



Resource conservation technology for sustainable production of wheat: A review

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Abstract

Wheat is a major food security crop in South Asia, with 42% of the wheat in this region grown following rice on 13.5 million hectares of land. Resource-conserving technologies, described in this chapter, offer considerable potential for improving the sustainability and productivity of wheat in the rice-wheat cropping system of South Asia. These include raising input use efficiency, cutting costs, providing various environmental benefits, and ultimately improving farmer livelihoods and helping to reduce poverty. The conservation technologies described here are in the form of reduced tillage, zero-tillage, and bed planting for wheat in the rice-wheat system. These technologies effectively attempt to solve the problems of late wheat planting and poor plant stands, which limit yields under rice-wheat rotations. Conservation agriculture systems appear to be appealing options to achieve sustainable and intensive crop production under different agro-ecological environments because they use available resources efficiently and maintain soil fertility. However, there is a need for wider scale testing of these new technologies under diverse production systems, as the CA technologies are site specific and therefore appraisal of CA is important to have significant adoption.

Keywords: resource conservation, sustainability, zero tillage, rice wheat cropping system

Introduction

Now a day the Indian agriculture has been improved through adoption of good quality seeds, increased input use along with higher investment and expansion of irrigated area from unirrigated. The higher production has been realised by putting stresses on natural resources mainly in soil and water. In recent years, stagnation in crop productivity, decline in soil health, lower water table and ecological imbalance has been observed in many areas (Sirmour, 2017). There are widespread problem of soil degradation in India by erosion (93.7 Mha by water and 9.5 M ha by wind), water-logging, salinization, soil acidity and other physical and chemical processes (Rattan Lal, 2016).

Resource-conserving technologies (RCT) have been developed in order to reduce the use of and damage to natural resources through agricultural production system and increase the use efficiency of resources. It can be defined as any method, tool or machine which improves the input-use efficiency, enhances crop productivity and increases farm gate income of the farmers, without having adverse impact on soil, underground water and environmental quality. Some of the RCTs that are being promoted in the rice-wheat belt of the Indo-Gangetic Plains are: laser land levelling, zero/reduced tillage, bed planting, rotary tillage, use of leaf colour chart, mechanical rice transplanter, system of rice intensification, surface seeding etc. New varieties that use nitrogen more efficiently may be considered RCTs. The adoption of RCTs is expected to yield benefits to the farmers in terms of reduced losses due to soil erosion, saving of energy and irrigation costs, savings on labour input, increased productivity and water-use efficiency, reduced pumping of groundwater, increased nutrient-use efficiency and adoption of new crop rotations. Used in isolation, any of these technologies may face specific problems (e.g. surface crusting or weeds in direct seeding

rice) or have limitations (e.g. zero tillage under irrigated conditions). The combination of resource-conserving technologies working in synergy is commonly referred to as “conservation agriculture” (CA). Conservation agriculture practices will only refer to the RCTs with the following characteristics: (a) soil cover, particularly through the retention of crop residues on the soil surface, (b) sensible, profitable rotations and (c) a minimum level of soil movement, e.g., reduced or zero tillage.

Resource Conservation Technologies in Wheat

- Wheat is a major food security crop, 42% of the wheat in this region is grown following rice on 13.5 million hectares of land. Resource-conserving technologies offer considerable potential for improving the sustainability and productivity of wheat in the rice-wheat system.
- The conservation technologies described here are in the form of reduced tillage, zero-tillage, and bed planting & residue management for wheat in the rice-wheat system.
- Farmer response to these technologies has been very favourable, and the area under these practices has risen from a few hectares in 1998 to more than 100 000 ha in 2001.

Zero tillage

In the zero- or no- till system, an inverted- T coulter or a chisel opener is attached to a normal seed drill. This coulter makes a narrow groove/slit in the soil for the placement of the seed and fertilizer in one pass. Soil is disturbed in a very narrow groove 5 cm wide and 5 to 7 cm deep. For proper seed germination, wheat should be planted at slightly more than field capacity soil moisture content. Intensive soil tillage is the main cause for the

reduction in soil organic matter and hence degradation of soils. Zero tilled soils are homogenous in structure with more number of earth worms. The organic matter content increases due to less mineralization. Extremely low input use efficiency has led to wastage of inputs and depletion of natural resources besides environmental degradation (Hobbs *et al.*, 1997).

Another benefit of earlier sowing under ZT is that *Phalaris minor*, a herbicide-resistant weed in wheat, is less competitive than when wheat is sown late under conventional tillage (CT), (Malik *et al.*, 2002) [23]. Evidence on yield effects of zero tillage is highly variable (Giller *et al.*, 2009). Where zero tillage is combined with mulching, a commonly described pattern is for yields to fall initially (Baudron *et al.*, 2011) [15], and then to increase over the subsequent decade or so, eventually exceeding yields in conventional tillage-based agriculture (Rusinamhodzi *et al.*, 2011) [25]. Wider adoption of ZT in wheat was due to a combination of both increased yields and reduced production costs (Fowler and Rockstrom, 2001; Knowler *et al.*, 2001). ZT can save US \$40–50/ha compared with CT (Malik *et al.*, 2002) [23].

Water shortage is increasingly becoming a global issue. Environmental impact from all uses of water, particularly irrigated agriculture urgently needs special attention and it is highly important to develop better understanding for water scarcity and its trend in future (Singh *et al.*, 2012) [29]. It is also necessary to consider possible strategies based on increasing water productivity (producing more crop per drop) leading to efficient management of the scarce water resources (Akhtar, 2006).

Advantages of zero tillage on wheat

The performance of zero tillage in wheat results that grain yield and number of effective tillers per m² increased significantly. Zero tillage recorded significantly higher yield and its attributing parameters as compared with yield and its component characters recorded under conventional tillage. Significant reduction in dry weight of weeds was observed with zero tillage over conventional tillage sown wheat. Infiltration of water in wheat was 60 per cent higher in zero tillage than conventional tillage on a silt loam soil. Lower values of available soil N and higher values of soil P and K under CT whereas ZT recorded higher values of available soil N and lower values of available soil P in wheat. 60-70 per cent saving of time and 67-80 per cent saving of fuel with zero tillage seeding technique over conventional tillage

Table 1: Energy budget and yield of wheat as affected by tillage at farmer's field

Treatment	Tractor hour/ha	Diesel req. (l/ha)	Tractor rent (Rs/ha)	Yield (kg/ha)
Zero tillage	1.54	6.38	380	3022
Conventional tillage	9.30	33.25	1900	2816

(Source: Singh *et al.*, 2012) [29]

Energy budget for the technology was prepared in a field trail and data obtained is presented in Table 1. Result shows that the zero tillage resulted in more yield with less energy budget, whereas conventional tillage wheat resulted in poor yield in comparison with more energy budget.

It was observed that adopting zero tillage also reduces weed emergence and quite low *Phalaris minor* population was

observed than in conventional tillage wheat (table 2). This may be due to the fact that weed seeds remained in deeper layer under zero tillage system in contrary to conventional system (Verma and Srivastava, 1989) [12].

Table 2: Irrigation time and weed emergence in farmers field under zero tillage practice

Treatment	Irrigation (hr/ha)	Weed density (Nos/m ²)		Crop color 7 days after irrigation
		<i>Phalaris</i>	Other weeds	
ZTW	10	35	12	Green
CTW	15	87	08	Pale

(Source: Singh *et al.*, 2012) [29]

Furrow Irrigated Raised Bed (FIRB)

FIRB system is a method where crops are sown on raised bed. This system was introduced in India in 1995 on the pattern of wheat grown in the Yaqui valley of Mexico. Generally, 2-3 rows of wheat are sown on the top of bed, 70 cm wide and irrigation is done through the furrows. The inter row bed space is used to control weeds by mechanical weeding during the early vegetative growth of weeds. It also improves input use efficiency. This technology is suitable for almost all types of soil, except black cotton soils. Bed planting in rice-wheat cropping systems may be a technique for improving resource use efficiency and increasing the yield. In this system, the land is prepared conventionally and raised bed and furrows are prepared manually or using a raised bed planting machine. Crops are planted in rows on top of the raised beds and irrigation water is applied in the furrows between the beds.

Bed-planting, another RCT, has the potential to conserve significant quantities of water (30–50%) (Kukul *et al.*, 2005) [19]. Other benefits of bed-planting include, reduced seed rates, conserved rainwater, facilitated mechanical weed control, minimized lodging in the wheat crop (Gupta *et al.*, 2000) [16]; cost reduction and conservation of resources (Lichter *et al.*, 2008) [21]. Fertilization application practices are also easily performed by trafficking in the furrow bottoms and the fertilizers can be banded through the surface residues, reducing thereby potential nutrient losses (Limon-Ortega *et al.*, 2002) [22] under permanent raised bed planting. It increases the yield of crop, better nutrient management, efficient irrigation and reducing the risk of crop lodging on beds (Hobbs and Gupta, 2003a) [5]. Bed planting has also been found to show better water distribution with efficiency, fertilizer use efficiency, reduced infestation of weeds and lodging (Hobbs and Gupta, 2003b) [6]. By growing wheat and maize crop on raised bed saving of 30% irrigation water was obtained.

Table 3: Comparison of crop yield between Raised bed & Flat bed

Crop	Yield on raised beds (t/ha)	Yield on flat bed (t/ha)	Water saves	% yield increase
Wheat	5.12	4.31	26.3	6.4
Rice	5.62	5.29	42.0	6.2
Maize	3.27	2.38	35.5	37.4
Gram	1.85	1.58	27.3	17.9
Carrot	36.3	28.6	31.8	26.9

(Source: Pandey *et al.*, 2007)

From the above table we can find that the yield is higher in raised bed method than the flat bed planting method.

Laser Land Leveling (LLL)

Laser land leveling is leveling the field within certain degree of desired slope using a guided laser beam throughout the field. The LLL is an alternative to achieve desired level of accuracy as this uses laser equipped drag buckets in leveling land. Unevenness of fields reduces input-use efficiency and creates larger biotic and abiotic pressures on crop growth, which ultimately reduce yield potential and add to the cost of production (Naresh *et al.*, 2016). Laser land leveling (LLL) was first introduced in India in 2001 in western Uttar Pradesh. With laser levelling, the unevenness of the field is reduced to about ± 2 cm, resulting in better water application and distribution efficiency, improved water productivity, better fertilizer efficiency, and reduced weed pressure. Several field studies conducted in the Indo-Gangetic Plains, where flooding is a common method of irrigation, have brought out that laser leveling technology could save irrigation water by 10-30 per cent, improve fertilizer-use efficiency by 6-7 per cent and enhance crop yield by 3-19 per cent, besides expanding cropped area by 3-6 per cent (Jackson *et al.*, 2009; Kaur *et al.*, 2012; Naresh *et al.*, 2011) [30, 29, 28].

This practice makes use of large horsepower tractors and soil movers that are equipped with global positioning systems (GPS) and/or laser-guided instrumentation so that the soil can be moved either by cutting or filling to create the desired slope/level.

(Walker *et al.* 2003) [26]. A review of various studies suggested that laser land leveling in Pakistan resulted in about 25% reduction in irrigation water application and an increase of about 30% in wheat yield as compared to conventional practices (non-laser leveled fields; Humphreys *et al.*, 2005, 2010) [18, 19, 17]. Similar increased yield and reduced irrigation water application in the case of zero tillage wheat and laser land leveling were reported in India and China (Jat *et al.*, 2009; Humphreys *et al.*, 2010) [14, 17]. For instance, Kahlowan *et al.* (2006) showed that the use of RCTs, including zero tillage, laser leveling and bed and furrow planting, reduced irrigation water applications between 23 and 45% while increasing yield.

Water savings of up to 50% have been reported in wheat and 68% in rice (Jat *et al.*, 2006) [13]. Laser land leveller consists of a laser source (transmitter) which emits a parallel laser beam to a laser receiver attached to a scraper bucket behind a tractor and the vertical movement of scraper bucket is controlled by a hydraulic jack in a control box for levelling the field.

There are two types of adopters

- Partial adopter: These adopter use laser land leveling for their field partially.
- Full adopter: They adopt laser land leveling for their field fully.

Among the wheat growers, 64% have partially adopted LLL and 36% have adopted it fully. Overall, partial adoption is common in both the cases (table 4).

Table 4: Different types of adopters of Laser Land Levelling

Types of adopter	Haryana		Punjab		Total	
	Number	Percentage (%)	Number	Percentage (%)	Number	Percentage (%)
Partial adopter	58	60.4	65	67.7	123	64.1
Full adopter	38	39.6	31	32.3	69	35.9
Total	96	100	96	100	192	100

(Source: Jeetendra *et al.*, 2010)

Crop Residues Management

Combine harvested rice field are being burnt which results in environmental pollution and loss of nutrients. It is estimated that the burning of one ton of straw releases 3 kg particulate matter, 60 kg CO, 1460 kg CO₂, 199 kg ash and 2kg SO₂. Zero-tillage crop planting, avoids burning of straw of about 10 t/ha which reduces release of 13–14 tons of carbon dioxide (Gupta *et al.*, 2004). Happy Seeder technology provides an alternative to burning which cuts, lifts and throws the standing stubbles and sows the seeds in one operation Pass. Traditionally, wheat and rice straw were removed from the fields for use as cattle feed and for other purposes. The incorporation of residues results in better physical, chemical & biological properties but in long term exp. It has been seen that the increase in wheat yield ranges from 0.0-0.5 t/ha over the burning treatment. Unlike removal or burning, incorporation of straw builds up soil organic matter, soil N, and increases the total and available P and K contents of the soil.

CA practices require a critical level of crop residues with objective, to protect the soil against weather aggressions and water erosion, to maintain soil moisture (Lal 1997) [20], to suppress weed growth and to provide shelter and food for the soil biota (Blanchart *et al.* 2006) [7]. The importance of crop residue cover as part of the CA system has been emphasized by several researchers (Govaerts *et al.*, 2009; Hobbs *et al.*, 2008) [8, 9]. Crop residue recycling in rice-wheat was found to increase rice as well as wheat yields by 13 and 8%, decrease cost effectiveness by 5

and 3% and energy efficiency by 13 and 6%, respectively, compared to residue retrieval, whereas yield advantage was to the tune of 9 and 3% compared to residue burning (PDFSR 2011) [24, 10]. However, decomposition rate and release of N from residues depends on soil, climatic conditions and the C: N ratio of plant residues (Prasad and Power, 1997) [11].

Table 5: Yield (t/ha) as affected by rice straw management in wheat and vice versa.

Treatment	Wheat	Rice
Straw removed	4.94	6.19
Straw burnt	5.10	6.25
Straw incorporated (40DBS)	5.17	6.34
Straw incorporated (20DBS)	5.22	6.29
Straw incorporated (20DBS) & 25%N applied at incorporation	4.95	6.33
Straw incorporated (10 DBS)	4.97	6.29

(Source- Singh *et al.*, 2004)

Rice Straw Management Practices

Incorporation of rice straw before wheat planting compared to wheat straw before rice planting is difficult due to low temperatures and the short interval between rice harvest and wheat planting. Farmers use different straw management practices: burning, removal, or incorporation. Rice and wheat yields under these practices are generally similar. In few studies,

wheat yields were lower during the first one to three years of rice straw incorporation 30 days prior to wheat planting, but in later years, straw incorporation did not affect wheat yields adversely. In contrast, rice straw incorporation gave significantly higher wheat yields of 3.51 tons per ha compared to 2.91 tons per ha with straw removal in Pakistan.

Site-specific nutrient management (SSNM)

Nutrient Management and recommendation process in India is still based on response data arranged over large domains. The SSNM provides an approach for need based feeding of crops with nutrients while recognizing the inherent spatial variability. It involves monitoring of all pathways of plant nutrient flows/supply, and calls for judicious combination of fertilizers, bio fertilizers, organic manures, crop residues and nutrient efficient genotypes to sustain agricultural productivity. It avoids indiscriminate use of fertilizers and enables the farmer to

dynamically adjust the fertilizer use to fill the deficit optimally between nutrient needs of the variety and nutrient supply from natural resources, organic sources, irrigation water etc. It aims at nutrient supply at optimal rates and times to achieve high yield and efficiency of nutrient use by the crop. Many studies in the country, show that by adoption of SSNM, across the locations, grain yields of more than 13 t/ha in rice-wheat system (with a contribution of 58% rice and 42% wheat) and 12-15 t/ha in rice-rice system (with a contribution of 48% *kharif* rice and 52% *rabi* rice), are achievable (PDFSR 2011) [24, 10]. It also helped in increase of organic carbon by 55.9%. It is, therefore, pertinent to further disseminate this technology, which has potential to enhance the productivity in the range of 3-4 t/ha – a marvelous achievement. SSNM approach involves three steps – establishing attainable yield targets, effectively use existing nutrient sources and application of fertilizers to fill the deficit between demand and supply of nutrients.

Table 6: Effect of crop residue management on organic C & total N content in soil under the rice wheat cropping system

Reference	Type of crop residues	Duration of study (year)	Residue management	Organic C (%)	Total N (%)
Beri <i>et al</i> 1995	Rice straw in wheat and wheat straw in rice	10	Removed	0.38	0.051
			Burnt	0.43	0.055
			Incorporated	0.47	0.056
Sharma <i>et al</i> 1987	Rice straw in wheat and wheat straw in rice	6	Removed	1.15	0.144
			incorporated	1.31	0.159

Conclusion

Based on findings of long-term experiments as well as experience of farmers participatory trials of RCTs in rice based systems, it can be concluded that direct seeded rice under double no till with laser land levelling reduced cost of cultivation and improved the crop yields and system productivity while conserving natural resources. The technology does not affect rice quality and can be practiced in different ecologies including upland, medium and lowland, deep water and irrigated areas by large as well as small farmers. The technologies effectively attempt to solve the problems of late wheat planting and poor plant stands, which limit yields under rice-wheat rotations. There is a future need to cultivate wheat on beds instead of by flat planting, to increase wheat NUE and grain yield. Laser land levelling enhances the yield and water productivity. 'RCT' in the rice-wheat cropping system has clearly indicated the superiority of RCT over conventional practices in terms of cost saving and more efficient use of inputs. By adopting RCT in wheat we can save time and also increase production sustainably which is much more desirable in our near future.

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