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Research Article

Effect of System of Rice Intensification (SRI) on Phenology and Yield of Rice

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ABSTRACT

Rice is grown in flooded conditions which results in substantial loss of water through deep percolation and reduces the crop water use efficiency. Therefore, a high water efficient rice production system is required to be practiced in the context of present water scarcity situations. Keeping in mind this hypothesis, the present field study on growth and yield of rice crop was carried out at experimental farm of the Indian Institute of Technology (IIT), Kharagpur during growing seasons of 2015-16 (both during *kharif* and *rabi* seasons) with two major rice production systems, (i) system of rice intensification (SRI) and (ii) conventional. Two water treatment levels along with 100% nitrogen applications with six replications were laid out in the experimental plots with randomized block design. Non-weighing lysimeters were used to measure water balance components in each plot. Results revealed that the grain yield was increased by 23.4 and 21% in SRI method of cultivation as compared to conventional practice. Also, the deep percolation loss of water was reduced by 37.8 and 38.8 cm in SRI plots as compared to conventional plots during *kharif* and *rabi* season, respectively. Crop water use efficiency in SRI method was increased by 18.8% in both *kharif* and *rabi* seasons as compared to the conventional practice. This indicates that SRI method of rice cultivation has huge potential in future to save scarce irrigation water as well as to improve crop water productivity.

Key words: System of rice intensification (SRI), Non-weighing lysimeters, Water balance components, Crop water use efficiency

Introduction

Increasing demand of water and variability in rainfall has reduced the water available for agriculture thus we need to adopt irrigation practices that are more water efficient and at the same time can increase the yield. In Conventional practice of rice cultivation the field is ponded with water throughout the cultivation period thus increasing the deep percolation losses and reducing the water use efficiency. About 75-85% of applied water in rice field is lost through deep percolation (Tan *et al*., 2013). With 43.194 million ha of land under rice cultivation, the calculated loss of water and energy is huge (Department of Agriculture, Cooperation and Farmers Welfare, Annual Report 2017-18). Thus we need to look for other irrigation practices which can improve the water efficiency in rice cultivation. The System of Rice Intensification (SRI) is one method of rice production that can improve the water use efficiency of rice

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cultivation. A French Jesuit missionary developed the SRI method while working with peasant farmers in Madagascar, based on certain insights on how to improve the growing environment for rice plants by changing certain long-standing cultural practices (Stoop *et al*., 2002).

Major SRI principles include raising of seedlings in carefully managed nurseries, transplanting of single, young seedlings (8–15 days old) at wide plant spacing (0.25m × 0.25 m), intermittent irrigation to avoid permanent flooding during the vegetative growth phase and manual or mechanical weed control. It should be noted, however, that SRI is not a 'standard package' of specific practices, but rather represents empirical practices that may vary to reflect local conditions (Uphoff, 2002). The main physiological principle behind the SRI is to provide optimal growing conditions to rice crops so that number of tillers can be maximized and phyllochrons are shortened, which is believed to play a key role in accelerating growth rates (Nemoto *et al*., 1995). It was also observed that tiller mortality is reduced under SRI. Furthermore, intermittent irrigation is believed to improve aeration in rice root zone, thereby causing a stronger, healthier root system with potential advantages for nutrient uptake (Stoop *et al*., 2002). Application of SRI method of rice cultivation has reported to increase grain yields of rice by 40-50% in few locations (Satyanarayana *et al*., 2006; Hameed *et al*., 2011; Thakur *et al*., 2013), however, the reports on water use efficiency in SRI method is limited. Therefore, in the present study, field experiments were carried out to determine the growth and yield attributes of rice crops along with crop water productivity under SRI method of cultivation and further to compare it with the data from conventional practices.

Materials and Methods

Study area

A field study has been conducted in the experimental plots of Agriculture and Food Engineering Department, Indian Institute of Technology Kharagpur (23.32° N, 87.31° E) during *kharif and rabi* seasons of 2015-16. The experimental site lies under the sub-humid subtropical region with an average annual rainfall of about 1600 mm, out of which about 70% of rainfall is received during monsoon season from June to September.

Experimental Details

The experiment was carried out in 18 plots of 3 m × 3 m to study the water flow dynamics under SRI and conventional practices of rice cultivation. A schematic diagram of field layout is shown in Fig. 1. Seventeen days old seedling of rice (variety IR-36) was transplanted after puddling. Two water treatment levels (conventional and SRI) with 6 replications of each treatment were designed in experimental plots. In SRI plots one seedling was transplanted at one hill whereas in conventional plots 3 seedlings were transplanted at one hill and a spacing of 25 cm × 25 cm was maintained between hills under both treatments.

Standard dose of nitrogen, potassium and phosphorous were applied during the growing season of paddy and these are 120 kg N ha^{-1} 60 kg P_2O_5 ha^{-1} and 50 kg K_2O ha^{-1}. Nitrogen fertilizer was applied as urea in four splits during both *kharif* and *rabi* seasons: 25% at the time of transplanting, 25% at tillering, 25% at panicle initiation and 25% at flowering. Phosphorous and potassium fertilizers were applied in the form of single super phosphate (SSP) and muriate of potash (MOP), respectively, during the trans-planting as basal dose. Ponding of 3-5 cm depth of water was maintained in all plots for the first 15 days during *kharif* season and for 25 days during *rabi* season and then a ponding depth of 3 to 8 cm was maintained in plots under conventional irrigation practice and 1 to 3 cm in plots under SRI method of cultivation during paddy growing seasons. During *rabi* season, variation in ponding depth was delayed by 10 days because initially the plant growth was very slow due to weather conditions.

Measurement of water balance components

Four non-weighing lysimeters with bottom open and two non-weighing lysimeters with

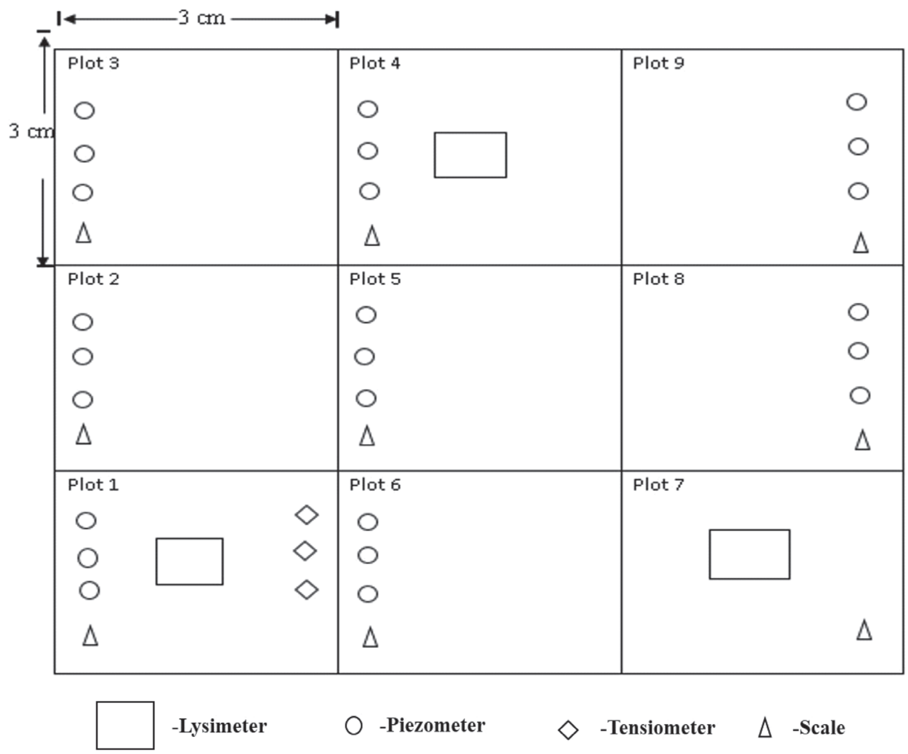

Fig. 1. Schematic representation of the field layout and location of instrument in the experimental field

bottom closed were installed in the experimental plots. Size of the lysimeter was of 1.25 m × 1.25 m × 1 m (Fig. 2). Bottom of each lysimeter was kept at 80 cm below the ground surface and the water going beyond 80 cm was considered as percolation loss. A combination of two bottom open and one bottom closed lysimeter was used to measure the daily crop evapotranspiration, evaporation and deep percolation losses from the plots each under SRI and conventional water management practices. Crop evapotranspiration together with deep percolation (ET_c + DP) was measured using a bottom open lysimeter in which paddy was grown (Fig. 2A), percolation together with evaporation (E + DP) was measured using another bottom open lysimeter in which there was no crop (Fig. 2B) and evaporation (E) was measured using a bottom closed lysimeter without paddy (Fig. 2C). Water level in the lysimeters was held at the same level as in the experimental plots and the rate of decrease of water level inside the lysimeters was recorded daily. Then, the values of evaporation, evapotranspiration and deep percolation at the specified time period were calculated as follows:

$$ET_c = \Delta H_{Ai} - (\Delta H_{Bi} - \Delta H_{Ci}) \qquad \ldots(1)$$

$$DP = \Delta H_{Bi} - \Delta H_{Ci} \qquad \ldots(2)$$

$$E = \Delta H_{Ci} \qquad \ldots(3)$$

where ΔH_A, ΔH_B, ΔH_C are the difference between the two consecutive readings in the lysimeters A, B, and C, respectively, in a given time step (i). In this study, the daily time step was used.

Measurement of plant growth indicators

Plant height and tiller count

Tiller count and plant height, data were collected at different growth stages from the experimental plots. For this purpose 4 hills were selected in the experimental plots and tiller count and plant height was measured at each hill. This process was carried out for three sampling units.

Above ground biomass

Plant samples were taken after 30, 50 and 70 days of transplanting (DAT) so as to measure the above ground biomass (Fig. 3). The collected plant sample was first washed and then oven dried

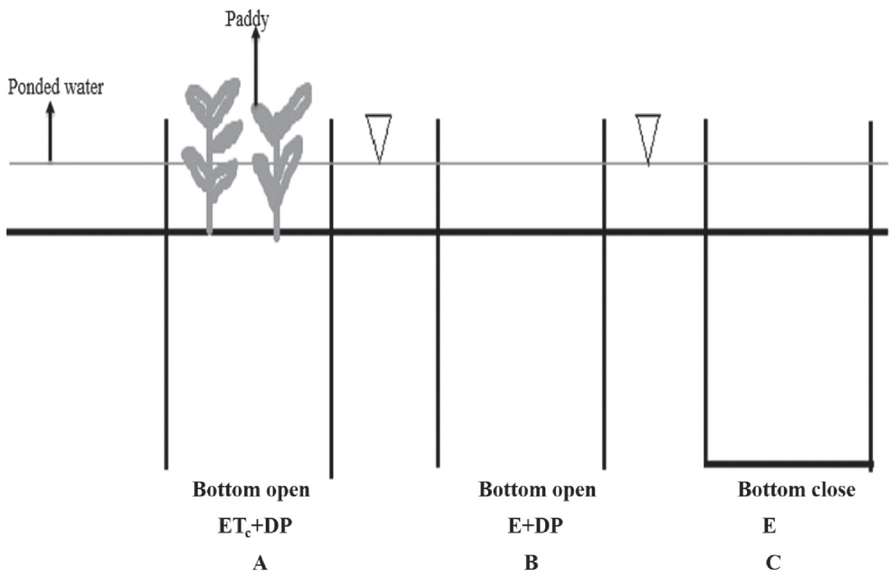

Fig. 2. On field measurement of ET_c, E, DP in a paddy field during rice growing season

A SRI | B Conventional

Fig. 3. Plant samples taken for measuring above ground biomass at 70 DAT from SRI and conventional plots

at 70°C for one day until its weight became constant. The dried plant sample was then weighed to get the above ground biomass.

Leaf area index

Leaf area index (LAI) was taken at 30, 50, 70 and 90 days after transplanting. In order to measure LAI 8 hills were selected from each plot, making sure that each hill is surrounded by living hills. Then the length and maximum width of each leaf on the middle tiller was measured and the area of each leaf based on the length-width was computed using the following formula:

$$\text{Leaf area} = K \times l \times w \quad \ldots(4)$$

where *K* is the "adjustment factor." *l* is the length, and *w* is the width. The value of *K* was taken as 0.75 for tillering, panicle and flowering statge and as t 0.67 for maturity stage (Gomez, 1972). Then the leaf area index was calculated by using the following formula:

$$\text{Leaf area hill} = \text{total leaf area of middle tiller} \times \text{total number of tillers} \quad \ldots(5)$$

$$\text{Leaf area index} = \frac{\text{Sum of leaf area/hill of 8 sample hills (cm}^2)}{\text{Area of land covered by 8 hills (cm}^2)} \quad \ldots(6)$$

Grain Yield

For obtaining grain yield rice plants were first harvested from 1 m × 1m sampling area marked at the center of each plot. The grains were then separated from the straws using a threshing machine and grain weights were recorded for each plot.

Water Use Efficiency

Crop water use efficiency: It is the ratio of crop yield (Y, kg/ha) to the amount of water depleted by the crop in the process of Evapotranspiration (ET_c, mm), which is given by

$$\text{Crop water use efficiency} = \frac{yield(Y)}{ET_c} \quad \ldots(7)$$

Field water use efficiency: It is the ratio of crop yield (Y, kg/ha) to the total amount of water used in the field (WR, mm), given by

$$\text{Field water use efficiency} = \frac{yield(Y)}{WR} \quad \ldots(8)$$

Results and Discussion

Water Balance Components

Taking 80 cm deep soil profile as one system, water balance components were measured for conventional and SRI practices using non-weighing lysimeters during the rice growing seasons in 2015-16. Figure 4 shows the amount of water lost through crop evapotranspiration and deep percolation in terms of depth (cm) during the *kharif* and *rabi* seasons of 2015-16. Under conventional practice during *kharif* season, 80 cm of water was lost through deep percolation whereas in SRI practice the deep percolation was 42.2 cm, thus reducing the deep percolation loss by 37.8 cm as compared to conventional practice. This was because the rate of percolation increases as the depth of standing water in the field increases. The amount of water used for crop evapotranspiration was more in SRI practice as compared to conventional practice as there were more number of tillers at each hills in SRI plots as compared to conventional plots. But the overall requirement of water was reduced by 35.8 cm under SRI practice in comparison to conventional practice. Similarly, during *rabi* season, the deep percolation loss reduced by 38.8 cm in SRI plots whereas the amount of water required throughout the season reduced by 37.8 cm.

Daily variation of crop evapotranspiration and deep percolation was measured throughout the *kharif* and *rabi* seasons of 2015-16 (Fig. 5). During *kharif* season, daily deep percolation loss was less in both conventional and SRI plots up to 55 DAT with a mean percolation rate of 0.32 cm day^{-1} and 0.24 cm day^{-1} in conventional and SRI plots, respectively. This was due to the shallower

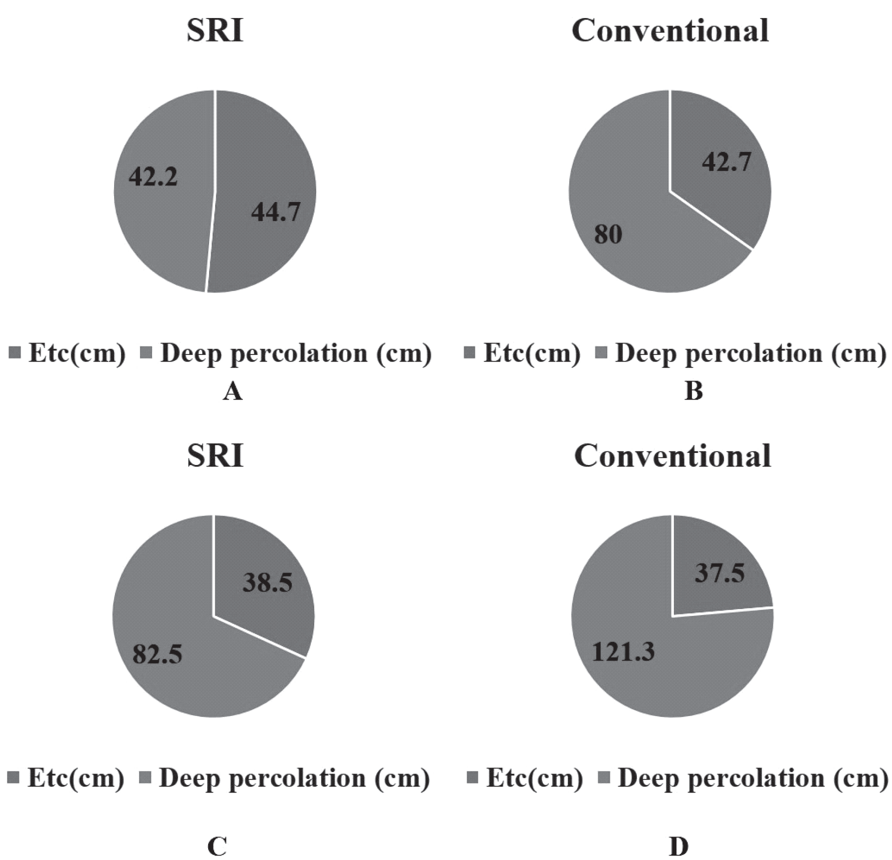

Fig. 4. Water balance components in SRI and conventional plots during *kharif* and *rabi* season 2015-16

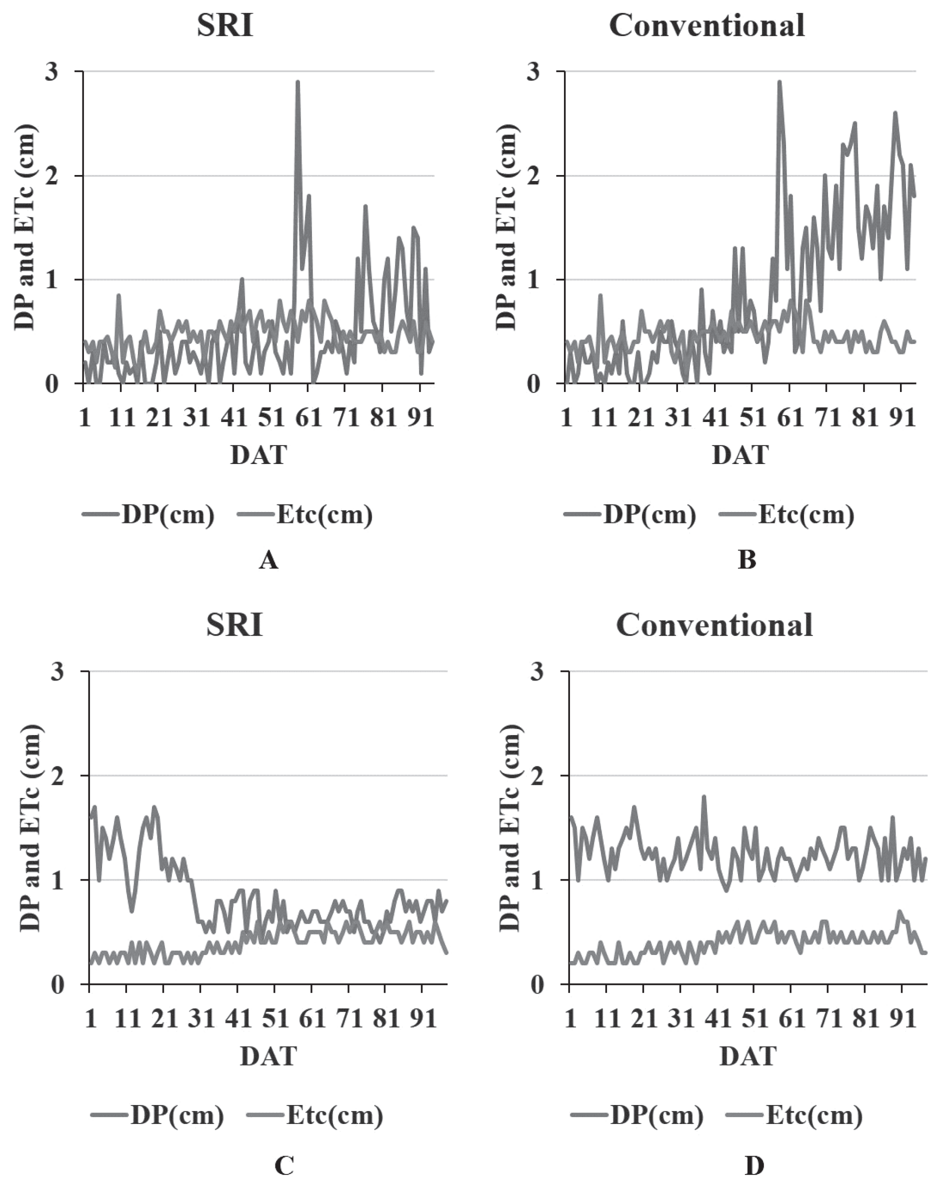

Fig. 5. Daily variation of deep percolation and crop evapotranspiration in SRI plots during *kharif* and *rabi* season 2015-16

groundwater table which led to capillary rise. The deep percolation rate then increased in the later part of the *kharif* season as groundwater table started depleting and the mean value of daily percolation rate was 1.56 cm day^{-1} and 0.76 cm day^{-1} in conventional and SRI plots, respectively for the later part of the season. During *rabi* season, the initial deep percolation rate was more in SRI plots as flooding condition was maintained in the plots for the first 25 days after transplantation and after that, as the standing water depth was reduced the rate of deep percolation also reduced. The rate of deep percolation in conventional plots was almost the same throughout the season as flooding condition was maintained throughout. During 30-35 DAT the growth rate of rice was very slow under both the water management practice due to inappropriate weather conditions for rice growth. This was well reflected in the crop evapotranspiration value which was quite low during this period with an average value of 0.27

cm day^{-1} during both SRI and conventional plots. The average crop evapotranspiration for 36-97 DAT was 0.45 and 0.44 cm day^{-1} in SRI and conventional plots, respectively.

Plant Growth Indicators

Tiller count

Tiller count was recorded at different growth stages in experimental plots for both water management practices and was found to be maximum at 70 DAT. Tiller count was more in SRI plots as compared to conventional plots during both *kharif* and *rabi* season of 2015-16 and can be attributed to the early transplanting of young rice seedling (seedlings < 15 days old) and wider spacing maintained between each plant at the time of transplanting in SRI plots as it preserves plants potential for tillering and root growth (Randriamiharisoa and Uphoff, 2002). The mean tiller count in SRI plots were 429 and 420 tillers m^{-2} for *kharif* and *rabi* season, respectively whereas the mean tiller count in conventional plots were 395 and 385 tillers m^{-2} for *kharif* and *rabi* season, respectively. Figure 6 shows the mean tiller count in SRI and conventional plots at 70 DAT for both the seasons along with the standard error within the replication. The standard error under both SRI and conventional practice were less indicating that there was not much variation among the replications of each treatment and the water management practice was followed uniformly in all the replications throughout the season.

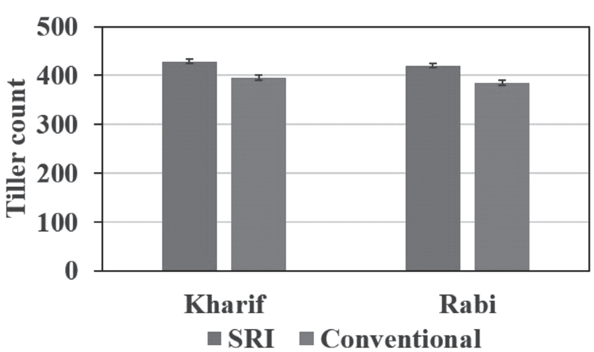

Fig. 6. Tiller count in SRI and conventional plots at 70 DAT during *kharif* and *rabi* season of 2015-16

Plant height

Plant height increased gradually and was found to be maximum at 70 DAT. Height of rice crop in SRI plots were more than that in conventional plots in both the season but there was not much of a difference between the two. The mean value of plant height during *kharif* season in SRI plots was 76.8 cm with a standard error of 0.13 cm whereas that in conventional plots was 75.51 cm with a standard error of 0.23 cm (Fig. 7). Whereas the mean value of plant height in *rabi* season, 2016 was 62.5 cm in SRI plots and 62.25 cm in conventional plots (Fig. 7).

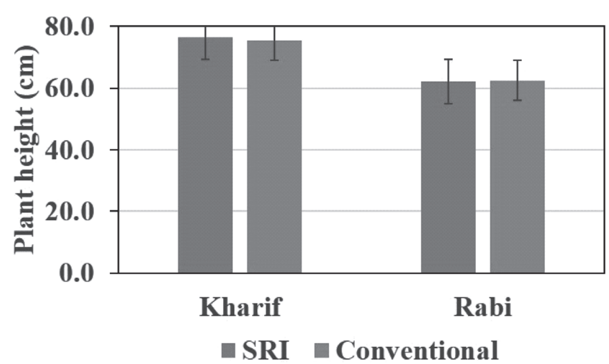

Fig. 7. Plant height in SRI and conventional plots at 70 DAT during *kharif* and season of 2015-16

Above ground biomass

The above ground biomass increased gradually with the crop growth stages as shown in the Figure 8. Initially at 30 DAT the above ground biomass was more in conventional plots during both *kharif* and *rabi* season, this was because initially the number of tillers in SRI plots were less than that in conventional plots. But as the number of tillers increased in SRI plots the above ground biomass gradually increased with time and was more than that in conventional plots after 50 and 70 DAT. It was also found that the value of above ground biomass during *rabi* season was less than that during *kharif* season at all stages and similar trend was followed in case of plant height and tiller count also, this was due to the slow growth rate during the first 35 DAT in *rabi* season due to inappropriate weather condition.

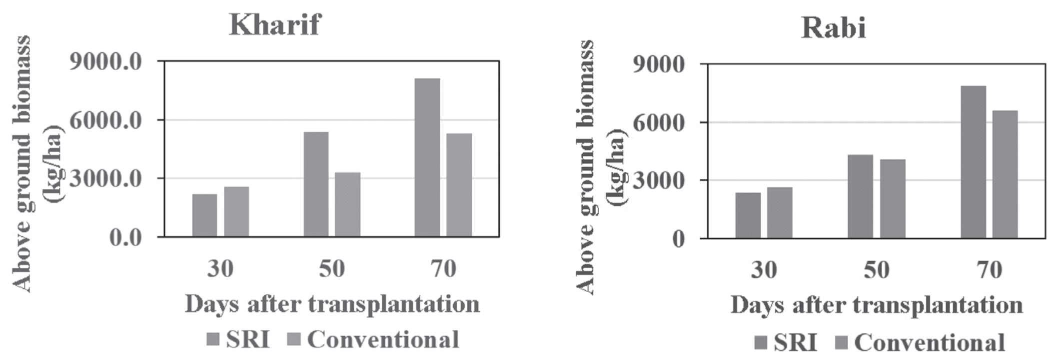

Fig. 8. Above ground biomass in SRI and conventional plots at different growth stages of paddy crop during *kharif* and *rabi* season of 2015-16

Leaf area index (LAI)

Figure 9 shows that LAI values increased gradually in the experimental plots at different growth stages. The LAI value was more in conventional plots than in SRI plots at 30 DAT for both the season as the above ground biomass was also more in conventional plots at that time. But after that LAI values were found to be more in SRI plots as compared to conventional plots indicating better growth in SRI plots.

Grain Yield

The yield responses of rice crop based upon two water application were characterized by grain yield (Fig. 10) The grain yield was more in SRI practice as compared to conventional practice which is in correspondence to the findings of Sinha *et al*. (2006), and Barison and Uphoff (2011). The yield was increased by 23.35% in *kharif* season and 21% in *rabi* season compared to conventional practice. Yield enhancement under SRI practice can be attributed to better tillering in SRI plots than that in conventional plots. Transplanting of single and younger seedling also improves root growth and its activity thus affecting the yield under SRI (Mishra and Salokhe, 2010; Zhang *et al*., 2009). Statistical analysis of the yield among the replications were performed and the standard error among the replications in SRI practice was 0.089 t ha^{-1} whereas that in conventional practice was 0.082 t ha^{-1}. F-test Two-Sample for Variances was also performed to check whether the difference among the yield under SRI and conventional practice was significant or not. The F value for both the season was greater than the critical F value thus the difference among the yield under the two water management practice was critical.

Water Use Efficiency

In order to estimate the water use efficiency (WUE) of rice, water use by the rice crop was estimated by the water balance analysis using the non-weighing lysimeters. Irrigation and rainfall were taken as inputs and deep percolation and

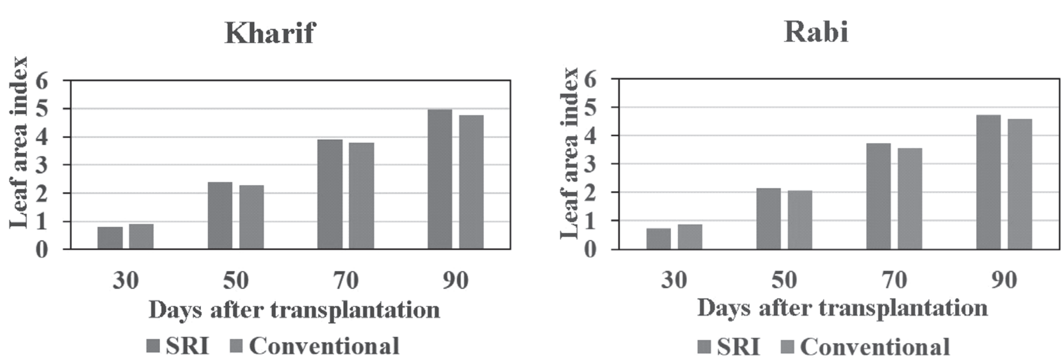

Fig. 9. Leaf area index in paddy plots under SRI and conventional practice at different growth stagesof paddy crop during *kharif* and *rabi* season of 2015-16

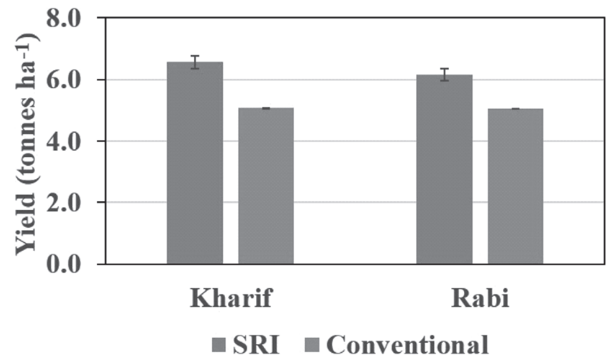

Fig. 10. Grain yield in paddy plots under SRI and conventional practice during *kharif* and *rabi* season of 2015-16

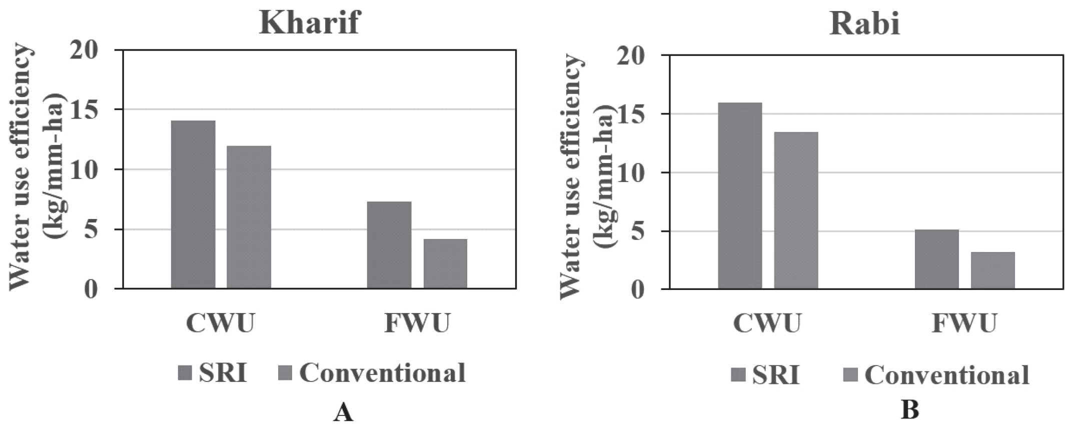

Fig. 11. Crop water use efficiency and field water use efficiency in paddy plots under SRI and conventional practices during *kharif* and *rabi* seasons 2015-16

crop evapotranspiration as outputs from the soil reservoir. Figure 11 reveals the crop water and field water use efficiencies of the paddy crop under SRI and conventional practices. The crop water use efficiency and field water use efficiency increased by 18.8% and 74.8%, respectively in SRI plots in comparison to conventional practice during *kharif* season, whereas in *rabi* season crop water use efficiency and field water use efficiency increased by 18.8% and 60%, respectively in SRI plots as compared to conventional practice. These, results were in correspondence to the findings of Thakur *et al*. (2013).

Conclusions

Food security and environmental sustainability are the major focus of Indian agriculture. Rice, being the staple crop of India, requires special attention to achieve food security without affecting our environment adversely. The conventional method of rice production has very low water use efficiency resulting in low productivity and huge losses of water and nutrient from the field. Thus, in order to increase the production and water use efficiency of rice, we need to adopt other rice cultivation practices. Under the present study grain yield was increased by 23.4 and 21% in SRI in comparison to conventional practice in SRI practice and deep percolation losses reduced by 37.8 and 38.8 cm in *kharif* and *rabi* season, respectively under SRI practice compared to conventional practice. The crop water use efficiency and field water use efficiency increased by 18.8% and 74.8%, respectively in SRI in comparison to conventional practice during *kharif* season, whereas in *rabi* season, crop water use efficiency and field water use efficiency increased by 18.8% and 60%, respectively in SRI in comparison to conventional practice. Thus, SRI proved to be a better method for rice cultivation in comparison to conventional practice for improving both yield capacity and water use efficiency of rice.

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