Resource Conserving Technologies in Rice Cultivation

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Rice (*Oryza sativa* L.) is staple food of more than 60 per cent of the world's population. Rice is the most important crop of India with highest area of 45 million hectares and second to china in production with 95 mt in 2008. The productivity of rice in India has been between 2 –3 t/ha which is satisfactory level considering the global standards with a scope for further improvement.However, the surplus production scenario has no room for complacency as growth rate is only about 1.4 –1.5 per cent (Subbaiah, 2005). Considering population growth at about 1.8 per cent, the demand for rice is going to be about 140 mt by 2025 AD (Subbaiah, 2005). .

Area under rice is expected to be reduced to about 40 m ha in the next 15-20 years owing to water shortage and urbanization in India. More than 80 per cent of fresh water is consumed for agriculture and 50 per cent of it goes for rice cultivation. Rice consumes about 3000 –5000 litre of water to produce 1 kg of rice (IRRI 2001). The per capita availability of water sources declined by 40-60 per cent in many Asian countries between 1955-1990 (Glieck 1993) and expected to decline by 15-45 per cent by 2025 compared to 1990 (Guerra *et al.* 1998). Therefore, rice could face a threat due to water shortage and hence there is need to develop and adopt water saving methods in rice cultivation so that production and productivity levels are elevated despite the looming water crisis.

Rice is also the main staple food of people in the North Eastern Region of India. The productivity of rice in the region is only about 1.6 t/ha compared to national average of 2 t/ha. The demand for rice is growing with ever-increasing population. The region is in deficit of about 1 million tonne of rice. Therefore, there is need for steady increase in productivity with limited resources like land, water etc.

Soil (land) health degradation is another such problem, especially in intensive agriculture including in North East India. Physical and biological deterioration of land with associated fertility depletion occurs due to poor agronomic management, waterlogging, acidification, salinization, alkalininization etc. Intensive cultivation along with poor or no addition of manure, residue removal/burning etc. are further aggravating the situation. Rice cultivation is becoming uneconomical due to higher input cost, low input responsiveness, high labour requirement and poor diversification.

Therefore, it is essential to develop suitable system of cultivation, which is not only economical and helpful for better growth and development but also enable to utilize valuable resources efficiently and conserves them. Blending of modern technology with indigenous resource conserving technologies would help to achieve such goals with people's participation. In the recent years, a lot of emphasis has been given in resource conservation in agriculture, as a result of which a number of technologies are developed /evaluated in agriculture with the ultimate objective of improving productivity and conservation of ecosystems. Some of such technological options suitable for rice cultivation are discussed in this chapter.

System of Rice Intensification

Water is the most important input in agriculture and rice consumes most of the available water resources of the country. The farmers are habituated to irrigate rice as much as possible and maintain high submergence throughout the crop period with wrong notion that yield could be increased with increased water input. The continuous land submergence leads to considerable loss of water through deep percolation and other means (Bouman, 2001). On the other hand, submerging rice fields brings a series of physical, chemical and microbilogical changes in the soil, which profoundly affects growth of rice plant as well as availability, loss and absorption of nutrients (Ghildyal, 1978). It is well documented that rice root degenerates under flooded condition and deprive healthy crop growth due to decreased feeding zone of the crop caused by lodging and death of the plants after water receded (Chaturvedi *et al.* 1995).

The System of Rice Intensification (SRI) is an improved method of rice cultivation developed through participatory on-farm research conducted at Madagascar during 1980s by Father Henri de Laulanie, a Jesuit priest in close collaboration with farmers to overcome the problem of rice cultivation in predominantly acidic soils of Madagascar. SRI is a system of growing rice that involves principles that are at times radically different from traditional ways of growing rice. It involves single seedling transplantation of young seedlings with care instead of the conventional method of transplanting multiple and mature seedlings from the nursery. SRI spaces rice plants more space and does not depend on continuous flooding of rice fields, uses lesser seed and chemical inputs, and promotes soil biotic activities in and around plant roots through liberal applications of compost and weeding with a rotating hoe that aerates the soil (Plate 1). These changed practices with lower inputs counter-intuitively lead to the yields of 7-8 t/ha, about double the present world average of 3.8 t/ha.

Tripura, a small state in the North Eastern region with SRI approach, has shown the way to the nation in improving the productivity of rice from 2.5 tonnes per hectare to about 3.5 tonnes per hectare (Uphoff, 2007). This is highly encouraging and it has a long way to go. The other states also have the similar opportunities.

- SRI involves the use of certain management practices which together provide better growing conditions for rice plants, particularly in the root zone, than those for plants grown under traditional practices
- SRI is a system rather than a technology because it is not a fixed set of practices. While a number of specific practices are basically associated with SRI, these should always be tested according to local conditions rather than simply adopted.

Plate 1. Rice under SRI at ICAR, Umiam, Meghalaya

Global SRI scenario

Until 1999, the only country in which the System of Rice Intensification (SRI) was known and practiced was Madagascar, an island nation off the southern coast of Africa. In Madagascar, methods of rice cultivation had remained quite 'traditional' as Malagasy farmers transplanted seedlings 5-6 weeks old in clumps of 5-6 plants, keeping their fields continuously flooded, with only casual weeding. Paddy yield in Madagascar was around 2 t/ha for many years. Soil was strongly acidic (pH 3.8-5.0) with low to very low in cation exchange capacity (CEC). There were serious problems of iron and aluminium toxicity, and less than half as much phosphorus was available as usually considered necessary for good crop yields. Farmers were too poor or isolated to purchase chemical fertilizers or new seeds.

A French priest, Father Henri de Laulanie (1993), who spent three decades in developing SRI through careful observation and experimentation, developed, refined and tried to explain the major increases in yield and factor productivity that his SRI practices induced, how they evoked more productive phenotypes from any rice genotypes.

Rather than pursue a strategy that relied primarily on external inputs, Laulanie started with whatever rice varieties farmers were already planting, and with whatever soil they cultivated. He figured out how farmers could improve their production just by changing the way that they managed their rice plant, their soil, their water and organic nutrients. To enhance the structure and functioning of their soil systems, farmers were advised to utilize compost, any decomposed biomass, since most households were too poor to have cattle and had little access to farmyard manure and could not afford to purchase and apply chemical fertilisers.

Cornell International Institute for Food, Agriculture and Development (CIIFAD) first started to work in Madagascar in 1993-94. SRI was being promoted by an NGO that Laulanie had established with Malagasy colleagues in 1990, Association Tefy Saina. This NGO trained farmers growing rice on small plots in the peripheral zone around Ranomafana National Park. Through SRI methods, it was hoped to reduce the slash and burn cultivation that was encroaching on the remaining rain forest ecosystems. By 1997, farmers around Ranomafana practising SRI had average yields of 8 t/ha for three consecutive years, a four fold increase from 2 t/ha.

In India also SRI technology started picking up. States like Andhra Pradesh, Tamil Nadu has done a good progress in this technology. Even in North East a lot of works are undertaken in SRI and ICM. Recently second National Symposium on SRI was held at Agartala, Tripura from 3-5 October, 2007 to popularise the technology in the region. ICAR Research Complex for NEH Region, Umiam, Meghalaya also initiated work on SRI and ICM since 2004. A number of demonstrations and on-farm trials are conducted by the Institute on SRI. Recently a subproject on SRI and ICM has been undertaken by Division of Agronomy, ICAR Research Complex for NEH Region, Umiam, Meghalaya under National Agricultural Innovative Project (NAIP) to popularise these technologies in South Garo Hills of Meghalaya.

Phyllochron Concept in Paddy

In SRI method, initially (2-3 weeks after transplantation) the field would looks terrible, as the seedlings are small and widely spaced. As there is no standing water in the field, the land looks dried up. At this stage the rice plant is preparing itself to tiller. To understand the concept of tillering, one has to know about phyllochron in paddy. Phyllochron is the time taken to form a new tiller with a leaf and root. This is mainly influenced by the temperature followed by day length, humidity, soil moisture, soil texture, availability of nutrients, aeration and sunlight. If all the conditions are favourable one phyllochron is completed in 5 days. Or else it might take 6-7 days or even more. It is ideal that the rice plant completes 12 phyllochrons by the time vegetative phase is over and panicle initiation has taken place. A new tiller after completing two phyllochrons also starts tillering. This means that the number of new tillers increases geometrically. If germination is considered as the first phyllochron stage, then it is ideal to transplant it in 2nd or 3rd phyllochron stage. This would not disturb the phenomenal growth that would take place from the 4th phyllochron. For maximum tillering plants has to complete as many phyllochrons as possible during their vegetative phase, which is only possible when seedlings are transplanted at 2nd or 3rd phyllochron stage. The same thing happens in SRI method. Whereas, in case of conventional transplanting seedling roots are traumatized when they are exposed to the sun and dry out (mainly feeder roots) results slow in subsequent growth and not as many phyllochrons are completed before PI. If seedlings are three or four weeks old when transplanted (as in case of conventional practice), the most important (late) phyllochrons, the stage when optimum tiller growth is attained, will never be reached.

In medium duration (125 days) variety, which has about 60 days of vegetative phase under normal growth condition, plants prepare to tiller in about 8-10 days after transplanting (DAT). Rapid tillering begins at 20-30 DAT. The field seems to explode with rapid tillering at 30-40 DAT. In medium duration varieties, about 60, 35 and 30 days are required for vegetative, reproductive and ripening phase, respectively.

Key differences among various rice cultures

There are some key differences among SRI, ICM and Conventional rice cultures (Table 1).

Table 1. SRI and ICM vs. Conventional methods of rice cultivation

Parameters	SRI	ICM	Conventional
Seed rate (kg/ha)	5 - 6	15 - 20	40 - 50
Seedling Age (days)	10 - 12	18 - 20	25 - 30
Spacing (Row x Plant) cm	25 x 25	20 x 20	20 x 15
Seedlings/hill	1	2	3 - 4
NPK + FYM	20:15:10 kg/ha + FYM 10 t/ha	40:30:20 kg/ha + FYM 5 t/ha	80:60:40 kg/ha
Water management	Only moist condition	Intermittent irrigation	Continuous flooding
Water requirement (mm)	900	1400	1800
Weed management	Weeds turn down into the field by a weeder	Manual and mechanical weeding	Weeds manually removed from the field/herbicides
Grain Yield (t/ha)	6.0 - 6.5	5.5 - 6.0	4.5-5.0

Warning

At the initial stage, the field will look barren and disappointing. There will be little green to see as plants are very few and spaced widely. But from fourth week onwards, the plants will show accelerated growth that attracts viewers and farmers curiosity.

Limitations of SRI

The main limitations for SRI are controlled release of water i.e., ability to control water and to apply water to the field when it is needed. The uprooting and transplanting of young seedlings need expertise and utmost care. When the fields are not kept flooded, there will be opportunity for greater weed growth.

Integrated Crop Management (ICM) - an Alternative to SRI

To overcome the above limitations and to begin with one can go for Integrated Crop Management. Here 15 - 20 days old seedlings are planted in wide spacing (20cm x 20cm or 25cm x 25cm). However, here for nursery preparation MMN (Modified Mat Nursery) is followed. Combined use of organic manure/compost and chemical fertilizer has shown to produce higher yields than either alone. Adoption of IPM will also be very effective for crops under ICM, as fewer incidences of disease and pest is expected due to healthy plants. Thus farmer can reduce or avoid pesticide application.

Advantages of ICM

- Seed requirement is less than conventional practice
- Saving on water as intermittent Irrigation is followed
- Cost of external inputs gets reduced as organic manures and fertilizers are used in integration
- Especially good for high rainfall areas like North East India
- It is easy to handle 15-20 days old seedlings compared to 10-12 days
- Incidence of pests and diseases is low as the soil is allowed to dry intermittently

- Higher yields due to increased tillering, panicle length and grain weight

Preparation of Modified Mat Nursery (MMN)

In MMN, the seedlings are raised in a 4 cm layer of soil mix arranged on a firm surface. A nursery of 100 sqm area and 10 – 12 kg of good quality seeds are sufficient for transplanting one hectare area. The soil mix (4 m^3 for 100 sqm of mat nursery) is prepared by mixing 75 – 80per cent soil, 15 - 20per cent well decomposed manure and 5per cent rice hull ash. To this soil mix, add 1.5 kg of powdered diammonium phosphate or 2 kg compound fertilizer (15-15-15) and mix well.

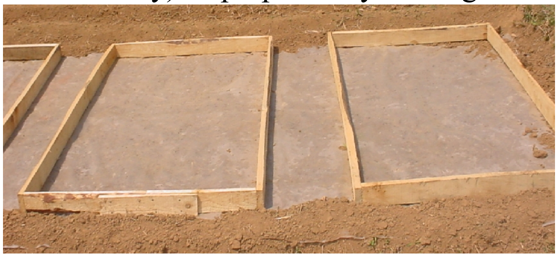

Plate 2. Wooden frame for MMN

A wooden frame of 1.0 m width, 0.04 m height and suitable length divided into equal segments of 0.5 m each is placed over the plastic sheet spread over even firm floor/surface (Plate 17). Each segment of the frame is filled with soil mix almost to the top. Pre-germinated seeds are sown uniformly, covered with the soil mix, and firmed gently with the hand. The seedbed is sprinkled with water. The bed must be protected from heavy rains for first 5 days. The bed can be kept moist by regular watering with rose cans until seedlings are ready for transplanting in 15 days. In warm weather, the seedlings reach 16 - 20 cm height with 4 leaves and no tillers in 15 - 16 DAS. Alternatively farmers can use locally available materials like bamboo, banana leaves for preparation of MMN. Even traditional nursery practice with slight modification e.g. use of sufficient amount of organic manures like FYM or vermicompost with sparse seeds rate of 100 – 150 g/m^2 would be adequate for SRI and ICM practice. Alternatively the nursery can be prepared on any compact surface in an open area (Plate 18 - 36). But care should be taken to give some support to the nursery bed by providing wooden plank as shown in Plate 16 or use any other locally available materials. In the absence of any such support, the soil mixture along with nutrients will be washed away by the heavy rains especially in North East. This would produce weak seedlings instead of robust seedlings. Plastic tunnels could be used in high rainfall areas like North East especially to avoid damage due to heavy rains.

Research achievements on SRI and ICM practice

Field trials on comparative performance of SRI, ICM and conventional rice culture (CRC) have revealed that SRI and ICM have recorded 10 - 30per cent more grain yield in comparison to conventional rice cultivation practice at different locations in India (Balasubramanian *et al.* 2006). Balachandran and Louis (2007) reported superiority of ICM over SRI, dibbling and conventional transplanting in enhancing grain and straw yield of rice at Pattambi, Kerala. Field experiment conducted at ICAR Research Complex for NEH Region, Umiam, Meghalaya (low in soil available N, P & high K) also revealed the similar results (Munda *et al.* 2007). SRI recorded the higher percentage of effective tillers, grain per panicle, ripening ratio and test weight but these values were at par with ICM. On the other hand significantly higher number of tiller per m^2 and panicles per m^2 were recorded with ICM compared with SRI and conventional practice. As a result of this the significantly highest grain yield was recorded with ICM, which was found at par with SRI (Table 2). Contrary to the yield, the Harvest Index was found slightly higher with conventional practice. This was mainly due to higher biomass production under SRI and ICM

Plate 3. Farmers visiting SRI/ICM experiments at ICAR Complex, Umiam

compared to conventional rice culture. A number of field visits were organised for the farmers to popularise the technology in the region.

Table 2. Effect of stand establishment methods and nutrient management on performance of low land rice

Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Harvest Index	Available Soil Nutrient at harvest (kg/ha)		
Establish methods				N	P_2O_5	K_20
SRI	52.93	69.68	43.17	276.8	13.08	191.1
ICM	54.48	71.37	43.29	271.2	12.14	186.7
CRC	49.95	65.52	43.26	262.3	11.29	174.4
SEd ±	0.74	0.97	0.27	2.24	0.47	5.76
CD (P=0.05)	2.05	2.69	NS	6.22	1.31	15.99

The significantly higher values of root length, root volume and root dry weight was recorded with SRI compared to control but remained at par with ICM practice (Table 3). SRI roots were found more active and healthy at harvest, whereas the roots under conventional practice were weak, thin and degenerated.

Table 3. Root parameters of rice as influenced by stand establishment methods

Establishment methods	Root volume (cc)	Root dry weight (g)
SRI	59.15	12.10
ICM	52.89	10.33
Conventional	42.40	7.78
SED ±	3.00	1.20
CD (P=0.05)	6.14	2.44

Effect of various nutrient management practices on different rice cultures were studied at ICAR Research Complex for NEH Region, Umiam, Meghalaya under low land condition for three consecutive years (2005-07). The experiment soil was low in available N and P and medium in K. The result of final year revealed that integrated application of fertilizer and organic manures recorded higher yield compared to individual application of either organic manure (FYM) or fertilizer. The SRI crop matured about 15 days earlier to conventional practice.

Field experiments on plant density and weed control measures under SRI at Dapoli, Maharashtra revealed that close spacing of 20 x 20 cm produced maximum grain yield (59.19 q/ha) and straw yield of rice which was followed by 25 x 25 cm and 20 x 15 cm spacing (Thorat *et al.* 2007). Under weed control measures, hand weeding thrice (at 15, 30 and 45 DAT) produced maximum grain yield (64.14 q/ha) and straw yield (Table 4).

Table 4. Grain yield and straw yield as influenced by planting density under SRI at Dapoli, Maharashtra

Spacing (cm)	Grain yield (q/ha)	Straw yield (q/ha)
20 x 15	52.16	54.73
20 x 20	59.19	60.40
25 x 25	53.01	59.03

Crops under SRI produced more number of tillers per hill compared to ICM and conventional methods (Fig 5). Tillers production in SRI increased at higher rate and reached at peak 50days after transplanting (DAT) and started decreasing from 60DAT but remained superior to ICM and conventional practice.

Modification of SRI for North Eastern Region

Since North Eastern region receives a very high rainfall during monsoon season, it is very difficult to practice all the principles of SRI as suggested for controlled irrigation condition. Results of field experiments conducted at ICAR Research Complex for NEH Region, Umiam, Meghalaya during 2004-2007 on SRI revealed that closer spacing of 20 x 20 cm with10-12 day's old seedlings were found better as this produced more number of tillers/m^2 compared to 25 x 25 cm spacing (Munda *et al*. 2007). Intermediate practices of 15-20 days old seedlings were found better under Meghalaya condition as this can resist damage from sudden heavy rain and also it is easier to transplant. Immediately after transplanting 10-12 days old seedlings, if there is a heavy rainfall, may cause damage to the seedlings.

Aerobic Rice

International Rice Research Institute (IRRI) developed the "aerobic rice technology" to address the water crisis problem in tropical agriculture. In aerobic rice systems rice is grown like an upland crop with adequate inputs and supplementary irrigation when rainfall is insufficient (Bouman 2001).

The new concept of aerobic rice may be an alternate strategy, which combines the characteristics of rice varieties adopted in upland with less water requirement and irrigated varieties with high response to inputs. In China, the water use for aerobic rice production was 55 - 56 per cent lower than the flooded rice with 1.6 - 1.9 times higher water productivity. Net returns to water use were also two times higher (Bouman 2001). It indicates that aerobic rice may be a viable option where the shortage of water does not allow the growing of lowland rice. Lafitte *et al.*, (2002) reported that most lowland cultivars could survive in well-watered aerobic soils. Several technologies have been developed to reduce water loss and increase the water productivity of the rice crop. They are saturated soil culture (Borell *et al.,* 1997), alternate wetting and drying (Li 2001; Tabbal *et al.* 2002), ground cover systems (Lin *et al*. 2002) and system of rice intensification (Stoop *et al*. 2002). However, the fields are still kept flooded for some periods in most of these systems, so water losses remain high. Aerobic rice is high yielding rice grown under non-flooded conditions in non-puddled and unsaturated (aerobic) soil. It is reported that these rice are responsive to high inputs and tolerates (occasional) flooding (Bouman and Tuong 2001). Aerobic rice promises substantial water savings by minimizing seepage and percolation and also greatly reducing evaporation (Bouman *et al.,* 2002). Experimentally growing high-yielding lowland rice varieties under aerobic conditions has shown great potential to save water, but with severe yield penalty (McCauley 1990; Peng *et al*. 2006). High yields could be sustained when aerobic rice is grown once in four crops, but not under continuous monocropping in Brazil (Guimaraes and Stone 2000) and Philippines (Ventura and Watanabe 1978). Yield decline under monocropping of aerobic rice has also been reported by George *et al*., (2002) and Peng *et al.,* (2006).

Field experiment was conducted at the ICAR Research Complex for NEH Region farm at Umiam (950 m msl), Meghalaya during rainy seasons of 2006 and 2007 revealed that the yield difference between aerobic (average yield, 1.67 t/ha) and flooded rice (average yield, 2.31 t/ha) ranged from 18.4 to 37.8 per cent (P<0.05) depending on varieties. Cultivation of rice under aerobic condition resulted in 27.5 per cent yield reduction over flooded rice. Among the yield components assessed, sink size (spikelets per panicle) contributed more to the yield and is considered to be most important factor responsible for yield gap between aerobic and flooded rice. The study suggests that, variety Sahsarang 1 with its moderate values of photosynthesis rate, transpiration rate and water use efficiency (WUE) along with higher grain yield seems to be better choice for both stress (aerobic) as well as normal condition.

Green leaf manuring in rice

The fresh N-fixing tree leaves @ 10 t/ha was incorporated into the rice soil as green leaf manure manually 20 days before transplanting. The nutrient and moisture content of different tree leaves are presented in Table 5. In the first year, highest grain yield (4.82 t/ha) was recorded with recommended NPK (80:60:40 kg/ha) followed by incorporation of *Erythrina* (4.48 t/ha) and *Parkia* leaves (4.13 t/ha). In the following year though the trend remained almost same, the gap between yield obtained with NPK (5.08 t/ha) and tree leaves incorporation reduced. Surprisingly, in the third year, all the tree leaves except alder surpassed the grain yield level that obtained with recommended NPK (5.13 t/ha). Significantly highest grain yield of rice in third year was recorded with incorporation of *Erythrina* leaves (5.67 t/ha) that remained at par with *Acacia, Parkia* and *Casia* leaves. The result indicated that green leaf manuring with N-fixing tree leaves left marked residual effect and therefore improved productivity level due to cumulative effect (Das *et al.* 2009a).

Table 5. Effect of different N-fixing tree leaves on productivity of lowland rice

Treatments	Nutrient composition (per cent)				Grain yield (q/ha)		
	N	P	K	Moisture	2003	2004	2005
Erythrina	3.24	0.47	1.54	73.62	4.48	4.83	5.67
Alder	2.24	0.41	1.37	66.22	3.50	4.10	4.67
Parkia	2.54	0.40	1.52	69.28	4.13	4.40	5.23
Acacia	3.19	0.43	1.36	65.37	3.92	4.66	5.30
Cassia	2.50	0.39	1.17	65.80	3.99	4.55	5.58
Recommended NPK	-	-	-	-	4.82	5.08	5.13
Control	-	-	-	-	2.80	3.13	3.35
CD (P = 0.05)	-	-	-	-	0.60	0.46	0.53

Source: Das *et al.* (2009a)

Azolla in Rice Production

Use of Azolla (a water fern used as biofertilizer) in rice production is probably one of the most economical and eco-friendly approach. It not only improves productivity and income but also saves fertilizer and improves soil health. The experimental results on *Azolla* indicated that *Azolla* compost (harvesting fresh and excess *Azolla* from tank and allowing it to decompose for about 45 days) @ 10 t/ha enriched with Rock Phosphate (RP) recorded highest grain yield of rice (42.6 q/ha) followed by application of recommended dose of NPK (40.2 q/ha). Sole treatment of *Azolla* dual cropping and *Azolla* compost also recorded significantly higher grain yield that was 57.6 per cent and 40.8 per cent higher than control, respectively (Hazarika *et al.* 2006).

In-*situ* residue management

Effective management of residues, roots, stubbles, and weed biomass can have a beneficial effect on soil fertility through addition of organic matter and plant nutrients, and improvement in soil condition (Munda *et al*. 2006 and Singh 2003). Rice straw contains organic materials and nutrients such as N 0.5–1.5per cent, P 0.2–1.0per cent and K 0.8– .0per cent (Mongkol and Anan 2006). It is well documented that the incorporation of organic manure or crop straw into soil improves soil fertility and increases crop yield (Gill and Meelu 1986; Eneji *et al*. 2001;

Plate 4. Rice under in-*situ* fertility management

Singh et al. 2001). The residual effect of incorporating rice straw into the soil provides a significant increase in grain yield after three years of practicing this method (Prasert and Vitaya 1993). Chutiwat and Direk (1997) have reported that incorporating rice straw into soil has increased grain yield 15–18per cent over burning. It has been reported that the application of cattle manure to low fertile soil at a rate of 10 ton/ ha has increased grain yields by 108–106per cent over no-fertilizer application in long term (Kanika 1998).

In a study at Umiam, Meghalaya (Subtropical condition) rice-vegetables were grown with minimum tillage. All the weed biomass and crop residues available were recycled into the field. Highest grain yield was recorded in cv. Sahsarang 1 (37.0 q/ha) followed by cv. Vivek Dhan 82 (31.99 q/ha) and Mendri (30.9 q/ha) and found significantly superior to cv. Manipuri (26.60 q/ha) (Munda *et al.* 2006). The nutrients recycled though rice straw ranged from 35.1 kg N/ha with rice –carrot sequence to 42.5 kg N/ha with rice-frenchbean, 9.6 kg P/ha with rice-carrot to 12.5 kg P/ha with sole crop of rice and 78.6 kg K/ha with rice-carrot to 91.9 kg K/ha in-case of a sole crop of rice. The nutrient recycled through vegetables residue varied from 3.3 kg N/ha with rice-carrot to 87.9 kg N/ha with rice-potato. In other hand, the nutrient recycled through incorporation of weed biomass ranged from 53.6 to 75.9 kg N, 7.1 to 9.6 kg P and 45.7 to 61.7 kg K/ha. Microbial population (cfu/g dry soil) in in-*situ* fertility management experiments (Bacteria, 129 x 10^4/g, *Rhizobium*, 61.6 x 10^4/g and PSM, 39.9 x 10^4/g) were found much higher than that found under inorganic fertility management (Das *et al.* 2008).

Conservation tillage

Traditionally, wet cultivation or puddling is used to reduce water percolation and to soften soil to assist transplanting of seedlings (So *et al.* 2001). Sharma and De Datta (1985) concluded that the only relevant benefits of puddling are the creation of soil tilth, reduction of water and nutrient losses and weed control and that other tillage operation that create similar conditions should produce identical rice yields.

Tillage often excessive as practiced in conventional agriculture is one of the most important drivers of land degradation (Reichert and Norton 1994, Papendick and Parr 1997, Solonius 2008). Continued and widespread use of tillage based production system along with removal, grazing and/ or burning of crop residues would further cause land degradation and unsustainable agriculture (Lumpkin and Sayre 2009). Soil puddling, which is done to facilitate transplanting and reduce percolation loss in rice culture (Tripathi 1992a), has been credited to the ill effects on soil structure (Cass *et al.* 1994, Bajpai and Tripathi 2000). Lal (1994) showed that the yield of rainfed agriculture may decrease by 29 percent over next 25 years because of erosion and other problems in conventional tillage based agriculture. On the other hand, systems based on high crop residue addition and no tillage tends to turn the soil in to a net sink of carbon (Reicosky *et al.* 1995, Bot *et al.* 2001). The minimum tillage could produce rice yield similar to that under conventional puddling with reduced expenses on field preparation (Bajpai and Tripathi 2000). The minimum tillage is aimed to least deterioration of soil physical condition and to reduce turn around time (Singh *et al.* 2004). Conservation tillage (CT) is seen as more appropriate strategy for rainfed production systems to promote conservation agriculture (CA). Minimal soil movement by dramatic reduction in tillage and retention of crop residues on the soil surface along with possible crop rotation to economically benefit the farmers are the key principles of CA (Lumpkin and Sayre 2009). Potential of zero tillage under rainfed condition of North East in rice and rice based cropping system with appropriate residue management has been reported by Ghosh *et al.,* (2009)

Rice can be transplanted after puddling involving single tractor operation or dry field preparation by rotavator followed by ponding of water and planking involving two tractor passes compared to 6-9 operation being followed by the farmers. In the presence of crop residues, green manuring or excessive weeds, we may require one more tractor operation by either harrow or rotavator with and without planking. For comparison, 7 tractor operations i.e. cross harrow, cross cultivator, planking, puddling harrow and planking we considered. Time and fuel consumption was evaluated at farmers field at 2 to 4 locations for three years and averaged. A savings of about 32 to 77 per cent in time and 39 to 85 per cent in fuel were observes under rotary in combination with harrow and/or planking and rotary tillage alone (Sharma *et al*. 2002).

The experience with the resource conservation technologies especially adoption of zero tillage on large scale by the farmers indicates the benefits and the next logical step is conservation agriculture (CA) leaving crop residues on the soil surface leading to improvement of soil health and to avoid environmental pollution and associated animal and human hazards caused by crop residue burning (Sharma *et al.* 2002).

Direct dry seeded and unpuddled transplanted rice

Direct seedling has advantages of faster and easier planting, reduced labour and less drudgery with earlier crop maturity by 7-10 days, more efficient water use and high tolerance of water deficit, less methane and often higher profit in areas with an assured water supply. Thus the area under direct seeded rice has been increasing as farmers in Asia seed higher productivity and profitability to offset increasing costs and scarcity of farm labour (Balasubramanian and Hill 2002). Weed control is a major issue in direct seeded rice and to overcome this problem, intensive efforts are being made by the agricultural scientist. In some soil, spray of micronutrient like Zn and iron may be needed to remove their deficiency.

Direct seeding of rice using zero till drill, rotary till drill, drum seeder as well as broadcasting under various field preparation or puddling options was tried at DWR research farm. Seeding depth was kept at 2-3 cm while using drill for seeding. For comparison purposes transplanting was also done under conventional puddling as well as under zero tillage and after field preparation with rotary tiller (Sharma *et al.* 2003a). The rice variety used was IR 64. Direct seedling was done in the first week of June on the same day when nursery was sown for transplanting. For weed control Sofit @ 1500 ml/ha was applied after four days of direct seeding followed by one weeding at around 35 days after seeding. Among the direct seeding options, the yield recorded was highest where rice was seeded using rotary till drill followed by broadcasting sprouted rice seed after preparation by rotary tillage and lowest when broadcasted under zero tillage. The mean yield in rotary tillage was significantly higher compared to zero tillage. Direct drilling by zero till drill and rotary till drill was at par and as good as transplanting under zero tillage or after file preparation by rotary tillage wand was significantly better than broadcasting and drum seeder but statistically at par with other transplanting or seeding options. The yield was marginally higher in conventionally puddle conditions compared to transplanting without tillage. After field preparation by rotary puddle conditions compared to transplanting without tillage, after field preparation by rotary tillage or direct drilling by zero or rotary till drill.

Direct wet seeded rice

In this system sprouted seeds are broadcasted or placed with drum seeder under puddle or unpuddled conditions. Wet direct seeded rice also reduced labour costs and effective herbicides for weed control have helped making this technology more popular. Seed rate in drum seeded rice varies from 50-75 kg/ha whereas in broadcasting method of seeding 20-30 kg/ha is sufficient. In wet seeded rice puddling can be avoided without any adverse effect o n rice yield. The observations at farmers field showed that mortality or sprouted seeds are higher under puddle compared to unpuddled conditions. A field trial on direct seeded rice was conducted with different seed rates varying from 30 to 80 kg/ha during 2002. Similar yield was recorded at varying seed rates suggesting that the seed rate can be further reduced. In 2003 rice season, an additional treatment of 20 kg/ha was include. The varying seed rates were kept based on earlier recommendation of the Directorate of Rice Research of 75-100 kg/ha. The variety used was IR 64 having a 1000 grain weight of about 26 grams. For a population of about $0.33x10^6$ plants/ha recommended for transplanting rice, the seed requirement is likely to be around 11 kg/ha after giving an allowance of 20 percent loss in germination percentage of seed.

Of rodent and bird damage are further added to the estimates, almost double the seed requirement (20 kg/ha) should be good enough. The trial was sown in the first week of July during 2002 and second week during 2003 when the transplanting is generally dome. The yield recorded was almost similar at seed rates of 20 to 80 kg/ha (Sharma *et al.* 2003b).

Leaf colour chart

Leaf colour is a fairly indicator of the nitrogen status of plant. Nitrogen use can be optimised by matching its supply to the crop demand as observed through change in the leaf chlorophyll content and leaf colour. The leaf colour chart (LCC) developed by International Rice Research Institute (IRRI), Phillipines can help the farmers because the leaf colour intensity relates to leaf nitrogen status in rice plant. The monitoring of leaf colour using LCC helps in the determination of right time of nitrogen application. Use of LCC is simple, easy and cheap under all situations. The studies indicate that nitrogen can be saved from 10 to 15 percent using the LCC (Sharma *et al.* 2008).

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