglongbing (HLB) bacteria. 38% of the tested samples were detected positive for both CTV and HLB. Based on the multi-locus sequence typing, *Candidatus* liberibacterasiaticus (CLas) isolates from Manipur had high genetic diversity, showing tandem repeat numbers (TRN) up to 21. Banana surveyed at different locations of NE India were found infected with banana streak viruses (BSV) and banana bunchy top virus (BBTV). Based on RCA-RFLP, banana streak viruse isolates showed diverse genetic patterns. Based on DNA-U3 and DNA-R, BBTV isolates from Manipur showed diverse genetic patterns. King chilli is another important crop of North East India. Out of a total of 153 king chilli samples tested, 54.23% were positive for chilli veinal mottle virus (ChiVMV) and 59.57% were positive for cucumber mosaic virus (CMV). A robust duplex RT-PCR assay was developed for simultaneous detection of ChiVMV and CMV. Eight papaya ringspot virus isolates from Manipur were characterized based on coat protein sequences. PRSV isolates from Manipur segregated into two distinct clusters. The existence of genetically distinct isolates of virus and virus-like pathogens infecting different horticultural crops indicated the possibility of their transboundary movement.

Management of Whitegrubs Using Pheromonesin Uttarakhand Hills

J. Stanley*, ARNS Subbanna, K.K. Mishra and A. Pattanayak

ICAR- Vivekananda ParvatiyaKrishiAnusandhanSansthan, Almora – 263 601, Uttarakhand
** Email: stanley_icar@rediffmail.com*

Pheromones are semiochemicals released by an organism that affect the behavior and physiology of other members of the same species. Pheromones are used in pest management as it is considered very effective and eco-friendly. Successful pest management using pheromones involve the isolation and identification of the pheromone. Scarab beetles also known as whitegrubs in its larval stage is a serious problem of hill agriculture as it attacks all the crops grown during June-October apart from grasses, ornamental plants, horticultural trees and forests. The grubs affect the plant by cutting the roots whereas the adult beetles feed on the leaves. These pests are managed effectively using light traps and entomopathogens like *Bacillus cereus* and *Brevibacteriumfrigoritolerans* in Uttarakhand hills. About 75 species of whitegrubs are identified in the region. Some of these species are less phototactic and escape from light trap catches and thus difficult to manage. One such species is *Holotrichiaseticollis* which is among the predomiant species of Uttarakhand hills. Pheromone of *H. seticollis*is isolated and identified as 1,2 1,3 and 1,4 diethyl benzene. The pheromone compound is biologically active as tested by Y tube olfactometer and trapped male beetles in field conditions. Anisole, a parapheromone is also found effective in attracting and trapping beetles in the field. Field experiments were conducted using anisole for the attraction and capture of male beetles of *H. seticollis* during 2017-2017. Treatments include pheromone trap with anisole, VL whitegrub beetle trap with anisole and VL trap with anisole and light source. The emergence of beetles started in the 2ndor 3rdweek of May and continued up to 4th week of July, with peak incidence during the last fortnight of June. The average beetle catches in pheromone trap was very low (8.1 beetles/ trap/ day) compared to VL trap with anisole (24.8/trap/day) and VL trap with light and anisole (26.3/ trap/ day). Though VL trap with light and anisole trapped more number of beetles it is not significantly higher than that trapped in traps only with anisole. Pheromone traps also attracts more number of beetles but the beetles get trapped in it are a few. Continuous trapping of male beetles of *H. seticollis* showed a reduction of 81% of pest in three years of experimentation.

Livestock Health Care Vis-À-Vis One Health Concept

Neela Madhav Patnaik[1], PriyajoyKar[2] and Maneesha Bhuyan[3]

Dairy Extension Division, National Dairy Research Institute, Karnal
Email: neelapatnaik@gmail.com

In livestock-dependent households and communities as in countries like India, the health of humans, livestock, and household economic welfare are closely related. The triad of animal, human and environment has many times fascinated researchers to go for innovative strategies for attaining optimal health without compromising the vested interest of one against the other. Understanding and addressing the health issues created at this intersection is the foundation for the concept of One Health. The health of each is inextricably connected to the others in the triad. The linkages between livestock rearing and human nutrition and health outcomes have been highly synonymous to each other. Broadly, they include positive effects of keeping livestock that generally improve a household's health and welfare status by providing milk, meat etc.; and negative effects of livestock ownership that may worsen human health via transfer of many diseases. With the increasing incidences of transfer of zoonotic diseases(brucellosis, anthrax etc.) threatening the health of field level functionaries, Antimicrobial resistance related issues in recent times; one health concept has paved the way for the researchers and policy makers towards devising strategies for improved health care management practices for human in general and livestock in particular. But this requires a collaborative effort of multidisciplinary research at local, national and global level so as to create feasible technology for the betterment of our future. The relationship between livestock health and productivity, and human health and welfare is complex phenomenon. Understanding the concept of one health in quantitative terms remains a critical requirement for developing sustainable poverty reduction and public health interventions through human and livestock health maintenance and improvement. The roles of both public and public institutions are very crucial in terms of technology generation and dissemination. The goal in developing such policies are aimed at reducing poverty in order to maximize the positive linkages of livestock rearing while minimizing their negative effects.

Epidemiology of Brown Spot of Rice (*Oryza sativa*) Incited by *Bipolarisoryzae*

[1]Rajesha G., [1]Bendangsenla, [1]D.J. Rajkhowaand[2] and S.V. Ngachan

[1]ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema, Nagaland 797 106
[2]ICAR Research Complex for NEH Region, Umiam, Meghalaya
Email: rajeshag337@gmail.com

The experiments were carried to study the influence of epidemiological factors on development of brown spot disease in different rice varieties under field condition during kharif season of 2015-16 and 2016-17. The correlation study under open field revealed that, development of blast disease was positively correlated with relative humidity in all the varieties except 2 varieties (Agoni Bora and RCM11) whereas temperature and rainfall were negative correlated in all the varieties during crop growth period during both the seasons. The maximum brown spot severity of 37.28 per cent disease index with maximum AUDPC of 185.37was observed at the time of harvest in 2016-17. The cumulative AUDPC of 1209.45 has been observed during the period.

Keywords: *Rice, Brown spot, Epidemiology, Disease severity*

Molecular Detection and Phylogenetic Analysis of Helicobacter spp. in Gastric Mucosa of Pigs with Gastritis

Seema R. Pegu*, D.K.Sarma, S. Rajkhowa and M. Choudhury

ICAR-NRC on Pig, Rani, Guwahati
**Email: drseemapegu@yahoo.com*

Gastric ulceration is a well-known problem in swine where intensive pig production occurs and that can lead to growth retardation, bleeding and death in pigs. An association between gastrospirillum-like organisms (GLO) and ulcerative lesions in the pars oesophagea in stomachs of swine has been reported. The aim of this study was to evaluate the presence of Helicobacter (H.) spp. in swine affected by gastritis. A total of 312 no.s of stomach samples from slaughtered pigs and 69 no.s from necropsied pigs from different slaughter points and pig farms of Assam were collected and subjected to gross pathological examination to evaluate the presence of gastric lesions. Mild to severe Gastristis were detected in 209 cases and Gastric ulcers were detected in 46 cases from samples collected from slaughtered and necropsied pigs. Positive urease test observed in 62 gastric mucosal samples. Histopathological examination revealed pyloric mucosa of pig with chronic gastritis. Other findings recorded were coagulative necrosis with hemorrhage, leucocytic infiltration with neutrophils and macrophages. Scanning electron microscopy of gastric mucosa revealed spiralled shaped Helicobacter organism in the lining epithelium of gastric mucosa. Forty one samples were found positive for Helicobacter spp. by PCR. All the samples were negative in H. suis and H. pylori specific PCR. Sequence analysis of PCR positive gastric samples of pig revealed 97% identity with 16S rRNA gene of Helicobacter sp., H. suis, H. heilmannii, H. pylori. Further investigations are essential to access the role of pigs as possible reservoirs of H. pylori and pig to human transmission route of Helicobacter spp.

Keywords: *Helicobacter spp., Gastritis, Gastric mucosa, Pig, PCR, Phylogenetic Analysis*

Theme-8: Mechanization, Processing and Value Addition for Income Enhancement

Post-Harvest Management, Processing and Value Addition in Agricultural Produces for Enhancement of Farmers Income

A Nath*, L.R. Meena and A.S. Panwar

**ICAR-IIFSR, Modipuram, Meerut, UP-250110*

Food processing includes a process under which any raw product of agriculture, dairy, animal husbandry, meat, poultry or fishing is transformed through a process (involving employees, power, machines or money) in such a way that its original physical properties undergo a change and if the transformed product has commercial value and is suitable for human and animal consumption. It also includes process of value addition to produce products through methods such as preservation, addition of food additives, drying with a view to preserve food substances in an effective manner, enhance their shelf life, quality and make them functionally. Food production has been steadily increased in India due to advancement in production technology, but improper post harvest management, processing, value addition and storage results in high losses in agricultural produces. According to World Bank Report, post-harvest losses in India amount to 12 to 16 million metric tons of food grains each year, an amount that the World Bank stipulates could feed one-third of India's poor. The monetary value of these losses amounts to more than Rs 50,000 crores per year. In India about 263.2 million MT (in 2013-14) of food grains are produces annually and out of which 60-70 % are stored by the farmers for their own consumption. In India, annually around 371830 tons of paddy was wastage at small and medium farmers level due to lack of proper drying, packaging and storage facilities. Moreover, most of the horticultural produces have very short shelf life and during the peak season, a great loss (20-40%) occurs due to lack of proper postharvest handling and processing. The minimization of these post harvest losses may be reduced by extending the shelf life of fresh horticultural produces either through pre and post harvest management practices or by processing it into different value added products. There are many technologies already developed in the past which are available in the literature but are not practiced may be due to either materials are not available locally, not much effective or the technology is more costly.

Therefore, it is essential to overcome the problems associated with the produce by proper handling and care after harvesting of agricultural produces. Shelf life of fruits and vegetables may be extended by utilizing different plant based coating materials viz., neem extract, tulsi extract, aloe vera extract etc. may be used locally which have anti fungal properties at farmers level so that more return will be generated from their agricultural produces. During the peak season, there is glut in the market, so excess production may be converted to different value added products at farmer’s level for off season availability and fetching two to three times more return from the same produces. Again, by simple post harvest management, processing and value addition operation viz., sorting, grading, packing, pulping, pickling, drying and dehydration will very easily double the return from the farm produces at farmer’s level. The Indian Economy is heavily dependent on agriculture, and this is projected to continue in the near future as well. The Agriculture and Allied Sector contributed approximately 13.9% of India’s GDP during 2013-14 (Ministry of Agriculture, 2015) and engages about 50% of the workforce. The Food Processing Industry is of enormous significance for India’s development because of the vital linkages and synergies that it promotes between the two pillars of the economy, namely Industry and Agriculture. A well developed Food Processing Industry with higher level of processing helps in the reduction of wastage, improves value addition, promotes crop diversification, ensures better return to farmers, promotes employment as well as increases export earnings. The sector is also capable of addressing critical issues of food security, food inflation and providing wholesome, nutritious food to the masses. Processing of food products mainly as part of a cottage industry has been a long established traditional practice imbibed in many cultures of the country. However, with changing lifestyle patterns, increasing income, increasing preference toward, Ready to Eat and packaged foods, the significance of the Food Processing Industry has increased enormously.

Over the years, agricultural production in India has consistently recorded higher output. India ranks number 1 in total food production globally. With respect to specific commodity it ranks number 1 in the production of production of milk, bananas, guavas, papayas, ginger, okra, pulses & buffalo meat. Further, India ranks number 2 in the world in the production of green peas, potatoes, tea, tomato, sesame, inland fish production. It is the fifth largest egg producer in the world. Abundant supply of raw materials, increase in demand for food products and incentives offered by the Government has impacted food processing industry positively. Despite the large production of food products in India, post harvest losses are of major concern. A nation-wide study on quantitative assessment of harvest and post-harvest losses for 46 agricultural produce in 106 randomly selected districts carried out by CIPHET, Ludhiana has estimated harvest and postharvest losses of major agricultural produce at national level to be of the order of Rs. 44,143 crore per annum at 2009 wholesale prices. In spite of a large production base, the level of processing is low (less than 10%). Approximately 2% of fruits and vegetables, 8% marine, 35% milk, 6% poultry are processed. Lack of adequate processable varieties continues to pose a significant challenge to this sector.

The country's current foodgrain production (including rice, jowar, bajra, maize, ragi, wheat, barley, gram and pulses) has been put at 225 million tonnes a year. Food processing industries play a crucial role in reducing post-harvest losses. Since most operations of this industry are rural based, it has the potential to generate high employment at low investment. Promotion of food processing also helps in energy conservation by reducing energy wastages in home cooking. Grain processing, with a share of 40%, is the biggest component of the food sector. Its basic feature is pre-dominance of the primary processing sector, sharing 96% of the total value, with the secondary and tertiary sectors adding about 4%. This area needs to be viewed as a high growth potential area. Indian Basmati rice commands a premium in the international market. The export of Basmati and non-Basmati rice has been steadily increasing. Fruits are rich source of several vitamins and minerals. Mango, papayas are rich in vitamin A. Cashew nut and walnut are rich in vitamin-B1. Bael, papaya, litchi are rich in vitamin- B2 and Barbados cherry, aonla, guava are rich source of vitamin-C. Some fruits are also rich in some minerals like litchi is rich in calcium (Ca) and dry karonda is rich in iron (Fe). Fruits and vegetables are perishables and seasonal. Unless excess production is processed and preserved, it will be wasted. In India only 1.0% of the total fruits and vegetables produced are processed in the 3000 food industries.Although India is the second largest producer of fruits and vegetables only 2% is being commercially processed and wastage is estimated to be very high.

The key issue facing the food and agribusiness sector is the viability and scalability factor, which in turn is linked to absence of efficient food supply chain mechanics effectively integrating backward and forward linkages in a seamless manner. With the right policy in place investment is expected to flow into integrating the backward linkages in to the supply chain and thereby having an impact on farmer incomes.

Microcontroller in Irrigation System

H. Dayananda Singh, Hijam Jiten Singh, and B. K. Sethy

ICAR Research Complex for NEH Region, Umiam, Meghalaya

Agriculture cannot be ignored as everyone depends on it for food. Now a day's there is decline in labour available for agricultural operation .The percentage of people employed in agriculture has been consistently declining, from around 60 % in 1999-2000 to 49 % in 2011-12. In absolute terms, between 2004-05 and 2011-12, there has been a net reduction of 30.57 million of labour from the agricultural sector. In order to retain field worker, rural wages have been increased by 17% on average since 2006-2007. Irrigation is one of the major labour required operation in field. Labour required for operating irrigation system in tomato, melon and water melon are 88.8 man h/ha, 54.6 man h/ha and 60.0 man h/ha respectively in a season. Use of automatic system and machinery can reduced the man power requirement and also save the input by applying only required amount. Automatic systems by using microcontroller are cheaper than other system. Microcontroller is a computing unit which takes decision and control the peripheral component based on the input provided to it. Microcontroller along with soil moisture sensor, GSM module and other components can control irrigation system efficiently. A study is going on to developed microcontroller based drip irrigation controller. The power required to operate the system will be provided by the solar system. The coding of the system is done in Code Vision AVR software. The system has the provision to change the limit of OFF and ON status of the water pump in field level through key board. Lab testing of the system is done and its performance is found to be satisfactory.

Keywords: *Irrigation, Microcontroller, Agricultural labour*

Performance Evaluation of Zero-Till Seed Drill for Sowing of Maize Crop on Terraces in Hilly Region

Hijam Jiten Singh*, H. Dayananda Singh and B.K. Sethy

ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Email: hijam_jiten@yahoo.co.in*

A study was conducted to evaluate a power tiller drawn zero-till seed drill for its performance for sowing of maize crop on terraces of 2-5 m wide. Various parameters such as machine, soil and crop parameters were considered during the field evaluation. The major parts of the seed drill consisted of main frame, seed box, flutted roller type seed metering mechanism, furrow opener, seed tub and attachment for seed rate adjustment. Maize seeds were sown directly after the harvest of turmeric without any prior tillage operation. Seeds were placed in the furrows at desired depths through adjustable system at the rate of 18kg/ha. The average depth of sowing was 2.5 cm and row-row spacing was 50 cm. Seed placement pattern in row was continuous. Soil moisture content, soil bulk density and soil strength were 18.35 %, 1.38g/cm^3 and 30.63 k/$cm^{2,}$ respectively at the time of sowing. The results from the study showed that, effective field capacity achieved was 0.12 ha/hr at a speed of operation of 1.8-2.0 km/h. The field efficiency, field machine index and fuel consumption were observed to be 63%, 77% and 0.96 l/hr, respectively. Considering the performance parameters, seed drill fitted with fluted feed roller type seed metering mechanism with two numbers of furrow openers was found satisfactory for use on terraces although plant to plant distance could not be maintained.

Keywords: *Maize, sowing, Zero-till Seed Drill, Terrace, Hilly Region*

Innovative Value Added Meat Products and Entrepreneurship Development in Meghalaya

L.S. Meitei, Bandita B. Banerjee, G. Kadirvel & S. Doley
ICAR Research Complex for NEH Region, Umiam, Meghalaya
Email: velvet.2007@rediffmail.com

The Northeastern part of India is renowned for its preference for animal based food. Meghalaya is one such State and is known for its traditional meat items. Through field survey at different locations of Meghalaya a total of 15 ethnic meat preparations have been identified of which six most popular ones have been documented that includes dishes like Doh Jem, Doh Snam, Tungrymbai, Achar Doh Sniang, Doh Snam, Dohkhlieh and Jadoh. ICAR-RC for NEH Region, Umiam, Meghalaya has taken the initiative of establishing a well equipped Meat Processing Unit in 2015 for hygienic meat processing and value addition, besides promoting entrepreneurship development in the region. It has endeavored to blend the traditional meat preparations with scientific approaches so that the popularity of the products can be enhanced beyond the geographic boundary of Northeast India. Some of the products processed in the unit include pork/chicken sausage, pork/chicken pickle, smoked pork/chicken, pork/chicken curry cuts, ham and pork/chicken nuggets. The unit has also produced some innovative meat products like concentrated pork curry, marinated pork, etc. The unit is involved in research work as well and is developing functional foods like pork sausage with bamboo shoot, pork sausage with blood fruit, chicken sausage with jaiur and chicken sausage with lomba. One of the mandates of the Unit is to encourage budding entrepreneurs in meat processing sector through trainings. To promote entrepreneurship, the unit has provided knowledge, skill, marketing network and technical support to around 25 potential youth under TSP (Tribal Sub Plan) and ABI Agribusiness Incubation) till date. Recently the unit has developed successful Private-Public Partnership model to market the meat products. It has materialized this concept by signing a Memorandum of Understanding with M/S Tynrai Farms on August, 2016 for marketing its products. At present, the unit is FSSAI licensed and functions to its optimum capacity.

Keywords: *Meghalaya, Traditional, Meat, Processing, Entrepreneurs, Training*

Effect of Heat Shrinkable Film on Storability of Assam Lemon under Ambient Conditions

Ng.Piloo*, S.R. Singh and A.K. Pandey

College of Horticulture & Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh
**Email: ngpiloo@gmail.com*

A study was conducted to observe the effect of heat shrinkable films on shelf-life and quality of Assam Lemon [*Citrus limon* Burm.f.] stored under ambient conditions. Fully mature green Assam Lemon fruits collected from Orchard of the College of Horticulture & Forestry, Pasighat were subjected to three treatments viz. T_1(Individual Shrink wrapping), T_2(Shrink Wrapping in trays) and T_3(Control treatment) and were stored in ambient condition (29-32^{o}C temperature and 55-78% relative humidity). Observations on PLW, TSS, titratable acidity, Sensory quality, colour and marketability were recorded. Results revealed that heat shrinkable films influenced the quality parameters of Assam Lemon during storage. However, Considering all the physical and chemical characters, it was found that T_1(Individual Shrink wrapping) was the superior treatment because of high marketable fruits, low physiological loss in weight (3.924%), better retention of colour, TSS(4.23^{o}Brix), titratable acidity(4.93%) with better sensory score followed by followed by T_2 (Shrink Wrapping in trays) and T_3 (Control treatment). The study indicated that Lemons could be stored up to 30-35 days when individually packed in heat shrinkable films with least PLW while maintaining the fruit quality at the same time.

Effect of Chemicals and Modified Atmosphere Packaging on Storage Life and Quality of Baramasi Lemon (*Citrus limon* L. Burm) Fruits

Simranbir Kaur[1*] and S.K. Jawandha[2]

Department of Fruit Science, College of Agriculture, P.A.U. Ludhiana-141004 (Punjab), India
**Email: simranbir-fs@pau.edu*

The present investigation entitled "Effect of chemicals and modified atmosphere packaging on storage life and quality of Baramasi lemon (*Citrus limon* L. Burm) fruits" was conducted in Department of Fruit Science, Punjab Agricultural University, Ludhiana during the year 2014. Mature green Baramasi lemon fruits of uniform size and colour were harvested and treated for 5-minutes in aqueous solution of gibberellic acid (25, 50 & 75 ppm), boric acid (1, 2 & 3%) and sodium benzoate (2, 3 & 4%). Treated fruits were packed in low density polyethylene (LDPE) bags and stored at ambient conditions. Fruit samples were analyzed after 15, 30, 45 and 60 days of storage for various physico-chemical characteristics. Results revealed that physiological loss in weight (PLW), spoilage, total soluble solids (TSS), reducing sugars, non-reducing sugars and total sugars increased with the storage period, whereas peel thickness and peel percentage showed a declining trend with advancement of storage period, other parameters like juice percentage, palatability rating, titratable acidity (TA), ascorbic acid showed an increasing trend during early periods of storage, but at end of storage a decline was recorded. The fruits treated with gibberellic acid @ 75 & 50 ppm and boric acid @ 3 & 2% were found to be moderately to very much desirable after 60 days of storage. Gibberellic acid @ 75 ppm along with LDPE packaging was found to be most effective in extending the post-harvest life of Baramasi lemon fruit at ambient conditions for 60 days by reducing the physiological loss in weight (PLW), spoilage and maintaining the palatability rating, peel thickness, juice percentage, peel percentage, acidity and vitamin C during entire storage period as compared to other treatments.

Enhancement of Farm Women Income through Promotion and Processing Of RTS Pineapple Juice under Longleng District of Nagaland

[1]Thungchano S. Ezung, [1]Manoj Kumar, [1]A. Namei, [1]K.L. Meena and [2]D.J. Rajkhowa

[1]Krishi Vigyan Kendra (KVK), Longleng, Nagaland
[2]ICAR Research Complex for NEH Region, Nagaland Centre
Email: mkumar_cprs@yahoo.co.in

Longleng is a hilly district of eastern Nagaland. Longleng is the most backward District of Nagaland classified by planning commission of India. The altitude of the district ranges from 260-1485 m above MSL with latitude 26° 29' 24.71640" N and longitude 94° 49' 10.7904" E, with annual rainfall about 2000 mm. Longleng district enjoys monsoon type of climate with a minimum temperature of 10°C in winter and a maximum of 28°C in summer. Climate of the district is favorable for Pineapple cultivation with total area of 300 ha with production (3100 tones) and productivity (10.33 t/ha). Before the intervention of the new technology in the District, KVK has done PRA in five nos. of village. During the PRA, it was found that there is no value addition and preservation of fruits and vegetables. Due to unawareness and knowledge on post harvest management plenty of pineapple fruit go wasted every year. Therefore, Krishi Vigyan Kendra (KVK), Longleng has taken initiatives to conduct hands on training programme to farm women for promotion on value addition, processing and preservation of Pineapple through making RTS (ready to serve) Pineapple Juice for their livelihood improvement. All together 120 numbers of individual farm women and SHGs from different villages were selected for hands on training programme during the year 2015-2017. After Demonstration, SHGs are preparing RTS in large scale and selling in the market for their additional income. The ingredients used for the preparation of RTS juice was ripe and firm fruit of Pineapple, sugar, citric acid, pineapple essence, colour and preservatives and the equipments were hand juice extractor, muslin cloth and PET bottles. Total 1048 nos. bottles (300 ml) of RTS juice were prepared and sold in the market with expenditure of Rs.9210.00 and gross Rs.21120.00 with net profit of Rs.11908.00 and benefit cost ratio of Rs.2.29. Therefore, it was concluded that if the farmer continued to practice processing and value addition of pineapple fruit it will not only enhance their income but will also reduce the wastage of the fruit.

Keywords: *RTS, Pineapple juice, Processing, SHGs, Income Generation*

Efficacy of Different Preservatives on the Shelf Life of Green Chilli Pickle

Y. Prabhabati Devi* and Deepak Singh

Krishi Vigyan Kendra, Chandel
ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat-795004, Manipur
**Email: prabhayumnam@rediffmail.com*

Chilli is a fruit plant from the genus capsicum member of the solanacene. They are widely used in many cuisines to add spiciness to dishes. Three quarters of the world population eat chilli every day. Chilli is highly perishable vegetable and abundantly available during May to July-August. It is very cheap during season and cannot be kept for a long period of time without processing and preservation. Preservation is the process of prevention of decay or spoilage of food thus allowing it to be stored in a fit condition for future use. Drying, smoking and value addition of chilli in the form of dry preserves, powder, sauce and pickle can extend the shelf life to some extent. By using proper preservative, the shelf life of green chilli can extend even one to two years. Mustard oil, salt, and vinegar are the common preservative used for long time back. Shelf life of pickle depends on the type of preservative used during the process of ma king pickle. In order to see the effect of preservatives on the shelf life, a study was conducted on “Efficacy of preservatives on the shelf life of green chilli pickle”. This experiment was conducted covering a period of one year. Observation was done at the end of each week for a period of one year to see the change in colour, smell and appearance of fungus and mold. In the first treatment, chilli pickle was prepared with 5% salt, spices and 10% mustard oil and stored in unsterilized bottle. In the second treatment, chilli pickle was prepared with 8% salt, spices and 20% mustard oil and stored in sterilized bottle. In the third treatment, chilli pickle was prepared with 9% salt, spices and 25% mustard oil and vinegar (10%) and stored in serialized bottle. In the fourth treatment, chilli pickle was prepared with 10% salt, spices, 30% mustard oil and 0.5% acetic acid and in the fifth; it was prepared with vinegar-cured chilli, 10% salt, spices, 35% mustard oil. The result showed that there was change in colour and smell from 1 and 1/2 month onwards in case of first treatment. In case of second treatment, change in colour and smell started from 4 month onwards. In the third, change started from 6 month onwards. In the fourth treatment, change started from 9 month onwards. And finally in the fifth treatment, there was no change in colour and smell up to 1 year. So the fifth treatment proved to be the best method for the preparation of green chilli pickle.

Value Addition of Locally Available Underutilized *Heirit* (*Ficus auriculata*) Fruit of Churachandpur District, Manipur

Sougrakpam Roma Devi, Laishram Kanta Singh and Niranjan Lal

Krishi Vigyan Kendra, Churachandpur
ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal, Manipur
Email: kanta_lai@yahoo.co.in

A large portion of Churachanpur district had been either under current *jhum* or abandoned *jhum*. There are many underutilized fruit crops available in the district which is yet to be explored. *Heirit* (*Ficus auriculata*) is one such underutilized fruit crops available plenty in Churachandpur district, Manipur. *Heirit* is a kind of fig and is highly perishable. Due to lack of storage and lack of knowledge for processing and preservation, a huge amount of fruits go waste every year. To tackle such problems, KVK Churachandpur took initiatives for the promotion of processing and value addition of such underutilized fruits and vegetables. Good quality *Heirit* fruits were selected for preparation of different value-added products like squash, RTS, Jam and Jelly. In the process of preparation of squash, mature and ripe fruits were selected and were washed with clean water, fruits 40 kg, sugar 25 kg, water 20 liters, class II preservative, bottle, and label were taken for preparation of 70 bottles of squash. The processed squash of *Heirit* fruit could reduce post-harvest losses to 15% from 85% losses. The shelf life of the *Heirit* squash was increase up to six months by preventing the growth of harmful micro-organism. The benefit cost ration of *Heirit* squash was estimated at 1.75. The value addition of underutilized fruit crops like *Heirit* could improve the livelihood security of many farmers of Churachandpur district, Manipur by enhancing their income generation.

Blended Beverage: Development of a Novel Product by Adding Value to Underutilized Crops of Northeast Hill Region

S.R. Assumi*[1], V.K. Verma[1], C. Aochen[2], H. Rymbai[1], K. Wanshong[1], R.L. Wahlang[1]and A.K. Jha[1]

ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Email: ruth.assumi@gmail.com*

Northeast hill region of India is endowed with a wide variety of underutilized crops. Therefore, this study was conducted for utilization and value addition from commonly found underutilized crops *viz*. chow chow (*Sechiumedule*), *Sohiong*(*Prunusnepalensis*) and mulberry (*Morusindica*),to develop a novel nectar blended beverage. In this region, *Sechiumedule*is mostly used as a cooked vegetablethus an attempt on beverage was made by blending with *Prunusnepalensis* and *Morusindica*. A total of 8 treatment combinations with different ratios of blendingwere prepared by adding 20% fruit pulp, adjusted to 15°Brix TSS and 0.3% acidity.The processed blended nectars were filled in pre-sterilized bottles, sealedand pasteurized at 85°C for 15 minutes.A dynamic change in colour (L*,a*,b*) in the blended treatments was observed with the increase in proportion of sohiong and mulberry, which is reflected in increased anthocyanin content (2.84 to 9.67mg $100ml^{-1}$). There was a balance between sugars and acid ratio which is crucial in controlling the flavor changes of product and amongst the different blendings,T_8(chow chow10%+*Sohiong*5%+mulberry5%) was rated superior by sensory panels (8.53 out of 9 point hedonic scale). These nectar beverages were found to be superior in quality without any significant changes at 6 months of storage in ambient condition (25±2°C). The study indicates that blending of available underutilized seasonal crops to beverage appears to be a promising product with high consumer acceptability.

Keywords: *Underutilized crops, Blending, Beverage, Novel Product*

Development of Nutraceutical Enriched Chow Chow Based Nectar

S.R. Assumi*[1], C. Aochen[2], K. Wanshong[1], R.L. Wahlang[1], N.A. Deshmukh[1]and A.K. Jha[1]

[1]Division of Horticulture, [2]Division of Biotechnology
ICAR Research Complex for NEH Region, Umiam, Meghalaya
**Email: ruth.assumi@gmail.com*

Chow chow (*Sechiumedule*), mulberry (*Morusindica*) and *Sohiong* (*Prunusnepalensis*)are indigenous crops commonly found in the state of Meghalaya. Chow chowis a nutraceutically rich vegetable and to date, unexplored for beverage development. Mulberry and *Sohiong* are highly perishable fruit cropsand due to its short-season availability, it has to be either consumed immediately or preserved in one form or the other. To add value to these crops while preventing wastage arising due to postharvest losses, nectar blended beverage was a desirable product as assessed in this study. Nectar beverage was developed by blending the pulps of chow chow, mulberry and *Sohiong*(in the ratio 10:5:5)which was adjusted to 0.3% acidity and 15°Brix total soluble solids with cane sugar syrup.This beverage contained considerable amounts of nutraceuticals*viz*. phenols (87.68mg GAE/L), flavonoids (107.52mg CE/100ml), antioxidant acitivity (94.19mg AEAC/L), anthocyanins (5.61mg/100ml) and ascorbic acid (6.11mg/100ml). Itexhibited high sensory score in terms of taste, flavour and overall acceptability besides, its rich colour and appearance contributed from mulberry and *Sohiong*pulp, a very good source of anthocyanins, thereby eliminating the need of incorporating artificial colourant in the product. Therefore, this beverage is a potential value added product which can be up scaled for commercialization and promotion.

Keywords: *Nectar, Chow Chow, Mulberry, Sohiong*

Post-Harvest Processing of Tea by Organic Small Tea Growers- A Case Study

Sarmah, Nomi[1] and A. Janakirani[2]

[1] Assam Agricultural University, Jorhat
[2]TNAU, Tamil Nadu

E mail: nomisarmah22@gmail.com

Organic agriculture is now being practiced in more than 130 countries with a total area of 30.4 million hectares, about 0.65% of the total agricultural land of the world. There is a growing demand for organic foods driven primarily by the consumer’s perceptions of the quality and safety of these foods and to the positive environmental impact of organic agriculture practices. Tea production in Assam is more than 180 years old by now.The cultivation of tea on small holding is comparatively a recent development. The study has focus on the post- harvest processing of tea by the Organic Small Tea Growers. . The investigation was carried out in Dibrugarh district of Assam since the district has highest area under Tea cultivation. A sample of ninety farmers were selected from six villages.Majority of the respondents were having collegiate education, they are engaged in agricultural activities. They have high experience in organic tea production as well as majority of them had visited their neighbouring tea plantations. Organic Small Tea Growers are practicing manual harvesting and processing of the tea leaves as there are lack of organic tea processing factory. The present study emphasizes on the processing of Organic tea by a Small Tea Growers who produce tea in his own processing unit manually by following the necessary steps *viz* steaming/ panfrying, hand rolling, drying, grading/ sorting and packaging.

Sustainable Livelihood Development through Processing and Value Addition of Fruit and Vegetable in North Eastern India

Ngankham Joykumar Singh[1], P.K. Sarangi[2] and Th. Anand Singh[2]

[1]Deptt. of *Agril.Engg, College of Agriculture, Central Agricultural University*
[2] *AICRP on PHET, Directorate of Research, CAU, Imphal*
**E-mail: joyngang@gmail.com*

India is the second largest producer of fruit and vegetable in the world next to China and accounts for about 15 per cent of the world production of fruit and vegetable. Large proportion of agricultural produce is wasted due to lack of proper harvesting, handling, packaging, loading, transporting, improper storage, lack of transportation & food processing facilities. The scenario of fruits and vegetable processing in the Northeastern India is more or less discouraging and has received little attention. The opportunity-gap with a little effort can be filled to a great extent with research and extension activities in the region. Inspite of excellent market potential and higher profit margin on fruit and vegetable based products, rural mass shows little interest towards this sector. Properly developed agro-processing sector would not only encourage rural entrepreneurship but also can make Northeast states a major player at the global level for marketing and supply of processed food products. The motto of the policy should be such that a grower should a primary processor in the fruits and vegetables processing and distribution system. It is presumed that when a grower earns more profit, the fruits and vegetables processing sector will boost up in the northeastern region and more people will be fascinated towards this sector. This article describes the various possible ways in introducing suitable mechanization and value addition of fruits and vegetables processing sector in the north eastern India in order to facilitate sustainable livelihood through entrepreneurship development and enhance the socio-economical status of the rural mass.

Entrepreneurial Potential of Ginger/Turmeric Washer cum Peeler for Small Farmers in NEH Region of India

Ngankham Joykumar Singh[1]*Prakash K. Sarangi,ThangjamAnand Singh and Y. Jekendra[1]

All India Coordinated Research Project on Post HarvestEngineering &Technology, Directorate of Research, Central Agricultural University, Imphal, India-795004
[1]*Department of Agricultural Engineering, CoA, CAU, Imphal*
**E-mail: joyngang@gmail.com*

Ginger (*Zingiber officinale* rose L.) of family *Zingiberaceae* is an important spice crop of NEH, India. It is a fibrous-rooted perennial plant with branched underground stems called rhizomes. The crop is cultivated in the hilly area of the region by small farmers. Traditionally the cleaning of rhizomes is done manually between the fingers in water which takes a lot of time (8-10 kgs in one hour) and it is laborious and time consuming. The peeling of skin is also very laborious and time consuming which is usually done by using knife. This operation results in high loss of materials and quality thereby loss in economic value of farmers. A versatile medium-scale manually operated low cost ginger / turmeric washer cum peeler having an effective capacity of more than 60 - 70 kg/h was developed to improve the socio economic status of ginger/turmeric growers of the NEH region. The developed ginger/turmeric rhizome washer cum peeler mainly consisted of a perforated revolving washing drum made of mild steel having of 600 mm length and 500 mm diameter and 1.0 mm thickness mounted between two bearings through a long MS shaft of 25 mm diameter. The washing

drum was encased in a water container plastic cylinder and rotates in a horizontal axis where rhizomes are loaded in batch for the washing and peeling operation. The rotational speed of the drum at 100 rpm and 10 minutes duration was found to work satisfactorily in removing the adhering dirt, stains, other foreign materials or caked dirt on the rhizome or between segments of the rhizome. The washing-peeling capacity; the amount of washed and peeled rhizomes unit time during the actual washing-peeling operation time was about 60-70 kg/hr which is about 7-8 folds increase as compared to the traditional method of washing and peeling besides, the machine does not require electricity to operate and suitable to use in farm condition to minimise the transportation cost.

Theme-9: Biodiversity Conservation, IPR and Seed Technology

Genetic Diversity of Horticultural Crops in Arunachal Pradesh

B.N. Hazarika

College of Horticulture and Forestry, CAU, Pasighat – 791 102, Arunachal Pradesh
Email: bnhazarika13@yahoo.co.in

The North Eastern Region is one of the eighteen mega- biodiversity hot spot which is characterized by fragility and marginality with rich biodiversity and ethnicity and social set up. Arunachal Pradesh situated between latitude of 26^0 30' to 29^0 28' North and longitude of 91^0 25' to 97^0 24' East stretching over 83,730 sq.km is the largest state area wise in North Eastern Region and blessed by nature with one of the richest flora and fauna on the earth. The state of Arunachal Pradesh has a wide range of climatic condition because of its unique position in the Indian subcontinent. Its unique phytogeographical positions, topography and high degree of precipitation are some of the important factors which are mainly responsible for its enormous biological diversity. It has humid subtropical or nearly tropical plains which receives high rainfall, temperate climate as well as snow covered high mountains. Varying range of climate and soil condition, moderate temperature and plenty of rainfall are conducive for growing an array of horticultural crops. Harnessing these resources with proper location specific farming activities has comparative advantage in relation to the plains. Based on the agro climatic condition of Arunachal Pradesh, the state has been divided into four horticultural zones *viz.*, Foot hills and valley (170-915 meters altitude), Mid hills (915-1803 m. altitude) ,High hills (above 1803 m. altitude) and Rain shadow areas .There is need to conserve the species diversity incorporating new technologies into the existing farming system for sustainable development. Considering topo-sequence and agro-climatic condition, there is wide potentialities exists for achieving higher economic growth and creating job opportunities in this sector. The paper will present genetic diversity of horticultural crops in Arunachal Pradesh.

Status of Crop Biodiversity Conservation in Northeast India: Role of NBPGR

A.K. Misra, Harish G.D. and Subarna Hajong

ICAR-National Bureau of Plant Genetic Resources, Regional Station Shillong, Umiam, Meghalaya
Email: akmisra@yahoo.com, anup.misra@icar.gov.in

The plant genetic resources (PGRs) are of paramount importance for the future and to ensure food and nutritional security of an increasing population. The PGR are prerequisite / backbone of any successful crop improvement programme. The collection, conservation and utilization of PGRs are important in national, as well as, in global context. Considering the value of germplasm collections for ongoing crop improvement, Nikolai Vavilov stated that "the practical plant-breeder uses this material as bricks with which he must construct new forms". These are our heritage to be conserved for current and future use for sustaining and strengthening the food security. The Indian subcontinent is one of the 12 mega-gene centers and represents three global biodiversity hotspots. This is evidenced through its rich diversity in domesticated plant species and crop wild relatives. The North-eastern (NE) region of India comprising of eight states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, is extremely rich and diverse in terms of PGR. The geography of the NE states of India is unique having snow capped peaks of the Himalayas, the ecological hot spots of the NE foothills and the Brahmaputra valley. High rainfall, humidity, varied topography and altitude, high natural selection pressures, environmental stresses have made the region rich both in floristic and crop diversities. The NE India comprises about 8% (2,62,179 Sq. Km) of India's total geographic area supporting around 50% of the flora (Ca. 8,000 species), of which about

32% (Ca. 2,526 species) is endemic. This region is described as 'Cradle of flowering plant' by Takhtajan in 1969, due to its angiosperm diversity. It is a part of the Vavilovian gene centre for many important cultivated plant species and it is well known for its richness in variety of landraces and primitive cultivars of several crops besides a huge floristic wealth of great economic importance. The region is also the home to more than 200 tribes in India who are the custodians of precious agro-biodiversity in this region. The various ethnic groups, practicing primitive agriculture, have preserved the local landraces and varieties of crop plants. These landraces are the product of many years of natural evolution and human selection and contain useful genes for resistance to biotic and abiotic stresses, as well as, adaptability to diverse climatic conditions. The traditional farming practices in the region encourage *in situ* conservation of precious agro-biodiversity. The NE India is the home to about 8,000 angiosperm species which belong to more than 200 families. Species richness is the highest in Arunachal Pradesh (62.5%) and the lowest in Tripura (20.0%). About 3,440 angiosperm species (43%) are endemic and 800 species are endangered.

The declared *in situ* conserved area is 5.53% of the total geographical area of the NEH region. *In situ* conservation is in the form of Biosphere reserve, National Park, Wild life sanctuary and Gene sanctuary. Sacred grove is also a novel method of *in situ* biodiversity conservation, also popular at community level especially in Meghalaya. The Nokrek, Manas, Dibru-Saikhowa, Dihang-Dibang and Kanchenjunga are the declared Biosphere reserve in the region. Besides this 17 National Parks and 55 wild life sanctuaries are exist in this region. Maintenance and continuous cultivation over the generation of various crop landraces in farmer’s field is another method of *in-situ* (on farm) conservation in NEH. Apatani plateau (Lower Subansiri district) and Khampti Valley (Lohit district) of Arunachal Pradesh is an example of *in-situ* conservation practice for rice landraces. Habitat preservation, another approach of *in-situ* conservation, is also popular in this region. *Nepenthes khasiana* (in Jaintia hills), *Liliummacklinae*and*Zizanialatifolia* (in Manipur) *Coptisteeta* (in Dibang Valley) and *Gymnocladusassamicus* (in Tawang district of Arunachal Pradesh) are examples of such kind of conservation.

North Eastern region being one of the primary and secondary centers of many crops exhibits wide variability for several cultivated crops and other plant species. Varied altitude, climatic conditions and topography support the cultivation of a large number of domesticated plant species, and thus facilitating generation of a spectrum of genetic variability under natural or farmers' selection pressures. Agriculture and allied activities are the main source of livelihood for the people of North East region. The cultivation of crops is done in terraced fields, along steep hillsides as well as in plains. Net sown area is highest in Assam (35.1%) followed by Tripura (26.7%). Arunachal Pradesh has the lowest net sown area (3.7%) in this region. Cropping intensity is highest in Tripura (156.5%) followed by Manipur (152.1%), Mizoram (136.4%) and Assam (123.6%). Traditional farming system is *jhum* or shifting cultivation. About 1.6 m ha area is under *jhum* cultivation. Among the cultivated crops, vast diversity exist in rice, maize and beans. In Sikkim, the economically important crops are large cardamom and tea, however maize and rice are also cultivated in considerable area. In Arunachal Pradesh, rice , maize and oilseeds are the major crops. In Assam, rice is the main crop and cultivated widely in low land valleys. Jute is cultivated in inundated flood plainsand hill slopes are utilized for tea cultivation. Other crops include wheat, oilseeds, pulses, etc. Meghalaya is an agricultural state whereapproximately 80% of population have agricultural livelihood. Common crop is rice, grows both in hill terraces and in the valleys. Alternate crops are maize, potato, vegetables, cotton and fruits. Besides the major food crops of rice and maize, several horticultural crops like citrus, pineapple, banana, guava, litchi, jackfruit, plum, pear, peach, etc. are also cultivated in this state. Potato, ginger, turmeric, black pepper, arecanut, cinnamon, betel vine, jute, short-staple cotton, mustard, etc are cultivated as cash crops. The major crops of Manipur, Mizoram, Nagaland and

Tripura are rice, maize, millets, oilseeds (rapeseed, mustard and niger), potato, fibres, sugarcane, yams and taros. Farmers also cultivate different types of vegetables like brinjal, chilli,onion, tomato, carrots, melons, spinach, cucumber etc., and a variety of plantation crops such as pineapple, citrus, cashewnut, jackfruit, tea, etc. The tribal dominated areas of these states are particularly rich in local variability of cereals (rice, maize, barley and wheat), pseudocereals (buckwheat, *Chenopodium*, amaranth and job's tear), millets (finger millet and foxtail millet), legumes (rice baen, black gram, winged bean, adzuki bean, *Dolichos*, soybean, sword bean and peas), oilseeds (*Brassica* spp., perilla and sesame), vegetables (brinjal, cucurbits, lady's finger and leafy vegetable such as amaranth, lai, lafa and spinach), fibres (*Corchorus*spp., tree cotton, kenaf and mesta), tuber and rhizomatous crops (taros, yam, ginger and turmeric), fruits (citrus, banana, mango, jackfruit and bael),spices (chilli and piper) and plantation crops (tea, arecanut, bamboo and canes). The diverse topography, altitude and climatic conditions of North Eastern region offers a great scope for cultivation of a wide variety of horticultural crops like tropical, subtropical, temperate vegetables and fruits. Among economically important plants variability is found in bamboos (78 taxa; Hore, 1998) orchids and aroids (15 species; Hooker, 1893). A plenty of herbal wealth exists in this region extending from the dry alpine scrub zone and sub-tropical zone in Arunachal Pradesh and Sikkim to tropical moist deciduous forest and tropical wet evergreen forest in Assam and Tripura. About 138 herbaceous and 59 tree species of medicinal and aromatic plants are being exploited commercially and traditionally to cure several diseases such as cancer, tuberculosis, leprosy, malaria, paralysis, etc. Several other plantspecies of this category need proper exploitation. These include *Coptisteeta*, *Pyrethrum* sp. and lemon grass.Tremendous potential diversity exist in wild species under different crop usage categories such as fruits, tuber and rhizomatous crops, vegetables, legumes, etc., which warrant it future exploitation. It is estimated that among the total 326 species of CWR, at least 132 prevail in the North Eastern region (Gautam*et al*., 1999). The occurrence of these species is primarily reported from secondary vegetation, open forest habitats of disturbed sites except for species like *Amomum, Musa,* etc., which also occur in dense forests. In this region, the compositions of dicotyledonous species are almost three times more than the monocotyledonous species. The dominant species belongs to the families are Orchidaceae, Poaceae, Cyperaceae, Rosaceae, Leguminosae, Asteraceae, Fagaceae, Magnoliaceae, Dipterocarpaceae, Urticaceae, Moraceae, Melastomataceae and Euphorbiaceae. North East India shares the maximum number of endemic and rare plant species showing discontinuous distribution. Many of them are threatened and need to be protected. Out of 1500 threatened forest species in India, about 650 species are from this region (Hore, 1998).

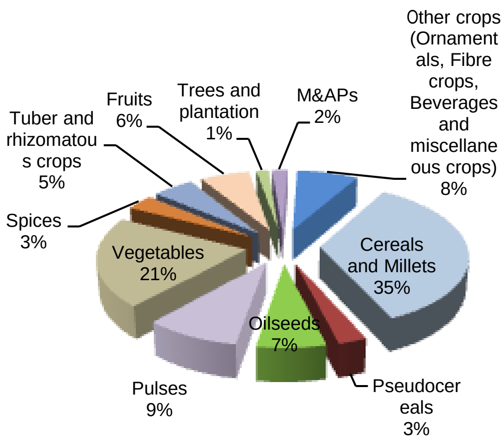
The management of such a vast wild as well as cultivated plant genetic diversity is a prodigious task. Wild and undisturbed forest areas are being maintained by the state forest departments. The tribal communities traditionally maintain the cultivated plants and their landraces. The ICAR-National Bureau of Plant Genetic Resources (NBPGR) established in August 1976 under the auspices of Indian Council of Agricultural Research (ICAR) has the mandate to act as nodal institute at national level for acquisition and management of indigenous and exotic plant genetic resources (PGR) for food and agriculture, and to carry out supportive research and capacity building through human resource development. The Bureau has its main campus at New Delhi with 10 Regional Stations located in different agro-ecological/ phyto-geographical regions of the country. The mandate of NBPGR is to act as nodal institute at national level for acquisition and management of indigenous and exotic plant genetic resources (PGR) for food and agriculture, and to carry out related research and human resource development for sustainable growth of agriculture with following objectives:

- To plan, organize, conduct and coordinate exploration and collection of desired indigenous and exotic PGR.

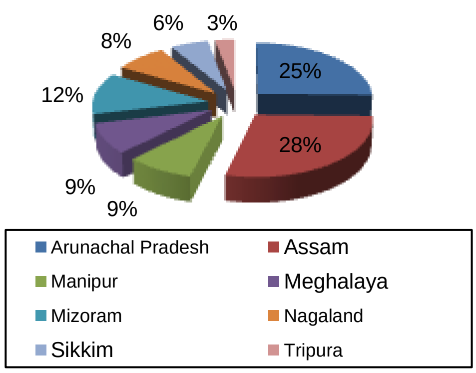
- To undertake introduction, exchange and quarantine for augmenting PGR.
- To characterize, evaluate, document and conserve crop genetic resources and promote their use in collaboration with other national organizations.
- To develop genomic tools, technologies, and approaches to discover and validate the function of genes of importance.
- To develop bio-informatics tools for exploitation of genomic information for enhanced utilization of PGR.
- To develop information network for effective utilization of PGR.
- To conduct research, undertake teaching and training, develop policy guidelines and create public awareness on PGR.

The major activity in NEH region is collection of germplasm, in addition to other PGR activities. Around 290 explorations trips were undertaken and over 30000 collections have been made. Crop group-wise maximum accessions collected in cereal and millets (32%) with rice and maize being the major crops, followed by vegetables (20%), legumes (9%) and other crops comprising of wild relatives of crops, ornamentals, fibre crops, oilseeds, fruits, tuber and rhizomatous crops and spices. In last five years forty five explorations were carried out in all the eight states of NE Region namely Arunachal Pradesh (12), Assam (5), Manipur (6), Meghalaya (2), Mizoram (5), Nagaland (7), Sikkim (3) and Tripura (5). In total, 3,103 germplasm samples (190 taxa) were collected – cereals and millets (992), pseudocereals (104), pulses (265), oilseeds (107), fibres (61), vegetables (964), fruits (158), spices and Medicinal & Aromatic Plants (M&AP) (73), crop wild relatives (322) and minor economic species (57).The noticeable collections include: cold tolerant rice genotypes (Arunachal Pradesh), scented rice (‘Chakhao’) rice germplasm (Manipur), soft rice (Assam), tall and high tillering rice (Nagaland) Mishmi and ‘Khamati rice (Arunachal Pradesh), maize landraces (Mizoram, Nagaland and Sikkim), frost tolerant type of banana (Arunachal Pradesh), tree cotton with long boll (Mizoram), natural coloured (brown-linted) cotton (Tripura), highly pungent bird’s-eye chilli (Mizoram), brown-netted cold tolerant cucumber (Meghalaya), carotenoid-rich cucumber (Mizoram and Manipur), scented ash gourd (Mizoram, Arunachal Pradesh and Tripura), extra-long-fruited yard long beans (Nagaland), scented sponge gourd (Tripura), etc.Indigenous knowledge documented from Barak Valley (Assam), Manipur, Mizoram and Nagaland.

Crop diversity collected



State wise collection



Many crop landraces have been collected for the first time, besides new species, distribution records, and uses. While genetic erosion has been apparently evident in twolevels – loss of crop species (e.g. drastic reduction in cultivation of Job’s-tears and buckwheat) and varietal erosion, its degree varies greatly with respect to topography (more in plains) and ethnic group (e.g. Nagaland tribal groups generally prefer to their own landraces). Conversely, exotic vegetables(e.g. *Abelmoschuscaillei*, *Capsicum chinense*and *C. frutescens*, *Solanumaethiopicum*and *S. macrocarpon*) and semi-wild/semi-domesticated edible species contributing to diversity in food habits through supplementing/ substituting native crops was also noted.The collected landraces require rigorous characterization and evaluation using latest toolsso as to unearth their potential for crop improvement, besides identifying probableduplicates as it is possible that the same material is being named differently by different tribal group. Explorers often faced challenges in collecting enough number of seeds in samples ofcrops cultivated at subsistence level (e.g. in kitchen garden), having big-sized seeds (e.g.cucurbits, beans), and also in crop wild relatives; which demanded the need for seedmultiplication at isoclimatic conditions before conservation/evaluation. Also constraints ingermplasm collection had been experienced from some areas, particularly inManipur, western Assam, and in some districts bordering Myanmar. Based on collected germplasm, gaps are identified for future exploration especially in a fine grid fashion in this region. Road connectivity to interior areas and in higher reaches in the recent years would serve as an opportunity to collect germplasm from unexplored areas in forthcoming years. Studies on ethno-botany of many tribals including domestication trends of wild economic plants from this area need an impetus. Information available in this report will help in the identification of crop diversity rich pockets, preparation of PGR maps, and establishment of *in situ* gene sanctuaries for important crop wild relatives and minor fruits.

Following are some of the thrust area for effective agro-biodiversity management in NEH region:

1. Accessions from widely distributed habitats are required to be augmented and conserved. Special missions are needed to be undertaken in the area of occurrence of rich diversity to collect and conserve the germplasm using *ex-situ* and *in-situ* approaches.
2. Emphasis needs to be given on targeted collection, conservation and sustainable management of economic germplasm and their wild relatives.
3. Efforts are needed in conservation of some of the hot spot and critical habitats such as *Citrus* Gene Century of Meghalaya.
4. Gaps identified in the management of the PGR should be bridged through appropriate research and development (R & D). Different organizations / institutes engaged in the R & D work should come together and work jointly to conserve the diversity.
5. There is a need of systematic documentation and updating the scientific data base.
6. Development of core sets for agro-climatic regions and/or agro-biodiversity centres
7. Prioritizing *in situ* conservation and linking with protected area network
8. Enrichment of germplasm holdings both in seed banks and FGB in view of future needs
9. Characterization and evaluation of germplasm for identification of trait-specific germplasm
10. Awareness generation at various levels through formal and informal education need to be emphasized in conservation of biodiversity.
11. Farmers have played a crucial role in the conservation of biodiversity. It is important that society recognizes and encourages this role through incentives, such as benefit sharing.

Utilization of Anther Culture Approach to Develop New Varieties from Hybrid Rice Cultivars in *Indica* Rice

G.J.N.Rao, G.Sahoo, P.V.N.Kishore, R.Misra and R.N.Rao

National Rice Research Institute, Cuttack -753 006

Doubled haploid breeding, an innovative approach, through anther culture, can hasten the breeding cycle of crop plants through production of homozygous recombinants in a single step from a cross combination. Doubled haploid approach offers several advantages over the conventional approach and can be easily integrated into breeding programs. The reproducible protocols developed at the Central Rice Research Institute made it possible to culture *indica* rices which are known to be recalcitrant. One of the attractive approaches of doubled haploid breeding was to isolate excellent genetic recombinants from elite hybrid rice cultivars. Though the yield advantage achieved through hybrid rice is significant, two major considerations i.e. high cost of the hybrid seed and ii. quality of the produce continues to be the major impediments for its large scale adoption in India. The doubled haploid approachcan effectively address both the problems and also offer significant savings in time, money, labor and space. The present study reports successful generation of a large number of doubled haploids from the elite hybrid rice cultivars like PHB 71, PA 6201, DRRH 1, KRH 2, Pusa RH 10, Ajay and Rajlaxmiusing theimproved protocols. For the first time in India, the efficacy of the doubled haploid approach was demonstrated through development and release of Satya Krishna (CR Dhan 10) and Phalguni derived from PHB 71 and KRH 2, respectively. The utility of doubled haploid breeding in shortening the breeding cyclein the rice varietal improvement will be discussed in detail.

Genetic Diversity Studies in Forage Sorghum

A.J. Gaikwad N.S. Bhagat and T.S. Kamdi

Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
Email: nilu.gpb@gmail.com

The research “Genetic diversity studies in forage sorghum” was undertaken to estimate the degree of divergence among the 32 genotypes of forage sorghum and thereby to identify potential and diverse genotypes for their utilization in hybridization programme by using D^2 statistics. The canonical analysis revealed that about 98.66 per cent of the total variation was accounted by the first three canonical roots. In vector I, green fodder yield, leaf breadth and plant height were important sources of variation. Whereas protein content, plant height and number of leaves were important sources of variation in vector II. In vector III dry fodder yield plant height, number of leaves and leaf stem ratio played important role in variation, the importance of these characters was also confirmed on the basis of variance of cluster mean. Considering the mean statistical distance as a guideline to select the divergent genotypes, 20 cluster combinations were identified. The divergent parents selected from these combinations may yield better segregants in hybridization programme. However, when divergent parents are crossed, heterosis is not always bound to occur. Therefore, while selecting the divergent parents from a particular cluster the information on mean and standard deviation of the genetic variance among the divergent parents should be taken into consideration as practically suggested by Arunachalam and Bandyopadhyay (1984). Hence, on the basis of mean and standard deviation of parental divergence, 94 cross combination have been finally suggested which are expected to yield desirable genetic gain in breeding programmes.

Keywords: *Genetic diversity, Mahalanobis D^2 statistics, Forage Sorghum*

Evaluation of Soybean Genotypes for Agro-morphological Traits in Meghalaya

Amit Kumar*, Avinash Pandey#, Banshanlang I, Sarika K and Anup Das

Division of Crop Production, ICAR Research Complex for NEH Region, Umiam, Meghalaya
 # ICAR-Indian Institute of Agricultural Biotechnology, Ranchi
**Email: amit4118@gmail.com*

Thirty-nine soybean genotypes were evaluated for agro-morphological traits and genetic parameters along with three checks *viz.*, RKS 18, JS 97-52 and JS 335. Analysis of variance and mean performance for yield and its components revealed significant differences among all the genotypes for all the characters. Significant correlations were found for plant height, test weight, number of branches per plant, number of clusters per plant and number of pods with yield per ha. Plant height was significantly correlated with number of branches per plant, number of clusters per plant, number of seeds per pod and number of pods panicle length. Test weight had shown negative significant correlations with days to fifty percent flowering, days to maturity and plant height. A Cluster diagram based on agro-morphological traits proposed two major clusters I and II. Among the clusters, cluster I was the largest with 22 lines whereas cluster II represented 20 lines. The crossing between distantly placed superior iso-cytoplasmic restorer lines of above two cluster pairs may provide desirable heterosis for developing high yielding varieties of soybean. The 3 principal components having greater than one eigenvalues contributed 67.32% of the total variation among forty-two genotypes of soybean. It was found that principal component 1 (PC1) contributed 31.27%, whereas PC2 and PC3 contributed 23.46% and 12.59%, respectively of the total variation. The traits, which contributed more positively to PC1, were days to flowering, days to maturity and plant height. Yield per plant, number of branches per plant, number of clusters per plant had contributed more positively to PC2. A trait by genotype biplot was generated to facilitate the visualization of interrelationships among traits and genotypes. Grain yield was positively associated with number of clusters and number of branches and negatively associated with test weight. Genotypes namely, PS 1569, DSb 30-2 and VLB 202 with long vectors were those that have extreme values for yield and its component traits whereas BAU 572, JS 97-52 and NRC 123 represented the highest maturity group.

Keywords: *Agro-morphological traits, Correlation, PCA, Soybean, Trait by Genotypes Biplot*

Genetic Diversity Analysis of Rice Varieties by Using Fluorescence-Based Microsatellite Markers

Banshanlang Iangrai[1]*, Patu Khate Zeliang[2], Arunava Pattanayak[3], Amit Kumar[1] and Anup Das[1]

[1]*Division of Crop Production, ICAR Research Complex for NEH Region, Umiam Meghalaya*
[2]*KVK, Peren, ICAR, Nagaland Centre, Medziphema*
[3]*ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora, Uttarakhand, India*
**Email: banshaniangrai@gmail.com*

Molecular characterization of the genotypes gives precise information about the extent of genetic diversity which helps in the development of an appropriate breeding program. In the present study, a total 30 fluorescently labelled Rice Genomic Noncoding Microsatellite Markers (RGNMS) were used across 68 rice genotypes for their characterization and discrimination. Among these 30 markers, 29 microsatellite markers showed polymorphism. A total of 609 alleles were detected at the loci of 30 microsatellite markers across 68 rice genotypes. The number of alleles per locus generated by each marker varied from 2 (RGNMS5 and RGNMS45) to 40 (RGNMS141) alleles, with an average of 20.3 alleles per locus. The polymorphic information content values ranged from 0.02 to

0.94 with an average of 0.74. RGNMS41 was found to be the best marker for the identification of 68 genotypes as revealed by PIC values (0.94). The frequency of most common allele at each locus ranged from 20% (RGNMS141) to 98% (RGNMS5 and RGNMS45). A moderate level of gene diversity exists among 30 loci studied across 68 rice genotypes, ranged from 0.03 to 0.93 with an average of 0.75. The heterozygosity ranges from 0.01 in RGNMS45 to 0.85 in RGNMS165 with an average heterozygosity of 0.42. The pair-wise genetic dissimilarity co-efficient indicated that the highest genetic distance was obtained between TRC-2007-1 and Charong phou (86.71 %) followed by TRC-2007-1 and Motodhan (86.47 %), Sukardhan and Aaha (84.24 %), TRC-2007-1 and Aaha (83.83 %), Satabdi and Posimot (83.71%), Sukardhan and Posimot (83.26 %) and Megilai and Charong phou (82.40 %). The lowest genetic dissimilarity among rice landraces was between Vietnam 1 and Vietnam 2 (31.71 %), followed by Khougjei phou and Col-4 (32.60 %), Sundari and IR-64 (34.06 %) and NDR-97 and Anjali (38.09 %). The dissimilarity values obtained for each pair wise comparison of SSR markers among the 68 rice genotypes were used to construct dendrogram based on Rogers coefficient and were grouped into four clusters. Maximum number of genotypes (21) in cluster III followed by cluster IV (19), Cluster I (17) and cluster I (11). The microsatellite marker based molecular fingerprinting could serve as a sound basis in the identification of genetically distant accessions and duplicate sorting of the morphologically close accessions.

Keywords: *RGNMS, Fluorescently Labelled SSRs, Heterozygosity, Gene Diversity, PIC*

Genetic Variability, Heritability and Genetic Advance Studies in Sweet Potato (*Ipomoea batatas* L.)

Pankaj Singh Bhadauriya, Chandra Deo, C. N. Ram, S.K.Verma and Sudheer Singh
Department of Vegetable science CHF, CAU, Pasighat-791102, East Siang, Arunachal Pradesh
Email:chandranduat@rediffmail.com

Thirty six diverse genotype of sweet potato collected from different location of India were evaluated for eighteen quantitative and qualitative characters in Randomized Block Design with three replications at Main Experiment Station, Department of Vegetable Science, NDUAT, Kumarganj, Faizabad(UP) during October, 2011 to March, 2012. On the basis of mean data, the existence of very high degree of variability was observed in the germplasm. The genotypes, NDSP-65 (375g) followed by SP-594 (354g), 187017 (336), NDSP-1-4 (333) and NDSP-1-3 (324g) were the best yield performer for tuber yield per plant. High genotypic coefficient of variability and phenotypic coefficient variability were estimated for number of branches per vine followed by internodal length, length of vine, number of leaf per vine, girth of tuber and acidity. High heritability coupled with high genetic advance in percent of mean were recorded for number of branches per vine, internodal length, length of vine, number of leaf per vine, acidity, average weight of tuber, number of tubers per vine, TSS and width of leaf. Tuber yield (q/ha) followed by tuber weight, internodal length, specific gravity and tuber length showed positive significant correlation with tuber yield per plant while, TSS and moisture per cent showed negative significant correlation with tuber yield per plant. Path coefficient analysis revealed that, tuber weight followed by tuber per vine, tuber yield (q/ha) showed higher value of positive direct effect on tuber yield per plant while, tuber yield followed by specific gravity via tuber weight and branches per vine, length of vine and laves per vine via tuber per vine, vine length and leaves per vine showed positive indirect effect on tuber yield per plant. Total of 36 genotype were grouped in to seven clusters. The highest intra cluster distance was found in cluster V and inter cluster distance between cluster IV and VI. Internodal length (31.59%) number of branches per vine (21.90%) and acidity (21.11%) were found as the important traits in clustering the genotype with different groups. Based on above finding it might be concluded that these are existing sufficient variability in the available germplasm. Genotype (NDSP-65 followed by SP-594, 187017, NDSP-1-4 and NDSP-1-3) may be exploited in future after further evaluation for stability test.

Improvement of Oil Quantity through Heterosis in Sunflower (*Helianthus annuus* L.)

Kirandeep Kaur[1]*, S K Dhillon[2], Mohd Shamshad[2] and B S Gill[2]

*[1] PAU Regional Reseach Station, Abohar, [2] Dept of Plant Breeding and Genetics, PAU, Ludhiana, *Email: kiran.kaur4554@yahoo.com*

The present investigation was focused on estimation of heterosis for oil content as well as oil quality of newly developed sunflower (*Helianthus annuus* L.) hybrids. 96 Hybrids along with their parents i.e. three CMS A-lines (67A, 47A and 11A) and 32 Restorer lines were evaluated in randomized block design with three replications at Punjab Agricultural University, Ludhiana during 2015 and heterosis was estimated over mid-parent, better parent and standard heterosis over commercial check PSH-1962. For oil content magnitude of mid-parent heterosis ranged from 12.54 (67A x P211R) to 33.34 (11A x P178R). Heterobeltiosis ranged from 23.83 (11A x P211R) to 31.95 (11A x PP178R). The standard heterosis over check PSH-1962 ranged from 17.89 (11A x P212R) to 22.26 (11A x P175R). Mid-parent heterosis for fatty acids such as palmitic acid ($C_{16:0}$) ranged from -42.79 (67A x P196R) to 65.28 (47A x P198R), for stearic acid ($C_{18:0}$) ranged from -48 (11A x P180R) to 164.83 (67A x P172R), for oleic acid ($C_{18:1}$) ranged from -42.76 (11A x P192R) to 64.82 (47A x P187R) and for linolic acid ($C_{18:2}$) ranged from -51.81 (47A x P187R) to 41.59 (11A x P1190R). Better parent heterosis for palmitic acid -49.39 to 46, stearic acid -58.4 to 123.91, oleic acid -49.35 to 58.07 and for linoloc acid -53.01 to 37.88. From 96 investigated hybrids 58 were recorded significantly positive heterosis over mid-parent, whereas 41 hybrids were recorded significant positive heterosis over better parent for oleic acid which is be most important unsaturated fatty acid. So from above study it is concluded that the mid and better parent heterotic effects were observed to improve oil quantity as well as oil quality of the parent of these eight hybrids and are suggested for use in sunflower breeding program.

Population Status and Conservation of Endangered Tree Species *Amentotaxus assamica* in Arunachal Pradesh

Lyngdoh, N[1*], Mao, A. A[2], Ravikanth G[3], Mukul Kumar[1] & Pandey, AK[4]

[1&4]College of Horticulture and Forestry, Central Agricultural University, Arunachal Pradesh-791102
[2] Botanical Survey of India, Regional Centre, Shillong, Meghalaya-793003
[3] Ashoka Trust for Research in Ecology and the Environment, Royal Enclave, Bangalore- 560 064
*Arunachal Pradesh-791102, India, * Email: lyngdoh@gmail.com*

Amentotaxus assamica Ferguson (Family: Taxaceae) is a rare and endemic tree confined to a small pocket of forest in the Anjaw district of Arunachal Pradesh, India. In the last population survey of the species, reported in the year 2006, only 22 individual were recorded with very few regenerants. Consequently, there has been growing interest in population exploration and conservation of the species. In an initiative by the Dept. of Biotechnology, New Delhi, a program was launched to carry out extensive population survey, quantify genetic variation of remnant populations and conservation of the species. Between 2013 and 2015 we conducted extensive survey in various areas of the Anjaw district especially the Dalai Valley, where it has been reported earlier. With the help of locals, we located four new populations of the species in the Dalai valley. Two of the populations had tree density of 104 and 175 individuals per ha. Sapling and seedling density at those two sites was also found to be high. At other sites the number of individuals located was only 4 and 6. Genetic analysis for two populations based on 7 ISSR primers showed Shannon Index values of 0.309 and 0.510. Conservation strategies and challenges for the species are discussed.

Keywords*: Eastern Himalayas, Shannon index, Biodiversity, Dalai Valley, Conservation*

Genetic Diversity Analysis in American Cotton

N.S.Bhagat, B.R.Patil and T.S.Kamdi

Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
Email:nilu.gpb@gmail.com

A study was undertaken to estimate the degree of divergence among the 50 introgressed lines of American cotton using multivariate Mahalanobis D^2 statistics at Cotton Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. These genotypes were grouped into seven clusters. Cluster I had highest number of genotypes (19) followed by cluster III (14), cluster IV (8) and cluster II (6), whereas, cluster V, VI and VII represented by single genotypes. The maximum genetic distance was observed between cluster V and cluster VII (D=9.66). Plant height recorded the maximum contribution (22.29%) towards genetic divergence. Cluster VII showed highest cluster mean values for the characters seed cotton yield per plant (78.67g), boll weight (3.7 g) and number of bolls per plant (21.30).Hence, these characters should be considered during formulation of hybridization program.

Keywords: *Genetic diversity, Mahalanobis D^2 statistics, Cotton*

Biodiversity and Conservation of Hymenopteran pollinators in NEH, India

Rachna Pande[1], Sandip Patra[2], Prabhulinga T[1]., Vivek Shah[1], Madhu TN[1]

[1]ICAR- Central Institute for Cotton Research, Nagpur, Maharashtra,
[2]ICAR RC for NEH Region, Umiam, Meghalaya – 793 103
**Email: rachna.ento@gmail.com*

Northeastern Himalayan region of India is one of the hotspots of the biodiversity in the world. Pollinators are a key component of global biodiversity, providing vital ecosystem services to crops and wild plants. Worldwide bees are the most important group of pollinators, visiting more than 90% of the leading crop types. In India, Northeastern Region roughly accounts for 6 per cent of the country’s area and rich in biodiversity. Native hymenopteran bee pollinators are known to be effective pollinators in several important crops in the region. As pollinator fauna is concerned, the region have all four types of honeybee species, other important bee pollinators and also have stingless bees in abundant in local areas as a major pollinators. Some economic important bee families of this region are Halictidae, Andrenidae, Megachilidae, Colletidae, Anthophoridae and Apidae. For many crops, the most widely used pollinators are the Honeybee (*Apis* spp.). However, honeybee colonies have been suffering decline due to a variety of factors in all over the world. So, it is imperative that we popularize the pollinators and conserve the alternative pollinators for our crops. In this context, the region has very fine floral rewards and variety of orchids as bee flora. Dominant families of this region, useful to bees are Fabaceae, Asteraceae, Scorphulariaceae, Rosaceae and Euphorbiaceae etc. The region also has some important multipurpose tree species which support the pollinators in supplying both nectar and pollen. During off season some of the weed sp. (*Buddleja asiatica, Ageratum conyzoides, oxalis sp.* etc.) provide nectar and pollen to the bee pollinators at different extent.

Keywords: *Biodiversity, Conservation, Bee, Pollinator, Northeastern Himalayas*

Evaluation of Growth Performance of 12 Bamboo Species under Different Planting Designs in Mid-Hills of Arunachal Pradesh

Rajesh A. Alone, Nirmal and H. Kalita

ICAR Research Complex for NEH Region, Arunachal Pradesh Centre, Basar 791 101
E mail: rajesh.scientist@gmail.com

The Bamboo is an important resource in the Indian socio-economic cultural-ecological-climate functional context with 1500 recorded uses. The most important traditional uses include housing, food and material for handicrafts. Worldwide, more than 2.5 billion people trade in or use bamboo. Modern manufacturing techniques allow the use of bamboo in timber-based industries, to provide bamboo flooring, board products, laminates and furniture. Bamboo is becoming a substitute for wood in pulp and paper manufacturing; about 25 per cent of the fibre used in the Indian paper industry each year comes from bamboo. Arunachal Pradesh occupies an important position among the bamboo bearing states of India. Bamboo forms a major constituent of Agroforestry systems of Arunachal Pradesh. Bamboos have become inseparable part of the culture and day to day life of the people particularly those living in the rural areas of Arunachal Pradesh.

An experiment was carried out at ICAR research farm, Gori, Basar in mid-hills of Arunachal Pradesh to observe the effect of spacing on the growth parameters of 12 bamboo species. The 12 bamboo species *viz. Bambusa balcoa*, *B. pallida*, *B. nutans*, *B. tulda*, *B. cacharensis*, *B. arundinacea*, *Dendrocalamus hookerii*, *D. sikkimensis*, *D. hamiltonii*, *D. sahnii*, *D. asper* and *Cephalostacyum pergracile* were planted at 3 different spacing *viz.* 5m x 5m, 6m x 6m and 7m x 7m in 3 replications in the year 1999. After18 years of planting the following results were obtained. At 5m x 5m spacing, the maximum clump circumference was recorded in *B. cacharensis* (16.08±0.06m) followed by *D. hamiltonii* (10.1±0.08m). In this spacing, the highest number of culms per clump was recorded in *D. hamiltonii* (63±0.26) followed by *D. sikkimensis* (58±0.74). At 6m x 6m spacing, the maximum clump circumference was recorded in *B. cacharensis* (13.9±0.08m) followed by *B. nutans* (10.5±0.1m). In this spacing, the highest number of culms per clump was recorded in *D. sahnii* (67±0.86) followed by *D. sikkimensis* (63±0.71). At 7m x 7m spacing, the maximum clump circumference was recorded in *B. nutans* (11.4±0.09m) followed by *B. pallida* (11.1±0.1m). In this spacing, the highest number of culms per clump was recorded in *B. pallida* (77±0.80) followed by *D. sikkimensis* (71±0.83). It is concluded that *D. hamiltonii* is performing better than others at 5m x 5m spacing in terms of number of bamboo culms per clump. *D. sahnii* are performing better at the 6m x 6m spacing and *B. pallida* and *D. sikkimensis* are performing better at 7m x 7m spacing.

Keywords: *Bamboo, Spacing, Clump Circumference*

Predominance of Lycosid Predatory Spider in Different Rice Ecosystems of Indo-Bangladesh Border

Samik Chowdhury[1*], T. Boopathi[1], Saurav Saha[1], S. B. Singh[1], Lungmuana[1], S.K. Dutta[1], Vishambhar Dayal[1], D. M. Firake[2], Anup Das[2] and S. V. Ngachan[2]

[1]ICAR Research Complex for NEH Region, Mizoram Centre, Kolasib, Mizoram-796081
[2]ICAR Research Complex for NEH Region, Umiam, Meghalaya-793103
Email- samikchowdhury33@gmail.com

Northeast India is one of the potential zone of Organic farming region and around most of the farmers not using insecticide for insect control and still rice ecosystem has rich with predator and parasitoids. Spider is one of the most abundant beneficial arthropods in rice ecosystem of Mizoram. Most of them are polyphagous predator in rice ecosystem, able to feed on various insect pest of rice ecosystem in Mizoram state. In the present study, our main objective was to describe the diversity of spider communities in the rice growing area of Mizoram. The study was conducted, in rice belt in Mizoram in Kolasib, Aizawl, Lunglei, and Chemphai distrct. About 1500 specimens were collected from different district of Mizoram and conserved for further characterization and evaluation. A total of 10 family, 20 genera and 31 species were collected from different rice productive area of Mizoram. The most dominant species were *Lycosa pseudoannulata* (Boosenbery & Stard) followed by *Oxyopes Lineatipes* (C.L. Koch), *Oxyopes javanus* Thorell, *Tetragnathus maxillosa* Thorell, *Thomisus pugilis* and *Phidippus audax*. The collective contribution of these six species was 70.52%. Lycosidae was the most dominant family in the ground sample while Tetragnathidae was the most dominant in the foliage sample. Immature of *Lycosa pseudoannulata* was peak recorded in late October.

Keywords: *Mizoram, Rice ecosystem, spider, Lycosidae and Tetragnathidae*

Genetics of *Heliothis* Resistance in Chickpea (*Cicer arietinum* L.)

S. D. Jadhav, N.S. Bhagat T.S. Kamdi and R.S. Mali

Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
Email:nilu.gpb@gmail.com

Line x Tester model was selected for the study. The 2 females (lines) *viz*., JAKI-9218 and ICCV-2 and 8 males (Testers) *viz.*, HC-5, ICC-506, PKV Harita, Chandrapur chanoli, JG-62, Gulak-1, AKG-10-1 and Bushy mutant and their 16 crosses were evaluated in Randomized Block Design, during *rabi* season of 2011-12. The data were recorded on the traits related with pod borer resistance *viz- Per cent* pod borer damage, Larval count at vegetative, flowering and pod formation stages and *Per cent* malic acid content, on five randomly selected plants. It was found that, non additive type of gene action was important in the inheritance of *per cent* pod damage. Additive type of gene action was involved in the expression of *per cent* malic acid content. The *per cent* malic acid content exhibited highly significant negative correlation with larval count at vegetative stage, at flowering stage, at pod formation stage and *per cent* pod damage.

Keywords: *Pod borer Resistance, Combining Ability, Chickpea, Correlation*

Heterosis in Relation to Yield and Yield Contributing Traits in Chickpea (*Cicer arietinum* L.)

S.D. Jadhav, N. S. Bhagat and T.S. Kamdi

Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
Email: nilu.gpb@gmail.com

Line x Tester model was selected for the study. The 2 females (lines) *viz*., JAKI-9218 and ICCV-2 and 8 males (Testers) *viz.*, HC-5, ICC-506, PKV Harita, Chandrapur chanoli, JG-62, Gulak-1, AKG-10-1 and Bushy mutant and their 16 crosses were evaluated to know the magnitude of heterosis over mid parent, better parent and two standard check (PKV *kabuli*-2 and Digvijay) in Randomized Block Design at the research field of Pulses Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during *rabi* season of 2011-12. The data were recorded on various yield and yield contributing traits. The cross ICCV-2 x Chandrapur Chanoli showed highest standard heterosis (25.57 %) for number of pods per plant. The highest significant standard heterosis for seed yield per plant was recorded by JAKI-9218 x Gulak-1 (22.08 %) over the best check viz., Digvijay. The promising crosses, JAKI-9218 x Gulak-1, ICCV-2 x HC-5 and ICCV-2 x Chandrapur Chanoli, selected on the basis of mean performance and heterosis response of the crosses have immence practical value as can be exploited for hybrid vigour or to isolate desirable segregants.

Keywords: *Chickpea, Heterosis, Line X Tester*

Genetic Diversity and Population Structure of *Perilla frutescens* (Linn.) Britt. Landraces from Northeastern Hill Region (NEH) of India

S.K. Singh[1*], P.C. Kole[2], A.K. Misra[3], Somnath Roy[4], Lalit Arya[1], Manjusha Verma[1], Rakesh Singh[1], Mukesh Kumar Rana[1] and K.V. Bhat[1]

[1]*ICAR-National Bureau of Plant Genetic Resources, Pusa Campus, New Delhi-110 112, India*
[2]*Palli Siksha Bhavana, Visva Bharti, Sriniketan, West Bengal-721 235, India*
[3]*ICAR-National Bureau of Plant Genetic Resources Regional Station, Umiam,793 103, India*
[4] *ICAR-- Central Rainfed Upland Rice Research Station, Hazaribag, Jharkhand-825 301 India*
**Email: sanjeevs99@rediffmail.com*

In the present study, diversity of 62 accessions of *Perilla frutescens* was assessed using STMS markers. These 62 accessions were collected from Meghalaya, Nagaland, Arunachal Pradesh, Manipur, Mizoram and Sikkim states of the North-eastern Hill (NEH) region of India. Fourteen STMS primers which showed reproducible and clear amplificons were selected for this study. A total of 92 bands were amplified of which 92.8% were found to be polymorphic. Polymorphic Information Content (PIC) for selected STMS primers varied from 0.32 for primer GBFM75 to 0.92 for primer KWPE57. The average PIC was observed to be 0.62, and the gene diversity varied from 0.41 to 0.92. Cluster analysis divided *Perilla* accessions into four groups. Based on population structure analysis three clear populations were obtained. The principal coordinate analysis (PCoA) in *Perilla* accessions with STMS markers showed that the variation explained by the first three components was 31.2%. Analysis of molecular variance (AMOVA), based on the hierarchical clustering showed 6% diversity among population, 87% among individuals and 6% within the individual, whereas the model based approach showed 21% diversity among population, 73% among individuals and 6% within the individual. The study based on genetic diversity and population structure showed that substantial diversity exists in *Perilla* accessions collected from NEH region of India.

Exploration and Collection of Tuber Crop Germplasm in Southern Districts of Assam

[1]G.D. Harish, P. Arun Kumar[1], S. Hajong [1] and A.K. Misra[1]

[1]ICAR-NBPGR Regional Station, Shillong, Meghalaya.
[2]Division of Crop Improvement, ICAR-CTCRI, Thiruvananthapuram, Kerela

An Exploration was conducted in the Southern parts of Assam comprising of Karbi Anglong, Dima Hasao, Hailakandi and Karimgunj districts. The region exhibits tremendous diversity for tuber crops like sweet potato, *Colocasia*, cassava, *Dioscorea*, *Amophophallus*, etc. The topography, soil, temperature and rainfall range are well suited for tuber crops cultivation. These tuber crops have potential to achieve nutritional security if brought into better agronomic background, by selecting high yielding types with superior nutritional composition. Tapioca, *Colocasia* and *Dioscorea* are common crops grown in the Jhum lands. Sweet potato and *Colocasia* are grown both in Jhum lands and the plains. In species *Dioscorea*, both *Dioscorea alata* and *D. esculenta* are grown in the backyards as well as harvested from the wild. Similarly, diversity in *Colocasia*, *Xanthosoma* and *Amorphophallus* was also observed. The crops were also found as mixed crop in Jhum-lands along with ginger, chilli, brinjal, beans, etc. A total of 89 tuber crop accessions comprising of yam (35), taro (28), sweet potato (8), *Xanthosoma* (6), cassava (5), arrow-root (4), elephant yam (2) and *Stemona tuberosa* (1) were collected. Out of four districts covered, diversity in yam and taro was observed in Karbi Anglong and Dima Hasao indicating greater scope for taxonomic studies. Typical to the North East tribal culture, women play leading role in all the farm activities. There is excellent scope for multi-crop explorations for both crop wild relatives as well as cultivated plants especially crops such as cucurbits, leafy vegetables, brinjal, cowpea and maize.

Keywords: *Assam, Exploration, Diversity, Tuber crops*

Assessment of Genetic Diversity among the Rice (*Oryza sativa* L.) Parental Lines using Morphological and Simple Sequence Repeat (SSR) Markers

Amit Kumar[1,2], Vidya Sagar[1,3], Vikram Jeet Singh[1*], Vivek Kumar Singh[1], Prolay Kumar Bhowmick[1], Gopala Krishnan S[1] and Ashok Kumar Singh[1*]

[1]Division of Genetics, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India;
[2]Plant Breeding, ICAR Reserach Complex for NEH Region, Umiam, Meghalaya
[3]ICAR-Indian Institute of Vegetable Research, Varanasi, India
Email: jeet2012vikram@gmail.com

Genetic diversity of 100 iso-cytoplasmic restorer lines were assessed at agro-morphological and molecular levels using 50 simple sequence repeat markers identified under generation challenge programme of IRRI. The analysis of variance showed considerable level of genetic variation among genotypes for most of the characters. Clustering based on agro-morphological traits had divided the lines into two major groups. A total of 78 alleles were identified with the effective number of alleles (Ne) and polymorphism information content (PIC) score of 2.48 and 0.26 respectively. The genetic diversity (GD) was estimated ranging from 0.02 to 0.62 with an average of 0.32. Neighbor-joining (NJ) analysis showed that the iso-cytoplasmic restorer, maintainer and elite restorer lines were arranged into three main distinct groups. Three out of four maintainer lines (Pusa 6B, IR 58025B and RTN 12B) along with commercially available restorer lines namely, PRR 78, DRR 714 and RPHR 1005-R were grouped together in cluster III. Model-based cluster analysis demonstrated that only 83 lines could be distinctly classified into three groups. Analysis of molecular variance showed that total genetic variance among populations, among individuals within populations and within individuals

was 40.88%, 50.38% and 8.74% respectively. These results suggested that the genetic diversity of the iso-cytoplasmic restorer lines was low; simultaneously relationship among maintainer and commercially used restorer lines was poor and close. Hence, it is very necessary to extend the genetic diversity during identification and development of parental lines for sustainable hybrid production.

Keywords: *Cluster Analysis, Genetic Diversity, Molecular Marker, Rice, Population Structure*

Genetic Variability Analysis by Morphological and Molecular Markers in Ricebean (*Vigna umbellata*)

Yengkhom Sanatombi Devi[1], Avinash Pandey[2], Amit Kumar[2], M.A. Ansari[3], Mayank Rai[1,] Wricha Tyagi[1]and Anup Das[2]

[1]College of Post-Graduate Studies, (CAU, Imphal), Barapani-793103, Meghalaya
[2] ICAR Reserach Complex for NEH Region, Umiam, Meghalaya
[3]ICAR Reserach Complex for NEH Region, Manipur Centre
Email: sana.yeng1990@gmail.com

One hundred and twenty genotypes of ricebean (*Vigna umbellata*) were evaluated to analyse genetic diversity using morphological and molecular markers. Data of 23 different quantitative traits were recorded for morphological study and revealed that a wide variability was observed for number of seeds/plant, days to 80% maturity, plant height at 50% maturity and primary branch length. The magnitude of phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all characters. High heritability coupled with high genetic advance were observed in hundred seed weight, yield/plant, number of pods/plant and 100 seed weight. The traits viz., 100 seed weight, days to 80% maturity, pod length and plant height at maturity were the major percent contributing towards genetic divergence in ricebean. All genotypes were grouped into 7 major clusters based on morphological data while 3 clusters from molecular data. Maximum inter cluster distance were observed between cluster I and cluster VII, while cluster IV and V were the minimum distance. Twenty three Simple Sequence Repeat (SSR) loci were polymorphic, producing a total of 59 alleles with an average of 2.57 alleles per locus. Among all 23 primers cG9589C1 was observed as most informative primer. Clustering pattern did not show any relationship between geographic distribution and genotypes grouped into a same clusters. Based on diversity analysis, better parents could be selected for different breeding programmes.

Keywords: *Cluster, GCV, Genetic diversity, PCV, PIC, SSR markers, Vigna umbellata*

Rice bean: An important Potential Crop of Northeast India

Subarna Hajong, Harish G.D. and A.K. Misra

ICAR-National Bureau of Plant Genetic Resources, Regional Station Shillong, Umiam, Meghalaya
Email: subarna.hajong@gmail.com, subarna.hajong@icar.gov.in

Rice bean (*Vigna umbellata* (Thunb.) Ohwi & H.Ohashi) an annual and moderately short-lived legume is identified as an underutilized crop. It is mainly grown for dried pulse, vegetable, fodder or green manure. Cultivated as well as wild forms of rice bean are found distributed in Northeast states while in other parts of the country cultivated forms are prevalent. In Northeast India, the crop is grown either as a mixed crop or sole crop both during summer and winter under shifting cultivation or in kitchen gardens and backyards. ICAR- National Bureau of Plant Genetic Resources

(NBPGR) has been actively engaged in collection of genetic diversity of Asiatic *Vigna* species and other grain legumes from different agro-ecological regions of the country. Efforts for rice bean germplasm collection particularly from Northeast India were initiated in the early 70s. Since then several exploration trips were undertaken in the predominantly tribal inhabited areas of Assam, Meghalaya, Manipur, Mizoram, Tripura, Arunachal Pradesh, Nagaland and Sikkim. The present rice bean germplasm holding at the National Gene Bank is 2,146 and approximately 100 germplasm accessions are currently being maintained as active collection at the Regional Station Shillong. Variability in plant height, stem thickness, number of pod per plant, pod length, seed shape, seed color etc. were observed in the germplasm collection. Promising germplasm accessions for day to maturity (IC524522, IC524068), branches per plant (IC524522, IC538870), pods per plant (IC419518, IC524522), 100 seed weight (IC524074), yield per plant (IC524074, IC524522) were identified which can be utilized in breeding programs. Despite being a crop of great potential and existence of its high diversity in the region, rice bean has been mostly neglected by plant breeders. Genetic diversity analysis of rice bean using molecular markers will also help in documenting the existing genetic variation and identify germplasm lines associated with valuable agronomic traits. This will help in the promotion and commercialization of rice bean cultivation among poor and marginal farmers, thereby ensuring food security of the region particularly in light of the changing global climate and in enhancing livelihood of the poor and marginal farmers.

Keywords: *Rice bean, Underutilized crop, Northeast India*

Increasing rice productivity in acid soil of NEH India: Marker-assisted backcross breeding for introgression of *Pup1* QTL into elite rice varieties

B. Bhattacharjee*, B. Kumari, M. Chakrobarty and J.P. Tyagi
**Centre for Biotechnology, ICAR Research Complex for NEH region, Umiam, Meghalaya*

Upland rice, the staple food of a large number of populations of North East Part of India, suffers serious yield reductions due to Phosphorus deficiency and Aluminium toxicity resulted from serious soil acidity. Therefore, the development of P-efficient rice varieties that can grow and yield better with low P supply might be a key solution for improvement of crop production in this situation. Phosphorus efficiency has typically been described by two separate components: P acquisition efficiency (PAE) and internal P utilization efficiency (PUE). PAE relates to P uptake from the soil and may be affected at the genotype level by differences in root size, root architecture or rhizosphere interactions that enhance Phosphorous bioavailability. PUE on the other hand measures how efficiently the P taken up is utilized to accumulate either grain yield or vegetative biomass. Enhancing P efficiency in plants can be achieved through either improving P acquisition and/or utilization. Use of P efficient genotypes may be a complimentary solution to produce good yield of this annual crops grown on acid soil of upland cropping systems area. Considering the importance of rice as a major crop for North East Part of India, genetic improvement of phosphorus efficiency is therefore an attractive prospect for plant breeders and this would undoubtedly have an enormous impact on global food production. With the identification of Phosphorus uptake 1 (Pup1), a major and large effect Quantitative Trait Locus (QTL) associated with tolerance of phosphorus (P) deficiency in soil also given a golden chance to the plant breeder to utilize Marker Assisted Backcross Breeding technique for development of P efficient rice. Pup-1, locus increases P-uptake under adverse conditions rather than increasing internal P-use efficiency. Keeping this in mind, we targeted for introgression of the major QTL/gene *Pup1* into popular rice varieties of North East India, through the process of marker-assisted backcross breeding to improve P acquisition efficiency (PAE). Cultivation of such QTL introgressed rice varieties (i.e. elite rice varieties possessing *Pup-1*) can be helpful in enhancing the rice production and productivity in different rice growing ecosystems.

Genetic Diversity Study of Few Rice (*Oryza sativa* L.) Varieties of Assam

Jutika Das[1], R. Kandali, S. Rathi and T.C. Sarmah

Department of Biochemistry and Agricultural Chemistry,
College of Agriculture, Assam Agricultural University, Jorhat-13
Email: jutidas5@gmail.com

Rice is the second most important cereal crop next to wheat. The rice husk and bran, the by-products from paddy milling are mostly used as animal feed, for particle board and as fuel source. It is now viewed to have high nutritive value. Being rich in protein and vitamin, rice bran is used as a cattle feed. The rice bran processing has now gained momentum, with increasing consumer demand for oil, extracted from bran. The genetic diversity of a few rice varieties of Assam was analyzed by using Simple Sequence Repeat (SSR) Markers. For all the twelve primers used in the present study, amplified products were found to be polymorphic, except for the primer RM574. The Jacard coefficient of similarity based on SSR the similarity value ranged from 0.200 to 0.786 high genetic diversity among the varieties. Dendrogram constructed based on chemical analysis data and SSR data revealed two major clusters (A & B). Based on chemical analysis data, cluster A, subcluster I included the variety '*Ranjit*' and subcluster II included five varieties *viz*. '*Tora bao*', '*Kunkuni joha*' '*Kola joha*', '*Gheu bora*' and '*Bokul bora*'. On the other hand, subcluster III, included one variety '*Birohi*'. In cluster A, variety '*Gheu bora*' and '*Bokul bora*' was genetically almost similar. In cluster B, group I included variety 'Black rice'. Based on SSR data, in cluster A, subcluster I included two varieties '*Ranjit*' and '*Birohi*'. In cluster B, subcluster I include three varieties '*Tora bao*', '*Kola joha*' and '*Bokul bora*' and subcluster II included three varieties '*Gheu bora*', '*Kunkuni joha*' and 'Black rice'. In cluster B, variety '*Gheu bora*'and '*Kunkuni joha*' was similar on the basis of SSR primer analysis.

Emergent Need of Community Gene Bank for Conservation of Land Races in Sikkim

R. K Avasthe, Chndramani Raj, Shweta Singh, Ashish Yadav and Raghvendra Singh

ICAR- National Organic Farming Research Institute (ICAR-RC, Sikkim Centre), Tadong, Gangtok

Email: raj.chandramani@gmail.com

Development of a state can only be achieved when food and nutritional security is ensured to each and every individuals and this can happen with the existence of ample amount of agrobiodiversity in the region. The agrobiodiversitydeals with variability of animals, plants, and microbes that are used directly or indirectly for food and agriculture. Sikkim, with small geographical area of 7,096 sq.km, is known for its remarkable biodiversity in India. Being a part of inner ranges of the Himalaya, Sikkim topography is comprised of low hills, mid hills, high hills, alpine zones and snow bound land. About 69 crop species of food, vegetable, fruit, ornamental and commercial importance are cultivated between 300 and 2000 m elevation. Great diversity is found within most of the food crops and large part of the arable land is planted with local cultivars. According to modest estimates, more than 178 cultivars or landraces are available among the 69 crop plants grown in Sikkim. Rice has greater genetic diversity in Sikkim. About 55 landraces could be distinguished in rice. Some 26 landraces of maize were reported in addition to 6 landraces of finger millet; 14 local cultivars of rajmash, 7 rice bean, 9 each in chillies and chow-chow, 4 in rai sag; about 11 clones of large cardamom, 5 landraces of ginger and 4 clones of banana. The rich agro-biodiversity in the hill has evolved over time and space due to extreme variations in altitude and environmental conditions. In addition to the physical and ecological conditions and the natural evolutionary process, the diversity that exist on-farm has also been greatly influenced by diverse social, cultural and economic conditions of the farming communities. Numerous ethnic groups with varying socio-cultural preferences and needs have contributed to the diversity and farmers have accumulated a wealth of knowledge on these diversities. Although this traditional agriculture has proved to be inherently sustainable over centuries and rates high in terms of self-reliance, diversity and the depth of its indigenous knowledge, the modernization of agriculture, changes in agricultural practices and cropping patterns has led to the erosion of genetic diversity. In addition, thegradual changes in climate of Sikkim,increase in mean minimum temperature by 1.95ºC and rainfall by 124 mm during 1981-2010, has put agrobiodiversity on vulnerable mode and there is constant threat of losing them. The change in climate has also showed significant impact on the emergence of new diseases and evolution of minor pathogens to major one. This year, we noticed sudden outbreak (≥80%) of turcicum leaf blight of maize on VivekSankul (Almora developed variety) which was earlier moderately resistant to this disease while moderate resistance to high resistance in the local germplasm of maize against the disease. The identified source of resistance in local landraces/germplasm could be utilized in future to improve susceptible cultivars if properly saved and maintained. The loss of biodiversity would bring a host of interconnected issues, including a change in land use patterns, a loss of genetic biodiversity, family members seeking income from external sources, rural to urban youth migration, and ultimately the loss of traditional knowledge systems in Sikkim.Therefore, there is an urgent need for the promotion of sustainable agriculture with the constant development of new crop varieties which are resilient to biotic and abiotic stresses. For this purpose, community seed banks at local level having the seeds and plants with wider genetic diversity is essentially required. This could be conducted in benefit sharing basis to reward and promote supporting farmers through on-farm or in-situ conservation which means to revive landraces and increase seed diversity in the state.The developed diversity could be managed and promoted as genetic common resources and the access to these resources are granted at fair and equitable sharing basis. The new varieties or genotypes with specific characteristics can also be developed for location specific needs and environments.

Chitinolytic Properties of *Bacillus thuringiensis* Isolates from Uttarakhand Himalayas Confers Antifungal Activity and Elevated Entomopathogenicity

A.R.N.S. Subbanna*, C. Chandrashekara, J. Stanley and A. Pattanayak

ICAR-Vivekananda ParvatiyaKrishiAnusandhanSamstan (ICAR-VPKAS), Almora, Uttarakhand
Email: subbanna.ento@gmail.com; Avupati.Subbanna@icar.gov.in

Chitin is the second most abundant biopolymer in nature, after cellulose. It is an important structural constituent of fungal cell walls and the exoskeletons, peritrophic membrane of arthropods such as insects and crustaceans. All organisms that have chitin also have the degrading enzymes, chitinases (EC 3.2.1.14), which are presumably required for morphogenesis of cell walls and exoskeletons. The renowned and widely used insect pathogen, *Bacillus thuringiensis* (Bt),besidesproducing target specific insecticidal proteins (Cry toxins) also produces unrelated proteins during its vegetative growth including chitinases, which is majorly nutritive in function by being a soil bacterium. Indeed, the involvement of chitinases in pathogenicity of bacterium is also reported and explained by chitin rich skeletal structures in both insect pests and plant pathogenic fungi (PPF). Keeping in view, Eighty Btisolates native to Uttarakhand Himalayas were tested for their ability to produce chitinases. All the isolates showed detectable chitinase activity, among which 11 were considered as potent and further analyzed for pathogenicity against four major soil born PPF (*Rhizoctoniasolani*, *Fusariumsolani*, *Alternariapori* and *Pyriculariagrisea*) and toxicity against three major insect pests (*Helicoverpaarmigera*,*Thysanoplusiaorichalcea* and *Mythimnaseparata*) under *in-*

vitro conditions. All the isolates showed more than 90 % growth inhibition of the tested PPF, except for *Fusariumsolani*, where the maximum inhibition was 86.3 %. This antifungal activity was manifested in the form of mycelial beading and direct degradation of fungal hyphae. However, substantial direct toxicity was not observed in bioassays with insect pests except for larval growth inhibition. Whereas, a combination of chitinases with Cry proteins of *Bt* strain HD1 improved the mortality in *T. orichalcea*. PCR amplification and sequencing of representative three isolates VLBt15, VLBt35 and VLBt109, showed 99 % similarity with other *Bt*serovars and strains of *B. cereus*. The study showed *Bt*isolate, VLBt268 was found to be highly bioactive, signifying its possible utilization as biocide and *chi* gene in transgenics development.

Genetic Diversity of Important Legume Vegetables in North Eastern States of India

Veerendra Kumar Verma*, Avinash Pandey and Anjani Kumar Jha

Division of Horticulture, ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya
**Email Email:verma.veerendra@gmail.com*

North Eastern States of Indian being a hot spot of biodiversity, the wider variability has been observed in different legume vegetables especially Indian bean (*Lablab purpureus*), French bean (*Phaseolus vulgaris*) and cow pea (*Vigna unguiculata*). Legume vegetables are playing a pivotal role not only in the income generation but also in nutritional security of the populace, soil conservation and improving its fertility. The ICAR Research Complex for NEH Region, Umiam, Meghalaya is maintaining, diverse genetic resources in Indian bean (167), French bean (175) and cowpea (35). Indian beanis an important indigenous multipurpose legume vegetable of India. The wide range of variation was observed for plant growth, flower, fruit and seed colour, shape and size. The days taken to first flowering ranged from 30-90 days, pod length (6.2-24.5cm), pod weight (4.1-13.5g), number of seeds per pod (3.1-7.7) and yield per plant (0.185- 2.43 kg). Out of 167 accessions, Selection-1 was identified as a unique short duration (90 days) determinate line found suitable for the rainfed cultivation. This genotype is having white flowers, green pod, length ranged from 12-15cm, width (3-4cm), raceme length (25-30cm), number of pods/plant (12-18), yield per plant(150-180g/plant). Under French bean, out of 175 accessions, 145 are pole type and 30 bush type. Among the bush type, Selection-17 was identified as the best performing genotype for yield per plant (158.0g) and pod length (16.0cm) followed by ArkaKomal (148.9g), RCFB-3(113.0g) and Arka Anoop (112.0g). Among the pole type accecessions (145), the best performing genotype was a new collection from Manipur with pod length ((18.0cm), pod yield per plant (310g). The other high yielding germplasm were MZFB-47(290g), MZFB-45(280g), RCMFB-1(266g) and Collection-3(250g). Cow pea is the third most important legume vegetable crop of the region, and wide variability was also observed for days to first flowering (30-37days) and average pod length (19.40-49.70cm). Out of 35 accessions, MZCPC-1 (429.50g), RCCPC-2 (380g) and RCCPC-2(360g) were identified as high yielding accessions for higher yield per plant. The identified high yielding accessions could be utilized by the breeders for crop improvement and also by the growers for improving yield, income and nutritional security.

Sperm micro-RNA: An Impending Genomic Approach to Identify Male Fertility

Pranab J. Das[1&2*], Partha P. Das[2], Juwar Doley[1] and Sitangshu M. Deb[1]

[1]*ICAR-National Research Centre on Pig, Rani, Guwahati, Assam-781131*
[2]*ICAR-National Research Centre on Yak, Dirang, Arunachal Pradesh-790101, India*
[*]*Email: Email: drpranabjyotidas@gmail.com*

MicroRNAs (miRNA) are single-stranded, non-coding RNA molecules, comprised of 20-24 nucleotides sharing a partial or full complementary region with the messenger RNAs (mRNA). Mature miRNAs are regulating gene expression through mRNA degradation, translational repression,chromatin modification and silencing through base pairing to the 3' UTR of target mRNAs. Mammalian genomes are predicted to encode ~200-500 unique miRNAs that together regulate the expression of at least one-third of all genes. The roles of sperm-borne miRNAs are critical for their key developmental process, the aspect of fertility in farm animals are still in nascent stage. Thus, our current goals were to identify miRNAs in yak sperm as well as establish a foundation to investigate their likely association with male fertility in farm animal. The method involved by collecting fresh ejaculates by the artificial vagina, processed by centrifugation using BoviPure™. Top layer with mature sperm was further evaluated for their concentration and motility along with morphological characteristics; the mature sperm cells were subjected to isolation of total RNA through Trizol method. The concentration and purity of RNA were checked by spectrophotometer and through internal control genes for protamine 2 (*PRM2*) and protein tyrosine phosphatase, receptor type C (*PTPRC*), respectively. Subsequently, small RNAs were isolated by mirVana miRNA isolation kit (Ambion). The RNA was poly adenylated and subjected to RT (Reverse Transcription) PCR for synthesizing small RNA cDNAs (src DNAs) using adapter attached oligo-dT primers. A total, 20 miRNAs of male fertility were picked up from different mammals to evaluate the copy number variation. The PCR was carried out for these miRNAs using srcDNAs as a template with the miRNA-specific forward primer and adapter-specific universal reverse primer. Based upon the expression levels of the analyzed 20 sperm derived miRNA in the yak, five miRNAs have significantly differed in the expression pattern of fertile and sub-fertile Yak bull. Further, present a link between the expressions levels of miRNAs and mse-tsRNAs in sperm and bull fertility also established. The investigation of miRNAs shed more light on the roles these small non-coding RNAs in an organism's genome and its impact on male fertility. This research revealed the association of miRNAs governing the yak bull fertility which could be further implicated in other farm animals as well as human fertility.

Keywords: *miRNA, Sperm, Male Fertility*

Theme-10: Medicinal, Aromatic and Spices Crops for Income Enhancement

Genetic Improvement of Harar (*Terminalia chebula Retz.*)

[1]N.B. Singh,[2] Sanjeev Thakur, [2]Kamal Sharma and [2]Mahantappa Sankanur

[1]CPGS, CAU, Umiam
[2]Dr YS Parmar University of Horticulture and Forestry, Nauni-Solan, HP

Introduction

Terminalia chebula is one of the very important indigenous multi-purpose tree species belongs to Family Combretaceae and popularly known as "Myrobalan" and it is commonly known as Harrar, Harra, Hirda and Haritaki. In India it is distributed throughout the greater part except arid zone (Troup, 1921). It is found in sub Himalayan tract from the Ravi eastward to West Bengal and Assam, ascending upto an altitude of 1,500 m in the Himalayas, whereas in Himachal Pradesh it is confined to sub-tropical zone (400-900 m elevation) in pockets. In peninsular India, it is found in mixed deciduous forests to dry deciduous forests and extend upto elevation of 900 m. It can grow in different environmental conditions. Soil supporting Harar vary widely in depth and composition. It also withstands fire and exhibits a remarkable recovery from scars and burns after fire. It coppices very well,the coppice-shoots being often very vigorous. It is a moderate-sized to large deciduous tree of the sub-tropical climate with a rounded crown, spreading branches and usually a short trunk. Bark is dark brown, often longitudinally

The species is prized for its fruit which has medicinal value. The fruit is extensively used for the treatment of diarrhoea, dysentery, heartburn, flatulence, dyspepsia and liver as well as spleen disorders. It is one of the main constituents of trifla which is a known panacea for stomach disorders. In addition to medicinal properties, Harar fruit is used in tanning and dyeing industries. The tree is lopped for fodder in some areas during lean period and also provides good quality durable timber. The annual demand for the Harar fruit in India is 6778.4 tonnes which is growing @ 4.6 per cent annually.The fruit both fresh and dried has a ready market at Amritsar, Hoshiarpur and Delhi. The fruit is also exported to Pakistan and Gulf countries. The harvesting of fruits starts from Aug- Sept and continues till January. Majority (90%) of the trees bear small sized fruits of inferior quality locally known as kachra. Large sized fruits fetch a premium price, minimum three times higher to that of kachra type. Varieties with large fruits are used for making 'Murabba' and are, therefore, called as 'Murrabi' variety. The fruits of murabbivarieties are three to five times larger as compared to that of kachra type. The cost of picking, grading and transportation being the same for low as well as high quality fruits, profit margins are far less for low quality fruits. Artificial reproduction of harar is through seedling plants which show wide variation in growth, size and quality of fruits. However, the farmers are interested in true to type plants with early bearing quality fruit. This paper describes the work done in this species in order to develop suitable varieties and propagation techniques. As Harar is well distributed in the North East region, suitable strains and propagation techniques already standardized can be planted in this region for the benefit of farming community

Reproductive Biology

The reproductive biology studies have suggested that leaf fall and flushing events occur during pre-monsoon season; leaf flushing extends into the monsoon season. Flowering occurs during late dry season and early monsoon season. The flowers are bisexual and obligately outcrossed and this is enforced by self-incompatibility. Protogyny is a device to promote outcrossing, but it is weak. However, it is partly substantiated by gradual anther dehiscence over a period of six hours. The plant is entomophilous and cross-pollination is effected mainly by 42 species of insects including large bees, wasps and butterflies. The natural fruit set is around 7.83% as against the 65.67% realized in manual xenogamous pollinations. The study suggests that T. chebula does not suffer from pollinator limitation to maximize fruit set but from the limitation of compatible pollen and flower. Fruits fall to the ground when mature and dry, but wind is also instrumental in shedding fruits. The fallen fruits are dispersed by mainly animals and then to some extent by rain water and finally the seeds germinate and establish seedlings depending on the soil status.

Regeneration status of Harar

The study was confined to five natural populations of Harar (*Terminalia chebula*Retz) distributed in three districts of Himachal Pradesh. In every natural population quadrats were laid down randomly to study the regeneration status along with percentage size class (girth class) occurrence of Harar trees. Most of the individuals in these populations were found to be almost of the same size producing flowers and fruits but no seedlings had been successfully established showing complete absence of natural regeneration of Harar (recruits, un-established or established) within its natural populations. However recruits of Harar were found in some agricultural fields of Jamun Ki Sair and recruits, un-established and established regeneration was found in grassland in the buffer zone of natural population in Rakkar. Complete absence of natural regeneration of Harar in its natural population confirms the urgency of propagation of the species with the help of artificial techniques, reduction of destructive harvesting methods such as hacking tree branches and lopping pressure, establishment of community-based pulp extraction enterprises near the forest ecosystem to help in returning back the seeds to the ecosystem enabling greater chances of regeneration by extracting the pulp and reusing the seeds for regeneration.

Variation studies

Wide range of variation was found in different fruit and seed characteristics (Table 1). Fruit length varied from 3.17 cm to 7.80 cm whereas fruit diameter ranged from 1.98 cm to 3.57 cm. Large variation was also found in fresh fruit wteight (11.5– 38.45 g) and dry fruit weight. (3.99- 15.45 g). Variation in fruit size and weight indicate that selection could be effective for large sized fruits.

3.2.1 Selection of Superior strains

Table-1: Variation for fruit and seed characteristics in *Terminalia chebula*accessions

Character	Minimum	Maximum
Fruit length (cm)	3.17	7.80
Fruit diameter (cm)	1.98	3.57
Seed length (cm)	1.43	3.36
Seed diameter (cm)	0.64	1.71
Fresh fruit wt. (g)	11.5	38.45
Dry fruit wt. (g)	3.99	15.45

Four promising strains as per evaluation of the scientists associated with the work and substantiated by the farmers and traders have been identified.

i) JachhHarar -1 (JH-1): Selection from village Pragpur, Tehsil Dehra, DistrictKangra. Mother tree age, height, girth, spread were 90 years, 18.0 m, 1.60 m and 16.40 x 12.30 m, respectively. Mean fruit length, diameter and dry weight is 6.53 cm, 3.23 cm and 10.35 gm, respectively. Fruit is long necked, pale yellow in colour, high quality and locally known as koonj.

ii) JachhHarar -2 (JH-2): Selection from village KothiHarar, District Bilaspur. Mother tree age, height, girth, spread were 250 years, 12.5 m, 2.20 m and 24.0 x 22.0 m, respectively. Mean fruit length, diameter and dry weight is 5.43 cm, 3.15 cm and 15.45 gm, respectively. Fruit is oval, light yellow with reddish tinge, high quality Murabbi type.

iii) Jachh Harar-3 (JH-3): Selection from village Tamber, Tehsil Palampur, District Kangra. Mother tree age, height, girth, spread were 70 years, 22.0 m, 1.65 m and 15.0 x 13.5 m, respectively. Mean fruit length , diameter and dry weight is 5.00 cm, 3.31 cm and 10.00 gm, respectively. Fruit is oval, pale yellow, high quality Murabbi.

iii) Jachh Harar-4 (JH-4): Selection from village Kaller, District Bilaspur.. Mean fruit length , diameter and dry weight is 5.00 cm, 2.61 cm and 12.00 gm, respectively. Fruit is necked, pale green, high quality Koonj.

Biochemical Analysis of fruit

For biochemical analysis, fruit from different seed sources from of Himachal Pradesh was analysed for macro and micro minerals, tannins, Vitamin C and other biochemical traits. As evident from the Table 2 & 3, significant variation was found for these traits in different seed sources. Overall, profile of various macro & micro minerals as well as other chemical nutrients showed that fruits of *T. chebula* are highly nutritious

Table-2: Macro and micro mineral contents (mg/100g) in *Terminalia chebula* fruits of different accessions.

Macro & Micro Minerals	Range	Mean
Phosphorus	47.65- 92.21	65.14
Sulphur	51.14- 65.20	59.57
Zinc	0.348- 1.013	0.574
Copper	0.167- 0.332	0.177
Magnesium	30.60- 59.88	45.96
Calcium	40.96- 103.00	73.25
Mangenese	0.049- 0.232	0.117
Potassium	341.2- 502.6	382.2
Iron	1.141- 1.606	1.446

Table-3: pH, titrable acidity, ascorbic acid, total carbohydrates, tannins, ash, nitrogen and proteins of *Termialiachebula* fruits of different accessions.

Biochemical constituents	Range	Mean
Titrable Acidity	545.80- 900.80	718.8
Ascorbic Acid (mg/100 g)	5.765- 11.920	7.763
Total carbohydrates (%)	3.708- 6.514	5.097
Tannins (%)	27.27- 40.01	33.25
Ash (%)	3.410- 3.602	3.510
Nitrogen (%)	0.152- 0.315	0.219
Protein (%)	0.953- 1.968	1.384

Propagation studies

Seed germination studies

Harar seed is obstinate to germinate. Our studies indicated that dormancy is mechanical due to hard endocarp which allows water and air to pass inside freely but caused obstruction to embryo growth. Different pre-treatments given to soften the hard endocarp had resulted in variable response. Maximum germination (45 %) was observed when kernel was extracted from hard seed coat.

Grafting studies

Maximum grafting success (88-89 %) was observed in the month of May and June followed by July and August (85 & 84 %) under poly cap technique.

Molecular characterization

Unweighted Pair Group Method with Arithmetic Mean (UPGMA) dendrogram based on ISSR markers resolved into fourmajor clusters**.** The similarity coefficient among 8 genoytpes ranged from 0.22 to 0.67 (Table 6). A critical perusal of dendrogram revealed that the distribution of various genotypes into clusters and within cluster was somewhat random**.** Cluster one comprised of only one genotype viz. P-7,showing 22 per cent similarity with rest of the genotypes under study.Cluster II comprised of two genotypes viz. P-1 and P-6showing 30 per cent similarity with cluster III and *67*per cent similarity between the two. Thus, these genotypes showed maximum degree of similarity in their genetic makeup. Whereas, genotypes P-6 and P-5 showed least similarity index (0.10)amongst the genotypes studied. On the basis of banding pattern ISSR's were effectively used for molecular characterization of Harar genotypes used in this study.

Cluster III comprised of two genotypes*viz.*,P-3 and P-8showing 54 per centsimilarity in their genetic makeup.Cluster IV a major cluster having three genotypes were grouped in to two sub clusters. Sub cluster one having genotype P-4 showed 38 per cent similarity with sub cluster II. Second sub cluster comprised of two genotypes *viz.*,P-2 and P-5 which showed 44 per cent similarity between themselves.Cluster I, the most diverse cluster was having one genotype P-7. It showed clear-cut distinction from rest of the genotypes of the cluster and had different genetic makeup.

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Effect of Soil Application of Mg, Zn and Mn on yield, Nutrient Content and Soil Fertility Status of Large Cardamom at Sikkim

B.A. Gudade*, K. Dhanapal, Ashutosh Gautam, S.S. Bora, R. Chhetri, Subhash Babu[1] and A.B. Rema Shree[1]

Indian Cardamom Research Institute, RRS, Spices Board, Tadong, Gangtok-737102, Sikkim
[1]ICAR Research Complex for NEH Region Umiam -793103, Meghalaya
[2]Indian Cardamom Research Institute, Spices Board, Myladumpara, Idukki-685553, Kerala
Email: bgudade@gmail.com

Field experiment was conducted at Kabi Research Farm, Indian Cardamom Research Institute, RRS, Spices Board Gangtok, India to find out the role of soil application of Mg, Zn and Mn on growth and nutrition in large cardamom. The experiment laid out in randomized block design, consisted eight treatments *viz.* $ZnSO_4$ (5 kg/ha), $ZnSO_4$ (10 kg/ha), $MnSO_4$ (10 kg/ha), $MnSO_4$ (5 kg/ha), $MgSO_4$ (10 kg/ha), $MgSO_4$ (5 kg/ha), $ZnSO_4$ + $MnSO_4$ + $MgSO_4$ (10 kg/ha) and control. Result showed that among the fertility treatments, soil application of $ZnSO_4$+$MnSO_4$+$MgSO_4$@10kg/ha resulted in maximum number of immature tillers (7.12). Highest number of spike/clump (3.03) recorded in $ZnSO_4$+$MnSO_4$+$MgSO_4$@10kg/ha followed by treatment $MgSO_4$@5 kg/ha (2.98) as compare to control. Maximum number of capsule/spike (4.90) recorded in treatment $ZnSO_4$+$MnSO_4$+$MgSO_4$@10kg/ha followed by treatment $MgSO_4$@5 kg/ha (4.79). Highest dry yield/clump (34.09 gm) observed in treatment $ZnSO_4$+$MnSO_4$+$MgSO_4$@10kg/ha followed by treatment $MgSO_4$@5 kg/ha (33.42 gm). Maximum dry yield (151.50 kg/ha) recorded in the treatment $ZnSO_4$+$MnSO_4$+$MgSO_4$@10kg/ha followed by treatment $MgSO_4$@5 kg/ha (148.52 kg/ha) as compare to control. With respect to nutrients status in large cardamom, application $ZnSO_4$+$MnSO_4$+$MgSO_4$ @10kg/ha had significantly higher Mg (0.54%), Zn (55.01 ppm) and Mn (493.60) content in leaf over the control. Change in soil fertility status due to treatment application were noticed at the end of experiment, among the different treatments, application of $ZnSO_4$ + $MnSO_4$ + $MgSO_4$ @10 kg/ha proved its superiority over the others and its effect was statistically non-significant on available Fe and B in soil. Soil application of $ZnSO_4$+$MnSO_4$+$MgSO_4$@10kg/ha recorded the significantly higher Mg (49.03 ppm), Zn (4.20 ppm) and Mn (20.10 ppm) content in soil.

Keywords: *Large cardamom, Mg, Mn, Soil Application, Zn*

Evaluation of Therapeutic Properties and Nutritional Quality of Commonly used Plants (*Roselle sabderiffa, Curcuma angustifolia and Sechium edule*) by Indigenous People of North east India

K. Puro*[1], S.R. Assumi[2], C. Aochen[3], R. Sanjukta[1], S. Das[1], S. Ghatak[1], A.K. Jha[2], K.P. Mahapatra[4], I. Shakuntala[1] and A. Sen[1]

[1]Animal Health Division, [2]Horticulture Division, [3]Biotechnology Division and [4]Agroforestry Division, ICAR Research Complex for NEH region, Umiam – 793103. Meghalaya
E-mail: akulepuro@rediffmail.com

Plants are traditionally use and claims to have medicinal properties in treatment of various ailments. The present work deals with *in-vitro* studies of commonly use plant by the indigenous people of northeastern hill region to evaluate the therapeutic properties and also to assess the nutritional benefits for good health. The Roselle (*Hibiscus sabdariffa*) calyx is one of the main ingredients in the culinary recipes of various delicacies of tribal cooking of the northeast. It is also use

for treatment of many diseases. The proximate value and nutritional quality, antioxidant activity, antimicrobial properties, anti-proliferative activity and apoptosis-inducing capacity of aqueous extract of roselle calyces were evaluated. The budding flowers of East Indian arrowroot (*Curcuma angustifolia)* flower is commonly consume by the tribal population of the north east. Its beneficial properties in terms of its anti-proliferative activity and bioactive compounds – total phenols, flavonoids and free radical scavenging activity were estimated using aqueous and ethanolic extract, respectively. Chow-chow (*Sechium edule*) is one of the common vegetables found in almost every house of the indigenous people in the north east and widely consumes both the leaves and fruits. It is believed to have medicinal benefits. Therefore, two varieties (dark green and light green colour fruit) were evaluated for its proximate value and nutritional quality, contents of bioactive compounds, its antioxidant potential, anti-proliferative activity and apoptosis-inducing capacity. The results indicated its potential benefits for health which substantiated the belief of the indigenous people to include these plants in their dietary habits to stay healthy. They could be further tested and validated for use as supplement in the food. Future studies with greater scientific robustness in terms of standardization of dose for its effectiveness, safety and tolerability will permit the formulation of safe, effective therapeutic herbal formulations which can be used as an acceptable source for curing many health issues and restoring general health.

Keywords: Health, Bioactive, Anti-Proliferative, Medicinal Plants

Turmeric Value Chain for Sustainable Livelihood Improvement: A Success Story

NA Deshmukh*, S K. Barik**, A K Jha, VK Verma, M. Bilasini Devi, H Rymbai, SR Assumi and H D Talang

ICAR Research Complex for NEH Region, Umiam-793103, Meghalaya, India
** *CSIR*-National Botanical Research Institute (*NBRI)*, *Lucknow*
Email: nadeshmukh1981@gmail.com

Turmeric is a wonder nutraceutical spice, grown traditionally in north eastern region of India particularly Meghalaya an area of 27.99 thousand ha with a production of 77.65 thousand tonnes (Horticultural Statistics, 2016). The attractive colour, high curcumin and dry yield, turmeric produced in the region has high domestic as well as international demand. But low productivity, production in remote hilly terrains on small patches, non-availability quality rhizomes of high yielding variety, poor production and post production practices and lack of entrepreneurship among the tribal farmers are the major bottlenecks in turmeric promotion. Thus considering the above, the good production and post production practices for turmeric were promoted amongst farmers in Ri-Bhoi and Jaintia Hills of Meghalaya in participatory mode. Front Line Demonstrations were conducted with help of Self Help Groups (57 SHGs) in 30 villages involving a total of 622 farmers. Intervention of Institute developed variety, Megha Turmeric-1, having high dry yield (16.37% recovery) and curcumin content (6.8%) led to increase in productivity of fresh turmeric from 10-12 t/ha to 20-22 t/ha under farmers' fields, getting average net return of Rs. 1,41,604/ha with a high B:C ratio (2.52). To promote processing and value addition of turmeric under inter institutional collaborative project with North Eastern Hill University, Shillong, one "*Turmeric Processing Unit"* was established at Laskein village, West Jaintia Hills District, Meghalaya (capacity:300 kg dry or 1500 kg fresh weight turmeric per day). The activities are being handled by women members of SHGs *viz.*, processing; record keeping and sale of turmeric. Further to address the growing demand of quality planting materials of cv. Megha Turmeric-1, Ri-Bhoi Mihngi Multipurpose Co-operative Society Ltd, Bhoirymbong, Meghalaya has been licensed for planting material multiplications. Calendar of operations and short messages (SMS) were

prepared and disseminated through *KIRAN (Knowledge Innovation Repository in Agriculture for Northeast)* web portal both in English and *Khasi.* Further, services of web platform were also extended for market linkages. This participatory value chain linkage, not only increased the productivity and developed entrepreneurship in rural tribal youths, but is also helping in achieving sustainable livelihood.

Amomum aromaticum **Roxb. a Rare Species of Cardamom Found in North East India**

Poulami Das*, R. Kandali, P. Dutta, Aiswarya Barua and T.C. Sarmah

Assam Agricultural University, Jorhat.
Email:poulamidas1512@gmail.com

Wild cardamom (*Ammomum aromaticum* Roxb.) has been recently discovered in large patches of forests of Tripura by forest department during 2014-15. It is popularly known by the local tribals as ‘Beering’ in their vernacular language, whose stump is used in the local culinaries to induce aroma to the dishes. Botanically it belongs to Zingiberaceae family. Processed dry fruit is the economic produce which can be used largely as spice because of its sweet aroma and in the ayurvedic medicine because of its medicinal value. The present investigation was intended to study the morphological characteristics, chemical composition and medicinal property of *A. aromaticum* Roxb. The plant materials were collected from forest of Tripura- Kunjaban village, Kalyanpur block, Khowai district and authenticated. The morphological data were taken from the mature plant to narrate the botanical information. Leaf and seed samples of this species were analysed for total alkaloids and total phenolics. From the results of the present investigation it was observed that a significant variation in the total phenolic content in the leaf and seed was obtained which were 12.7 mg/g and 10.1 mg/g, respectively. The alkaloid content of the leaf was found to be 1.27 g/100g and in case of seed it was 4.2 g/100g on dry weight basis. The antimicrobial activity of different solvent extracts of leaf and seeds of *A. aromaticum* Roxb were evaluated against. *Escherichia coli, Staphylococcus aureus* and *Bacillus subtilis.* The methanol extract of seeds showed potential antimicrobial activity against these human pathogens. Moreover, the genomic DNA was extracted from the mature fresh leaf tissues of *A. aromaticum* Roxb and the extraction procedure was standardized. From the study it was observed that this new spice species have the potential economic value and its cultivation can boost the income of spice cultivating farmers of North East India. More studies will be required to find out the favourable conditions to achieve the full potential of the plant in order to establish this plant as one of the important spice species.

Antioxidant, Anti-Inflammatory and Anti-Cancer Activity of Nutgall Tree (*Rhus semialata* Murray): A Potential Underutilized Fruit Crop of North Eastern Himalayan Region

S.S. Roy, Thangjam Surchandra Singh, Priyanka Khoirom, Blessa Sailo, S.K. Sharma, M.A. Ansari, Chongtham Tania, Ch. Premabati Devi, N. Prakash and S.V. Ngachan

ICAR Research Complex for NEH Region, Manipur Centre, Imphal

Nutgall Tree (*Rhus semialata* Murray) is one of the underutilized fruit crops of Manipur. The plant is believed to be rich in bioactive properties. The present study was undertaken to assess the antioxidant, anti-inflammatory, anti-diabetic and anti-cancer activity of stem bark extracts of nutgall tree collected from Ukhrul district of Manipur. In DPPH radical scavenging assay the aquash extract of *Rhus semialata* Murray showed high antioxidant activity (0.40 mg IC_{50} value). The extract was again screened for anti-inflammatory activity. Interestingly, the extract has shown selective Cyclooxygenase-2 enzyme inhibitory activity to the tune of 71.98%, which suggests that the extract can be a good candidate for non-steroidal anti-inflammatory drugs. The extract was further investigated for bioactive compounds present in stem bark extract and three compounds have been isolated and identified. The Compound 1 and 2 have been identified as Gallic acid and Methyl gallate. Another compound has shown close resemblance with Gallotannin. These compounds were tested for their anti-cancer activity against U937 breast cancer cell line using MTT assay. Among the three compounds, Compound 1 (Gallic acid) significantly reduced the cell viability in a dose-dependent manner and minimum cell viability (< 40%) was recorded with a dose of 100 µg mL^{-1}. The present study discovered the hidden potential of a neglected species and suggests that consumption of stem bark extract of nutgall tree would be beneficial to fight against degenerative diseases for ensuring a healthy living.

Keywords: *Nutgall tree, Rhus semialata Murray, Antioxidant, Anti-cancer, Underutilized*

Bioactivity Guided Evaluation of Wild Edible Plants of Loktak Lake Ecosystem in Manipur for Antioxidant Activity, Phenolic and Flavonoid Content

Thangjam Surchandra Singh, S.S. Roy, Pintubala Kshetri, Priyanka Khoirom, Ch. Premabati Devi, M.A. Ansari, S.K. Sharma, Blessa Sailo, N. Prakash and S.V. Ngachan

ICAR Research Complex for NEH Region, Manipur Centre, Imphal

Redox reactions are crucial for the success of many biological processes, but they can also be damaging to the human body. Low levels of antioxidants can result in high levels of reactive oxygen species. They often accompany mitochondrial decay, stress and toxic overload over a long period of time. These diseases include diabetes, cancer, cataracts, immune system decline, cardiovascular disease, brain dysfunction and atherosclerosis, etc. The excess of free radicals is neutralized by antioxidants produced in the organism (endogenous) or acquired from the diet (exogenous). Endogenous antioxidants act as a first defense mechanism in the body. Wild edible plants which grow naturally contribute significantly in local food basket. These plants are believed to be rich in phenolic and flavanoid compounds and an important source of natural antioxidants. With this background, the present study investigated the antioxidant activity, phenolic and flavanoid content of 28 diverse wild edible plants resources of Loktak lake ecosystem of Manipur. Antioxidant activity measured by three different methods viz. DPPH, ABTS and FRAPS revealed wide diversity among the plants. The antioxidant activity of the plants was found in the range of 1.71-263.7 µM TEAC/g fresh weight. The dendogram based on three antioxidant assays clustered the 28 plants in 3 distinct clusters. The first cluster comprised of 2 plants which showed maximum antioxidant activity. The second cluster is a group of 5 plants which showed medium antioxidant activity. The remaining 21 plants are grouped in the third cluster showing less antioxidant activity compared to the plants grouped in first and second cluster. In all the methods the first three plants showing maximum antioxidant activity are *Ludwigia adscendens* (L.) H. Hara Syn. *Jussiaea repens* L. > *Gynura cusimbua* (D. Don) S. Moore > *Persicaria sagittata* (L.) H. Gross Syn. *Polygonum sagittatum* L. These three plants showed antioxidant activity ranging from 99.5-263.7 µM TEAC/g fresh weight. The phenoloic and flavanoid content among the plants was found in range of 1.00-22.03 mg GAE/g fresh weight and 1.07-33.67 mg QE/g fresh weight, respectively. Highest phenolic (22.03 mg GAE/g fresh weight) and flavanoid (33.67 mg QE/g fresh weight) content was observed in *Gynura cusimbua* (D. Don) S. Moore. All three antioxidant assays showed positive correlation to phenolic and flavanoid content. However higher correlation was noticed in between antioxidant activity and phenolic content as compared to flavanoid content.

Among the different antioxidant assays, highest correlation is observed between DPPH and phenolic content with 'R' value of 0.951. The study suggests that wild edible plants are rich source of antioxidants and their consumption would be help to improve the quality of human life.

Keywords: *Wild edible plants, antioxidant, DPPH, ABTS, FRAP, phenolics, bioactivity, Loktak lake*

Proximate Composition, Antioxidant, Antibacterial and Insecticidal Property of *Zanthoxylum armatum,* an Indigenous Medicinal Plants of Northeast India

*Raj Kumari Sanjukta, D.M. Firake, Surmani H., Samir Das, K. Puro, S. Ghatak, I. Shakuntala and A. Sen

ICAR Research Complex for NEH region, Umroi road, Umiam, Meghalaya – 793 103, India
**Email: rajkumari.sanjukta@gmail.com*

Zanthoxylum armatum (Rutaceae) is an important indigenous medicinal plants extensively used in folklore alternative medicine and foods in Northeastern part of India. In the present study *Z.armatum* extracts of various solvents were investigated for and their antioxidant analysis, antibacterial property and insecticidal properties. *Z. armatum* parts were extracted using four extraction solvents with decreasing polarity, these included hexane, ethylacetate (non-polar), methanol, water (polar) solvents respectively by successive solvent extraction scheme using Soxhlet extraction method. Proximate analysis of the whole plants powder was evaluated. The antioxidant and antibacterial property of the n-hexane, ethyl acetate and methano-aqueous (1:1) extracts of *Z. armatum* was analysed using DPPH scavenging assay and agar gel disc diffusion assay, respectively. Antibacterial property of the different fractions of Z. *armatum* was determined against *E. coli (*ATCC 25922*), Salmonella Typhimurium (ATCC 49416), klebsiella pneumoniae (ATCC 700603), Acinetobacter baumannii (ATCC 19606)* and *Staphylococcus aureus (ATCC 25923).* Insecticidal activity including antifeedent and ovicidal action were also checked against *Spodoptera litura.* Proximate ananlysis indicated carbohydrates, proteins, fats and crude fibers in sufficient amount. Among all the extracts tested for in vitro antioxidant activity using DPPH, n-hexane extract has shown maximum antioxidant activity and it increased with increasing concentration. An effective antibacterial property was observed from the various extracts of *Z. armatum* but n-hexane fraction was found to be most effective against the tested bacteria. The insecticidal potential including antifeedent and ovicidal action of *Z. armatum* demonstrated for the first time against Oriental leafworm, *Spodoptera litura*. Overall findings revealed that, the n-hexane pericarp and leaf extract of *Z. armatum* has strong antifeedent, ovicidal and larvicidal properties against *S. litura.* Sub-lethal dose (LC_{10}) of pericarp extract was found to have adverse effects on the biology; demonstrating its potential for disrupting the life cycle of *S. litura.* Further studies are needed to fully characterize the toxicity of *Z. armatum* extracts. Overall, the results of our study suggests the versatile potentials of *Z. armatum* as an effective antioxidant, antibacterial, and insecticidal properties, which encourages further investigation of their use as nutraceutical or therapeutic agents against pathogens and pests of veterinary and agricultural importance.

Documentation of Ethno-Medicinal Plants Used in Treatment of Stomach Disorders by Forest Fringe Communities in North Bengal, India

Saroj Biswakarma, Biplov Chandra Sarkar, Vineeta and Sumit Chakravarty

Department of Forestry, UBKV, Pundibari-736165, Cooch Behar (W.B)
Email: sarojkhati001@gmail.com

The present study was carried out in the eight forest fringe villages of Chilapatta Reserve Forest in foothills of the eastern sub-Himalayan mountain belts of West Bengal, India. The aim of the study was to find out the ethno-medicinal plant resources used against stomach related disorders and their application procedure prevailing in the study area. A total of 400 respondents including traditional medicinal practioners were selected randomly for personal interview schedule through open ended questionnaire. A total of 43 plant species belonging to 40 genera and 31 families were documented. These documented species were dominated by trees (22) followed by herbs (11), shrubs (6) and climber (4). The plant families dominating the list were Combretaceae, Rutaceae and Lamiaceae with 3 species each. Among various stomach related disorders, gastroenteritis was cured by maximum number of plant species (15), followed by dysentery (14) and stomach pain (9). The most dominant plant parts used were leaves (20) followed by fruit (13) and bark (8). The plant parts are employed by the inhabitants in the form of infusion, decoction, paste, latex etc. either as a sole drug or in the combination of other species. The collected evidence and their therapy can be useful tool for conservation of traditional knowledge. The same can be utilized by scientific community for further evaluation and recommendations to the practicing communities.

Keywords: *Ethnic, Gastroenteritis, Therapy, Traditional Knowledge*

In vivo Integrated Disease Management Study on Growth and Agronomical Characters Against *Fusarium* Root Rot in Coriander (*Coriandrum sativum* L.)

M.S.V. Satyanarayana*, K. Gopal and Syed Sadarunnisa

College of Horticulture, Dr. Y.S.R. Horticultural University, Anantharajupeta, YSR Kadapa, Andhra Pradesh-516 105
**Email: shivamaaragaani7@gmail.com*

Fusarium solani, an incitant of *Fusarium* root rot in coriander which causes economical yield loss and damage to coriander crop in Andhra Pradesh. The diseased plants showed poor growth and partial or fully damaged root system with conspicuous reduction in yield. To permit environment safe and to avoid dispensable use of fungicides sprays an integrated disease management trail was conducted against *Fusarium* root rot disease with Neem cake, Carbendazim + Mancozeb and *Trichoderma harzianum* in seven treatments and three replications under field conditionsusing direct and combined applications. Results from the present study depicts application of Neemcake @250kg/ha + *Trichoderma harzianum* @5kg/ha significantly showed better growth and yield paramters *viz*., Plant height (37.7cm), No. of. Branches/plant (4.7), No. of. Umbels/plant (6.3), No. of. Umbellets/umbel (5.0), Root length (16.5cm), Seeds/umbel (6.7) and Yield/plant (1.8g) over the control plot.

Keywords: *Fusarium solani, IDM, Coriander, Root rot*

Standardization of Extraction Parameters to Maximize the Oil yield in Vetiver Roots

C.S. Raghav[1] and Nidhi Dubey[2]

1. ICAR-KVK West Siang, Basar, Arunachal Pradesh-791101
2. Directorate of Plant Protection, Quarantine and Storage, Faridabad (Haryana)-121001

Five popular methods of distillation/ extraction, namely Clevenger apparatus, Solvent extraction, Steam distillation, Field distillation unit and DegBhapka method, and four pre-distillation root treatments, namely, dry and water/solvent soaking, chopping and whole root were standardized for total recovery of vetiver root essential oil and rate of recovery in terms of duration of distillation. It was found that the highest recovery of oil was recorded in case of solvent extraction followed by steam distillation, Field distillation Unit, Deg Bhapka, and Clevenger method in all cases of pre distillation rhizome treatments. As far as total recovery of oil is concerned no effect of soaking was observed as the total recovery of oil was same with a given method of extraction, except in case of Clevenger method where soaking rhizomes enhanced 0.03% yield in both unchopped and unchopped rhizomes. Regarding effect of pre-treatment of chopping, in each method of distillation the total yield of chopped rhizomes increased by 0.02% as compared to unchopped roots in both dry and soaked rhizomes. The highest yield was recorded in case of chopped rhizomes under solvent extraction method followed by steam distillation, degbhapka, field distillation unit and Clevenger method in both dry and soaked rhizomes. Therefore, vetiver roots should be chopped into 1 inch pieces and soaked for 6 hrs. before distillation/ extraction. The solvent and steam distillation method are best from the yield point of view., while DegBhapka and steam distillation methods are better from perfumery value.

Keywords: *Vetiver Root, Essential Oil, Distillation Methods, Soaking, Oil Yield, Recovery Rate*

Success Story: Ginger (*Zingiber officinale*) based Intercropping for Higher Income of Farmers

H. Rymbai, Anup Das, S. B. Nongbri, Y. Law and A.K. Jha

ICAR Research Complex for NEH Region, Umiam, Meghalaya, India – 793 103
Email: rymbaihort@gmail.com

Ginger is one of the most important cash crops and India is the largest producer of ginger in the world (32.75%). Meghalaya contributes 19.6% to the national ginger production. The traditional practices of ginger cultivation are *jhums* system and bun system. Over the last few years, there is a concern of low sustainability management in ginger cultivation. The region has a huge potential for ginger production through proper management of resources and refinement of farmers' technology. A field experiment was conducted during 2016-17 to identify the most suitable and high income generations intercropping system in mawthei village. Quality planting materials of ginger cv. Nadia were supply to 30 farmers in an area of about 7 ha in 2016. Result showed that among different ginger based intercropping system, the highest net return was obtained from Ginger + Maize + Frenchbean + Pumpkin (Rs4,04,775per ha) followed by Ginger + Maize + FrenchbeanRs3,89,625per ha. The highest Ginger Equivalent yield (t/ha) was recorded in Ginger + Pumpkin19.48) and lowest in ginger as sole crop (7.50). Highest BCR was recorded in Ginger + Maize + French bean + Pumpkin (3.83) and lowest in Ginger + Colocacia (2.65). The productivity of the intercropping was evaluated by the land equivalent ratio (LER). In this study the land equivalent ratios as an indicator of biological efficiency in intercropping system were always greater than one exception of ginger + colocasia. Highest LER was obtained from ginger + maize + Frenchbean (2.62) followed by ginger + maize (2.11). Therefore, intercropping system such as Ginger + Maize+ Frenchbean + Pumpkin and Ginger + Maize + Frenchbean had higher return than ginger as sole crop.

Theme-11: Participatory Research and Technology Dissemination

Way Forward For Conservation Practices and Sustainability of Farming Systems of North Eastern States of India

K.K. Datta

College of Post Graduate Studies, Central Agricultural University (Imphal), Umiam, Meghalaya,

Email: kkdatta2007@gamil.com

There are two major challenges before Indian agriculture today: ecological and economical. The conservation of our basic agricultural assets such as land, water, and biodiversity is a major challenge. How to make agriculture sustainable is the challenge. Increasing productivity in perpetuity without ecological harm is the need of the hour. Assessing vulnerability of community to climate change and enhancing their adaptive capacity through community based adaptation and policy efforts found that water stresses (mainly flood and drought) have been playing major role in determining the adaptive capacity of food system. In addition, food is increasingly becoming unsafe due to use of ground water contaminated from arsenic and fluorides. Population, affluence and technology are the key three driving forces with environmental change. The inter-linkages of these three main building blocks of food security are, in-turn, strongly connected to the way land is allocated for fulfilling different aspirations of the community. As agriculture become the victim of dynamic of land use pattern, it is necessary to quantify the likelihood impact and assess the trade-offs of each land use decision on sustainability of the agro-ecosystems in a system approach, by which a proper integration of biophysical, socio-economic and land evaluation models can be applied to arrive at an economically viable, environmentally sustainable and socially acceptable optimal land use management decisions for conservation of our natural resources. The impacts of climate change on the nutritional levels of the population are likely to be similar to the impacts of seasonality, when food shortages and the reduction of intake adversely affect nutrition status, year after year, on a cyclical basis.

The indirect impacts of climate change on nutrition security would be unhealthy environment. Nutrition-infection is a vicious cycle and climate change will impact the infectious diseases scenario and malnutrition due to the effects of one on the other. Dealing with climate change, generally two approaches were suggested. One is *mitigation* and the second is *adaptation.* Maintaining the diversity in crops has been a time tested practice of multi-cropping, which is an insurance under climate change conditions. Organic farming reduces the emission of GHG and it taps more carbon. Folk varieties along with mixed cropping can cope with the climatic aberration largely. Traditional knowledge and the broadening of the food basket by cultivation and utilization of forgotten varieties of grain, vegetables, legumes, fruits, and green leafy vegetables are the major suppliers of micro-nutrients and protein and play a vital role in the diets of the poor. This is a more viable proposition to counter the challenges of climate change especially growing drought and flood resistant varieties. The biodiversity impacts have substantial social and economic consequences as they result in the irrevocable damage and degradation of ecological services that people, societies and businesses depend on. Thus, without a concerted effort to protect and conserve biodiversity the entire human race would be in danger. Loss of species and habitats, wetlands conservation, wildlife trade, pollution, and climate change are concerns requiring effort to be effectively addressed. As businesses have a two-way relationship with biodiversity, encompassing both the impact of companies on biodiversity, and the impact of biodiversity on companies, they have prime responsibility & significant influence on the conservation of biological diversity. At the same time, the involvement of key policy makers in the promotion of legal and policy regimes that protect the rights of countries, individuals, communities and corporations, can assist in accomplishing the goal of biodiversity conservation and sustainable development. Therefore, in order to protect, conserve, restore biodiversity, a concerted response from governments, the business community and society is required. This Multi-stakeholder Partnership (MSP) involving governments, industry, local community, conservationists, forest departments and other user groups, may lead to win-win situation. Gene Campaign successfully demonstrated the longetivity and sustainability of indigenous varieties of paddy and other food grain varieties in Manipur and parts of North East states. This has not only shown higher community acceptability but has also proved as a viable source of local food security through grain banks Sustainable agriculture with integrated approach, organic low input farming practices, agro-based income generation activities, promotion of improved livestock breed and water management practices can improve food and nutrition security. It is not possible without proper investment, infrastructure and market development, innovate techniques, compilation and promotion of traditional teachings and system and Research and Development. The capacity building of community on climate change and adaptation issues is an essential aspect.

Conservation agriculture involving continuous minimum mechanical soil disturbance, permanent organic soil cover and diversified crop rotations provides opportunities for mitigating greenhouse gas emission and climate change adaptation. Farmers must broaden their perspective and shift conservation concepts and programs to get away from managing for only yield and erosion control and move to managing soil carbon (C) for crop production sustainability and maintaining environmental quality. Management emphasis on diverse rotations must be combined with maximum biomass and yield production and the use of cover crops to maximize the carbon input into the soil system. Agricultural policy should play a prominent role promoting conservation agriculture in developing agro-environmental instruments to support a sustainable development of rural areas and respond to societies increasing demand for environmental services. Environmental protection and nature conservation require enhanced management skills that create extra work and cost for the farmers, but in no other sector can so much be achieved for the environment with so little input. We must no longer take for granted the contribution made to society by farmers through environmental measures but must compensate them appropriately through stewardship payments. The true economic benefits can only be determined when we assign monetary values to externalities of environmental quality. It makes more economic sense to take account of nature conservation from the outset than to have to repair damage after it is done, and in many cases the repair may not even be possible. Conservation agriculture without intensive tillage can play a major role in sequestering soil C and providing long-term global economic and environmental benefits. Conservation agriculture with enhanced soil C management is a win-win strategy. Most of the strategies whereby Agriculture can contribute to climate change mitigation and the adaptation of the agriculture sector to the, apparently, inevitable changes are already known. Fortunately, these same initiatives cross over with recognised practices to ensure long term sustainability of land, the agriculture sector and those dependent on its outputs. Stabilizing food security in the light of increasing population, dietary changes, spiraling oil, commodity and fertilizer prices only strengthen the need for dramatic reductions in input/output ratios across all components of the Agricultural sector.

Immediate emphasis should focus on “what can be initiated now” with understood, in-place technology that has shown success elsewhere and which has been taken up by farming communities as their new “best practice and practice of choice”. One aim is to ensure widespread uptake within minimum or no risk scenarios. Benchmarking (pre-change), monitoring and evaluation of the impacts of the altered practices will be required, to demonstrate positives (and negatives) and provide the means to convince others of the need and the positive impacts of change. Economic, environment and social indices all need to be collected, to show the cross cutting nature of the altered practices. Practitioners of Conservation Agriculture render a number of services to humanity, present and future, in the community in which they live and the district where they farm as well as in the state, country, region and global environment in which they work. These services include the provision of cheaper more reliable supplies of food as well as a range of environmental services such as increased soil health, reduced water pollution and runoff and decreased 'greenhouse gas' emissions. In recent years much attention has been given to the rewarding of farmers practicing Conservation Agriculture and other reduced tillage systems for their reduction of Carbon emissions. The actual reduction, however, tends to be very site and tillage-system specific. Assessment and monitoring are therefore expensive and only really warranted on larger farms. As a result, especially with the current price of Carbon credits, few if any systems exist which attempt to quantify benefits let alone reward African farmers for their part in these reductions, especially the small scale farmers who make up by far the majority of African agriculturists. The most challenging issue in managing common pool resources is that of designing institutions or the process of working rules for collective action in the implementation of watershed development projects. Conservation Agriculture (CA) in simple and practical terms implies conservation (including protection and upgrading) of natural resources base that sustains the diversified and inter-linked activities comprising agriculture. Conservation of the natural resources base (and therefore agriculture) is determined by pattern and processes of resource use (e.g. land use) under comprehensive or broad based agricultural systems, involving crops, livestock, farm forestry, water-moisture management etc. One of the components of agricultural systems particularly in developing countries is the provision of village commons or common property resources (CPRs), especially in fragile and marginal lands with limited and high risk crop production potential.

Furthermore, to understand the place and role of CPRs in facilitating conservation agriculture two additional issues are focused. First, we look at agriculture as a broad based phenomenon, where diversified, interlinked activities – annual and perennial cropping, livestock, farm forestry, horticulture and water – moisture management etc. are treated as pillars of agricultural system. Though for illustrations greater focus will be on crop based farming systems. A major challenge confronting agricultural scientists, economists and environmentalists is how to reconcile the (conflicting) goals of efficiency defined in terms of maximization of net present value of agricultural production in the long run and conservation or sustainable agriculture. The former is necessary for meeting the growing requirement of food and other agricultural produce of the rapidly increasing world population, particularly in developing countries and the latter for ecological and food security. At each level of decision making in India, climate policy is embedded in wider policy concerns. In the international realm, it is being woven into broader foreign policy strategy, while domestically; it is being shaped to serve national and sub-national development interests. Some common drivers at all levels finds that their influences over policy are not uniform across the different arenas, and in some cases, they work in different ways at different levels of policy. We also indicate what this may mean for the likely acceptability within India of various climate policies being pushed at the international level.

Impact of Improved Technologies Demonstrated under TSP in Meghalaya

A.K. Tripathi, A. Roy*, N.U. Singh, N.A. Deshmukh, T. Samajdar, B. Kumar, P.K. Sinha and A. Yumnam
ICAR Reserach Complex for NEH Region, Umiam, Meghalaya

Tribal Sub Plan (TSP) for Scheduled Tribes has been an important strategy in the planning process of Indian administration introduced in the 5th Five-year Plan to ensure that outlays and benefits from the general sectors of the Plans flow to STs at least in proportion to their population both in physical and financial terms. ICAR RC for NEH Region has also been distributingseeds, planting materials and other inputs, along with the demonstration of different technologies in the region. Therefore an economic assessment of such interventions under TSP was felt as the need of the hour to evaluate the impact and devise corrective measures. For this, a survey was conducted by following the ex-post facto experimental design. Data collected through Focused Group Discussion (FGD), in which both the beneficiary and non-beneficiary farmers under various demonstration programmes in agriculture, horticulture, livestock and fishery sectors in the state of Meghalaya were interviewed.The average net income from the crossbred pig was Rs.73,050/- , a little less than double of that in local pig which earned an average net income of Rs. 41,928/-.In case of backyard poultry farming with scientific management and improved variety (Vanaraja), the average monthly income realized by famers in the adopter category was around Rs. 5000 per month, whereas in case of non-adopters it was found to be Rs. 3000 per month. The result of rice demonstrations (cv. Gomti, Naveen, Swarnamashuri, Ranjit, Shasharang, RCM 9, RCM 10 and RCM 11) showed that the beneficiary farmers were able to obtain additional rice yield in the range of 38.6 to 50.2 % with an average yield in the range of 3.8- 5.5 tonnes against the non-beneficiary farmers who could manage only 2.7 - 3.1 tonnes per hectare.The TSP interventions resulted in significant increase in cropping intensity (>118 %) which ultimately led to higher annual income resulting in substantial change in the living standards of beneficiaries with more than 28 % expenditure on comforts (entertainments and modern assets) followed by 18 % and 16.8 % expenditure on health and education, respectively.The study also revealed that the demonstration conducted on various technologies needs to be integrated with suitable farming system model which will have more impact through component approach. One of the grey areas of TSP was that Natural Resource Conservation, which has to be properly addressed in an appropriate manner and given top priority for sustainable development of hill agriculture.

Growth and Reproduction Performance of Pigs Maintained on Different Diets

Asem Ameeta Devi and Deepak Singh
Krishi Vigyan Kendra, Chandel, ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat-795004 (Imphal), Manipur
**Email: prabhayumnam@rediffmail.com*

The present study was carried out on 12 Hampshire crossbred pigs maintained by 4 farm women from Chandel district of Manipur with an objective to study the effect of different types of diets on growth and reproduction performance of pigs under village management condition. Each farmer was provided with 3 weaned crossbred piglets having 2 females and one male. Out of which the first 2 farmers were maintained their piglets on 40% Rice bran and 60% rice fermented waste (Diet I), whereas pigs of later 2 farmers were maintained on 30% crushed maize, 30% rice bran and 40% rice fermented waste (Diet 2). Although the higher weight at 6 month of age was recorded in pigs maintained on diet 2 (54.14 ± 0.72 kg) in comparison to diet I (52.53 ± 0.89 kg) differences between these two groups was non-significant statistically. Similarly non-significant effect of diet was also noticed on reproductive performances of sows. Age at sexual maturity, age at first farrowing, litter size at birth and at weaning in diet I and diet 2 were found 8.61±0.63 and 8. 19 ±0.71 month, 12.92 ± 0.75 and 12.47 ± 0.69 month, 8.99 ± 0.44 and 9.33 ± 0.26 and 7.96 ± 0.51 and 8.99 ± 0.44 respectively. On the basis of above finding it was concluded that both the diets are equally good and there was no significant difference found among the two diets.

Horizontal Spread of Vanraja Poultry Bird in Chandel district of Manipur After Intervention of FLD

Asem Ameeta Devi and Deepak Singh

Krishi Vigyan Kendra, Chandel, ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat-795004 (Imphal), Manipur
Email: prabhayumnam@rediffmail.com

The poultry is one of the most important components of the farming system to improve the economy within a very short duration of time. It provides additional income and job opportunities to a large number of rural populations in the shortest possible time. In Chandel district, poultry rearing under backyard system is a traditional way in early days. People used to rear 2 to 3 desi birds. The indigenous fowls are far less poor performance compare to the improved birds as they are reared under scavenging system. But there is a wide gap exists between the demand and availability of poultry production in the region as the demand for chicken and eggs is steadily increasing over fast few years. The situation is further widened by more population of desi/local bird which lay fewer eggs and small size of body. In order to short out the problem KVK introduced dual purpose Vanaraja birds since 2010 onwards for both meat and egg production. More than 15 villages had been covered for Vanaraja rearing and it spread horizontally from one farmer to another. In response to increasing consumers demand, many farmers have started small scale poultry enterprises in their operations to increase farm income. Poultry are efficient converters of feed to meat and egg and it requires very less space for rearing. Since this improved bird Vanaraja can thrives very well on locally available feed ingredients as feed cost have a major impact on the profitability of poultry farm operation. In order to minimize feed cost a proper feed formulation is essential with locally available feed ingredients; local grasses, vegetable leaves and kitchen residue with inclusion of rice bran and 20% maize will minimize the feed cost upto 50%. Since the minimum investment on starting poultry farming the acceptability among the people was found to be high as these birds have a triple advantage in terms of colour, hardiness like local birds, early laying age, high egg production and large body size in compare with local desi bird. Therefore Vanaraja birds are one the most suitable bird required for sustainable livelihood under small scale intensive system of farming in Chandel district of Manipur.

Impact of Frontline Demonstrations on Productivity and Profitability of Sequential Vegetable Production under Low Cost Plastic Tunnel in Temperate Humid Region

Boniface Lepcha*, Ravikant Avasthe, Raghavendra Singh, Pallabi Phukan, N.J. Singh, P.K. Pathak and J.K. Singh

Krishi Vigyan Kendra, ICAR-NOFRI, East Sikkim, Ranipool-737135, Sikkim, India.
**Email: yenob79@gmail.com*

Sikkim is blessed with varied agro-climatic conditions which favour cultivation of variety of vegetables. However, weather extremities limit the production potential and in turn profitability. Protected cultivation of high value vegetables is a very important tool to cultivate vegetables even during weather extremities in the region. Moreover, a viable cropping sequence may play significant role in making farming more profitable particularly for small and marginal farmers. Potentiality of recommended technology through front line demonstration was endeavored in this study with an objective to find out the impact on performance of off-season vegetable-based cropping sequence under low-cost plastic tunnel to enhance the profitability of vegetables under mid hills of Sikkim. Krishi Vigyan Kendra, ICAR-NOFRI, Ranipool, East Sikkim conducted 60 Frontline Demonstrations on farmers field during 2013 - 2016 at five different villages *viz*., Sajong, Timpyem, Nandok, Thanka and Lossing villages of East Sikkim. Twelve vegetable growers from each village were selected through purposive random sampling technique to constitute a total sample size of the study comprised of 60 nos. (12 x 5 nos.). The area considered under each demonstration was 100 sq.m. Soils of experimental sites were sandy clay loam with pH range of 5.5-5.5.8, available N 228.5-233.6, P 12.9-14.3 and K 182.3- 186.5 kg/ha, respectively. Cropping sequence of cabbage (3rd wk of January) - fenugreek (4th wk of April) - coriander (3rd wk of July) - broccoli (2nd wk of October) was grown during frontline demonstration programmes. Visits of the farmers and extension functionaries were organized at demonstration plots to show the significance of large scale cultivation of year round vegetable cultivation. Yield data was collected from farmer's practices (control plots) and demonstration plots and cost of cultivation, net income, benefit: cost ratio and extension gap was calculated and analysed. Average yield of vegetable crops increased by 55.82 per cent under recommended practice over control. An average net profit of 233.25 per square meter was recorded with recommended practice where as it was 81.63 per square meter in farmer's practice. Benefit: Cost ratio varied from 5.2 under demonstrations to only 2.8 for control. The extension gap ranging between 53-74 kg per sq.m was recorded during the period of study. Practicing farmers should be educated through various means for adoption of improved agricultural production to reverse the trend of wide extension gap. Front line demonstration of recommended technology revealed that yield potential and net income from off-season vegetable-based cropping sequence under low-cost plastic tunnel cultivation can lead to economic improvement and empowerment of farmers.

Impact of Front Line Demonstrations of soybean and groundnut production technology on production and productivity in Chandel district of Manipur

Deepak Singh*, Ts. Leenda Mosang, KL.Levish Chongloi, Y. Prabhabati Devi, A. Ameeta Devi, Thockchom Motilal Singh, K. Sonamani Singh and N. Prakash[1]

ICAR- Krishi Vigyan Kendra, Chandel
[1]ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal, 795004
**Email: deepaksingh_pp@yahoo.com*

The present investigation was conducted on 107 demonstrations of Soyabean (Var.JS-335) and 56 demonstrations of groundnut (Var. ICGS76) during 2007-2008 to 2016-17.The data were collected through structured interview schedule and with available records at KVK. The results revealed that higher average yield and percentage increase in front line demonstration was observed and attributed to the improved variety along with technology demonstrated through front line demonstration in soyabean and groundnut crops. Economic analysis of yield performance of demonstrations revealed that on an average for the period under study, higher gross returns were recorded in soyabean and groundnut demonstration with relatively higher benefit cost ratio. Further with additional cost of Rs.1688/ha and Rs.5490/ha in demonstration yielded additional net returns of Rs. 1280 /ha and Rs. 26135/ha with incremental benefit cost ratio of 8.50 and 5.92 in soyabean and groundnut demonstration respectively attributing to higher profitability and economic visibility of the demonstrations. The mean knowledge and adoption scores of beneficiaries were higher comparatively

than the non-beneficiaries. It was observed that majority of beneficiaries had medium to higher knowledge and adoption of soyabean and groundnut production technology promoted through front line demonstration by KVK. This might be due to the concentrated educational efforts made by KVK scientists in implementation of front line demonstrations. Training attained, information seeking behaviour, risk orientation and economic motivation characteristics of beneficiaries have exhibited positive and significant increase in knowledge and adoption of beneficiaries. The data signified strong satisfaction of farmers about the services rendered by scientists through Frontline demonstrations and in turn promoted the physical and mental active involvement of the beneficiaries, ultimately lead to increase in knowledge and adoption level of beneficiaries and higher yields and economic net returns.

Vanaraja Poultry Birds Production among Farmers in Mid Hills of Arunachal Pradesh

Jini, D[1]., Doley, S[2]., Bhagawati, R[3] and Kalita, H[1]

[1]ICARAP centre Basar, West Siang district, Arunachal Pradesh 791101.
[2]ICAR Reserach Complex for NEH Region, Umiam Meghalaya
[3]ICAR-NRRI-RRLRRS, Gerua, Hajo
Email: donoxini@gmail.com

The study was under taken to know the adoption of improved practices after introduction of Vanaraja poultry birds. Three circles of west siang district viz, Daring, Tirbin and Aalo were purposively selected. Nine villages from these circles were selected randomly. Total 36 tribal poultry farmers were selected with previous experience of rearing indigenous birds. Vanaraja poultry birds around 600 nos were procured from ICAR Nagaland centre reared for 1 month under ICAR farm condition. Hand on training of farmers was imparted to the farmers before distribution .Data were collected individually through a structured and pre-tested interview schedule from respondents. It was observed that majority (66.7%) of beneficiaries constructed poultry sheds from locally available material such as bamboo, wire mesh, and toko leaves etc. Majority (55.5%) adopted the housing space of 2-3 ft^2 per bird than previous ones. Cent per cent of beneficiary adopted scavenging cum feeding within the vicinity of their houses. About 33.8 per cent allowed scavenging from 3 to 6 hours per day. The birds scavenged in two schedules early morning from (8-11 A.M.) till noon and late afternoon till 4.00 PM evening. Around 44.4 per cent clean their shed on monthly basis with application of lime in the bedding materials. More than 64.7 per cent had successfully performed chick brooding from provided vanaraja parent with available local birds. Previously around 8 per cent did vaccination but after intervention around 52.7 per cent vaccinated their birds against Ranikhet disease. 77.8 per cent of the farmers applied ectoparasiticide drugs for flea infestation which was earlier done with application of ash. Before intervention 63.8 per cent threw their dead birds in open space but after intervention 75 per cent properly buried their birds. More than (52.8 %) of the respondent consulted ICAR scientist, 30.5 per cent veterinary doctors and Para -vets (16.7%). Overall significant difference in mean value was observed after introduction of Vanaraja with respect to housing and health care ($P<0.001$) whereas feeding and breeding were non-significant. The major constraints perceived by farmers were, (74.4 %) poor brooding capacity of birds, (70.4%) vent picking vice, (59.2 %) easy prey to predators and (44.4 %) was damage of crop field.

Keywords: *Vanaraja, Adoption, Constraints*

The role of ICT for Transfer of Technology in Agriculture in North Eastern India: Reaching the Unreached Farmers and Empowering Them

Kankabati Kalai[1] Loukham Devarani[2] and Nivetina Laitonjam[2]

[1]*Department of Agricultural Extension, College of Agriculture, IGKV, Raipur*
[2]*School of Social Sciences, College of Post Graduate Studies, CAU, Umiam, Meghalaya*
Email: kankakalai@gmail.com; loukham.d@gmail.com; nivelaitonjam@gmail.com

Agriculture is considered as backbone and plays vital role in India's economy. Contributes around 17 per cent of total GDP and is higher than the world average which is only 6.1 per cent. It is also most important occupation for north eastern people. In north east large population live below poverty line which is around 40.01 per cent. Most of the farmers in this area are small farmers and mostly practice slash and burn type of agriculture for their living. Rice is the main crop grown which covered area around 61 per cent of the gross cropped area, followed by other crops. However, the productivity of rice in North east region was found to be below the national rice productivity average. Farmers' following the traditional method/slash and burn type of agriculture is not sole reason behind the low productivity in the region. The region is dominated my irregular rainfall pattern during the wet season and cultivation is entirely rain-fed. Areas being remote, hilly covered with difficult mountain terrain, and underdeveloped roads, the farmers are deprived of the information and technology, and access to it become distant reality, which also hinders socioeconomic development of the region. Inadequate manpower, extension worker and limited extension service are another reason behind such condition. The ratio of extension personnel to farmers in India is found to be around 1: 2879. With such ratio it's hard to provide extension service to large number of farmers effectively. Moreover the present extension system does not have inherent marketing element, which in fact, is closely associated with the development of agriculture. In such situation ICTs comes to rescue, and bridge the gap by reaching the unreached and providing information about crop, market related information, any event taking place anywhere, at any time, available to any farmer anywhere at any time, thereby facilitating an environment for more remunerative agriculture. Some of the Projects like e-arik, e-village, e-kiosk, and m4agri has played innovative role in empowering the farmers' community with production, protection and market information in remote areas of northeast. Such more steps in coming days can bring more opportunities, and improve socioeconomic back ground of the farmers in the region.

Keywords: ICT, Agriculture, Transfer of Technology, Farmer, Northeast

Sustainable Livelihood through Backyard Poultry Farming at Longleng District Nagaland: A Success Story

Lily Ngullie[1], Manoj Kumar[1], K.L. Meena[1] and D.J. Rajkhowa[2]

[1]*Krishi Vigyan Kendra (KVK), Longleng, Nagaland*
[2]*ICAR Research Complex for NEH Region, Nagaland centre Medziphema*
Email: drlilngully@gmail.com

Rearing of chicken at backyard is practised in Nagaland since time immemorial. Indigenous poultry birds are reared with low input or no input venture. The birds mostly depend on the natural resources available at the backyard through scavenging and kitchen waste. The average body weight of local indigenous birds ranges from 600-700 g at 6 months of age, which creates a wide gap in the demand and availability of poultry meat in the rural areas. The performance of Vanaraja- a dual

purpose bird under low input semi intensive farming system was evaluated in the backyard of Mrs. Mhono Phom, a housewife belonging to Yachem village of Longleng district. She developed interest in poultry farming, after attending training programme conducted by KVK Longleng. On trial basis, KVK Longleng provided 100 numbers of day old Vanaraja chicks for rearing at her backyard. The overall survivability percentage was 92 per cent till 20th week. Result revealed that average body weight of Vanaraja chicks at 4th week was recorded 299.3 ±76.5 g per bird that increases up to 2864± 472.03g per bird at 20th week. The average age at first laying was 178 days with an average annual egg production of 158 eggs per bird. Commercial starter ration was given for 8 weeks thereafter allowed to scavenge in the backyard during the day time. The birds were supplemented with additional feeds like maize, paddy grains and green leafy vegetables. The input comprises of the cost of chicks, feeds, medicines, vaccines, housing and other miscellaneous expenditure amounting to Rs. 70,700 only. A total of 4 male and 32 female with a ratio of 1:8 birds were maintained for egg laying and the remaining birds were sold for meat purpose. The income was from the sale of live birds at the rate of Rs. 300 per kg and eggs at the rate of Rs.6 per egg. The overall expenditure was Rs. 70,700 and income from the sale of live birds was Rs. 74,280 and Rs. 19,440 from sale of eggs. She earned net profit of Rs. 23020 in 2015-16. With the profit, she again purchased 100 numbers of Vanaraja chicks and continuing the enterprise till date. The meat and egg of Vanaraja bird was highly accepted by the public and her success has motivated the fellow villagers especially the women folks and unemployed youth to initiate poultry farming as a means of sustainable and profitable enterprise besides providing nutritional security to their family members.

Enhancing the Productivity and Income through Improved Practices of Low Land Rice under Longleng District of Nagaland

Manoj Kumar[1], E. Lireni Kikon[1], K.L.Meena[1] L.K. Baishya and D.J. Rajkhowa[2]

[1]*Krishi Vigyan Kendra (KVK), Longleng*
[2]*ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema*

Longleng district falls under the subtropical hill zone of Eastern Nagaland. Agriculture is the main stay of the people, in which Low land (Pani Kheti) is one of them for their livelihood. Farmers of the district practiced traditional rice cultivation with low yield after maximum inputs (seeds and labour). Before the intervention of the improved technology in the Pongching village of the District, Krishi Vigyan Kendra (KVK), Longleng was conducted base line survey through Participatory Rural Appraisal (PRA). During the PRA survey, It was found that farmers using more seed rate (40-50 kg/ha), seedling age (30-40 days) for transplanting, more seedling (6-8/hill) and less spacing (10 x 10 cm) and ultimately getting less yield with more expenditure due to lack of knowledge of improved cultivation practices of low land rice. Therefore, Krishi Vigyan Kendra (KVK) took initiative to replace the farmer's practices through disseminations of improved technology for enhancing the productivity and income. Before the intervention of new technology, awarness -cum- training programme on lowland rice was organised in the village. All together 16 nos. of farmers were participated in the training programme and took interest for adopt the improved practices. After that hand on training programme of nursery sowing, transplanting was conducted at farmer's field during the year 2014-15 to 2016-17. Farmer's fields are regularly monitoring of by the agronomy Scientist up to the harvest of the crop. Results of improved practiced found that average yield (3 years) was recorded 4.47 t/ha against 3.24 t/ha with farmers practices. Net profit and B: C ratio were recorded Rs.33210/ha, Rs.19080/ha and 2.62, 1.96 with improved and farmers practices respectively. Percentage increase yield and net profit were 38.2 and 73 % with improved practice as compared to tradition cultivation. The successful demonstration on low land rice by following the principles of "learning and doing" and "seeing and believing". After the successful intervention of technology, farmers growing new intervention technology of rice cultivation. The impressive performance of the technology awakened the farmers, farm women of the village and neighbouring villages to adopt this technology helps to increase net income of the farmers.

Implementation of Participatory Approach in Ri-Bhoi District of Meghalaya for Livelihood Improvement: A Practical Example

[1]Pankaj Kumar Sinha, [1]Bagish Kumar, [1]A. Roy, [1]N.U. Singh, [1]A. Yumnam and [2]A.K. Tripathi

[1]ICAR Research Complex for NEH Region, Umiam
[2]ICAR Agricultural Technology Application Research Institute (ATARI), Guwahati

Till now enormous efforts has been put forward to increase the production and productivity as well as addressing allied issues pertaining to farmers' welfare of the North-Eastern Hill Region (NEHR) by different stakeholders of the Indian National Agricultural Research System. Almost all effort emphasizes the traditional approach of technology generation and transfer which deprived the adequate participation of the farm families and therefore lacks comprehensive farming system approach. But in the present scenario, a thorough understanding of the unfelt need of the farmer in a specific village situation and design interventions accordingly in a participatory mode, taking into due special consideration the natural resource base, post-harvest processing, value addition and marketing of produce is needed. Hence, by considering all the facts an initiative has been taken under Farmer FIRST project of ICAR in two clusters of villages namely Marngar and Sarikushi in Ri-Bhoi district of Meghalaya. Based on PRA and agro-ecosystem analysis as well as considering the farmer's unfelt need various module based approach has been intervene in the adopted village in a participatory mode. Such as Promotion of pulses (Pea and Lentil)/ vegetables in maize and rice fallow under crop based module, demonstration of low cost scientific backyard piggery houses (Deep Litter Housing) and Poultry sheds (Low Cost Poultry Sheds) with the improved breeds of Poultry (Vanaraja and Gramapriya) and Piggery (Hampshire-87.5% Cross) under Livestock based module,demonstration of IFS model with crop husbandry, piggery, poultry, duckery, fisheries, mushroom cultivation, vermicomposting, vegetable farming and agro forestry component under Integrated Farming System module etc. The initial results are very encouraging as farmers show their interest in adoption of different technology. Apart from that, many nearby village farmers have approached the IFS adopted farmer to help them in establishing IFS. Two Training programme on Mushroom cultivation had been organized for the farmers under the project. The beneficiary farmers have already constructed mushroom houses and started cultivation. In addition to that, two of the farmers took innovative steps to cultivate the mushroom and sold in the near market. One of the farmers got Rs. 6000/- (Six Thousands only) with an investment of Rs. 1500/- (One Thousand Five Hundred Only) including the labour and spawn cost within two months. By seeing this many farmers have decided to go for mushroom cultivation in the coming season as now it is difficult to get the paddy straw for the mushroom production. As the project is in the initial phase, but the interest and enthusiasm of the farmers has given the thumbs up to the approach of the project and certainly implies that the participatory method of the project planning and implementation is the key of success for the project.

Impact of Front Line Demonstration on Cabbage Yield in Churachandpur District, Manipur

R.K. Roshan[1], Nongallei Pebam[2], Niranjan Lal [1], N Prakash[3] and L. Basil [1]

[1]KVK Churachandpur, ICAR RC Manipur Centre
[2] Medical Directorate, Imphal West, Government of Manipur
[3]ICAR Research Complex for NEH Region, Manipur Centre
Email: roshanrk940@gmail.com; leipebam@yahoo.co.in

Cabbage is one of the most important vegetable crops of the Churachandpur District, Manipur. One of the major constraints of traditional cabbage cultivation is low productivity due to non-adoption of recommended package of practices and improved varieties by the cabbage growers of the district. To replace this anomaly, KVK Churachandpur under ICAR Research Complex for NEH Region, Manipur conducted 20 frontline demonstrations (FLDs) on recommended production technology of cabbage var. Green Hero in eight different villages of the district namely Tollen, Kholmun, Talian, Henkot, Yaiphakol, Mata, Matiyang, L Molvom during Rabi season for four years (2012-2013, 2013-2014, 2014-2015 and 2015-16). The present study was carried out with the objective of finding the yield gaps between improved package of practices and existing farmers practice of cabbage and to educate the cabbage growers about its scientific cultivation, right from nursery raising stage till harvesting, to increase the productivity of the crop. The average yield of cabbage in FLD ranged from 320.00– 335.00q/ha whereas in existing practice only140.00 q/ha was recorded. Per cent increase in yield after the adoption of the improved technology over existing practice was recorded in range of 128.57 to 139.29. The extension gap ranging between 180-195 q/ha during the study period. The technology gap decrease from 80% to 65% which clearly indicated the farmer's cooperation, in carrying out such demonstrations with encouraging results in subsequent years. The decreasing trend of technology index i.e., from 25 to 19.40 clearly shows the feasibility of the new technology at the farmers' fields. The lower the value of technology index more is the feasibility of the technology.

Keywords: *Cabbage, KVK, FLD*

Farmers' Attitude towards Adoption of Organic Vegetable Production Technologies in Selected Villages of East Sikkim

Pallabi Phukan*, Ravikant Avasthe, Boniface Lepcha, Raghavendra Singh, N. J. Singh and P.K. Pathak

Krishi Vigyan Kendra, ICAR-Sikkim Centre, East Sikkim, Ranipool-737135, Sikkim, India
**Email: pallabi.phukan83@gmail.com*

Sikkim has the pride of becoming the first state of India by adopting organic farming concept for healthy living and sustainable agriculture to maintain the ecology and environment for healthy and wealthy future of the Sikkimese people. Farming in Sikkim is done without the use of synthetic fertilizers and pesticides, providing access to safer food choices and making agriculture a more environment-friendly activity. In this context, State departments as well as line departments of Sikkim continuously assist farmers through capacity building and input distribution as well demonstration programmes. But, adoption/ rejection of any technology is totally dependent upon farmers' attitude. As attitude towards a practice is measured by the perception of usefulness and also can lead to better understanding of the technology's usefulness, thus leading to propensity to adopt these technologies. Keeping this in view, the present study was designed to ascertain the level of attitude of the farmers towards adoption of organic vegetable production technologies. The present study was carried out using ex-post facto research design during 2016-17 in the purposively selected East District of

Sikkim. Study was undertaken in the three blocks namely Gangtok, Ranka and Martam of East Sikkim. A comprehensive list of all the vegetable growers of selected villages was prepared and farmers were categorized into marginal farmers (<1 ha), small farmers (1-2 ha), medium farmers (2-5 ha) and large farmers (>5 ha). A proportionate sample from each category was drawn randomly to have total sample size of 150 farmers selected using random sampling method from ten revenue villages. The method of summated rating suggested by Likert (1932) was followed in the development of scale to measure the attitude of farmer towards the organic farming. A total of 20 statements, expressing the attitude of farmers towards the organic vegetable farming were collected based on the applicability of statements to study area. The responses were obtained on a five point continuum *viz.* Strongly Agree (SA), Agree (A), Undecided (UD), Disagree (DA) and Strongly Disagree (SDA) with a score of 5, 4, 3, 2 and 1, respectively for the positive statement and for the negative statement reverse scoring was adopted. Primary data was collected using pre-tested questionnaire during the year 2016 through face-to-face interviews using semi-structured questionnaire to collect data.

Majority of the respondents (51.3%) were between the ages of 35 and 50 years *i.e.* most of the farmers were middle aged, in their economically active stage with 55.3 per cent male respondents and 44.7 per cent female respondents.. In case of farmers' category, 42 per cent of the respondents were categorized as small farmers followed by medium farmers (30%), marginal farmers (19.3%) and large farmers (8.7%).. It was also found from the study that 46.7 per cent of the respondents had favourable attitude towards adoption of organic vegetable production technologies whereas the most prominent attitudinal statement as ranked by the farmers was statements that organic farming will keep environment free from pollution (4.59) followed by changing to organic system is an exciting new challenge (4.43) which ranked 2nd. Organic agriculture has great potential to fetch premium price in the national and international markets. So, in Sikkim it is very pertinent to fix prices of organic products as well as establishment of proper marketing and storage facilities so that it may encourage the producer and also enhance the farmers' attitude towards commercial organic vegetable production.

Participation Pattern of Tribal Women in Livestock Management and Their Characterization

Monsumi Borah, Manoshi Baruah Deka and Sayanika Borah

Department of Extension and Communication Management, College of Community Science, Assam Agricultural University, Jorhat
Email: monsumibora0@gmail.com

The tribal population in India constitutes a significant part of the population and the women in a tribal society are found to play a significant role in the economy of the family through adopting various means of livelihood. Though there are a large number of studies on tribal communities but only a few are focused on characterizing the tribal women. Thus the present study on "Participation pattern of tribal women in livestock management and their characterization" was carried out with the following to assess the participation and the decision making pattern of tribal women in livestock management and their characterization. Respondents were selected using simple random sampling technique from tribal dominated villages of North-West development block and Titabar development block of Jorhat district. From each of the block 60 tribal women were selected. Thus total numbers of respondent were 120. Data was collected using structured interview schedule and analyzed using appropriate statistical techniques .The livestock management was found to be one of the most popular forms of primary and additional livelihood sources among the respondents. It was evident from the data that amongst the livestock management activities, independent participation was highest in fodder management (60.00%), management of produce (53.33%), cleaning of shed (52.50%), selection of suitable breed (46.67%) and so on. With regard to characterization of tribal women in terms of their participation pattern in livestock management, the tribal women participated in almost all livestock related activities except for construction of shelters. Pertaining to decision making, independent decisions was found to be highest in cleaning of sheds ,then fodder management ,selection of site for rearing and so on. It can also be characterized from the findings that the respondents' independent decisions dominated the scenario in case of livestock management. The decision making process was found to be positively associated with mass media exposure, extension contact, organizational membership, livelihood source of the respondent, indicating that improving the information delivery system using both electronic and print media the decision making and livelihood of tribal women can be scaled up.

Impact of Front Line Demonstration on Growth Performance of *Vanaraja* Chicken in West Siang District of Arunachal Pradesh

M.S. Baruah[1], D. Datta[1], C.S. Raghav[1] and H. Kalita[2]

[1]*ICAR-KVK West Siang, ICAR-Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, India – 791101*

[2]*ICAR-Research Complex for NEH Region, Arunachal Pradesh Centre, Basar, India – 791101*

Email: ddatta1988@gmail.com

The present investigation was conducted to evaluate the performance of *Vanaraja* chicken rearing under backyard system between the improved technologies demonstrated under Front Line Demonstration (FLD) by *Krishi Vigyan Kendra*, West Siang District, Arunachal Pradesh and farmer's practice (FP). All together 60 number of farmers from 12 randomly selected villages of West Siang district of Arunachal Pradesh having experience of poultry rearing for more than two years were selected for the study. The study (from August, 2015 to July, 2017) reveals that, the technologies demonstrated in FLDs recorded higher body weight over FP. At 20 weeks of age under FLD the body weight of the birds were recorded 2200±2.23g which was 18.41% higher than that of FP (1795±2.11g). The mortality after 21 weeks of age was recorded as 10 % in FLD whereas in FP it was recorded as 15 %. The average age at first egg of *Vanaraja* under FLD was found to be 22.14 ±0.33 weeks with a 125 numbers of annual egg production, while in case of FP the average age at first egg was recorded as 23.42±0.13 weeks with an annual production of 112 numbers of eggs. The estimated benefit cost (B: C) ratio for *Vanaraja* chicken rearing under FLD and FP was recorded as 2.84 and 2.25 respectively which indicated that under improved rearing techniques demonstrated under FLD *Vanaraja* chicken gives much more profit than that of rearing techniques under FP.

Participatory Approaches for Sustainable Agriculture in Northeast India: Status and Way Forward

Mayanglambam Victoria Devi, Loukham Devarani and S.S.P. Jyothi

College of Post Graduate Studies, CAU (Imphal), Meghalaya

[*]*Email: naonao.vm@gmail.com*

Participation is defined as voluntary contribution by the people in the public programmes to solve their own problems. Participatory approaches are a product of long lasting interaction between researchers, development workers, government agents and local populations. It includes people's involvement in decision-making processes, in implementing programmes and their sharing in benefits of development programmes. Participatory approaches are becoming important as it enhances social cohesion, adds economic value and promotes sustainability. Different participatory approaches *viz.*,

Rapid Rural Appraisal, Participatory Rural Appraisal, Participatory Learning Methods, Participatory Learning & Action, Participatory Assessment, Monitoring & Evaluation, Farming Systems Research, Agro-Ecosystem Analysis and Participatory Technology Development, *etc.* are practicing in various corner of the World to bring development. Northeast (NE) India is blessed with luscious greenery, unspoilt beauty and has abundant diverse natural resources in terms of fertile and organically rich soils, ample rainfall & water resources and great climatic diversity supporting diverse cropping possibilities. NE is also famous for its diversity in culture: different ethnic groups, dialects, indigenous knowledge, beliefs, technology and practices. The potential for socio-economic growth of the region is widely recognised by government and international organisations mainly. However, the various diversities and the resulting differences in needs, opportunities and problems make it challenging and for implementation of developmental programmes. Respecting the local culture, incorporating local knowledge and technologies and developing sensitivity to the needs of the people is necessary. The paper highlights the present status of agriculture and extension in the region and brings out the importance and scope of participatory approaches as a means for achieving sustainable agriculture. Number of projects and schemes at national and international level has been implemented to improve the livelihoods of vulnerable groups in sustainable manner through participation of local people for their own development. In light of various available participatory approaches and cases of usage of these approaches, certain recommendations are proposed for sustainable agriculture, biodiversity conservation and livelihood enhancement.

Keywords: *Participatory, Agriculture, Sustainable, Development, Northeast*

KVKs are at the Crossroad: A Policy Call for Redefining and Redesigning

[1*]Bagish Kumar, [2]Pankaj Kumar Sinha, [3]A.K. Singha, [4]R.Bordoloi, [5]N.Uttam Singh, [6]Anirudha Roy and [7]Anjoo Yumnam

[1, 2, 5, 6&7]*ICAR Research Complex for NEH Region, Umiam*
[3&4]*ICAR-ATARI, Zone VII, Umiam*
**Email of Email bagishagri@gmail.com*

Krishi Vigyan Kendras (KVKs) are the grass root level organizations working towards reducing the time lag between technology generation and its dissemination process at field level under different farming systems for increasing production, productivity and farm income on a sustainable basis.This organization is meant for application of proven agricultural technology through assessment, refinement and demonstration in micro agro-climatic situations. The mandate of KVK is *Technology Assessment and Demonstration for its wider Application and to enhance Capacity Development (TADA-CD).* To implement the mandate effectively and efficiently, the activities such as On-farm testing, frontline demonstration, different capacity development programmes of farmers, rural youth, extension personnel etc. have been defined and systematically designed by each KVK based on location specificity of the respective districts. It has been widely recognized that KVKs are gaining overwhelming popularity due to their proactive role in transferring new technology at field level yielding significant social and economic impacts. They have an edge in technology transfer over other service providers by virtue of their having better technical expertise of human resources and infrastructure including demonstration units in their premises. But, off late a question mark has also been posed on the efficiency of this multidisciplinary institute. By, considering this fact a study has been conducted on the activities of KVK based on secondary data collected form “indiastat” with the objective “to analyse the mandated activities of KVK”. The Annual Growth Rate (AGR) and Compound Annual Growth Rate (CAGR) have been calculated for the period 2006-07 to 2016-17.

The results show that the CAGR of 20% was observed in the case of on-farm testing conducted with the negative annual growth rate of 10% and 19% during 2014-15 and 2016-17 respectively. Frontline demonstrations, on the other hand, showed only 8% of CAGR with the negative annual growth rate of 12% and 46% during 2011-12 and 2014-15 respectively. The CAGR of only 3% have been recorded with respect to Farmers training and again the negative annual growth rate has been observed during the year 2011-12, 2013-14, 2014-15, 2015-16 and 2016-17 of 4%,14%, 5%, 5% and 2% respectively. The KVK has been established with the aim to upgrade the knowledge of Extension Personnel involve in the dissemination of technology but the analyzed data shows that the CAGR of only 4% has been observed in this case with the negative annual growth rate during 2007-08, 2010-11, 2013-14, 2014-15 and 201-17 of 18%, 17%, 84% and 29% respectively. The reason for this result might be due to overshadowing the mandated activities by the intensive involvement in non-mandated activities, very hectic reporting system, lack of motivation among the staff of KVKs, political interference, duel nature of rules and regulation for the KVK etc. The very basic purpose of KVK is diluted and sandwiched between ICAR and host institute. KVK has all the potential to become the model institution for technology dissemination but it requires the revamping, re-engineering and rethinking to keep it on the track for which it was designed.

Quality Protein Maize Cultivation - a Boon For Meghalaya Farmers

Meghna Sarma and Rajumoni Bordoloi

KVK, Ri-Bhoi, ICAR Research Complex for NEH Region, Umiam, Meghalaya
Email: *meghnasarma3@gmail.com*

Meghalaya covers Maize area of about 17.3 thousand ha with a total production of about 26.9 thousand MT and productivity of 1554 kg/ha (Crop Production statistics of Meghalaya, 2012-13).The area under Maize has remained the same for many years. The production and productivity are also constant. The constraints in achieving are cultivation of low yielding variety, local land races in acid soils with AL toxicity and non-availability of improved variety of seed. Normal maize has been found to be deficient in two essential amino acids i.e. Lysine and Tryptophan which leads to poor net utilization and low biological vale of traditional maize. In order to overcome this problem, QPM has been developed by maize breeders which contains nearly twice the quantity of essential amino acids, lysine and tryptophan which makes it rich in quality protein. Most of the farmers in Meghalaya cultivate only local varieties of maize for their own consumption and the rest meager amount left is being fed to the poultry and pigs. Observing this particular lacuna in research outreach KVK Ri-Bhoi introduced QPM (var. HQPM-1) in 7 villages of Ri-Bhoi district of Meghalaya in the year 2012-2013 and 2013-14.The results of the demonstration showed significant effect on grain yield of maize in farmers' field without the use of any fertilizers. Maximum yield of 42.7 quintal/ha against local yield of 29.5 q/ha was recorded with no incidence of disease and pest attack from the farmers field. The farmers were also highly satisfied with the performance of QPM as it has also reduced the feeding cost of pigs and poultry. With the introduction of HQPM-1 the area of maize has considerably increased within three years.

Productivity and Economic Performance of Lentil in Rice-Fallow for Nutritional Security as Influenced by Cultivars and Tillage Methods

N. Arunkumar Singh, Mokidul Islam*, Tanmay Samajdar** and Tarunkr Das[1]

Krishi Vigyan Kendra, Sangsanggre
** KVK, Ribhoi, Umiam, Meghalaya*
*** KVK, West Tripura, Tripura*
Email: naoremarun@yahoo.co.in

Field technology demonstrations were conducted at 859 farmer’s field of three districts covering an area of 238.68ha in 89 villages of Garo Hill districts, Meghalaya during Rabi season, 2013-2016 to evaluate the performance of lentil varieties i.e. HUL-57, WBL-77 and Patnai (local cultivar) under normal, relay and zero tillage cultivation methods in rice –fallow system. Results revealed that the higher significant values under normal cultivation incorporating bio fertilizer (Rhizobium) in terms of seed yield (+31.06% over relay; +87.84% over zero tillage), net return (+12.9% over relay; +140.96% over zero tillage). However, as per the economics of benefit cost ratio, highest value was found in relay cropping as compare to other sowing methods. Significantly lower seed yield was obtained from zero tillage than normal and relay cultivation methods. Among the varieties tested, WBL-77 produced the highest seed yield (+5.79% over HUL-57; +83.62% over Patnai) with a net return of (+12.94% over HUL-57; +140.49% over Patnai) and a benefit cost ratio (+14.34% over HUL-57; +53.52% over Patnai). The lowest production, net return was found in zero tillage cultivation method.

Keywords: *Tillage methods, Lentil*

Performance of Vanaraja Birds in Churachandpur District of Manipur

L. Babita Devi*, W.R. Singh and N. Lal

Krishi Vigyan Kendra, Churachandpur, ICAR Research Complex for NEH Region, Manipur Centre
**Email: drbabitalais@rediffmail.com*

Backyard poultry plays an important role for sustainable livelihood especially for rural farmers. Churachandpur is a hill district that is situated in the south west part of Manipur with majority of the people usually reared nondescript local birds in the backyard system which is low in productivity. Therefore, Backyard Poultry farming with improved dual purpose breed (Vanaraja) was introduced in the year 2009-10, both to meet the protein demand of the population as well as source of income. The average body weights recorded at 6^{th}weeks and at the time of laying were 670 grams and 2110 grams respectively. In an average, female weighs 2.6kg while the male weighs 3kg at 8 months of age respectively. The first egg lay was recorded at the age of 162±2.4 day. Average egg production per annum was 147 eggs /hen/annum with an average egg weight of 55 grams. Mortality till the age of 8 week was less than 10%.The demonstration was successfully spread to 22 surrounding villages in Churachandpur benefitting 78 farmers. It can be suggested from the present study that the bird is well adapted to the local traditional managemental practices and has potential to perform well under the agro-climatic condition of Churachandpur district of Manipur.

Electronic media- An Effective Tool for Technology Dissemination

Gitasree Goswami[1,] Sanghamitra Mohapatra[2,] Manju Dutta Das[3], Manoshi Baruah Deka[4], Sayanika Borah[5] and Pompi Malakar[6]

Deptt. of Extension and Communication Management, Faculty of Community Science, AAU
E-mail: goswamigitasree@gmail.com

Electronic Media is the major source of modern culture and entertainment. In the world of today, media has played a significant role in strengthening the society. It is considered as "mirror" of the modern society. Considering the important role played by the electronic media, a research study entitled “Electronic media- an effective tool for technology dissemination” was undertaken with the objectives to collect relevant material and develop a Compact Disc (CD) on food preservation and to assess the effectiveness of the developed CD. The script of the documentary on food preservation was written in local language so that villagers could be benefited like other respondents (staffs and students). According to the story board clippings for the CD were shot. Voiceover on food preservation was done in the studio and *Cyber Link Power Director* software was used for editing process of documentary. A close ended evaluation schedule was prepared to evaluate the developed compact disc. Sixty respondents were selected purposively for the evaluation of the developed compact disc. One way ANOVA was used to find out the effectiveness of the CD. The main objective of the CD was fulfilled as all the three respective groups gained the required information of importance and need through the CD on food preservation. As a result, it can be concluded from the study that the subject matter of the CD on food preservation had shown significant result for the villagers. CD has played a major role in education of illiterate and semi-literate rural population as an effective electronic media. Hence, it may be recommended that need based and relevant electronic media may be produce and promote in educational and dissemination of information irrespective of their educational status.

Role of Participatory Video technology in Women Farmer-to-Farmer dissemination of Agricultural Information – a Case of Digital Green

Jyothi S.S.P*[1], Loukham Devrani[2], Punitha P[3] and Mayanglambam Victoria Devi[1]

[1]*PhD Scholar, Agriculture Extension, CPGS, CAU, Barapani, Meghalaya*
[2]*Assistant Professor, Agriculture Extension, CPGS, CAU, Barapani, Meghalaya*
[3]*Scientist, Agriculture Extension, ICAR-NEH Manipur*
**Email: ssp.jyothi@gmail.com*

The present study has been based on the secondary data available on the Digital Green website for the State Odisha and district Kheonjhar. The respondents observed were only the women farmers who had access to the social groups existing in the villages. Through these groups the screenings were done and the adoption by the viewers was observed. It has been observed that every women of the group has viewed all the screenings and the average adoption rate of the women farmers was 17%. This shows that the rate of transfer of technology among the women groups is more compared to the other farmers of the village. The participatory nature of the video making and homophily of the group has fostered dissemination of agricultural information to the target beneficiaries more effectively.

Keywords: *Participatory Video, Women farmer, Odisha, Digital Green, Agriculture, Extension*

Indigenous Technical Knowledge (ITK) Practiced by Dairy and Piggery Farmers in Meghalaya

M. Defenderson Shadap[1] and *Sao Evalwell Dkhar[2]

[1]*Directorate of Agriculture, Shillong, Meghalaya.*
[2]*College of Post Graduate Studies, Central Agricultural University, Umiam.*
**Email: sao27evalwell@gmail.com*

Indigenous Technical Knowledge (ITK) in the field of animal husbandry and veterinary is a practical knowledge that has been developed from the experiences of the farmers who made use of their talent in solving some of their problems under their local conditions using locally available materials. ITKs are still in vogue in rural Meghalaya therefore identification and documentation of such indigenous practices is very important, lest they disappear or endanger to extinction. The study was conducted in two districts *viz*., East Khasi Hills and Ri-Bhoi districts taking two villages from each district. The information was documented using Focus Group Discussion and also through interviewing with the farmers who practiced ITK in their livestock management. ITKs on care and management such as healing of wounds, diarrhoea, foot and mouth disease, increasing body mass, bone fracture, etc. of dairy and piggery are recorded.

Keywords: *ITK, Livestock, Traditional, Documentation, Animal Husbandry*

Theme-12: Agribusiness, Socio-Economic and Policy Issues

Socio-economic and Cultural Harmony between Shifting Cultivation (Jhumming) and the Hill Farmers of North East India

A.K. Tripathi[1], A. Roy[2], N.U. Singh[2], B. Kumar[2], P.K. Sinha[2] and A.Yumnam[2]

[1]*ICAR Agricultural Technology Application Research Institute (ATARI), Guwahati*
[2]*ICAR Research Complex for NEH Region, Umiam*

Shifting cultivation or *jhumming* has been practised and followed by the ancestors and forefathers of the present hill farmers of north east India. Their festivals, rituals and customs are all centred on this age-old practice of *jhum* cultivation. Thus, socially *jhum* cultivation plays a role in maintaining harmony and solidarity among the people. Farmer's perception about the rationality of *jhum* practiced by the *jhumias* were collected through questionnaire survey from the states of Meghalaya, Arunachal Pradesh and Manipur to understand the socio-economic and cultural aspects linked with *jhum* cultivation. Economics of *jhum* farms were worked out to examine the income and nutrition securing capacity of the system. Across the locations, all farmers had the opinion that *jhum* cultivation is having least risk and uncertainty in comparison with other method of cultivation. It is mainly due to the fact that more than 20 crop mixtures are grown in the *jhum* field. About 90-98 % farmers had the opinion that *jhum* is the only system which can provide almost all requirements of family *viz.*, food, fuel, timber and cash requirement for the family and livestock. There is close dynamic relationship between *jhumming* and the economic and social life of the *jhumias.* Crops such as rice, millet, maize, chili, cucumber, sweet potato, tapioca, local beans provide for direct consumption as well as production of primary processed products such as rice and millet wine, chutneys, chips, pickles, etc which they either sell or use in community occasions and festivals. The exploration on the cultural rituals and festivals followed by the *jhumias* during different stages of *jhumming* revealed that the requirements for foods, drinks and other miscellaneous items required for performing rites and rituals such as flowers, fruits and leaves are all provided from the *Jhum* fields. The study has revealed a harmonious co-existence of the hill farmers in the system of shifting cultivation, untouched by the outside influences. But still, to enhance their living standard, income improvement may be strategized through inclusion of cash crops in jhum farms, capture the organic market, afforestation with multi-purpose tree species and integration with livestock enterprise.

Carpenter Worm: An Indigenous Delicacy in Nagaland, India with Nutritional and Economic Potential

C. Aochen*, R. Krishnappa, D.M. Firake, A. Ningombam, S. Pyngrope, S.R. Assumi and S.V. Ngachan

ICAR Research Complex for NEH Region, Umiam, Meghalaya, India
**Email: aaochen@gmail.com*

Carpenter worm (*Prionoxystus robiniae*) is a popular delicacy among the indigenous population of Nagaland, India. Mostly confined to oak-growing areas in Northern and Southern Angami regions of Kohima and neighboring Phek district, this pinkish-red larva is highly relished. These worms are culturally significant during the Te-l Khukhu festival of Southern Angami region, annually held in July. The larval consumption is also cited for medicinal value in certain ailments. From a single tree, a minimum of 800 larvae is harvested and 100-200 larvae may fetch around □ 1000 to 2000. Rearing of carpenter worm is gaining popularity in Nagaland and is a viable source of income for the rural population. This study aims at evaluating the nutritional value of the larva for the first time. Proximate analyses present a high value of crude fat (37%), protein (48%), and a good source of energy (504.4 kcal/100 g). A high polyphenol value of 25.2 mg GAE/g also correlated with its high antioxidant capacity and pigment content. The larva also provides appreciable dietary minerals, with very high zinc content (7.41 mg/100g). Thin Layer Chromatography (TLC) was standardized for a solvent system of *n*-butanol:acetic acid:water (40:10:10). TLC identified the essential amino acids, *viz.,* methionine, lysine, leucine, histidine, threonine. This pioneering study, therefore, establishes the significant value of Carpenter worm larva as an exotic dietary supplement among the indigenous Naga population, thereby adding more value to its promotion and commercialization.

Keywords: *Carpenter worm, Culture, Indigenous Food, Mineral Content, Nutritional Value*

Success Story on Oyster Mushroom Cultivation in Longleng, Nagaland

[1]E. Lireni Kikon, [1]Manoj Kumar, [1]K L Meena, Rajesha G and [2]D J Rajkhowa

[1]Krishi Vigyan Kendra (KVK), Longleng, Nagaland
[2]ICAR research Complex for NEH Region, Nagaland Centre
Email: lirenikikon@yahoo.com

Mushrooms have been gathered and consumed from the wild since time immemorial for food and medicinal purpose. This practise is still continuing even today but most of the world's supply comes from commercial mushroom growers. The importance of mushroom as a food is for the presence of vitamins and minerals. The protein contain on dry weight basis of mushroom (19-40%) is very high in comparison to rice (7.3%) wheat (13.2%) and milk (25.2%). In Longleng district, mushroom production is not being taken up by the farmers. Although farmers are interested, there is lack of knowledge. KVK Longleng is conducting time to time trainings and demonstrations for the farmers but due to lack of infrastructures and demonstration unit, mushroom production could not be taken up in the district. Rice being the main food in Longleng, large quantity of paddy straw is available for use as substrate for mushroom cultivation. More over due to the pleasant weather, mushroom can be grown throughout the year using the different *Pleurotus spp*. Therefore, low cost mushroom production unit was established at Hukphang, Orangkong and Pongching villages under TSP-Mushroom 2014-2015. Mushroom production unit was constructed in the selected villages and critical inputs like sprayer, weighing balance, tekshi (pot), rope, poly bags were provided. Spawn was also provided on need basis. Beneficiaries were, Anghpubu SHG comprising of 12 nos. female farmers from Hukphang village; Shonela SHG, Orangkong village involving 14 nos. females and in Pongching village and Longleng Town individual farmers. Hands on training cum demonstrations on oyster mushroom cultivation were conducted by Krishi Vigyan Kendra, Longleng for all the selected beneficiaries. On completion of the training, the beneficiaries started the cultivation. Among them, the success of Anghpabu SHG, Hukphang is worth mentioning. After completing the skill oriented hands on training, the group started cultivating mushroom with 20 bags (3 crops). From that, 72kg fresh mushroom was harvested which they sold @ Rs. 150 per kg. In that year itself, they could earn net profit of Rs. 7800 /- with B: C ratio 3.61. They sell their produce in the villages and in the district local markets. Therefore, there is no marketing problem at present. Now, they are also invited to share their experiences whenever KVK Longleng organizes training on mushroom cultivation.

Resource Use Structure, Productivity and Efficiency of Bt Cotton In Beed District Of Maharashtra

G.A. Wadkar, M.S. Jadhav, R.R. Surywanshi and H.R. Shinde

Department of Agricultural Economics, College of Agriculture, Kolhapur, Maharashtra

The present study was intended to depict the picture of resource use structure, productivity and efficiency of Bt cotton in Beed district of Maharashtra state with following specific objectives viz, To examine the resource use structure of Bt cotton and to estimate the resource use productivity and resource use efficiency of Bt cotton. Bt cotton in Beed district is getting increasingly popular among farmers. Ashti and Majalgaon tahsils and their villages from each tahsil were selected purposively on the basis of highest area under Bt cotton. The total sample consists of 90 Bt cotton growers comprising 30 each from small (below 40), medium (0.41 to 0.80) and large (above 0.81) size groups. Data collected pertained to the year 2015-16.For estimating the resource use productivity and efficiency on the sample farms, Cobb-Douglas type of production function was used. The findings of the investigation revealed that, resource use structure varied among the size groups of Bt cotton growers. The average per hectare hired human labour use was 44.55 man days and family human labour use was 44.28 man days, while the use of bullock labour was 5.20 pair days, Machine power was 14.51 hrs. Seed rate was 1.45 kg and N, P, K was 100.97 kg, 79.83 kg and 93.81 kg respectively. The production function analysis revealed that, the value of Coefficient of multiple determinations was 0.57 at the overall level. It indicated that the nine resources together explained 57 per cent variation in the output of Bt cotton production activity of all size groups of holding pooled together. The regression coefficient of the resource variable viz., Irrigation (X_9) Significant at 1 per cent level, Manure (X_4) significant at 5 per cent level and Nitrogen(X_5) were positive and significant at 10 per cent level of significance. Indicating that Irrigation, Manure and Nitrogen charges found influencing input with magnitude of 0.029, 0.024 and 0.116, respectively. However, negative and non-significant regression coefficient of the resource variable namely Human labour (X_1) and potash(X_7) indicated that inefficiently used these resources. With regard to resource use efficiency, MVP/MC for nitrogen was found to be highest 14.76 followed by Phosphorus (6.92), plant protection (2.97), irrigation (1.43), Potassium (1.87) which are positive. It implied that there was scope to increase these resources in Bt cotton production. On the contrary, in regard to, human labour (-0.15),and potash (-3.75) negative. Therefore this study suggest that the Bt cotton growers should be given adequate and timely supply of inputs like quality seed, fertilizers, pesticides etc. at reasonable rate, also supply credit in time to purchase above inputs.

Evaluatation of Knowledge Level of Trainees on Different Farming Practices in Bareilly District of Uttar Pradesh

K.L. Meena, T.R. Chauhan, H.R Meena and A. Namei

Krishi Vigyan Kendra (KVK), Longleng, Nagaland
Email: drklmeenakvk@gmail.com

The study was conducted in Bareilly District of Uttar Pradesh. The state has a geographic area of 29.44 million ha which is about 9 % of the land area of the country. It lies between lat. 23º 52' and 31º 28' N and long. 77º 5' and 84º 38' E. Total animal population in the state is 661 lakhs. In this study we includes training programme organized between 2002 to 2007 during this five years more than 8 training programme were conducted at KVK in each subject/topic as listed Animal husbandry, Horticulture, Fishery science, IPM management, INM management, Home science, Piggery farming and Fodder cultivation and production. The main objective of a training programme is to bring about a desired change in the trainee since knowledge is a pre-requisite to the proper utilization of improved farming practice by the farmers and is ultimately linked with the increased socio-economic status of the farmers. Therefore, it was thought essential to work out the knowledge level of farming operators. In order to have accurate and valid information an exhaustive list of participants, who have been the beneficiaries of any of the training programme was made from each selected subject. Twenty five respondents from each subject were selected applying proportionate random sampling hence, total of 200 respondents were interviewed through questionnaire. The data pertaining to the knowledge level of respondents regarding farming practices revealed that knowledge about animal science practices 41.00 per cent of respondents belonged to medium level of knowledge followed by 30 and 29 per cent belonged to low and high level of knowledge respectively. In case of crop science practices, 46 per cent of respondents belonged to medium level of knowledge, followed by 38.50 and 15.50 per cent belonged to high and low level of knowledge, respectively. Further, in case of home science practices 43.50 and 42.00 per cent of respondent had medium and high level of knowledge followed by 14.50 per cent low level of knowledge. Findings regarding horticulture 46.50 per cent respondents had high level of knowledge about horticulture practices, whereas 42.00 and 11.50 per cent of respondents in the sample had medium and low level of knowledge.

Economics of Tomato Cultivation in Meghalaya: an Empirical Analysis of Resources

Ram Singh[1], S.M. Feroze[1] and K. Johny Singh[2]

[1]*School of Social Sciences, College of Post Graduate Studies, Central Agricultural University, Barapani-793103, Meghalaya*
[2]*Ph D Scholar, Visva-Bharati, Bolpur, W.B.*
Email: ramsingh.cau@gmail.com

Tomato (*Lycopersicon Esculentum L)* belongs to Solanaceae (the Poisonous Nightshade family). Technically it is a fruit not a vegetable but, belongs to the vegetable garden. Tomatoes are consumed either cooked or raw and are low in calories and an excellent source of Vitamins A and C. The agro-climatic condition in Meghalaya is favourable for the cultivation of vegetables throughout the year. It was initially felt that tomato could not be cultivated during summer months in the high altitude regions due to heavy blight infestation. However, formulation of a spray schedule has been successful in controlling the disease. Cultivation of tomato has spread to different parts of Meghalaya, even in the regions with high altitude. This advantage is reflected in good prices fetched by vegetables during the off-season in neighbouring states. Meghalaya has total area of 2195 ha with total production of 52.05 thousand metric tonnes (GoM, 2015). The crop is still confined in few district of the state. Farmers in the region are still unaware about the economic benefits of the tomato crop cultivation. Any rejection and adoption of the crop in the region depends upon its cost and return. Keeping the economic importance of the tomato in view, the present study is an effort to assess its cost-benefit to make it more commercialize in the state.

Household Level Feasible Agricultural and Allied Intervention-An Innovative Approach to Food and Nutritional Supplement for Hilly Tribal Folks

Sanjay Kumar Ray[1*], S.K. Baishya[1], D.J. Rajkhowa[1], S. Hazarika[2], Anup Das[2] and S.V. Ngachan[2]

[1]ICAR Research Complex for NEH Region, Nagaland Centre, Jharnapani-797106
[2]ICAR Research Complex for NEH Region, Umiam-793103, India
Email: sanjayray2006@gmail.com

Nagaland is endowed with enormous rainfall, fertile soil health and diverse agro-ecological situations. In spite of that, the state is still deficit in vegetable, fruit, pulse, fish, meat, milk and egg production. Most of tribal poor families of Wokha district in Nagaland are often suffered to fulfill their daily food and nutritional requirements due to a number of production constraints. Agriculture and allied sector plays important role to complete food and nutritional requirement, therefore, diverse agricultural interventions at household level hold promise. As such the study was undertaken to evaluate the impacts of various feasible agricultural and allied interventions at household level for enhancing diversified food production to improve livelihood of tribal families. Different interventions such as the introduction of rooftop rainwater harvesting (capacity 72,000 litre) system, establishment of nutritional gardening (600 sq m) in backyard, cultivation of year round off-seasonal crops (cucumber, king chilli, coriander and tomato) under polyhouse (60 sq m), growing of homestead mushroom (20 beds), and backyard poultry (1 month aged 50 nos. vanaraja birds) and piggery (02 nos. of exotic breed) rearing were promoted at twenty (20) farmer's residence of Wokha District. Water was utilized for all enterprises besides rearing of fish into water harvesting pond**.** Promotion of nutritional gardening enhanced average fruits and vegetables yield by 19% and 233% over the existing homestead farming system respectively. Harvested water was successfully fulfilled annual water requirement for different homestead enterprises, besides producing an average 23.5 kg fish for family consumption. Water productivity ranges for different enterprises were varied from 1.12 to 14.56 kg/m^3. Off-seasonal cultivation of vegetables gave addition annual net return of Rs. 5,400/- besides fulfilling the annual family requirements. Rearing of backyard poultry laid on an average 1340 nos. of eggs annually. Growing of homestead mushroom effectively fulfilled family requirement besides producing marketable surplus of 108 kg mushroom per year. Rearing of pigs added additional annual net income of Rs 27,500/- in family budget. Household level intervention of diverse agricultural enterprises fulfilled 95%, 57%, 100%, 36%, 21% and 100% family (5 members) requirements for vegetables, fruits, egg, meat, fish and mushroom respectively. Finally, it could be concluded household level feasible agricultural intervention is a sustainable and economically viable option for poor tribal families.

Keywords: *Food, Tribal Family, Diverse Agricultural Intervention, Nutritional Security*

Adoption of Improved Marigold (*Tagetes erecta* L.) Cultivation Technology among the Farmers of District Meerut

Virendra Pal, Naveen Chandra and Omvir Singh

Krishi Vigyan Kendra, Hastinapur, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut- 250110 (UP)

E-mail: dvpgangwar77@gmail.com

Marigold (*Tegates erecta* L.) is one of the important commercial flower crops of Western Uttar Pradesh. The current study was conducted in four villages in Sardhana and Mawana tehsil of district Meerut. To the selection of respondents, a comprehensive list of all the marigold growers were prepared from selected village. The production of marigold flowers is largely in the hand of small and

marginal farmers and productivity is low as compared to other countries. The major reasons are lack of high yielding varieties, pest and disease infestation, losses due to weed emergence, post harvest handling etc. The findings indicated that majority of farmers (61.5 %) had medium level of adoption regarding improved marigold cultivation technology, while 18.77 and 10.87 per cent respondents had low and high adoption level, respectively. To the study further indicated that practice wise adoption of the respondents was more in time of sowing followed by irrigation, land preparation, seed rate, seed treatment, harvesting and drying, whereas less adoption level was recorded by the farmers in practice like high yielding varieties, weed management and plant protection.

Farmers Satisfaction with Adoption Behavior for Management of White Flies in Okra (*Abelmoschus esculentus* M.) Growers on Ridge of Western Uttar Pradesh

Naveen Chandra, Virendra Pal and Omvir Singh

Krishi Vigyan Kendra, Hastinapur, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut- 250110 (UP)
Email: nchandra120@gmail.com

Western Uttar Pradesh is considered as the main okra producing state having 18.07 per cent area of the total okra producing area in county. A large area under Meerut, Baghpat, Ghaziabad, Muzaffarnagar and Saharanpur district of western Uttar Pradesh has already being declared as important vegetables of the country due to dense okra crop during the season kharif and rainy. Being a pest of quarantine an importance, white fly has been considered under most serious agricultural pest. The loss in the okra crop yield ranges from 01-21 % with a mean of 16 % in okra growers. At present, majority of okra growers mainly depend on synthetic pesticides viz. imidacloprid 17.8 % SL, thiamethoxam 25% WG and acetamiprid 20% SP for this pest. On an average of the data of three consecutive year during the demonstration of technology at farmers field, 27 per cent increased okra yield on ridge was obtained by the farmers.

Bioconversion of Chicken Feather Waste into Feather Protein Hydrolysate (FPH) Using *Chryseobacterium sediminis* RCM-SSR-7

S.S. Roy, Pintubala Kshetri, M.A. Ansari, S.K. Sharma, Chongtham Tania, Thangjam Surchandra Singh, N. Prakash and S.V. Ngachan

ICAR Research Complex for NEH Region, Manipur Centre, Imphal
Email: subhrasaikat@gmail.com

Accumulation of feather waste is becoming a major issue in solid waste management. As 90% of feather weight is constituted by keratin they may be used as organic nitrogen fertilizer. Keratin is a structural protein and is very hard to degrade by common proteolytic enzymes. However, they can be degraded naturally by kearatinolytic microorganisms which produce a class of proteolytic enzyme known as keratinase. In the present study all total 141 bacterial isolates were obtained from soil samples collected from five North Eastern states. Among the 141 isolates, 72 isolates were found to be positive for feather degradatin and the most promising strain *Chryseobacterium sediminis* RCM-SSR-7 was used for preparation of feather protein hydrolysate (FPH). The strain could use chicken feather as sole carbon and nitrogen source for growth. Three parameters (feather concentration, pH and incubation time) were studied to optimize feather protein hydrolysate (FPH) preparation using response surface methodology. The optimum condition for FPH preparation was achieved at 5% (w/v) feather concentration, pH 7.5, 30^{o}C and 84 h incubation time with 80% recovery. FPH was found to be rich in essential amino acids and nitrogen. FPH exhibited radical scavenging activity with an IC_{50}

value of 0.102 mg ml^{-1}. *In vitro* digestibility showed that FPH is 86% digestible with pepsin and trypsin treatment. This study revealed that FPH produced by *Chryseobacterium sediminis* RCM-SSR-7 has the potential to be used as organic fertilizer and animal feed ingradients. Field efficacy of feather hydrolysate as nitrogen fertilizer was studied in cauliflower. Application of feather hydrolysate as nitrogen source is comparable to the chemical fertilizer based on their effects on the growth and yield performance of cauliflower Highest whole plant weight and curd weight is observed when feather hydrolysate and urea is applied in 3:1 (i.e. 75% feather hydrolysate+25% urea). The study suggests that bioconversion of chicken feather waste in to feather protein hydrolysate not only can reduce the environmental pollution but also useful in organic agriculture.

Keywords: *Keratinolytic Bacteria, Feather Degradation, Feather Protein Hydrolysate, Cauliflower*

Temporal Dynamics of Cereals Production in the States of North Eastern Region of India: An Interstate Comparative Study

[*]N. Uttam Singh, [**]Kishore K Das, [*]A. Roy, [*]AnjooYumnam, [*]P.K. Sinha, [*]Bagish Kumar and [*]A.K. Tripathi

[*]*ICAR Research Complex for NEH Region, Umiam, Meghalaya*
[**]*Department of Statistics, Gauhati University, Guwahati, Assam*
Email: uttamba@gmail.com

This paper investigates the temporal variations in area, production and yield of cereals in the states of north eastern India. The study period was from 1966-67 to 2014-15 and it has been divided into five periods: 1966-67 to 1974-75, 1975-76 to 1984-85, 1985-86 to 1994-95, 1995-96 to 2004-05 and 2005-06 to 2014-15 to have an understanding of decadal performance among the states. Growth rate performance of the period 2005-06 to 2014-15 may be regarded as the best among the five study periods. The comparison of production growth rates in all the periods has revealed that Nagaland exhibits better performance followed by Arunachal Pradesh, Assam, Tripura and Meghalaya while Manipur, Mizoram and Sikkim are running behind. Growth performance of Nagaland has shown even better than that of north east total and national average. The decomposition analysis reveals that sources of output growth in the states of the region are due to yield improvements (64%) followed byarea expansion (36%).Variance analysis depicts that yield varies slowly over each study period with a large variability among the states suggesting the identifiable state specific factors. Study shows in 2005-06 to 2014-15 the average yield of an individual state over the years ranges between 264.5 (Mizoram in 2008) to 2875.2 (Tripura in 2015) and varies by 1363.8 across the states (between variation), but varies by 306 for each individual state over time (within variation). Similar pattern has been observed in rest of the periods as well as in the entire period. Over the north eastern region, area, production and productivity of cereals have shown a steady upward trend in every period of the study. Despite of a positive growth in cereals production during the last decade, north east region still has a deficit of 207 thousand tons of cereals against the requirement of the last census year. Though the projected figure of the year 2021 (0.7%) is surplus for whole NER, it is to remember that Meghalaya, Mizoram and Assam have shown deficiency in cereal requirement as per last census year. If the current scenario is continuing, in 2021 except Arunachal Pradesh, Nagaland and Tripura, all other remaining states will be deficit in cereals requirements. Considering that cereals are irreplaceable staple of the region and states like Mizoram and Sikkim showing decreasing growth rates in area under cereals during the last decade, the scope of meeting the cereals requirement of the region depend highly on productivity improvement.

Keywords: *Cereal Production, Growth Rate, Decomposition, Variance, Requirement Projection*

Technological Empowerment of Rural Women towards Rice Farming

Pompi Saikia, Manoshi Baruah Deka, Manju Dutta Das

Department of Extension and Communication Management, Faculty of Home Science, Assam Agricultural University, Jorhat-13

Email: pompisaikia.aau@gmail.com

This study examined the role and level of participation of women farmers in rice production in Nagaon district, State of Assam. Data for the study were obtained from 200 respondents and summarized using frequency distribution, percentages and logistic regression. A careful study of the socio economic conditions of farm women is a prerequisite for the suitable design and successful implementation of Governments' developmental programmes. The result indicates that majority of the respondents (61.75%) had medium level of technical knowledge followed by low (24.00%) and high level of technical knowledge (14.25%).Our analysis reveals that in Rice cultivation all the activities except weeding and ploughing is dominated by women in the sample area. Majority of the rural women were involved independently in activities like processing (62.25%), transplanting (57.75%), cleaning (55.50%), drying (54.25%) and winnowing (52.00%). Though their participation in different rice production activities were high but less than fifty per cent of the respondents took independent decision in all most all the activities of rice production .Overall a rural woman spent almost 8 hours per day in household work and care of family members followed by almost 6 hours in farm work and only one and half hours was spent for her personal care. This study however recommends that government should facilitate the availability of credit facilities, inputs and infrastructural facilities and also revitalize and encourage ago-based industries so as to improve the efficiency in processing and marketing of rice products.

Keywords: *Technological Knowledge, Rural Women, Rice Farming and Time Use Pattern*

Groundnut Cultivation Transform the Livelihood of the Farmer: a Success Story of Mrs. Hb Dongal

Khumlo Levish Chongloi[1*], M.A. Ansari[2], Hb. Lungni Anal[3], G.P. Kabui[4], Deepak Singh[1] and N. Prakash[2]

[1]ICAR-Krishi Vigyan Kendra, Chandel
[2]ICAR Research Complex for NEH Region, Manipur Centre, Lamphelpat, Imphal
[3]Forest Research Institute, Dehradun
[4]ICAR-Krishi Vigyan Kendra, Imphal West
**Email: levischongloi@gmail.com*

In most of the villages of Chandel district, cultivation of groundnut was not so popular. This could be due to lack of production technology and also unavailability of suitable cultivars for Manipur conditions. Observing the conditions and situation, there is an ample scope for its production in Chandel district as the foothills and river banks are lying and kept fallow. To popularize its cultivation and production technology, training and demonstration programme was organized in the collaboration of ICAR Research Complex for NEH Region, Manipur Centre under the sponsorship of Directorate of Groundnut Research; Junagadh. We selected Mrs. Hb. Dongnal, 50 years of age from Lambung Village, who is one of the proactive farmers for technology demonstration in 1.00 ha during 2012-13. Earlier, Mrs. Hb. Dongnal, was cultivating rice and hardly produced 2.0 t/ha. She is hard working and attended the various training programmes on scientific crop productions. The cultivar ICGS-76 was demonstrated on her field. She was enable to harvest 2.50 t/ha. In a one hectare, she spent Rs.51475/- as cost of cultivation. She sold groundnut @ Rs 50/kg and earned total gross income of Rs 125000/ha and net returns of Rs 73525. The B: C ratio from earlier rice cultivation was hardly 1.2 to 1.4. However, the groundnut cultivation had doubled the B: C ratio to 2.42. The high yielding variety ICGS-76 (groundnut) was proven very successful thereby increasing the cultivated area in the surrounding villages too. Her success story has inspired and inculcated the surrounding active farmers as “Seeing is Believing”. She is very much thankful to the KVK, Chandel, ICAR Research Complex for NEH Region, Manipur Centre for the implementing the programme under the sponsorship of Directorate of Groundnut Research; Junagadh.

Safe and Judicious Use of Pesticides in Agriculture

C S Raghav[1], Nidhi Dubey[2], S S Dagar[3] and H. Kalita[4]

[1] ICAR-Krishi Vigyan Kendra, West Siang District, Basar, Arunachal Pradesh
[2] Directorate of Plant Protection, Quarantine and Storage, Faridabad, Haryana
[3] Horticulture Division, CPWD, IP Bhawan, ITO, New Delhi
[4] ICAR RC for NEH Region AP Centre, Basar, West Siang, Arunachal Pradesh
Email:drcsraghav@gmail.com

Indiscriminate and unsafe use of pesticides in agriculture has created threat to the environment, human beings, animals, avian, aquatic and wildlife and other living beings. lt has also disturbed the ecological balance of the nature. While the indiscriminate use of pesticides deteriorates the soil water and air quality and enhances the cost of crop production, the unsafe use of these pesticides creates several diseases and ailments in living beings. Every year several incidences of pesticide poisoning are reported throughout the country. Similarly, the incidences of developing pesticides resistance in insects and pests is on the increase, forcing the farmers either to enhance the pesticide doses to control the pest or to adopt genetically modified (GM) crops. Needless to say that the issue of effect of consumption of GM crops on human beings is still under debate. The main reason behind the indiscriminate use of pesticides in agriculture and also the incidences of pesticides poisoning is lack of knowledge among the farmers about the implications of injudicious use of pesticide and standard guidelines on use and handling of pesticides. Disseminating the information to the farmers and other stakeholders about safe and judicious use of pesticides in agriculture through the extension functionaries, developmental and other concerned agencies could, thus, be an effective tool to prevent or minimize the multifarious detrimental effects of pesticide. This paper covers all important information on safe and judicious use of pesticides in agriculture for disseminating knowledge and creating awareness among the farmers, extension functionaries and other stakeholders to enhance quality crop production and safeguarding their health. Key words: lnsects and pests, Pesticides, lnsecticides, Judicious and safe use of pesticide, Soil health, standard guidelines on pesticides use, Quality crop production.

Strategies for Empowering Women for Sustainable Societal Development

Supriya Das*

Government Degree College, Dharmanagar, Tripura (N), India
**E-mail:supriyajb79@gmail.com*

In a country like India with above 1.30 billion population of which almost 0.65 billion are women, it is important that women takes part in all developmental activities. Education and awareness is the first step in that direction. Gender analysis is a tool to better understand the realities of the women and men, girls and boys whose lives are impacted by planned development activities. Sustainable development requires the full and equal participation of women at all levels alongside men. It is clearly inappropriate to try and address problems, to identify strategies, or to implement the programmes, if only half of the populations (men/women) concerned are involved in the process. Partnerships and equality between men and women are the basis of strong families and viable societies in a rapidly changing world. Women have been consistently excluded from decision-making across history and societies; which resulted imbalance, marginalization, suffering and conflicts. Creating greater gender equity will contribute to building peaceful, democratic and prosperous societies.

Some important aspects which needs emphasis are women should be trained to develop their capabilities of decision-making and individual thinking; There is a need to change the attitude and perception of male members towards the women; Women should get the quality food and nutrition to maintain their health, so that they can effectively contribute in social development; Socio-cultural norms and taboos should be removed to provide women more freedom and facilities to work optimally; Information technology should be strengthened for getting the information timely and accurately for adequate decision making and planning activities; Better health care facilities needed for women; Household industries like agro-industries should be established for processing of agricultural produce ; More employment opportunities should be generated in all development fields; More women extension workers should be recruited for facilitating the women farmers' for timely providing information related to basic areas like agriculture, health etc.; Harassment and exploitation of women in home and outside should be checked; Technologies evolved should be socially acceptable, economically viable, drudgery reducing and gender need based and Participatory approaches for solving of gender issues should be adapted.

Keywords: *Gender Equity, Sustainable Development, Capacity Building*

Livelihood Diversification and Their Determinants among the *Jhumias* of Manipur in North Eastern Region: An analysis

Punitha P.

ICAR RC for NEH Region, Manipur Centre, Imphal
Email: kppunithaa@rediffmail.com

Shifting cultivation or Jhum is a traditional land use form practised by the farmers of North Eastern Region. This form of land use was practised by farmers solely or as a dual system in which both Jhum and settled cultivation (wet land) were taken up. Jhumias dependency on Jhum was explicitly mentioned in various literatures. However, there were no recent literatures which portray on the extent of dependency by the farmers on Jhum and other source of livelihood. Hence, an attempt has been made to study the extent of livelihood diversification of Jhumias in Manipur and to analyse the factors determining the livelihood diversification of Jhumias. Mixed method research design (Descriptive, Exploratory, Ex-post facto) and multistage sampling technique was applied in the present study for selecting samples from both Watershed Development Project in Shifting Cultivation Area (WDPSCA) and Non-WDPSCA. Among the 240 samples, 80 samples from WDPSCA and 160 samples from Non-WDPSCA were selected for the study which comprises of 33 per cent and 67 per cent from WDPSCA and Non-WDPSCA respectively. The selection of samples was based on stratified random sampling with proportional allocation. The Simpson Diversity Index (SDI), chi-square test and multiple regression analysis were used in the study to understand the level of livelihood diversification and factors determining the livelihood diversification. Results revealed that majority (60%) of the respondents had low level of livelihood diversification in WDPSCA whereas, in Non-WDPSCA, majority (49.37%) of the respondents found to exhibit medium level of livelihood diversification. The variable viz., number of livestocks, distance to district headquarter, market distance, training attended on farm activities, distance from house to Jhum field, Jhum size has influenced the livelihood diversification.

Dynamics and Performance of Women Groups in Changing Socio-Economic Scenario of Rural Women

Manoshi Baruah Deka

Department of Extension and Communication Management, Faculty of Community Science, Assam Agricultural University, Email: manoshib.deka@gmail.com

Self-help groups in India established themselves as credible institutions for financial inclusion, livelihood promotion and social development and cultural changes. As a result many official agencies, civil society organizations and corporate bodies are adapting, or partnering with, SHGs in pursuing of their own agendas. Because of this all-round support from village level volunteers to the Government of India and from international NGOs to Multilateral and Bilateral Donors, SHGs are growing at an exponential rate the increasing number of SHGs every year shows its potential; however, sustainability of it has always been questioned, hence the present study was conducted on dynamics and performance of women groups in agriculture and allied sectors with the objectives to study the dynamics of women self-help groups and their growth pattern ,identify the contributing factors for sustainability of women group and to understand the role of women groups in income generation and poverty alleviation. The study was conducted in the state of Assam with covering 400 women groups. The results showed that majority of the groups were active while one fifth discontinued. SHG provided a platform for seeking loans and to scale up the marketing of their produce. The major contributing factors for sustainability were regular convening meetings with

participation of all members and involvement in entrepreneurial and income generating activities Theempowerment scale developed and validated included three aspects, i.e. socio-psychological, economic and legal-political indicating SHG movement holds great promise for poverty reduction and empowerment of women as evident from a number of studies, including this one. Further, evolving an ecosystem to support the SHGs and their institutions will go a long way in realizing the vision of poverty free India.

Small Tea Growers of Assam –Prospects for Sustainable Economic Development

Nayanmoni Saikia[1,] Manoshi B. Deka[2] and Manju Dutta Das[3]

Department of Extension and Communication Management, Faculty of Community Science, Assam Agricultural University, Jorhat
Email: manoshib.deka@gmail.com

Tea is one of the most important agricultural plantation crop and major revenue generator in Assam which is more than 190 years old by now. The cultivation of tea in small holdings is of recent origin playing an important role in economic growth of the state. It has been reported that the young educated generation has been attracted towards tea cultivation rather than being involved in cultivation of other traditional crops. Seeing the situation the present study has been conducted to find out the socio –economic profile of the small tea growers of Jorhat district and analyse the situation of the small tea growers in terms of alternative for economic development. Data were collected through interview technique with structured interview schedule prepared by the researcher. The findings revealed that more than half of the respondents were between 36-50 years age, had organisational membership , were in medium socio economic status , had tea cultivating area 1.1-2 ha, (85.83%) engaged 5-7 seasonal labour. (57.5%). Small tea growers were facing different problems lack of knowledge on cost fixation and absence of land documents were faced by all the respondents. All the selected small tea growers were economically benefited by having a small tea garden which can be further enhanced through capacity building programmes on business management , diversification and value addition to name a few along with revisiting the existing policy for enhancing their income and sustainable economic development.

Social Media Usage and its Affinity Level among Generation Y Agricultural Scholars

Bai Koyu[1] and Rajkumar Josmee Singh[2]
[1] *Ph.D. Scholar, SSS, CPGS, CAU, Umiam, Meghalaya – 793 103*
[2] *Assistant Professor, SSS, CPGS, CAU, Umiam, Meghalaya – 793 103*

By 2017, at least a third of the planet will be engaged regularly through social media. As the internet becomes more visual, new photo sharing (and increasingly, short video) sites have ridden the wave to mass audiences. The pace of change in modern social channels and tools is constantly accelerating. The internet is a hungry beast, and social media requires constant care and feeding. Social Media (SM) is defined as a form of electronic communication through which users can create online communities to share information, ideas, personal messages and other content. In 2018, it is estimated that there will be around 2.55 billion social network users around the globe, up from 1.87 billion in 2014. This pilot study examined to find out the SM usage in relation to its advantages and related problems and also to find out Generation Y agricultural scholars psychological affinity to SM. The affinity was interpreted using Griffiths' five components that determine behavioral affinity: tolerance, salience, conflict, withdrawal and relapse. Survey method was employed for getting response from 45 respondents. Some of the major findings from the study revealed that Facebook was the most widely used social media by the respondents. 91.9 % of the respondents primarily used SM for downloading study materials. 31.1 % of the respondents spend 1 hr on social media for agriculturally related issues. 53.3 % of the respondents were extrovert while remaining 46.7 % were introvert. The major advantages of using SM is 'Exposure to latest knowledge, skills and technology in research endeavors (68.9 %) followed by "Gaining more visibility in research areas (57.8 %). 40 % of the respondents reported neutral on SM affinity followed by 33.3 % respondents who feels that they have affinity to SM. The results indicated that this sample of Generation Y agricultural scholar suffers from four components, tolerance, salience withdrawal and relapse. They also suffer from intrapsychic conflict, but not interpersonal conflict. Major problem associated with SM in dissemination of information were costly data charge for high speed internet connectivity (88.9 %) being followed by erratic internet connectivity in the campus (84.4 %).

Keywords: *Social media, Affinity and generation Y Agricultural scholars*

Miscellaneous

Collection, Conservation, Evaluation And Utilization Of Underutilized And Minor Fruits In Tripura And Other North-Eastern State

Sukhen Chandra Das1 and 2M. Datta
1College of Agriculture, Department of Horticulture, Lembucherra, Tripura (w)-799210, India.
2Principal, College of Agriculture, Lembucherra, Tripura (w)-799210, Tripura. India.
E-mail:sukhenchandra@rediffmail.com

Tripura and other North- Eastern region are endowed with vast natural resources. North-Eastern region is covered by picturesque hills and dales, deep and green valleys which have added beauty to its landscape and possesses rich biodiversity, which is under increasing threat from various biotic and abiotic factors. The diverse agro-climatic conditions, fertile and acidic soil with good depth and abundance rainfall favour the cultivation of various underutilized and underexploited fruits crops. There are 40 (fourty) different types of underutilized and minor fruits or wild traditional fruits grown in the state of Tripura and they are Carambola (Averrhoa carambola), Elephant Apple (Dillenia indica), Jalpai (Elaeocarpus floribundus), Star Aonla(Phyllanthus acidus), Jack fruit(Artocarpus heterophyllus), Latka(Baccauea sapida), Paniala(Flacourtia jangomas), Bael(Aegle marmelos), Jamun(Syzygium cumini), Karonda(Carissa carandas), Amra(Spondias pinnata), Passion fruit (Passiflora edulis), Satkara(Citrus macroptera), Aonla (Emblica officinalis), Wood apple(Feronia limonia), Ber(Ziziphus mauritiana), Fig(Ficus carica), Annona spp, Tamarind (Tamarindus indica), Chapalish(Artocarpus chaplasha) and others underutilized fruits namely, Jambu (Syzygium samarangense), Velvet apple(Diospyros discolour), Tal (Borassus flabellifer),Jamrul, Bhali Jamun, Monkey jack(Artocarpus lakoocha), Bilimbi(Averrhoa bilimbi), Khudijam(Syzygium cymosa), Cane berry, cow and Jambura(Citrus grandis) are endowed with food, nutrition and medicinal value. All this crops are easier to grow and hardy in nature, producing a crop even under adverse soil and climatic conditions. This crop urgently need for conservation for future crop improvement programmed. This crops provides food, nutrition to human being. Over the years many important underutilized fruits have become extinct and the extinction rate is increase due to the influence of human activity. Presently, conservation status is very poor but there is urgent need to conserve the threatened or endanger species and genotypes of Tripura.
Key word: *Underutilized, Minor fruits, conservation evaluation and utilization.*

Material and Methods

The state of Tripura with an area of 10,491 sq. km and eight districts (North Tripura, Unakoti, Khowai, Dhalai, Sipahijala, Gomati, South Tripura and West Tripura) of Tripura. Survey and collection works has been conducted in all the districts of Tripura and some parts of other North-Eastern states. During the course of survey and collection, first hand information on the utilization of underutilized fruit and some minor fruit crops in the rural and interior area of the state and other north eastern has been recorded and collected. The uses of plants particularly for utilization of different parts were confirmed by many cross checking as possible in different localities and maintain the standard procedure.

Conclusion

North –Eastern is blessed with huge plant genetic resources especially horticultural crops with special reference of fruit crops. The increase in area and production of these under utilized and minor fruit crops will not only provide nutritional security and save money on import but also export of fresh fruit crops and seed in further expected to boost region economy. All this crops are easier to grow and hardy in nature, producing a crop even under adverse soil and climatic conditions. More over, these crops are playing a vital role in nutrition, livelihood for rural and interior peoples for employment and income generation of the state and other North–Eastern states. Systematic cultivation Horticultural crops as well as fruit crops are very less. There is tremendous scope to popularize these in non-traditional areas and these crops may earn lot of foreign currency in the state other North–Eastern states in near future. Further, the huge genetic diversity in various horticultural crops with special reference of fruit crops has vast scope for collection, conservation and utilization for benefit of peoples in the state and other North–Eastern states.

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Participatory Extension and Research for the Development of Rural people

Dr. Arpita Sharma

Assistant Professor, Dept of Agricultural Communication, College of Agriculture, GBPUA&T, Pantnagar.

Corresponding Address: 4/884 Jha Colony Pantnagar, Udham Singh Nagar, Uttarakhand-263145

Participation of rural people is necessary at each and every step of programme designing to evaluation. It means to involve rural people in identifying the problems, Need Assessment, determining ways to overcome, designing a plan and procedure to solve the problems of rural people and carrying them out. Community Participation is an active process by which the target group can develop and execute the programme. Active participation is necessary for the empowerment of rural people. Participatory tools like PRA mapping, time line, time trends help the extension worker to understand the problems of rural people and solve them. It provides a plateform to the rural people to come and suggest their views for any programme or any technology. Participatory approaches include many steps as Rapport building, Need Assessment, Need Prioritization and designing a programme and plan and ultimately implement this plan to solve the problems of rural people. Present paper aims to discuss the importance of Participatory Extension and Research for the Development of Rural people.

Keywords: *Participatory, Extension, Research, Development.*

Multidrug resistance diarrhoeagenic Escherichia coli (DEC) from piglets in Mizoram, India

Puii,L.H[1]., Shakuntala, I[2]., and Singh, S.B[3]

1,3. ICAR-RC for NEH Region, Mizoram Centre, Kolasib

2. ICAR-RC for NEH Region, Umiam, Barapani

A total of 105 faecal samples from diarrhoeic piglets (0-3 months) were collected from different parts of Mizoram. All the samples were processed for isolation and identification of Escherichia coli by standard bacteriological methods. All the isolates were subjected to antibiotic resistance profile by disc diffusion method using commonly used antimicrobial discs. All the isolates were also subjected to detection of selected virulence marker genes by multiplex and single PCR assay. A total of 306 E. coli was isolated from piglets. Enrofloxacin was recorded as most sensitive (78.43%) followed by norfloxacin (76.47%) and gentamicin (70.59%). Majority of the isolates exhibited high degree of resistance to cloxacillin, nitrofurantoin, ampicillin, amoxycillin and sulphomethaxazole. Based upon the multiplex PCR assay, a total of 46(15.68%) isolates from piglets

were recorded as positive for at least one virulence gene and classified them under nine different virulence gene profile group. Altogether 17, 30 and 47 isolates were recorded as STEC, EPEC and ETEC respectively. In addition, 45 isolates were carrying multiple virulence genes. Majority of the isolates exhibited resistance to more than three antimicrobials. It may be concluded that multidrug resistance diarrhoeagenic E. coli are prevalent in piglets in Mizoram.

Key words: *E.coli, ETEC, STEC, EPEC.*

Insect - Pest Diversity of Turmeric and Their Distribution Pattern In Jorhat District of Assam

S.S. Bora[1], A. Rahman[2], P.Patgiri[3] and B.A.Gudade[4]

1. Ph.D Scholar, Dept. of Entomology Assam Agricultural University and Scientist, ICRI, RRS Tadong.

2 & 3. Principal Scientist, Department of Entomology, Assam Agricultural University, Jorhat 785013 Assam, India

4. Scientist, ICRI, RRS Tadong

Email for correspondence: sasankabora@gmail.com

Turmeric is an important spice crop grown in Assam. Insects associated with Turmeric are one or other way has great impact on production of this crop. A total of 29 numbers of insect found to be associated with turmeric in Jorhat condition of which 9 species of insect found in abundance, 14 species occasionally and 5 are rare. Among the insects found in turmeric eco-system 21 are identified as pest and 8 are natural enemies. Out of 21 insect pest, two pests viz., *Conogethes punctiferalis Guen.* and Udaspes folus Cram. identified as major causing economical damage to the crop.

Keywords: *Turmeric, Insect, pest and abu ndance.*

Maize-legume intercropping for diversified sustainable crop production in mid hills of Meghalaya

A. K. Singh

Assistant Professor (Agronomy)

School of Natural Resource Management

College of Post graduate Studies (CAU-Imphal)

Umiam-793103 (Meghalaya)

Corresponding e- mail ID: adityakumar1972@yahoo.co.in

Maize is the second most important food crop of North Eastern Hill Region (NEH) with its productivity much below than the national average. Being an exhaustive crop, it is very responsive to higher doses of nutrients especially nitrogen (N). However, difficult accessibility coupled with higher cost and apathy among the farmers to use fertilizers and other chemicals, they are struggling to harvest its optimum yield potential in the region. A possible way to supplement some of the N requirement for increasing maize productivity would be through its intercropping with N fixing legumes. Since maize is planted at wider row spacing of 60-75 cm, it offers good opportunity to grow a short duration legume in between two rows or paired of maize rows. Legumes play a vital role in human nutrition also as they are rich source of protein, calories, certain minerals and vitamins. Inclusion of legumes as intercrop with cereals supplies the additional nutrients by converting atmospheric N in available form through symbiotic biological N fixation (BNF) by Rhizobial strains. The most common advantage of intercropping was observed in forms of greater yield per unit land area by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops. Moreover, intercropping improved soil fertility through BNF with the use of legumes, allows lower inputs through reduced

fertilizer, better soil conservation through greater ground cover, and offered higher financial return than sole maize alone.

Arbuscular Mycorrhiza: A Potential Biofertilizer for Sustainable Hill-Farming

S. N. Bhowmik
ICAR Research Complex for NEH Region
Tripura Centre
Lembucherra-799210

Introduction

Agriculture is the backbone of Indian economy. Though blessed with rich natural resources of soil, water, and vegetation; India yet confronts poor quality of life. Hill agriculture constitutes a major portion of agricultural area in the North Eastern Region (NER) and also houses the majority of the poor. Low productivity, unpredictable climate swings and low dosage of chemical fertilizers better characterize hill farming system. Biofertilizers, particularly arbuscular mycorrhizal (AM) fungi, could be a bridge between removal and addition to soil nutrients where farmers can scarcely afford costly chemical fertilizer and too in a risky environment. The beneficial role of AM fungi in phosphate deficient, low fertile soils or soils with poor water holding capacity is now well established. Hence the organism is of prime importance for problematic soils in restoring natural ecosystems and producing agronomic, horticultural, and forest plants with minimal chemical inputs.

This article makes an attempt to present briefly the scientific knowledge of arbuscular mycorrhizal biofertilizer, and usage technology keeping in view of the inherent constraints met in procurement of vital agricultural input by the poorer section coupled with improper conservation of fragile ecosystem by the society as a whole and living sustainably thereof.

What Are Biofertilizers?

Biofertilizers, more commonly known as microbial inoculants, are preparations containing certain soil organisms that can improve soil fertility and crop productivity.

Although the beneficial effects of AM fungi in improving soil fertility and productivity was known approximately 40 years ago and their existence was recognized more than a century, commercial exploitation of such microbial inoculant is of recent interest and practice. The term "mycorrhiza" was coined by A. B. Frank, a researcher in Germany, more than 100 years ago. It means "fungus-root," and stands for the mutualistic association existing between a group of soil fungi and higher plants. There are many types of mycorrhizal associations of which the endomycorrhizal association of the arbuscular type are the most widespread geographically as well as within the plant kingdom.

AMF FUNCTIONS

Role in plant nutrition

AM fungi absorb effectively macro and micro nutrients from low fertile soil particularly immobile nutrients such as P, Cu, and Zn and then translocate these nutrients to the plants with whose roots they are associated. This has been made possible due to the fact that AM fungi increase the surface area of absorption of the roots and increases root phosphatase activity.

Role in plant health and protection

AM fungi contribute to plant health and productivity independently of their role in enhancing nutrient uptake. For example, the fungi have been found to be involved in the control of plant diseases, including nematode infection. AM fungi stimulate hormone production in plants, aid in improving soil structure, enhance leaf chlorophyll levels, and improve plant tolerance to water stress, salinity, soil acidity, and heavy metal toxicity.

Role in safeguarding environment

High levels of P in soils can result in pollution of water bodies like lakes, wells, ponds etc. by eutrophication , when eroded soil rich in P is deposited in them. Plants' reliance on AM fungi association minimizes P fertilization, which on turn reduces the risks of eutrophication in water bodies and water quality deterioration. AM fungi, therefore, are an important component of nutrient management programs that aim to reduce environmental pollution.

Factors Influencing the AMF Inoculation Effect

The degree to which mycorrhizal fungi enhance the nutrition and health of associated plants depends on many biotic and abiotic soil factors, as well as other environmental factors that influence the host, the fungi, and their association. The most important factors include abundance of AMF infective propagules, soil P status, variation in the degree to which target plant species rely on the mycorrhizal condition at the prevailing soil-solution P concentration, and soil treatment, including the type of previous crop or native vegetation.

Abundance of AMF Propagules

Effectiveness of mycorrhizal fungi may not be rapidly expressed if the number of infective propagules contained in an inoculum is low. Many instances of poor inoculum performance may in fact be a result of a low level of infective propagules. All other things being equal, if high quality inoculum is introduced into a soil containing a very low density of indigenous AMF fungi, the probability of obtaining a positive response to inoculation is high. However, if the soil contains high levels of infective propagules to begin with, it is unlikely that plants will respond to additional inoculation.

Soil P Status

There are critical ranges of soil-solution P concentration at which the host-fungus association is truly mutualistic, i.e., where the benefit each partner derives from the association outweighs the costs. Mycorrhizal inoculation will have its maximum effect on plant growth at soil P concentrations near-optimal for mycorrhizal activity or at soil P concentrations that are barely accessible to the unaided root.

Variation in the dependence of plants on AM fungi

Mycorrhizal dependency is a measure of the degree to which a plant species relies on the mycorrhizal condition for nutrient uptake and growth as the concentration of P in the soil solution is increased. It is well established that plant species and cultivars within a given species vary in their response to AMF colonization. Most of the variation may have to do with the ability of plant species to take up P at very low soil-P concentrations in the absence of mycorrhizal fungi.

Soil disturbance

The activities of AM fungi can be severely curtailed by soil disturbance in both native and agricultural ecosystems. In native ecosystems, soil disturbances caused by land clearing and mining operations can be so severe that mere inoculation of the affected areas with AMF may not be able to restore the symbiotic function of the fungi. The impacts of disturbances that have been studied in agricultural ecosystems are generally less drastic. On the other hand, the activities of AMF are known to be adversely impacted even by disturbance such as mechanical planting operations in otherwise undisturbed soils. Soil disturbance due to tillage can adversely influence the abundance and diversity of AMF. In no-till and reduced-tillage systems, maintenance of the integrity of this hyphal network contributes to more rapid AMF infectivity and more efficient nutrient uptake than is possible in more severely disturbed soils. In soils severely disturbed by tillage, the native AMF populations are not likely to initiate AMF formation on the target crop rapidly, and the process can be enhanced by inoculating the soil with high-quality AMF inoculum.

Sources of AMF Inoculum

Soil as inoculum

Soil from the root zone of a plant hosting AMF can be used as inoculum. Such soil inoculum is composed of soil, dried root fragments, and AMF spores, sporocarps and fragments of hyphae. Soil may not be a reliable inoculum unless one has some idea of the abundance, diversity, and activity of the indigenous AMF.

Crude inoculum

Crude inoculum is obtained after a known AMF and a suitable host are grown together in a medium optimized for AMF development and spore formation. Such inoculum is the most common type available for large-scale crop inoculation. It consists of spores, fragments of infected roots, pieces of AMF hyphae, and the medium in which the inoculum was produced.

Root inoculum

Infected roots of a known AMF host separated from a medium in which crude inoculum was produced can also serve as a source of inoculum.

Inoculum Application

Methods of applying AMF inoculum include mixing inoculum with soil, placing inoculum as a layer at various soil depths, applying it as a core below the seed, banding it in much the same way as fertilizers are applied in bands, dipping roots of seedlings in a viscous suspension containing AMF propagules, and placing AMF propagules adjacent to roots at the time of transplanting.

Mixing inoculum thoroughly with the soil is the most straightforward method of applying inoculum in the field as well as in the greenhouse, but it is effective only when large amounts of inoculum are applied. This approach is better with crude inoculum than it is with root inoculum, because root fragments do not readily disperse in soil. Inoculum can be placed at various depths (up to 5 cm) from the surface of the soil as a layer or applied in bands near the seed row (generally 5 cm below and 5 cm to the side of it).

Any type of inoculum can be placed close to seedling roots at the time of transplanting. For example, spores can be applied directly onto roots either at the time of transplanting or to roots of an established plant after making a hole adjacent to the roots. Crude inoculum and root inoculums can also be applied to established plants by placing inoculum in holes bored into the soil where roots are likely to be contacted. Before planting, seedling roots can be inoculated by dipping them in a viscous medium (1% methyl cellulose or 10--20% gum arabic) containing AMF propagules, usually spores.

Amount of Inoculum to Apply

The amount of inoculum to apply directly to soil is dependent on the quality of the inoculum. If a crude inoculum contains four to eight infective propagules per gram, application of 50 g/kg soil usually produces rapid initiation of AMF colonization of target plants with a minimal lag period. Root inocula are generally more effective in stimulating plant growth in quantities substantially lower than are normal for crude inocula.

Yield Responses

Crop responses to AM biofertilizer depends on soil type, host variety and AM fungi strain in addition to a number of biotic and abiotic factors. When a species of Rhizobium and AM fungi are coinoculated, the growth of legumes such as clovers, groundnut, pigeon pea, chickpea, and soybean, etc. is enhanced to a greater degree in phosphate deficient soil. Efficient use of the AM biofertilizer can effectively substitute for P applications up to 222kg P2O5 ha-1.

Conclusion

The arbuscular mycorrhizal fungi (AMF) are universal and ubiquitous rhizosphere microflora forging symbiosis with plethora of plant species and acting as biofertilizers, bioprotectants, and biodegraders. The arbuscular mycorrhizal symbiosis is suggested to be the ideal solution to the improvement of soil fertility and the rehabilitation of degraded hill lands. The voluminous literature has revealed that AMF improve the overall growth of terrestrial plants growing under diverse agroecological zones. Furthermore, the tripartite symbiosis between legume mycorrhizal–rhizobium has shown superior improvements in legumes. AMF alleviates various types of environmental stresses in plants suggesting their roles in helping plants to adapt and grow in stressful environment. Use of arbuscular mycorrhizae inoculum therefore may serve as an alternative to agrochemicals.

Effect of fertilizer and weed management in summer urdbean (*Vigna mungo*) production system

H. Kalita and R. Chakrabarty
Regional Agricultural Research Station, Shillongani, Nagaon-782002, Assam
**Corresponding author:hemen.kalita07@rediffmail.com*

Pulses are the most important crop in respect of both human and soil health. In Assam, pulses occupy 142170 ha of land with a production of 107571 t (2015-16). Among the pulses, urdbean (Vigna mungo L.) has the highest area (51579 ha), however, its productivity (658 kg/ha) is lower than that of total pulses (757 kg/ha). The crop is grown in both summer and Kharif season in the state. Weed and fertility management become difficult for urdbean production in summer. Therefore, a field trial was conducted at RARS, Shillongani, Nagaon to study the effect of fertility and weed management on productivity of urdbean and soil microbes in summer 2015 and 2016. Amongst the fertility levels, half of recommended dose (15:35:15 kg N, P2O5, K2O/ha) + 2% urea spray at 35-40 days after sowing (DAS) resulted in the highest grain yield (965.74 and 838.89 kg/ha in respective year), which was significantly superior to all other levels except the recommended dose. Pendimethalin 1kg/ha as pre-emergence + hand weeding at 30 DAS proved to be the most efficient in managing weeds in urdbean production system and accrued in the highest grain yield (954.17 and 838.43 kg/ha in respective year). Combination of these two treatments emerged to be the highest yielder (1058.33 and 977.78 kg/ha). Under this treatment combination, mean NPK uptake by crop was 44.2, 4.8 and 7.3 kg/ha respectively, whereas, mean NPK removal by weeds were minimum (166.7, 20.5 and 31.1 kg/ha respectively). The population of fungi in soil before sowing and after crop harvest under this treatment combination was 21 x 104 and 37 x 104 cfu/g of soil and that of bacteria was 23 x 107 and 45 x 107 cfu/g of soil, respectively. However, the highest fungal and bacterial growth rate during the crop season was recorded under micronutrient spray (Zn + B + Mo) at 20-25 and 40-45 DAS + hand weeding at 20-25 DAS.

Keywords: *Urdbean, productivity, fertility and weed management, NPK uptake, NPK removal by weeds, fungal and bacterial population*