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Review

A review on the enhancement of rice production in paddy field with minimum input of water

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Fresh water resources are decreasing globally, because of climate change and increasing competition of industrial and urban development. Scarcity of water resources in world's leading rice-producing countries, such as China and India has threatened the production of rice crop, which is the main staple food in Asia, particularly China, India, Indonesia, Bangladesh, Vietnam and Pakistan. Hence increasing demand of rice needs more attention towards this crop production globally. On the other hand it is an aquatic crop; needs more water as compared to wheat, maize etc. Therefore it is imperative to investigate the ways to get good yield with minimum input of water. In this context, an effort has been made to review the water saving techniques for the enhancement of rice production in paddy field with minimum input of water.

Key words: Water saving techniques, yield, growth of rice crop.

INTRODUCTION

According to United Nations world population has reached to 7 billion, a mile stone in human history. UNFPA reported most of the population growth will happen in developing countries. World has been changing over the last decade politically and economically in significant ways. However, food security still remains an unfulfilled dream; there has been progress on a global scale - but not for all. In order to meet the population pressure crop yields from each unit of land harvested must be increased by intensifying production. A considerable increase in overall production is essential and is a major challenge for extended land and water resources. Future yield increases may be limited compared to past trends (FAO, 2006), but by 2030, food production must double to keep pace with demand (Friedrich and Gustafson, 2007). On the other hand annual amount of available water resources for agriculture is decreasing globally because of climate change and increasing competition of industrial and urban development. Scarcity of freshwater resources, such as in the World's leading rice-producing countries China and India has threatened the production of the flood-irrigated rice crop (Singh et al., 2006).

To keep up with increasing demand for food combined with increasing water scarcity, several water-saving techniques, such as alternate wetting and drying (Cabangon et al., 2003) and aerobically grown rice have been developed in order to increase water productivity (that is, grain yield over water input, WP) of rice production (Waqar et al., 2007).

It is estimated that a total irrigation potential of some 402 million ha in developing countries, of which half is currently in use. However, water resources will be scarce in South Asia, which will be using 41% of its renewable freshwater resources by 2030, the North/ East Africa; will have 58% of the total amount of fresh water produced annually. To meet increased demand of other sectors, these areas will need to free additional water resources by achieving greater efficiency in irrigation water use (FAO, 2002).

The pressure to reduce water use in irrigated agriculture is mounting, especially in Asia where it accounts for 90% of total diverted fresh water. Rice crop is an apparent

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target for water conservation; which is cultivated on more than 30% of irrigated land and accounts 50% of irrigation water (Barker et al., 1999). Reducing water input in rice crop can progress societal and environmental sectors; water saved may be used to other areas. A reduction of 10% water used in irrigated rice would lead up to 150,000 million m^3; correspond to about 25% of the total fresh water used globally for non-agriculture purposes (Klemm, 1999). However, rice is very sensitive to water stress; attempts to reduce water may result in yield reduction and can have pressure on food security. Reducing water input for rice will change the soil from submergence to greater aeration. These shifts may have profound and largely unknown effects on the sustainability of the lowland rice ecosystem.

To develop socially acceptable, economically viable, and environmentally sustainable novel rice-based systems is the need of time that allow rice production to be maintained or increased in the face of declining water availability (Tuong and Bouman, 2003; Gleick, 1993; Guerra et al., 1998; Waqar et al., 2007).

New technologies for water saving such as alternate drying and wetting, raised beds and direct seeding are being tested for rice cultivation in South Asia (Bhuiyan and Tuong, 1995; Guerra et al., 1998; Van der hoek et al., 2001). Similarly, laser land leveling and zero till wheat sowing are seen as interventions to improve efficiency of water resources for wheat (Hobbs, 2001). Most of the studies compared the traditional practices and the new approaches for mass produced per unit area. It is essential to determine crop yield and water saving from a system perspective. The question how efficiently water is being used in an agro-ecological context is also extremely important. Therefore, the system performance should be evaluated considering the crop water productivity (production per unit of water) along with the yield per unit of land. Water use efficiency and productivity in rice-wheat zone of Punjab, Pakistan was studied at watercourse and field levels. In addition, different interventions for rice and wheat stand establishment were compared (Waqar et al., 2004; Shaxon and Barber, 2003; Aulakh, 2005; FAO, 2000).

It is high time to develop effective integrated natural resource management interventions, which allow cost-effective rice cultivation with increased soil aeration while maintaining the productivity, environmental services, and sustainability of lowland rice ecosystems.

TECHNOLOGIES FOR ENHANCING RICE PRODUCTION IN PADDY FIELD

Several technologies have been developed in order to save inputs and get maximum productivity by increasing the efficiency of resource utilization for rice crop in paddy field, some of them are discussed; as by their application yield can be enhanced with less water.

Selection of suitable period of crop plantation

Nielsen (2004) described selection criteria for suitable period of rice cultivation and suggested that i). Cultivate in rainy season and harvest at the end of season, ii). For non photoperiod sensitive varieties (110 to 120 days) the harvesting date should be planned at the end or rainy season in order to set the growing date, iii). Cropping calendar should be planned suitable to wet and dry season.

Increase yield per unit evapo-transpiration (germplasm development)

Germplasm development has played an important role in increasing water productivity in rice production. By increasing yield and simultaneously reducing crop duration and the outflows of evapo-transpiration, seepage and percolation, the modern “IRRI varieties” have about 3-fold increase in water productivity compared with the traditional varieties (Tuong, 1999). Advancement in the development of tropical japonicas also called “new plant type” (IRRI, 1998). Peng et al. (1998) reported that the photosynthesis to transpiration ratio was 25 to 30% higher for the tropical japonica than for the indica type (Tuong and Bouman, 2003). Developing and using new varieties reduces the duration of crop and minimum usages of inputs.

Laser leveling

The use of laser-guided equipment for the leveling of surface-irrigated fields has settled good results. It reduces the unevenness of the field to about ±2 cm, resulting in better water application and distribution efficiency, improved water productivity, increased fertilizer efficiency and reduced weed pressure. Savings of up to 50% in wheat and 68% in rice have been reported by Jat et al. (2006).

Therefore, Laser land leveling is the most effective innovation in the field of agriculture especially for less and equitable usage of inputs for maximum production.

Direct seeding

According to PDCSR (2005) direct seeding of rice compared with transplanting saves labor and fuel. Seeding into dry soil save water as there is no puddling and the total growing period from seed to seed is reduced at about 10 days. However, yields and water efficiency of the subsequent rotation crops are increased. On the other hand, weed management is more difficult in dry direct-seeded rice than in the puddled and transplanted rice (RWC-CIMMYT, 2003). Direct seeded rice lowered total water input by 30%, whereas conventional transplanted rice on beds had a 15% reduction in the total water input (Waqar et al., 2007).

Better soil nutrient management

Better soil nutrient management results in higher yield although the amount of water consumed by rice remains almost unchanged. Each kilogram of nitrogen fertilizer applied to the field may produce 10 to 15 kg more rice (Guera et al., 1998).

Plant spacing

With wide spacing each plant gets more space, air and sunlight. As a result each plant gives more tillers. The roots would grow healthily and extensively and take in more nutrients. As the plant is strong and healthy the number of tillers would be more. The panicle has more number of grains and the grain weight would also be more. The row to row distance and within a row plant to plant distance should be 25 × 25 cm (WASSAN, 2006).

Water efficient (saving) irrigation regimes (WEI)

Since 1980s, in south China, a new irrigation technique for rice, emerged and was termed as 'water-saving irrigation'. In recent years the same technique has become widespread. The basic feature of this new irrigation technique is that there is no water layer above the soil surface in rice fields during the growing season of rice after the stage of recovering. This technique not only saves water and increases the rice yields but it also reduces soil and water pollution; improves soil aeration; improves the field's microclimatic condition; reduces rice diseases and insect pests; and improves the regional water balance (Mao Zhi, 1996).

According to perceived data from seven irrigation experiment stations in the Hunan, Jiangsu, Guangdong and Hubei provinces southern China, the groundwater table in rice fields rises up to the soil surface and keeps this level during the period of submersion under the flooding irrigation, and it can be lowered to 0.3 to 0.8 m below the soil surface during the period of no submersion under water-saving irrigation. The soil redox potential in rice fields under water-saving irrigation is 120 to 200% of that under flooding irrigation (Mao, 1993, 1996).

Weed control

Weed management became complicated further following the introduction of short-stature rice varieties and the practice of shallow water in the fields during the early stages which created an ecological environment more favorable to their growth. A sustainable program of weed management must be based on a combination of cultural and chemical means. Neither chemicals nor cultural practices alone can give satisfactory weed control (Bayer and Hill, 1993; Ferrero and Vidotto, 2007).

It is estimated that without weed control, a yield level of about 7 to 8 ton/ha, yield loss can reach as high as 90% (Oerke et al., 1994; Ferrero et al., 2002). Proper weed management also helps increase water productivity. Tuong et al. (1998) showed that water productivity, under experimental conditions at the IRRI farm, could be increased from 0.24 kg m-3 in un-weeded plots to 0.7 to 0.8 kg m^{-3} in plots where weeds were controlled by herbicide or by early flooding after seeding. Low water productivity in un-weeded plots accrued from very low yield as a result of severe weed infestation (Guera et al., 1998).

Mulching and green manure

The supply of organic matter to the soil through mulching and green manure is important for maintaining and enhancing soil fertility. Mulching material can come from crop residues or green manure crops; it provides feed for the soil life and mineral nutrients for the plants. If legume crops are used as green manure they can supply up to 200 kg/ha of nitrogen to the soil; in the case of rice, this can result in mineral fertilizer savings of 50 to 75% (RWC-CIMMYT, 2003). The spreading of mulch on the soil surface reduces evaporation, saves water, protects from wind and water erosion, and suppresses weed growth (Friedrich and Gustafson, 2007).

Climate and climatic change

Recent decades have seen an increase in the frequency and strength of harsh climatic events, including very high precipitations as well as extended drought periods and extreme temperatures (Met Office, 2005). Agricultural production systems are highly vulnerable to these changes (Friedrich and Gustafson, 2007).

Crop water requirement can assist in the adaptation to climate change, by improving the resilience of agricultural cropping systems and making them less vulnerable to abnormal climatic situations. Better soil structure and higher water infiltration rates reduce the danger of flooding and erosion following high intensity rainstorms (Saturnino and Landers, 2002). Increased soil organic matter levels improve the water-holding capacity and hence the ability to cope with extended drought periods. Yield variations under conservation agriculture in extreme years (dry or wet) are less pronounced than under conventional agriculture (Shaxon and Barber, 2003; Bot and Benites, 2005).

These innovative technologies collectively or separately put good impact on water savings and yield of crop. These techniques not only improve the yield but also improve the soil fertility.

CONCLUSION

These practices are universally applicable to get maximum benefits and are successfully applied under the concept of advanced agriculture in different cropping systems around the world without negative environmental impact. The combination of these different innovative approaches such as mulching, better soil nutrient management and direct seeding results not only in water saving but also increased crop productivity and soil fertility.

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