Effect of Mechanical Planting on Grain and Straw Yields, Water Use Efficiency and Profitability of Rice Cultivation




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Abstract

Experiments were conducted in rainfed condition to study the effect of mechanical planting methods on straw and grain yields, water use efficiency and net returns from rice cultivation. Field efficiency of planting machines was compared with the traditional method of manual transplanting with root washed seedlings. Variations in yields of straw and grain and water use efficiency due to use of machines were not significant compared to the manual transplanting. Compared to manual transplanting, saving in cost of planting with the use of machines was substantial (average: Rs. 1,048/ha` against Rs. 9,250/ha) which reduced the total cost of production by 24 % and enhanced the net profit by 42 % (to Rs. 31,465/ha).

Introduction

In recent years in India, scarcity of labour and high labour wage has hit rice cultivation hard. In this scenario returns from rice farming are marginal since increase in market price of the produce is not in same proportion to the increase in cost of production. Transplanting, weeding - especially in uplands and aerobic conditions and harvesting are the major labour intensive operations in rice cultivation. Time available for transplanting in all the production seasons, namely Kharif, Rabi and Boro is limited. Delay in transplanting reduces yield and profitability. Compared to traditional (manual) transplanting, mechanized planting of rice reduces labour requirement, speeds up planting process and reduces cost of operation substantially.

Pandey (2002) reported performance of 8 row self propelled mat type transplanter using 21 days old rice seedlings with 4 plants/hill and 46 hills/m². Labour requirement of the transplanter was 42 man-hours/ha with cost of operation of Rs. 1,130/ha against the cost of manual transplanting of Rs. 2,240/ha. Singh and Vasta (2007) reported field capacity of a manual rice transplanter as 0.03 ha/h. Use of the transplanter reduced labour requirement to one-third and cost of paddy cultivation over traditional method of manual transplanting by 54-73 %. Manjunath *et al.* (2009) reported working efficiency of 8 row paddy transplanter and suggested that the transplanter should work in an area of 28 ha per year to achieve breakeven point for cost reimbursement. Jha *et al.* (2011) adopted four planting practices, namely, direct sowing in dry fields, direct sowing of sprouted seeds in puddled field using drum seeder, mechanical and manual transplanting. They reported that the direct seeding of sprouted seeds gave significantly higher grain yield of rice (5.70 t/ha), followed by direct seeding under dry field (5.32 t/ha) and mechanical transplanting (5.21 t/ha), whereas the lowest yield was recorded in manual transplanted rice (5.11 t/ha). Mohapatra *et al.* (2012) found that planting by seed drill with sprouted seeds does not affect yield and water use efficiency. They also found that planting more plants in a unit area by sprouted seed drill or transplanters, compared to a single plant, as advocated in the system of rice intensification (SRI), increased grain yield and water use efficiency. Avasthe *et al.* (2012) reported optimum hill spacing of

Fig.1 Four row manual drum seeder

Fig.2 Six row manual drum seeder

Fig.3 Four row manual rice transplanter

Fig.4 Self propelled 8 row transplanter

Fig.5 Self propelled hill seeder

Fig.6 Tractor drawn seed drill

20 cm × 20 cm in hilly acidic soil where wider and narrower spacing than this resulted in reduced grain yield.

From field water balance studies, Mohapatra (2006) determined grain water use efficiency (GWUE) of several rice cultivars for upland, shallow lowland and deep water situations under rainfed ecosystem. He reported that evapotranspiration (ET) of a cultivar mainly depends on its duration.

Materials and Methods

The experiment was conducted at Central Rice Research Institute, Cuttack, Odisha, India in rainfed environment of shallow lowland condition in Kharif season of years 2010-12 with rice CV 'Gayatri'. The soil was aeric endoaquept with available N: 190 kg, Bray's P: 20 kg and K: 203 kg per hectare before start of the experiment. Same nutrient level was maintained in all the treatments by addition of 5.0t farm yard manure (FYM) and 60:30:30 kg NPK per hectare. All FYM, P and K and 20 kg N were applied as basal dose. Twenty kg N was applied each time after 3 weeks of plant establishment and at panicle initiation stage. Nurseries raising and direct seeding were done at same time. In wet land condition, CRRI four and six-row manual drum seeders (**Figs. 1** and **2,** respectively) with sprouted seeds, CRRI 4 row manual rice transplanter (**Fig. 3**) and self propelled 8 row transplanter (**Fig. 4**) with mat type seedlings were used. Twenty two days old seedlings were used in case of transplanters and manual transplanting. Sprouted seeds were sown by drum seeder. CRRI self propelled hill seeder (**Fig. 5**), CRRI bullock drawn seed drill and CRRI tractor drawn seed drill (**Fig. 6**) were used with dry seeds in dry land condition. There was one weeding by use of conoweeder in direct seeded plots. The crop was free from diseases and insect attacks. The crop was harvested after 155 days of germination.

The experimental plots were arranged with randomized complete block design (RCBD) with 3 replications.

Grain water use efficiency (GWUE) was determined as the ratio of grain yield and evapotranspiration (ET) of the crop. As per the procedure adopted by Mohapatra (2006), ET was computed from the field water balance (FW) of rainfall:

$FW = R - R_o - S_p \pm S_r + W_s$.....(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 (irrigation).

Average rainfall during growth period of 'Gayatri' (15th June to 18th Nov. of the years 2011 and 2012) was 1,292 mm. Runoff was measured during these years from a 100m^2 plot to which inflow was blocked from all sides. A 5-slot device with a buried drum was used to measure runoff. In few cases runoff could not be measured. Their values were obtained from the graph between rainfall of individual showers and corresponding runoffs. Total value of runoff was found to be 443 mm which was 34.3 % of rainfall.

Table 1 Planting machines with specifications

Planting method/ machine	Planting material	Seed rate (kg/ha)	Source of draft	Hill spacing	Plants/ hill	No. of rows in one swath
CRRI 4-row manual drum seeder	Sprouted seeds	50	Manual	15 cm × 20 cm	4-5	4
CRRI 6-row manual drum seeder	Sprouted seeds	53	Manual	15 cm × 20 cm	5-6	6
CRRI 4 row manual rice transplanter	Mat type seedlings	60	Manual	14 cm × 24 cm	4-5	4
Self propelled transplanter	Mat type seedlings	60	4hp engine	14 cm × 24 cm	4-5	8
CRRI self propelled hill seeder (walking type)	Dry seeds	50	3hp engine	15 cm × 20 m	4-5	3
CRRI tractor drawn seed drill	Dry seeds	55	35hp tractor	15 cm × 20 cm	5-6	10
CRRI bullock drawn seed drill	Dry seeds	58	Animal	15 cm × 20 cm	6-7	3
Manual transplanting (traditional)	Root washed seedlings	63	Manual	15 cm × 20 cm	2-3	NA

Seepage and percolation were measured by drum culture, i.e. by use of buried bottom-closed and bottom-open drums. These were found to be within 2 % of rainfall during crop growth period (S_p = 26 mm). The low value could be attributed to the saturated aquifer condition and rice fields, all around the experimental plots, limiting the scope of horizontal and vertical outflow inside the soil. Soil profile contribution was measured by taking soil samples from field before planting and after harvest of the crop. This was found to be negligible due to saturated condition of soil at the time of planting and harvest of the crop (S_r = 0.0). Irrigation water was not applied (W_s = 0.0). Using Eq.1, value of ET of 'Gayatri' was determined as 823 mm.

Plant height from 10 hills and number of unproductive tillers and ear bearing tillers from a square meter area were recorded before harvest. Dry grain and straw yields were recorded from the whole plot (50 m^2 each).

Cost inputs including seed, FYM, fertilizer, nursery raising, tillage, puddling, planting (direct sowing by seeders, mechanical and manual transplanting), harvesting, threshing and labour required for these operations were recorded for different treatments, separately, to arrive at the total cost of production. Returns from rice cultivation were determined from local market rates of straw (Rs. 100/q) and paddy (Rs. 1,000/q). Profitability (net returns) from rice cultivation was determined as the difference of returns and total cost of cultivation.

Planting machines with specifications adopted in the experiment is given in **Table 1**.

Results and Discussion

Planting Efficiency

Results presented in **Table 2** show that there was a significant variation in planting capacity of different implements. Average capacity of sprouted seeders was 0.047 ha/h compared to 0.075 ha/h of manual dry seeders and 0.38 ha/h of tractor drawn seed drill. Planting capacity of 6-row seeder was higher than 4-row seeder but the operator faced difficulty to turn the 6-row seeder at corner of the plots. Planting capacity of self propelled transplanter (0.205 ha/h) was 9 times faster than manual transplanter (0.022 ha/hr) and 82 times faster than manual transplanting (0.0025 ha/h). Missing hills due to manual and self-propelled transplanters were within 8 % and 5 % respectively. Sprouted seeders required leveled puddled-field with maximum standing water depth of 10 mm. Plant mortality was noticed where standing water was higher due to rotting of young shoots.

Grain yield

There was no significant difference in number of unproductive tillers (Average: 56.7 Vs. 57.3/m^2: 1.1 %), ear bearing tillers (Average: 303.2 Vs. 307.8/m^2: 1.5 %), plant height (Average: 106.1 vs. 108.6 cm: 2.3 %), grain yield (Average: 5.73 vs. 5.85 t/ha: 2.1 %) and water use efficiency (Average: 0.697 vs. 0.711 kg/m^3: 2 %) between mechanical planting (including all seeders and transplanters) vs. manual transplanting. This finding is slightly different to the finding by Jha *et al.* (2011) who reported that 10.4 % and 3.4 % higher grain yields were obtained from direct seeding of sprouted and dry seeds respectively than manual transplanted rice. But the present study is in agreement with the findings of Avasthe *et al.* (2012) where they found that hill spacing, wider than 20 cm × 20 cm, generated higher number of tillers per hill but

failed to produce corresponding increase in panicles/m^2 and narrower spacing increased panicles/m^2 but shortened panicle length with reduced number of grains which reduced the grain yield.

Straw Yield

Unproductive tillers were 15.7 % of total number of tillers (Average: 303.8/m^2). Straw yield was slightly higher in case of manual transplanting (9.5 t/ha) compared to mechanical transplanting (9.13 t/ha) and direct seeding (8.23 t/ha). Contribution of straw yield towards net returns was significant with an average of Rs. 8,985/ha at local market rate of Rs. 100/q.

Cost and Net Returns

There was a significant saving of cost in direct seeding and transplanting due to use of machines, compared to manual (traditional) transplanting (average cost of Rs. 1,048 against Rs. 9,250/ha). Cost of manual transplanting was higher by 13 times than sprouted seed drills (cost: Rs. 672/ha), 7 times than self propelled transplanter (cost: Rs. 1,157/ha), 5.8 times than self propelled hill seeder (cost: Rs. 1,364/ha) and 4.2 times than manual transplanter (cost: Rs. 1,772/ha). Initial investment of tractor drawn and self propelled implements is high but it is compensated with the speed and efficiency of planting operation. Although yield from different planting methods did not vary significantly, the cost of planting made a significant difference in total cost of cultivation and net returns. Highest net return of Rs. 34,138/ha was obtained from self propelled transplanter followed by manual transplanter (Rs. 32,580/ha) compared to Rs. 22,222/ha of manual transplanting. Average net return from dry seeded plots was Rs. 30,863/ha against Rs. 30,476/ha of sprouted seeded plots, Rs. 33,359/ha of mechanically transplanted plots and Rs. 22,222/ha of manually transplanted plots.

Conclusions

Manual transplanting is the most expensive input in traditional rice cultivation but the planting cost of Rs. 9,250/ha can be reduced to Rs. 851/ha by use of dry seeders, to Rs. 1,364/ha by self propelled hill seeder, to Rs. 672/ha by sprouted seeders and to Rs. 1,157/ha by self propelled transplanter. Compared to manual transplanting, mechanized direct seeding and transplanting decrease total cost of cultivation by an average of 24 % (from Rs. 45,778/ha to Rs. 34,789/ha) and increases net returns by 42 % (from Rs. 22,222/ha to average of Rs. 31,465/ha). Maximum area is transplanted in an hour by the self propelled transplanter in puddled soils by using mat type seedlings. In well drained, puddled condition, where standing water remains within 10 mm, plant-

Table 2 Effect of planting implements on productivity, GWUE and net returns (CV 'Gayatri', Kharif, 2010-12)

Planting implement	Planting capacity (ha/h)	Cost of * planting (Rs./ha)	Total cost of cultivation (Rs./ha)	Plant ht. (cm)	Unproductive tillers/m^2	Ear bearing tillers/m^2	Straw yield (t/ha)	Grain yield (t/ha)	GWUE (kg/m^3)	Net # return (Rs./ha)
Four row manual drum seeder	0.04	772	34,788 $	105.6	53.3	295.3	8.75	5.59	0.679	29,862
Six row manual drum seeder	0.053	572	34,290 $	107.4	58.0	301.6	8.38	5.70	0.693	31,090
Bullock drawn seed drill	0.07	936	35,040 $	105.7	58.3	297.8	8.75	5.63	0.684	30,010
Tractor drawn seed drill	0.38	766	34,764 $	105.9	60.0	302.2	9.0	5.76	0.700	31,836
Self propelled hill seeder	0.08	1,364	35,508 $	106.1	55.7	302.4	9.25	5.70	0.693	30,742
Four row manual rice transplanter	0.022	1,772	34,920	105.7	59.3	308.9	9.0	5.85	0.711	32,580
Self propelled 8 row transplanter	0.205	1,157	34,212	106.2	52.0	314.2	9.25	5.91	0.718	34,138
Manual transplanting	0.0025	9,250	45,778	108.6	57.3	307.8	9.5	5.85	0.711	22,222
SEm ±	-	33.27	255.43	0.182	2.31	5.425	0.156	0.109	0.013	1,470.3
CD (P = 0.05)	-	68.84	528.48	0.377	4.78	11.224	0.323	0.226	0.028	3,042

* Excluding cost of seed/nursery operations $ Includes cost of 1 weeding by cono-weeder
# Rate of paddy = Rs. 1000/q, Rate of straw = Rs. 100/q

ing by sprouted seed drills is most economical. Compared to manual transplanting, it reduces cost of planting to 1/14th and increases net profit from rice cultivation by 37 %. In dry land situation tractor drawn seed drills work efficiently and give a high net return of Rs. 31,836/ha. Although grain and straw yields and water use efficiency do not vary significantly, wide variation in cost of planting due to use of different implements results in significant difference in net returns.

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