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Effect of mechanical planting and weeding on yield, water-use efficiency and cost of production under modified system of rice intensification

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The system of rice intensification (SRI) is gaining steady acceptance by the farmers of rice-growing countries due to advantages like lower seed requirement, less pest attack, lower crop duration, higher water-use efficiency and the ability to withstand higher degree of moisture stress than traditional process of rice cultivation. For further improvement on these advantages, SRI is being adopted by farmers with modifications on age of seedlings, hill spacing, use of organic and inorganic nutrients and maintenance of soil aerobic condition to suit local climates and management techniques. Transplanting and weed management require more labour in SRI compared to traditional practices. These operations are spread over a couple of weeks in a production season, causing labour scarcity in rice growing areas. The scarcity causes delay in agricultural operations which affects crop productivity. Due to high labour cost, profit from SRI cultivation is marginal. SRI mechanization to reduce cost of planting and weeding has potential to reduce cost of rice cultivation by SRI substantially.

A study at Acharya NG Ranga University, Andhra Pradesh, India (ANGRAU) showed that use of cono weeders increased efficiency of women labourers by 76% compared to the use traditional hand weeding. The weeding efficiency of cono weeder varied between 75 and 100% in light to heavy soils. SRI transplanting and weeding require 50% more man-days than traditional transplanting and weeding. Use of markers for line transplanting and modified IRRI weeders reduced labour requirement in SRI by 50–55%, compared to rope-line transplanting and hand weeding. Weeding by cono weeder lessened fatigue of labourers because the weeder allows standing position of the operator during weeding.

Pandey (2002) reported performance of 8-row self-propelled Chinese mat type transplanter using 21 days old rice seedlings with 4 plants/hill and 46 hills/m^2. The transplanter covered 0.12 ha/hr with 62.1% field efficiency. Labour requirement of the transplanter was 42 man-hours/ha with cost of operation of ₹ 1 130/ha against manual transplanting of ₹ 2 240/ha. A yield of 5.80 tonnes/ha was obtained by mechanized transplanting against 5.00 tonnes/ha by manual transplanting.

Guohui (2010) reported in the workshop on SRI at the China National Rice Research Institute (Hangzhou), the yield of 16 tonnes/ha in Sichuan by SRI methods with Super-1 hybrid rice using triangular method of transplanting. This method maintained wide spacing but increased plant population by 50% over what it would be with a square transplanting of single seedling/hill.

As per SRI recommendation, young seedlings of 8-9 days are required to be planted. Mohapatra *et al.* (2011) found that transplanting such young seedlings, root washed or mat type, by transplanter causes damage to seedlings, more missing hills and more number of plants/hill. They found that 16 days old seedlings gave better yield and water-use efficiency than eight days old seedling. This facilitated use of transplanter with mat type seedlings.

From field water balance studies, Mohapatra (2006) determined water-use efficiency (WUE) of several rice cultivars for different land-water situations under rainfed ecosystem. Evapotranspiration values (ET), obtained from field water balance were found independent of locations but were dependent on duration of cultivars.

Keeping the above facts in view, a study was undertaken at CRRI, Cuttack, India during four seasons of 2009–10 (two each in *kharif* and *rabi*) to study the efficiency of planting and weeding implements, developed at CRRI, on grain and

*Short note

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straw yields, water-use efficiency and profitability of rice cultivation. A shallow water depth was maintained in fields in *kharif* season by rain water. In *rabi* season irrigation water applied at appearance of hairline cracks in soil to maintain saturation. Same nutrient level was maintained in all the treatments with 5 tonnes farmyard manure and 80:40:40 kg NPK/ha.

Under SRI method, eight days old seedlings of variety, Gayatri in *kharif* and Naveen in *rabi* were transplanted at the rate of one plant/hill at 30 cm × 30 cm hill spacing. Under traditional method, 25 days old seedlings were transplanted randomly (close to 15cm × 20cm spacing) with 2–3 seedlings/hill.

Field efficiency of CRRI truncated conical sprouted drum seeder (Fig 1), CRRI manual transplanter (Fig 2) and Chinese self-propelled transplanter (Fig 3) was compared with traditional transplanting method. Sixteen days old mat type seedlings were used in transplanters at 14 cm × 23 cm hill spacing with 4 plants/hill. Sprouted seeds, i e seeds after one day of germination, were sown by the drum seeder with hill spacing of 15 cm × 20 cm and 4–5 seeds/hill. Number of hills covered in one swath of CRRI transplanter, Chinese transplanter and drum seeder were 4, 8 and 6 respectively.

Data on weeding experiments were recorded in *rabi* season only because *kharif* season crops were free from weeds due to continuous standing water in the field. The crop was free from insect-pests and diseases in all the seasons. Plots were line-transplanted by traditional method. To study the saving of cost in weeding, field efficiency of finger weeder, CRRI star-cono weeder, CRRI bullock drawn weeder and CRRI power weeder were compared with manual weeding and no weeding. The width covered by cono and finger weeders in one pass was 12cm and 7.5 cm respectively.

Time taken for planting and weeding to cover 120 m^2 area by implements and manual operations was recorded. Plant height from 10 hills and number of ear bearing tillers from a m^2 area were recorded before harvest. Sun dried weight of straw and grain were recorded for determination of biomass yield.

Water-use efficiency (WUE) was determined as the ratio of grain yield and evapotranspiration. Yield was recorded from the whole plot (each measuring 8 m × 4.5 m). ET was computed from the water balance in crop field. Field water use of the crop (FW) was obtained from:

$$FW = R - R_o - S_p \pm S_r + W_s \quad (1)$$

Where, R= rainfall,

R_o= runoff,

S_p= seepage and percolation,

S_r = soil profile contribution or retention, and

W_s= water applied from sources other than rainfall.

Field components of rainfall were measured in rice field in the following manner:

- Rainfall (R): Daily rainfall data was recorded by rain gauge.
- Surface runoff (R_o): Runoff from 50 m^2 area was measured for individual showers by using a multi-slot device and a buried drum.
- Seepage-percolation (S_p): It was measured daily by drum container technique.

In *kharif* season, since the cultivation depended entirely on rainwater, W_s was taken as zero. In *rabi* season, there was no runoff (R_o=0). Using Eq.1, evapotranspiration of Gayatri and Naveen were determined as 823 mm and 673 mm respectively.

The experimental plots were arranged with randomized complete block design (RCBD) with three replications.

As seen from Table 1, rate of area coverage with the Chinese transplanter was highest whereas cost of planting was lowest in case of sprouted drum seeder. This finding is in conformity with the findings of Manjunatha *et al.* (2009). There was no significant variation in number of ear bearing tillers (EBT), plant height, straw and grain yields and water-use efficiency due to the machines and the traditional method. Cost of manual transplanting including nursery operations in SRI was higher by 11 times than sprouted seed drill, 3.6 times than CRRI transplanter and 5.4 times than Chinese transplanter. Grain yield and WUE of SRI was lower by 13% compared to planting by implements (Table 1). The study showed that sprouted drum seeder is the best technique to reduce the cost of rice-planting where depth of standing water in the field remains within 10–15 mm. When higher standing water depth in the field does not allow use of

Fig 1 CRRI 4-row sprouted seed drill

Fig 2 CRRI 4-row mat type transplanter

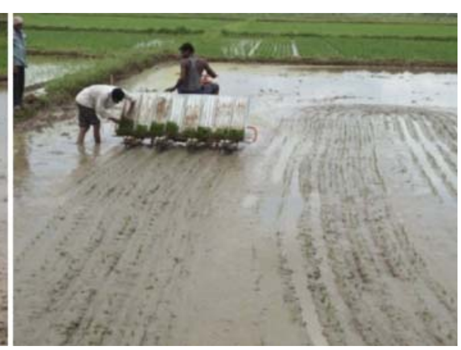

Fig 3 Chinese 8-row mat type transplanter

Table 1 Effect of planting and weeding methods on biomass yield, WUE and cost of cultivation (Var. Naveen, *rabi* 2009 and 2010)

Planting[1]/weeding[2] method	Area coverage (ha/hr)	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)	WUE (kg/m^3)	Cost of planting[1]/ weeding[2] (₹/ha)	Total cost of cultivation (₹/ha)	Net returns[3&4] (₹/ha)
Traditional[1]	0.0036	4.52	7.05	0.66	5 250[1]	25 078	9 312
SRI[1]	0.0033	3.77	6.15	0.55	5 725[1]	21 195	2 650
CRRI drum seeder[1]	0.12	4.19	7.13	0.61	515[1]	16 355	16 300
CRRI transplanter[1]	0.032	4.36	6.61	0.64	1 611[1]	18 046	15 738
Chinese transplanter[1]	0.192	4.48	7.29	0.66	1 052[1]	17 487	17 311
No weeding[2]		2.10	5.53	0.31	0	19 390	-3 698
Manual weeding[2]	0.0065	4.31	7.24	0.63	5 688[2]	25 078	5 587
CRRI finger weeder[2]	0.008	4.07	6.87	0.60	3 750[2]	23 140	7 560
CRRI star-cono weeder[2]	0.02	4.43	7.34	0.65	2 250[2]	21 640	11 262
CRRI bullock drawn weeder[2]	0.08	3.96	6.42	0.58	1 815[2]	21 205	7 939
CRRI power weeder[2]	0.075	4.15	7.05	0.61	2 220[2]	21 610	9 234
CD (5%)		0.36	0.67	0.53	128.38	473.95	327.81
CV (%)		4.89	5.41	5.00	2.6	1.25	2.00

[3] Paddy (grain) rate: ₹ 800/100 kg, [4] Straw rate: ₹ 80/100 kg

sprouted seed drill, mat type transplanters can be used without any adverse effect on productivity.

Plots with alternate wetting and drying were infested with heavy weed growth. Three weeding operations were required to weed out these plots. Manual weeding was done in randomly planted (traditional) plots. Mechanical weeders were used in line-planted plots. Highest rate of area coverage with lowest cost of weeding was found in case of bullock-drawn weeder because it covered six rows in a pass compared two rows of the power weeder. But the weed destruction was better in case of power weeder (74% vs. 55% in two passes). As seen from Table 1, highest WUE and straw and grain yields were obtained from star-cono weeder. Advantages with the star-cono weeder may be attributed to better churning of soil and higher weed damage resulting in higher new root development. Variation in plant height was not significant due to different methods of weeding.

Average cost saving due to weeders was 127% (₹ 2 509 against ₹ 5 688/ha) compared to manual weeding. Average WUE and grain yield in weeded plots was double compared to un-weeded plots (4.18 against 2.1 tonnes/ha). The study shows that self-propelled power weeder is a better substitute to hand weeding and weeding by finger and star-cono weeders. This finding is in conformity with the findings of Parida (2003) and Tajuddin (2009). Average straw yield from weeded plots (6.98 tonnes/ha) was higher by 26% than the un-weeded plots.

SUMMARY

Efficiency of planting and weeding equipments developed at Central Rice Research Institute, Cuttack was compared with traditional method of planting and weeding in relation to biomass yield, water-use efficiency (WUE) and net returns from SRI. The study showed that low plant density and high labour cost of SRI resulted in lower yield (3.77 against 4.52 tonnes/ha) and net returns (₹ 2 650 against ₹ 9 312/ha) compared to traditional method of cultivation. Mechanized planting and weeding of SRI enhanced its productivity to 4.24 tonnes/ha and profitability to ₹ 12 192/ha. But it required that age of seedlings is increased from 8 to 16 days and density of hills is increased from 11 to 31/m^2 with 4 (instead of single) plants/hill. Among mechanical planters, seeding by sprouted seeds on puddled soil by drum seeder was found to have significantly lower planting cost (₹ 515 against ₹ 1 332/ha) and lower total cost of production (₹ 16 355 against ₹ 17 767/ha). Average WUE (0.61 kg/m^3) and grain yield (4.18 tonnes/ha) in weeded plots was double to un-weeded plots. Average cost of (single) weeding by weeders was ₹ 2 509 against ₹ 5 688/ha of manual weeding. Among the weeders, high efficiency in weed destruction and soil churning by star-cono weeder resulted in highest grain productivity and profitability in its favour.

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