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Review Article

Strategies for Developing Compatible Genotypes for Conservation Agriculture System

Suneetha Kota, V. Ravindra Babu and Brajendra

Indian Institute of Rice Research, Hyderabad, Telangana, India
**Corresponding author*

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A B S T R A C T

The rice-wheat production system has played an important role in the food security and has remained its cornerstone for rural development and natural resource conservation. But, now evidences of second generation problems have started appearing such as declining productivity, plateauing of crop productivity, declining soil organic matter, receding ground water table, diminishing farm profitability etc., which are mainly attributed to intensive conventional production systems (Hobbs and Gupta, 2000; Sharma *et al.*, 2003; Gupta and Sayre, 2007). At present, the challenge is to produce more food from the same land and water resources by alternative systems, while sustaining soil and environmental quality and improving farm profitability sustainable (Gupta and Seth, 2007). This necessitates that more attention be given to issues of sustainability and conservation agriculture.

Introduction

Conservation agriculture (CA) 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 (FAO 2007). Over 90% of the conservation agriculture based technologies are being practiced in just five countries namely, USA (25mha), Brazil (24 mha), Argentina (18 mha), Canada (13 mha) and Australia (9m ha). Of late, China and India also started practicing conservation agriculture technologies. In India, more than 2 mha area under the rice-wheat based system in the Indo-gangetic plains is under resource conservation technologies. According to UN Food and Agriculture Organization (FAO), the three basic principles are:

Continuous minimum mechanical soil disturbance for erosion control

Maintenance of permanent organic soil cover

Diversified crop rotations for annual crops and plant associations of perennial crops

Rice wheat cropping system is dominant on fertile and irrigated alluvial soils of north-west India, particularly in Punjab and Haryana. In the cropping practice of rice, many farmers especially in Punjab and Haryana are shifting from transplanting to direct sowing (Erguiza *et al.*, 1990). The varieties developed for conventional tillage system do not necessarily have the same performance and specific genotypes are recommended for no-till (Chevalier and Ciha, 1986; Yang and Baker, 1991). For such cropping system, vigorous modern rice cultivars are increasingly required, which would not only facilitate rapid seedling establishment under a wide range of field conditions but also have increased competitive ability against weeds. Genetic improvement is one of the most efficient approaches to develop rice cultivars suited to conservation agriculture based technologies. Infact, most breeding programmes have not systematically addressed variety development for conservation agriculture. Varieties and hybrids adapted to dry seeding in zero till rice wheat systems are in high demand. CA based resource conserving technologies (RCT's) such as zero tillage and bed planting are being promoted in rice-wheat system.

Basic strategies for conservation agriculture

Zero tillage farming/ no till farming

Excessive tillage is considered harmful to the soil structure and also contributes to soil erosion. Adoption of zero tillage and associated practices have not only resulted in increase in cereals and oilseed production but also improved the farm economy. Over the years wheat yields under zero tillage have increased benefiting from higher water accumulation and soil fertility caused by better stubble management (Kohli and Fraschina, 2010).

Residue retention

Residue retention or maintenance of permanent of soil cover either through the use of previous crop residues or cover crops is one of the key components of CA as it improves water infiltration, reduces erosion and improves surface soil physical properties in addition to benefiting many soil biological and chemical processes (Hobbs *et al.*, 2008). Crop residue mulch has the potential to retain soil moisture (Enrique *et al.*, 2002) and maintain the non-flooded rice production (Huang *et al.*, 2003, Qin *et al.*, 2006).

Soil and water conservation

Soil and water are the prime natural resources that must be managed efficiently and effectively for sustainable agriculture and crop productivity. Conservation agriculture involves soil and water conservation methods mutually reinforcing each other.

Mulch based cropping system

Root development and proliferation depend on soil moisture (Gajri and Prihar 1985) and grain yield under mulches is higher due to longer rooting and higher moisture content in the upper soil layers (Bonfil *et al.*, 1999). Further, non-flooded rice cultivation reduced water consumption by almost 50–70% compared with the continuously flooded system (Huang *et al.*, 2003, Qin *et al.*, 2006). However, there were only limited reports on mechanisms involved in water use efficiency and water stress physiology in particular in non-flooded rice cultivation with mulching (Liang *et al.*, 2003).

Genetic Improvement strategies

The breeding programmes need to adapt to the dynamics of the physical, chemical and biological changes occurring in the soil system which permit the crops to achieve increasing yields as a result of higher water holding capacity and accumulated over time. Selective exploitation of genetic variability in some of the agronomic characters such as early seedling emergence and establishment, as well as yield and yield components will help to identify the trait specific genotypes. Development of zero tillage or specific germplasm will increase the genetic base and sustainability of production system.

Components of conservation agriculture specific to rice

Aerobic rice cultivation

International Rice Research Institute (IRRI) developed the aerobic rice technology, to address the water crisis problem in tropical agriculture. Aerobic rice is grown like upland crop with adequate inputs and supplementary irrigation when rainfall is insufficient. The water use for aerobic rice production was 55 to 56 percent lower than the flooded rice with 1.6 to 1.9 times higher water productivity (Mishra and Chatrath, 2010). Conservation tillage methods like medium disturbance minimum tillage to low disturbance no tillage with maximum residue retention is being adopted in rice cultivation.

Alternate wetting and drying

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).

SRI cultivation

SRI (System of Rice Intensification) is a system rather than a technology. It is based on principle that rice has the potential to produce more tillers and grain than presently observed and that early transplanting along with optimal growth conditions like wide spacing, a vibrant healthy soil and aerobic soil conditions during vegetative growth. Water saving in SRI may be as high as 40% compared to conventional practice.

Direct seeded rice

Direct drill seeding of rice can be a potential option for faster and easier plantin, reduced labour requirement and drudgery, early maturity, better efficient water use and high tolerance to water deficit, less methane emission and higher income due to less cost of production (Balasubramaniam and Hill, 2002). In southern USA where much of rice is drill-seeded, breeders have developed semidwarf California rice breeding lines with good levels of seedling vigor and semidwarf rice germplasm with long coleoptiles and mesocotyles which promote seedling emergence (McKenzie *et al.,* 1994).

Organic farming

Organic farming reduces the use of chemical fertilizers. However, in India, it is still in its infancy and due research efforts are required to support the various requirements of the organic farming.

Breeding objectives to develop CA specific varieties

To screen adapted and unadapted germplasm for response to CA.

To implement a selection strategy to identify morphological and functional traits that facilitate selection criteria under zero tillage/ minimal tillage system

To identify parental material that represents extreme expression of traits and studies their inheritance pattern.

Identification of elite lines with superior adaptation to conservation agriculture technologies with stable yield which can be used as a reference collection for CA.

Characters of importance

In direct seeded rice the following morphological traits are important in addition to above mentioned traits. 1).Early plant vigour; 2).Genotypes with good emergence and establishment; 3).Weed suppressing ability; 4). Strong Culm; 4).Fast root and shoot growth; 5).High tillering capacity; 6).Genotypes suiting to water stress; 7).Nutrient use efficiency; 8).Genotypes suiting to soil factors under reduced tillage; 9).Pest resistance; 10).Root characteristics; 11).Shoot length; 12).Plant height; 13). No. of grains per panicle; 14).Test weight and other yield components; 15).Yield *per se*.

Early vigor has been considered as one of the important characteristics that determine successful crop establishment (Zhang *et al.*, 2005). In rice, high early vigor (early biomass accumulation) has been reported to be associated with weed suppression and yield under weed competition in direct seeded situation. Differences in early vigor of rice cultivars affecting weed competitiveness under direct seeded situation have earlier been reported by Garrity *et al.,* 1992; Dingkuhn *et al.,* 1998 and Caton *et al.,* 2003. Caton *et al.,* (2003) reported that early vigour was a highly repeatable trait that can be used to discriminate between rice cultivars that are more or less competitive with weeds.

Genetic enhancement of rice for conservation agriculture

Experiments on direct seeding, transplanted as well as zero till direct seeding were conducted during Rabi, 2010 to Rabi, 2011 at DRR, Hyderabad. Same set of genotypes were grown under the above said conditions. About 400 rice genotypes consisting of germplasm, released varieties as well as genetic stocks were screened to identify promising genotypes with specific traits. Differential response of genotypes for yield and yield components under direct seeding and puddled transplanted condition was observed. The *per se* performance of the genotypes under transplanted as well as under direct seeded condition varied. Interestingly, some of the genotypes were found to be perform better under both conditions, while some of them exhibited superior performance under direct seeded condition and *vice versa*.

The average yield under direct seeding condition was found to be 2822 kg/ha (Table- 3) with yield range between 644 kg/ha (N22) to 5384 kg/ha (IET 22051: RP 5125-2-4), while under puddled transplanted condition the yield range was between 2665 kg/ha (Panvel 3) and 5946 kg/ha (IURON 98) with an average yield of 4526 kg/ha (Table -4). Although there was significant yield reduction under direct seeding condition as compared to transplanted condition, some of the genotypes exhibited superior *per se* performance under direct seeding. The *O. glaberrima* introgression lines viz., RP 5219-9-6-7-3-2-1-1 (4856 kg/ha), RP 5125-2-4(5384 kg/ha), RP 5129-17-8-3-2 (3489kg/ha) recorded superior performance under direct seeding situation. In addition, the genotypes Kalinga II (4570 kg/ha), B644F-MR-6-0-0 (3645 kg/ha), Aathira (3906 kg/ha), Shakuntala (3847 kg/ha), Swarna Prabha (3782 kg/ha), IURON 82 (3678 kg/ha) etc exhibited superior performance during the all the years and seasons of testing. *Oryza rufipogan* introgression lines *viz.,* S-467, S-478, S-194 also exhibited superior performance under direct seeded condition based on their per se performance. Under zero tillage conditions also, the genotypes Aathira, IURON 26, IURON 73, Kalinga III and Swarna prabha were found to be promising. Therefore, these genotypes which are performing better and possessing useful traits are being utilized in the development of breeding material suitable for conservation agriculture. Under a given environmental condition viz., puddled transplanted and direct seeded condition, differential response of genotypes with respect to yield and yield components as well as the physiological traits was observed. Moderate to high heritability coupled with low to moderate genetic advance as percent of mean was recorded for yield and yield components under direct seeding and transplanted situation. Correlation analysis was done separately under direct seeding condition as well as under transplanted condition. Under direct seeded conditions, the characters viz., shoot biomass, number of tillers and productive tillers, specific leaf area etc., showed positive correlation with plot yield indicating that these traits may be considered during selection. The shoot biomass which showed positive correlation with yield is also an important indicator for early seedling vigor during the initial states of the crop establishment. Under this system of conservation agriculture, exact water and nutrient efficiency to support good biomass development leading to high grain yields.

The efficiency of varieties under zero tillage/reduced tillage production could be further be increased by tailoring rice varieties with suitable attributed for better crop establishment. Under this system of conservation agriculture, exact water and nutrient efficiency to support good biomass development leading to high grain yields. Genotypes with early vigour, an efficient root system, shorter duration coupled with high yield and disease resistance perform better under zero/reduced tillage systems. Identification or development of genotypes adapted to a range of soil fertility conditions especially low fertility conditions. Genotypes possessing high yielding performance under non-puddled conditions through genetic improvement are to be developed.

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