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Improved Measures for Conservation Agriculture Practices in Rice Farming System

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ABSTRACT

Conservation Agriculture is a concept for resource saving agricultural crop production to achieve sustained production and conserving the environment. Function of conservation agriculture is based on three key principles, *viz.* effective resource conservation, input optimization and optimum productivity of the farming system. Certainly, the advancement in conservation agriculture is possible through genetic improvement in crops and varieties, which are suitable for better adaptation to different farming system environments. Besides, improved varieties and technologies can be assumed to improve productivity with an optimized input level. In the case of rice, resource conservation is possible with proper technological intervention. Water is the one of the most important factor, which governs the productivity of rice in Asia. In the concept of conservation agriculture, rice growing systems such as aerobic rice, direct seeded rice, system of rice cultivation and alternate wetting and drying were introduced to conserve water. Several problems come to exist in rice growing environment under limited water such as pest, disease and weeds, which may reduce productivity. In this paper the problems associated with rice growing under limited water resources are discussed and possible solutions are analyzed.

Key words: Conservation agriculture, rice, organic farming

INTRODUCTION

Conservation agriculture is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels, while concurrently conserving the environment. Conservation agriculture is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way that does not interfere with, or disrupt, the biological processes. Conservation agriculture is based on the three key principles of effective resource conservation, input optimization and over all the productivity of the farming system. Certainly, the advancement in conservation agriculture is possible through better adopted high yielding varieties grown under optimized input level. This paper aimed to provide the strategies to improve the conservation practices suitable for different farming system environment.

WHY CONSERVATION AGRICULTURE ?

In India, one of the biggest challenges is feeding a population of 1.1 billion with food grains. The total demand for the cereals alone is ranged from 261.5 to 267.0 million tons by 2020-2021, as reported by Chand (2007) and Kumar (1998). In

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terms of percentage increase, improving yield levels would require serious efforts to sustain and improve the total factor productivity through research and development efforts. Therefore, crop production under this situation may depend on higher utilization of natural resources like water and inputs like fertilizer etc. The fertilizer consumption of India has increased from 105.5 kg ha^{-1} in 2005-06 to 144 kg ha^{-1} in 2011-12 (SIA 2013). The modest increase (1% annually) in water productivity (quantity per consumptive water use) will eliminate the additional consumptive water demand for grains (Amarasinghe et al. 2006). Furthermore, climate change is likely to impact agricultural land use and production especially due to less availability of water for irrigation.

Likewise, the effect of crop residues on the soil chemical properties is related to increase of soil organic carbon in the form of organic matter, which provides essential nutrients such as macro and micronutrients that directly stabilizes the soil structure (Martinez et al. 2007). The microbial population of soils may increase up to 30 to 40 percent. The combined and integrated action of fungi, actinomycete, bacteria and soil mesofauna transforms the organic matter into humus. In synthesis, crop residues on top of the soil may have multiple beneficial influences in the crop production. Certainly, diversification of suitable crop species grown in sequence or associations also helps in maintaining the sustainable productivity in several ways.

KEY PRINCIPLES IN CONSERVATION AGRICULTURE

Three principles of conservation agriculture outlined by conservationists and producers are a) continuous minimum mechanical soil disturbance b) permanent organic soil cover and c) diversification of crop species grown in sequence or associations. Continuous minimal mechanical soil disturbance is one of the important phenomena in the conservation agriculture. Tillage is one of the most “energy consuming” processes in the existing farming practices. Producers can save 30 to 40 percent of time and labour by practicing the no-till process as a conservation practices. When the soil residues are left on top of the soil, many phenomena occur in the soil-residue interphase, which are determinant for crop growth. These include, partitioning and balance of radiation, energy, water and carbon. As a result, more soil moisture is available for plants. The rains fall on the residue, dissipating their kinetic energy, without affecting the soil structure. The soil water infiltration may improve due to the lower kinetic energy of the water reaching the soil surface, decreasing the water runoff and soil erosion (Acevedo and Martínez 2003). Improved soil water balance generally enhances the soil water availability to the plants (Martinez et al. 2007). The lower solar radiation reaching the soil surface in no-till along with the higher water content of the soil decrease the mean soil temperature and thereby lowering the rate of biological processes.

IMPROVED MEASURES FOR CONSERVATION AGRICULTURE

Food production must be increased to meet burgeoning global population. However, declining investment in agriculture, reduced inputs and an increasingly variable production environment make this a significant challenge. Combining resource efficient agronomy with better adapted crop cultivars will be vital if the productivity of the world’s food producing systems is to be maintained or increased. The existence of genotype x resource conserving crop management practice interactions, traits controlling these interactions and breeding strategies that can be used to improve yield under conservation agriculture are discussed for improving conservation agriculture.

The development of short-statured wheat and rice cultivars warranted farmers to apply more N and resulted in yield increment. The semi-dwarfing genes also radically changed plant morphology, significantly improving harvest index. However, it is unlikely that the dramatic improvements achieved through either semi-dwarf wheat or rice is likely to continue for a long time. Certainly, water will become increasingly limiting factor in many cropping systems (Trethowan et al. 2005). Combining water and resource conserving agricultural practices, such as zero-tillage, more water-use-efficient cultivars will enhance the overall productivity and profitability of most cropping systems. In this paper, ways to improve the conservation agriculture practices in the farming system with special reference to water conservation is discussed with rice crops.

Rice is a predominant food crop of Asia and more than 80% of the developed freshwater resources are used for irrigation purposes, about half of which is used for rice production (Dawe et al. 1998). To produce 1 kg of grain, farmers have to supply 2-3 times more water in rice fields than other cereals (Barker et al. 1998). Rapidly depleting water resources threaten the sustainability of the irrigated rice, food security and livelihood of rice producers and consumers (Tuong et al. 2004). In Asia, 17 million hectare (Mha) of irrigated rice areas may experience physical water scarcity and 22 Mha may have economic water scarcity by 2025 (Tuong and Bouman 2002). There is also much evidence that water scarcity already prevails in rice-growing areas, where rice farmers need technologies to cope with water shortage and ways must be sought to grow rice with lesser amount of available water (Tuong and Bouman 2002). The important water management technologies adopted under various rice farming environment is discussed below to cover the productivity constraints.

Aerobic rice cultivation

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 and Tong 2001). This concept of aerobic rice may be an alternate strategy, which combines the characteristics of both upland varieties with less water requirement and irrigated varieties with high response to inputs. The water use for aerobic rice production was 55-56 percent lower than the flooded rice, with 16-19 times higher water productivity and net returns to water use was two times higher. The water productivity in aerobic rice is ranged from 0.45 - 0.55 g grain/liter of applied water as compared to 0.25-0.30 g grain/liter of applied water in conventional system. The results of aerobic rice indicated that it may be a viable option where shortage of water does not allow growing lowland rice. Several technologies have been developed to reduce water loss and increase the water productivity of the rice crop; these include the following practices such as saturated soil culture (Borell et al. 1997), alternate wetting and drying (Tabbal et al. 2002), ground cover systems (Lin et al. 2002), and system of rice intensification (Stoop et al. 2002).

However, 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 responsive to high inputs, can be rainfed or irrigated, and tolerates (occasional) flooding (Bouman and Tuong 2001). In any variety development programme, variety should perform well both under aerobic condition as well as under normal irrigated condition, so that chance of getting a good harvest in a good rainfall year is not skipped.

The high yielding variety MAS 946-1 was released for Aerobic Cultivation in South Eastern Dry Zone of Karnataka in 2007 (Gandhi et al. 2012). Similarly, a study conducted to evaluate the variety suitable for aerobic rice cultivation in Tamil Nadu summarized that the upland rice variety PMK 3 produced the highest grain yield of 3684 kg ha^{-1} and it was significantly superior to other rice varieties. The next best variety was ASD 16 (3138 kg ha^{-1}) and it was on par with MDU 3 (2943 kg ha^{-1}) and CO 43 (2805 kg ha^{-1}) (Martin et al. 2007).

System of rice intensification (SRI)

The system of rice intensification was developed in Madagascar by Fr Henri de Lau Lanie in association with NGO- association Tefy Saina (ATS) and many small farmers in the 1980s is becoming popular in many countries including India. SRI is a system rather than a technology. It is based on the insight that rice has the potential to produce more tillers and early transplanting along with optimal growth condition like wide spacing, optimum humidity, a vibrant healthy soil and aerobic soil conditions during vegetative growth can fulfill this potential. Water saving in SRI may be as high as 40 percent as compared to conventional practice. In a field trial at Directorate of Rice Research (Hyderabad, India), SRI gave 166 percent higher grain yield than normal transplanting method. The varietal response to SRI and normal cultivation was wide SRI method gave nearly 46 to 48 percent higher yield in hybrids, 52 to 17 percent in HYVs while negative results were also observed in case of Pusa basmati due to its shy tillering habit under wider spacing. All the varieties are not promising for SRI cultivation method and response of cultivars to SRI varies as per their ability to exploit the natural resources.

Hence, there is a need to develop varieties that can give better response to SRI cultivation and must have compact plant type, profuse tillering, better root system, bolder grains, low water requirement, responsive to organic inputs (inorganic inputs constitute 25 to 50 percent only), and resistance to pest and diseases. Besides, rice matures 10 - 15 days earlier as compared to conventional practice and thereby vacates the land for timely sowing of succeeding crop. Therefore, genotypes used for SRI should be able to produce more with less duration. High yield varieties and hybrids are the most suitable cultivar for system of rice intensification. In addition, high tillering rice cultivars are also recommended for SRI.

Direct seeded rice

Direct Dry Seeding (DDS) in rice has advantage of faster and easier planting, reduced labour requirement and drudgery with earlier crop maturity by 7-10 days, better efficient water use and high tolerance of water deficit, less methane emission, and higher income due to less cost of production (Balasubramanian and Hill 2002). In both direct dry and wet seeded rice weed management is a major problem. Suitable genotypes needed to be developed for suitability under dry condition with better root system and competitiveness to weed. The genotypes with weed suppressing ability would a boon for the rice farmer's across the cultivation method and regions. Scientists are now able to identify some plant types that have the ability to compete successfully with weeds and give a good harvest even under no weeding conditions. In North East, variety Sahsarang 1 is said to have some abilities to compete with weeds. Development of such genotypes would reduce the requirement for tillage, save labour and herbicide use and thereby conserving resource base in agriculture.

Weed pressure is often two to three times higher in D-DSR than in transplanted crops. It is commonly observed that dry direct seeding is subject to relatively more weed pressure than wet direct seeding, probably because of differences in land preparation. Generally, weeds such as grasses, sedges, and broadleaf weeds are found in DSR fields. The dominant weeds in D-DSR fields are *Echinochloa crus-galli* and *Leptochloa chinensis* among grasses, *Cyperus difformis* and *Fimbristylis miliacea* among sedges, and *Ammania baccifera, Eclipta prostrata*, and *Sphenoclea zeylanica* in the broadleaf category. The reported yield losses from weeds on DSR range from 20 to 88 percent in India (DRR 1995). Under minimum tillage concept of conservation agriculture, emergence of weed might be increasing at an alarming rate. The selection of weed-suppressing rice varieties and use of clean seed are the basis for reducing weed pressure in DSR rice system is essential. In addition with suitable herbicide, manual weeding and adapting integrated weed management is essential.

Similarly, emergence of pest and diseases are high and causes severe problems due to varied plant densities under DSR. For example, under high planting density of DSR, more vegetative biomass are produced which are adopted to suppress weeds as well as to obtain high yields. The observed panicle densities are 700–800 m^{-2} in broadcast sown rice and 500–600 m^{-2} in row seeded rice in tropical developing countries, compared with >1,200 m^{-2} in temperate Australia. High tiller density leads to highly humid micro environments in the rice canopy that might favor the invasion of certain pests and diseases.

Insects such as stem borer, green leaf hopper, leaf folder, and gall midge highly emerge under DSR. Diseases like blast, ragged stunt virus, yellow orange leaf virus, sheath blight, and dirty panicle are also prevalent (Pongprasert 1995). Other insect pests that attack emerging rice seedlings are the golden apple snail [*Pomacea canaliculata* (Lamarck)] and rats. Protecting young seedlings against these pests is more difficult in DSR than in transplanted rice. In Philippines, farmers make narrow ditches to entice snails to pools of water and then handpicks them. In severe cases, molluscicides are used to control snails. Indonesian farmers reported that the rat problem is more serious in DSR than in transplanted rice, especially in broadcast sown crops. They use traps, barn owls (biological predator), and sulfur fumigation or poison baits to minimize rat damage.

Cultivation of resistant varieties can complement cultural practices to reduce pest problems under wet direct seeding. There are varieties resistant or tolerant to BPH, ragged stunt virus, blast, and bacterial leaf blight, but none for stem borers, thrips, leaf folder, sheath blight, sheath rot, and dirty panicle (Pongprasert 1995). Therefore, integrated pest management is a strategy that employs various tactics or control measures harmoniously to bring the pest population below the economic threshold level under DSR. In addition, adoption of the IPM strategy by combining resistant varieties, predator management, cultural practices, and/or the judicious application of pesticides will help control most insects and diseases (Heong et al. 1995) under DSR is highly essential.

Screening of rice varieties suitable for direct seeding in Punjab revealed that short stature and low tillering, medium and fine grain varieties, *viz.* KS-282, NIAB- IR9, IR-6, Basmati-2000, Super Basmati, 99512 and PK-5261-1-2-1 produced significantly higher yield than all the other varieties/ lines under test (Ali et al. 2007).

Organic Farming

To attain self-sufficiency in food grain production, high yielding varieties may play a major role as compared to traditional varieties. About 65 percent of India is under non-irrigated cultivation where the farming practices are still largely ‘organic by default’. The use of chemical fertilizers is comparatively low in eastern and northeastern part of the country and yet there is sufficient food production. This defies the myth that the output would fall if the farmers go back to organic farming. However organic farming in India is still in its infancy, and due research efforts are required to support the various requirements of organic farming. Presently the varieties suited to conventional farming conditions are also used in organic farming. Efforts should be focused on use of organic in basmati rice, where nitrogen requirement for the crop is less as compared to non-basmati rice.

Conversion of Rice from C_3 to C_4 Crop

In rice C_3 plants, photorespiration reduces net carbon gain and productivity by as high as 40 percent, as a result of this; C_3 plants are less competitive in certain environments. On the other hand, C_4 plants exhibit many desirable agronomic traits, high photosynthesis rate, faster growth and high water and input use efficiency. Therefore, efforts are on to convert rice to C_4 crop for realizing higher photosynthesis rate and yield. Development of such a genotype would save a huge amount of water, which could be utilized for increasing irrigated area.

Thermo-tolerance will also improve cultivar adaptation to early season temperature fluctuations, as the rate of emergence and general seedling vigour are influenced by temperature fluctuations. Good early vigor combined with vegetative frost tolerance is advantageous in areas where cold temperatures come rapidly after planting and early frost can occur. Nevertheless, changes in disease patterns linked to stubble retention remain the primary constraint to cultivar adaptation to conservation agriculture

Transgenic herbicide tolerance can also improve crop adaptation to zero-tillage as they effectively control weed competition and need only to be deployed in one element of the crop rotation. An example is the deployment of herbicide tolerant soybean in rotation with wheat, very common in Argentina in which weed growth in the subsequent wheat crop is significantly reduced (Cook 2006).

CONCLUSION

Conservation agriculture is a very important process to be looked at in order for the future generations both improvements in resource conservation and yield improvement. This paper addressed the improved measures for conservation agriculture in farming systems adopted in India with special reference to water conservation measures. In addition, crop and varieties, which are suitable for better adaptation to different environment, need to be improved through breeding traits. These improved varieties and technologies can be assumed for favorable productivity with an optimized input at any farming system. Optimizing inputs and the choice of cultivar for an effective resource conserving farming practice can improve overall productivity and yield potential of crops, especially traditional cultivars.

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