Resource Conservation Technologies (RCTs) in rice-wheat production: An Overview

Lalit Kumar[1]; Divya Rajput[2]; D. Sai Venkatesh[3]; A. Vinay Kumar[3]; P. K. Singh[4] and A. Srinivas Rao[3]

[1]Indian Institute of Farming System Research (IIFSR), Modipuram, Meerut, U.P., India

[2]Department of Agronomy, Chandra Shekhar Azad University Of Agriculture & Technology, Kanpur, Uttar Pradesh, India

[3]Department of Agriculture, Shobith University, Meerut, Uttar Pradesh, India.

[4]Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India.

ABSTRACT

Rice-wheat cropping system is the pre-dominant cropping system in India, which is labor-intensive, water-intensive, capital-intensive, and energy-intensive and it has become less profitable as these resources have become scarcer. This could be exacerbated by deterioration of soil structure, declining underground water, and lower land and water productivity, all of which pose a threat to the country's long-term viability. Moreover, continuous use of traditional agricultural practices such as tillage and crop residue burning has depleted the soil resource base and exacerbated soil depletion, resulting in a reduction in crop production. Furthermore, rising fuel, fertilizer, and other input costs necessitate efficient resource management in agriculture. This collected review literature focuses on various resource saving yet efficient technologies that can be adopted in rice-wheat system for improving and sustaining higher yields. However, adoption of conservation tillage practices can significantly improve the systems productivity by improving SOC pools and it help directly in building–up of soil organic carbon, labile organic carbon fractions and improve the fertility status of soil and production sustainability in RW system.

KEY WORDS: *Resource conservation technologies, Conventional tillage, Diversification, Precision farming, Zero tillage*

INTRODUCTION

Rice-wheat (RW) is the most important cropping system practised on 13.5 m ha area in South Asia, out of which 10.3 m ha is in the Indo-Gangetic plains (IGP) of India. The rice-wheat cropping system (RWCS) of India is vital for national food security contributing more than 70% of total cereal production in India (Singh and Kaur, 2012). A decline in land productivity of RWCS has been observed over the past few years due to continued cereal-cereal cropping system. Depleting soil organic carbon status, ground water, decreasing soil fertility and reduced factor productivity are other issues of concern (Prasad, 2005). Zero tillage (ZT) is a widely used RCT in Indo-Gangetic Plains (IGP), in which wheat is directly seeded in to the undisturbed soil after rice harvesting. ZT generally saves irrigation water in the range of 20–35% in the wheat crop compared to conventional tillage (CT). Adoption of furrow-irrigated raised-bed system (FIRBS) of wheat saves 25-30% seed, 30-40% water and 25% nutrients without affecting the yield (Jat et al., 2012)

The CA technologies involving no- or minimum tillage with direct seeding and bed planting, residue management (mainly residue retention) and crop diversification (Gupta and Sayre, 2007) have potential for improving productivity and soil quality, mainly by soil organic matter (SOM) build-up (Bhattacharyya et al., 2013). The RCTs bring many possible benefits including reduced water and energy use (fossil fuels and electricity), reduced greenhouse gas (GHG) emissions, soil erosion and degradation of the natural resource base, increased yields and farm incomes, and reduced labor shortages (Pandey et al., 2012).

Resource Conservation Technologies (RCTs) in Rice – Wheat systems

ZERO TILLAGE

Zero tillage (ZT) involves the use of a tillage implement that creates a narrow slot for the seed and does not disturb or turn over the soil in the process of planting the crop. The traditional approaches of ploughing which include 3-4 tillage operations are completely skipped. Hence, cost of production is reduced and timely planting of crop (wheat) is ensured. 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). 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), and then to increase over the subsequent decade or so, eventually exceeding yields in conventional tillage-based agriculture (Rusinamhodzi et al., 2011). Wider adoption of ZT in wheat was due to a combination of both increased yields and reduced production costs (Knowler et al., 2001). ZT can save US $40–50/ha compared with CT (Malik et al., 2002). In more than 1 million ha of land in the Indo-Gangetic Plains, ZT has effectively reduced the demand for water in rice-wheat cropping systems. Vincent and Quirke (2002) argued that the Indian economy would gain about US$1400 million over the next 30 years from the adoption of ZT in Northwestern India's rice-weed system due to savings in labor and herbicide costs and higher yields of wheat. Other benefits of ZT over CT include better soil quality, 75% fuel savings, and a higher degree of organic carbon (Malik et al., 2002).

PRECISION FARMING:

Precision agriculture refers to the application of precise and correct amounts of inputs like water, fertilizers, pesticides etc. at the correct time to the crop for increasing its productivity and maximizing its yields. The benefits of so doing are twofold i) the cost of producing the crop in that area can be reduced; ii) the risk of environmental pollution from agrochemicals applied at levels greater than those required by the crop can be reduced (Earl et al. 1996). Thus, it helps to improve input use efficiencies, economy, and sustainable use of natural resources, because it minimizes wastage of inputs. In other words, it may also be referred to 'Site-Specific Farming'. The practice of precision farming is viewed as comprising of four stages, information acquisition related to variability in environmental and biophysical parameters, their interpretation for input application, evaluation and control. To support precision farming, the important information technology tools are Global Positioning System (GPS), Geographical Information System (GIS) and Simulation Modeling for Decision Support System (DSS), remote sensing, yield monitor and variable rate technology. Global Positioning System (GPS) provides accurate site information and is highly useful in locating the spatial variability. Earl et al. (1996) postulated a potential benefit of £33.68 ha-1 couldbe possible combining variable nitrogen application and targeting subsoiling to headlands for a crop of wheat.

INTEGRATED FARMING SYSTEMS

Integrated Farming Systems hold a special position in conservational agriculture as in this system nothing is wasted, the byproduct of one system becomes the input for other. For example, crop residues from the field can be used for animal feed, while manure from livestock can enhance agricultural productivity by improving soil fertility as well as reducing the use of chemical fertilizers (Gupta et al., 2012). Moreover, the system helps poor small farmers, who have very small land holding and a few heads of livestock to diversify farm production, increase cash income, improve quality and quantity of food produced and exploit unutilized resources. Animals play key and multiple roles in the functioning of the farm. These not only provide meat, milk, eggs, wool, and hides; but can be converted into prompt cash in times of need. Animals transform plant energy into useful work: animal power is used for ploughing, transport, marketing and water lifting for irrigation (Gupta et al., 2012).

DIVERSIFICATION/INTENSIFICATION

A shift from sole cropping to a diversified/ intensified farming system is highly warranted. The increased cropping intensity/diversification is intended to minimize isk, improve biodiversity and diversify income sources and enhance resource sustainability. It will be a key strategy for future gains in crop production. Short duration pulses, oilseeds and other high value crops will find their definite niche as sequential or intercrops, rather than replacing the major cereal crops having higher yield stability (IIFSR 2015). Hence, an increased cropping intensity will contribute substantially to additional demands of food and cash crops. Pigeonpea, the most important wet season grain legume crop in south Asia has shown potential for rice crop diversification in Indo-Gangetic Plain (IGP). The introduction of extra short duration (ESD) pigeonpea (ICPL-88039) and Furrow Irrigated Raised Bed (FIRB) planting technique in the region has shown tremendous potential for increasing the water productivity and economic growth of the farmers with the limited resources. Development of new crop varieties with more efficient photosynthetic apparatus and shorter duration would be of massive help in increasing cropping intensity (IIFSR 2015). Similarly, bio-intensive diversified cropping systems would enable small and marginal farmers to utilize limited land and water resources in more efficient manner

BED PLANTING:

Bed-planting, another RCT, has the potential to conserve significant quantities of water (30–50%) (Kukal et al., 2005). 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); cost reduction and conservation of resources (Lichter et al., 2008). 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) under permanent raised bed planting. The raised bed planting technique also provides an opportunity for crop diversity through inclusion of different crops as well as feasibility of inter or relay cropping, thereby opening avenues for generating alternate sources of productivity growth through efficient use of resource base. Bed-planting is widely adopted in the Indo- Gangetic Plains, proved to be a successful conservation technology. Akbar et al. (2007) reported about 36% water saving for broad-beds and about 10% for narrow-beds compared to flat sowing, and 6% increased grain yield of wheat and 33% of maize. In both cases, the furrows act as pathways for drainage during excessive rains and conserve rainwater in dry spells (Astatke et al., 2002). However, the use of direct dry seeding on flat and raised beds while resulting in considerable water savings generally had negative impacts on rice yield (Humphreys et al., 2010).

DIRECT SEEDED RICE (DSR):

The shortages of labor and water, and soil fertility issues are causing increasing interest in shifting from puddling and transplanting to DSR. According to Pandey and Velasco (2005), low wages and adequate availability of water favour transplanting, whereas, high wages and low water availability favour DSR. The recent shift from transplanting to DSR in Southeast Asian countries has been caused by labor shortages and rising wages (Pandey and Velasco, 2005). DSR can reduce the labor requirement by 50% compared with transplanting (Santhi et al., 1998). The DSR system provides incentives for saving water (Humphreys et al., 2010). In Northwest India, about 35– 57% water savings have been reported in research experiments in DSR sown into unpuddled soils (Singh et al., 2002). Direct-seeded and transplanted rice grown on raised beds decreased water use by 12–60% when compared with flooded, transplanted rice in the IGP (Gupta et al., 2012).

SYSTEM OF RICE INTENSIFICATION (SRI):

At present, SRI methods have been adopted in almost 50 countries, including major rice-producing nations such as India, China, Vietnam and the Philippines (Uphoff, 2012). The principles of SRI originate from experiments conducted by farmers in Madagascar to improve rice productivity for resource-poor producers. Today, SRI is usually understood as a package of possible practices, which have to be adapted to local conditions (Stoop, 2011). SRI produce higher yields with less water and seeds (Zhao et al., 2009). Moreover, studies found rice under SRI to be more robust against extreme weather events, pests, and diseases due to improved plant vigor and root strength (Stoop et al., 2002). Alternating irrigation aims to tackle various challenges such as the loss of soil quality and water scarcity, whereas early transplanting and wide spacing are both meant to boost tillering (Thakur et al., 2010). However, a few studies identified higher labor requirements of SRI as a constraint to adoption (Senthilkumar et al., 2008). Other studies showed that higher labour inputs occurred only in the early phase of adoption; labour requirements seem to decrease with growing SRI experience (Barrett et al., 2004; Uphoff, 2012).

ZERO TILLAGE IN WHEAT PRODUCTION

Growing of wheat has become more attractive in last few years with the use of this RCT of conservation agriculture that implies planting of crop in previously unprepared soil by opening a hole, narrow slit or band of smallest width and depth required to obtain proper coverage of seed. The modern concept of ZT implies seeding a crop mechanically in undisturbed soil covered with plant residues. The major constraints in wheat production in West Bengal are excessive soil moisture after rice harvest, delayed sowing, shorter winter season, imbalanced use of nutrients, poor mechanisation and deficiency of micronutrients, particularly boron. In this situation, resource conserving technology such as adoption of zero tillage has been found to be the very good option for successful cultivation of wheat (Mandal et al., 2014).

CONCLUSION

The adoption of various resource conservation technologies (RCTs) leads to sustainable improvement of RWCS by improving soil health, nutrients and water efficiency with higher sustainable yields. RCTs reduce the cost of cultivation by saving labor, diesel, time, fertilizers, pesticides and farm energy, and also by reducing environmental pollution. In addition, it improves the efficiency of natural resources, benefits the environment, improves farmers' livelihoods and ultimately helps to reduce poverty.

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