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Research Paper

Impact of different crop-establishment methods and weed management practices on productivity of lowland rice (*Oryza sativa*)

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ABSTRACT

Field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore, during winter (*rabi*) season of 2011–12 and 2012–13 to evaluate different crop-establishment methods and weed management practices in lowland rice (*Oryza sativa* L.) in strip-plot design with three replications. The experiment consisted of 3 establishment methods, viz. conventional planting (C_1), system of rice intensification (SRI) marker planting (C_2) and SRI machine transplanting (C_3) assigned in horizontal strips and six weed management practices, viz. conoweeding 4 times at 10, 20, 30 and 40 days after transplanting (DAT) (W_1), pre-emergence (PE) pretilachlor 50% EC @ 0.75 kg/ha + conoweeding at 20 and 40 DAT (W_2), PE pretilachlor 50% EC @ 0.75 kg/ha + early post-emergence (EPOE) bispyribac-sodium 10% SC @ 20 g/ha (W_3), PE pretilachlor 50% EC @ 0.75 kg/ha + EPOE bispyribac 10% SC @ 20 g/ha + conoweeding at 40 DAT (W_4), EPOE bensulfuron + pretilachlor @ 0.66 kg/ha + conoweeding at 30 and 40 DAT (W_5) and unweeded control (W_6) were allotted in vertical strips. The results revealed that machine planting resulted in significant increase in growth characters, viz. plant height and leaf area index; yield attributes, viz. tillers/m^2, panicles/m^2, grains/panicle and yields (grain and straw) of rice. With regard to weed management practices, conoweeding 4 times at 10 days interval starting from 10 DAT exhibited maximum values of growth and yield components and recorded higher grain yield. The combination of mechanical transplanting with conoweeding four times at 10 days interval starting from 10 DAT registered significantly higher growth characters and yield attributes, which in turn exhibited higher grain yield, which was comparable with mechanical transplanting with pretilachlor (0.75 kg/ha PE) + bispyribac (20 g/ha EPOE) + conoweeding at 40 DAT.

Key words : Grain yield, Growth characters, Herbicides, Lowland rice, Machine planting

Rice is one of the most important staple food crops for more than half of the world's population and its cultivation secures livelihood for about two billion people. India will need to produce 130 million tonnes of rice by 2030 compared with the present production of 102.75 million tonnes. System of Rice Intensification (SRI), a revived method of transplanted rice cultivation by exploiting the genetic potential of rice provides a favourable growing environment to increase the productivity and economic returns. Besides, it enhances soil health with reduction in input use such as seeds, water, etc. Manual transplanting is the most common practice being followed under lowland ecosystem. Escalating labour cost make transplanting more expensive which, invariably leads to delay in transplanting and results in reduction of yield and profit (Gangwar *et al*., 2008). Due to increase of labour scarcity, even the SRI planting may become very costly and hence, the machine planting may solve the labour scarcity by using mat nursery reducing the cost of cultivation since large area can be transplanted within a very short period.

Among the various factors responsible for low rice production, weeds are considered to be as one of the major limiting factors due to manifold harmful effects. Weeds compete with crops for nutrients, water, light and space. Weeds are the most competitors in their early growth stages than the later and hence, the growth of crops slows down and grain yield decreased. To reduce the cost of rice production, it has been urgently needed to adopt alternate methods of weed control, viz. mechanical, biological and chemical weed control in combination with manual weeding. Hence, the present study was put forth on different crop-establishment methods and weed management practices to enhance the productivity of lowland rice.

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MATERIALS AND METHODS

Field experiments were conducted at wetland farms of Tamil Nadu Agricultural University, Coimbatore (11< N, 77< E and at an altitude of 426.7 m above mean sea-level) during the winter (*rabi*) season of 2011–12 and 2012–13, to examine the rice performance under various crop-establishment methods and weed management of rice. The soil of the experimental site was clay loam in texture, low in available nitrogen (224 and 23l kg/ha during respective season) medium in available phosphorus (19.0, 17.8 kg/ha during respective season) and high in available potassium (446, 549 kg/ha during respective season). The experiment was replicated thrice in strip plot design with three crop-establishment techniques, viz. conventional planting (C_1), system of rice intensification SRI marker planting (C_2) and SRI machine planting (C_3) assigned to horizontal strips and 6 weed management practices, viz. conoweeding 4 times at 10, 20, 30 and 40 DAT (W_1), pre-emergence (PE) pretilachlor 50% EC @ 0.75 kg/ha + conoweeding at 20 and 40 DAT (W_2), PE pretilachlor 50% EC @ 0.75 kg/ha + early post-emergence (EPOE) bispyribac 10% SC @ 20 g/ha (W_3), PE pretilachlor 50% EC @ 0.75 kg/ha + EPOE bispyribac 10% SC @ 20 g/ha + conoweeding at 40 DAT (W_4), EPOE bensulfuron + pretilachlor @ 0.66 kg/ha + conoweeding at 30 and 40 DAT (W_5) and unweeded control (W_6) were allotted to vertical strips. 'Rice CO(R) 49' was used as test variety in this experiment.

SRI machine planting and marker planting involved 12 days old single seedling/hill at 30 cm × 20 cm and 25 cm × 25 cm spacing, respectively in comparison to conventional transplanting (CT) of 21 days old 2–3 seedlings/hill at 20 cm × 10 cm spacing. The seed requirement in SRI marker and machine planting was 8 kg/ha and for conventional planting was 40 kg/ha. Raised bed nursery for SRI planting, tray type nursery for SRI mechanical transplanting and conventional nursery for conventional transplanting were prepared. The average 5 hills of each plot was recorded from randomly selected plants considered as the height of the plant for each plot. Leaf-area index were estimated measuring the length and width of the leaf and multiplying by a factor of 0.75. The average number of tillers of 5 hills was considered as the total tiller/hill. Four quadrates of 0.25/m^2 area were marked in each plot and panicles were counted and presented as panicles/m^2. The number of filled grains/panicle averaged and the number expressed as filled grains/panicle. Randomly selected 1,000-grain were dried to 14% moisture and weighed to obtain 1,000-grain weight (g). Grain and straw were sun dried to 14% moisture level and weight was recorded for each plot and computed on hectare basis.

RESULTS AND DISCUSSION

Plant height and leaf-area index

Crop-establishment methods and weed management practices had significant influence on plant height during both the years of experimentation (Table 1). Among the crop-establishment techniques, mechanical transplanting (C_3) recorded significantly higher plant height than others. With machine transplanting, seedlings are planted at uniform depth facilitating early establishment of seedlings that increased the plant height significantly than manual transplanting (Pasha *et al.,* 2012). However, it was comparable with SRI marker planting during both the years. Among the weed management practices, conoweeding 4 times at 10 days interval starting from 10 DAT (W_1) recorded lucidly higher plant height which was on par with pretilachlor *fb* bispyribac + conoweeding on 40 DAT (W_4) compared to other treatments. Frequent stirring due to conoweeding might have facilitated better growing environment and enhanced plant height of rice. Senthilkumar (2002) reported taller plants due to conoweeding than other treatments. Pretilachlor (0.75 kg/ha PE) + bispyribac (20 g/ha EPOE) + conoweeding at 40 DAT controlled the weeds effectively at early stages in the present study, might have provided amenable conditions for rice plant to grow, in turn increased the plant height.

Crop-establishment methods and weed management practices had significant interaction with each other during both the years. Mechanical transplanting with conoweeding 4 times at 10 days interval starting from 10 DAT (C_3W_1) recorded significantly higher plant height, which was comparable with mechanical transplanting pretilachlor *fb* bispyribac + conoweeding on 40 DAT (C_3W_4) over all other combinations. Mechanical weeding could enhance the plant height by aeration and incorporation of weeds as green manure increased the organic carbon content of the soil. This is in accordance with the findings of Vijayakumar *et al.* (2006) and also younger seedlings have more vigourous root growth and lesser or no transplanting shock which stimulate cell division and encourage stem elongation resulting in increased plant height. Because of increased root shoot ratio under wider spacing, ultimately the plant get sufficient space to grow and the increased light transmission in the canopy leads to increased plant height.

Crop-establishment methods and weed management practices had significant influence on leaf-area index (LAI) during both the years of experimentation (Table 1). Among the horizontal strips, mechanical transplanting (C_3) recorded significantly higher LAI which was on par with SRI marker planting than conventional planting. It is an important index to strengthen the source–sink relationship because wider plant spacing produced more leaves with greater size (Ghuman *et al.,* 2008). Similarly, mechanical planting and SRI marker planting was planted with wider spacing and produced more leaf area might be due to the presence of better formation of source. Among the vertical strips, conoweeding four times at 10 days interval starting from 10 DAT (W_1) recorded lucidly higher LAI than other weed control treatments. This may be due to complete removal of late emerging weeds by mechanical weeding. This is in conformity with the findings of Suseela (2007). This was comparable with pretilachlor (0.75 kg/ha PE) + bispyribac (20 g/ha EPOE) + conoweeding at 40 DAT (W_4). There was no adverse effect of herbicides on young seedlings and use of herbicide significantly reduced the labour cost as opposed to intensive manual and mechanical weed control encouraged for SRI

Yield attributes

Crop-establishment methods and weed management practices had significant influence on yield attributes, viz. tillers/m^2, panicles/m^2, grains/panicle and 1,000-grain weight (Table 1). Among the establishment methods, SRI machine transplanting (C_3) produced distinctly more number of tillers/m^2, however, it was comparable with SRI marker planting (C_2). This might be due to higher input efficiency under SRI method of cultivation, providing better aeration, more spacing and less competition, which enabled plants to grow vigorously. The plants in SRI method had better partitioning of dry matter, which led to increased tillers/m^2. These results are in conformity with the findings of Singh *et al.* (2012), who reported that wider spacing (30 cm × 30 cm) produced significantly more tillers/hill than the narrower spacing (25 cm × 25 cm).

In vertical strips, conoweeding four times at 10 days interval starting from 10 DAT (W_1) produced more tillers/m^2 which was followed by pretilachlor (0.75 kg/ha PE) + bispyribac (20 g/ha EPOE) + conoweeding at 40 DAT (W_4) compared to others. This is also in agreement with the reports of Sridevi and Chellamuthu (2012), who reported that due to conoweeding root volume get increased and produced strong tillers which improved the yield attributes.

Crop-establishment methods and weed management practices had significant interaction with each other during both the years. SRI machine transplanting with conoweeding four times at 10 days interval starting from 10 DAT (C_3W_1) recorded significantly more tillers which were comparable with SRI marker planting than conventional planting. Younger seedling, wider spacing, intermittent irrigation and mechanical weeding helped in produc-

Table 1. Effect of crop-establishment methods and weed management practices on growth, yield attributes and yields of rice (pooled data of 2 years)

Treatment	Growth attributes			Yield attributes			Yield	
	Plant height (cm)	Leaf-area index	Tillers/m^2	Panicles/m^2	Filled grains/panicle	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Crop-establishment methods								
C_1	48.9	2.97	259	250	139.7	16.8	4.05	8.94
C_2	58.1	3.74	361	286	220.2	17.25	5.66	9.80
C_3	64.7	3.91	371	311	231.2	18.45	5.85	10.91
SEm±	0.8	0.06	5.0	4.0	5.1	0.65	0.14	0.14
CD (P=0.05)	2.0	0.14	12.0	10.0	12.4	NS	0.34	0.34
Weed management								
W_1	66.9	4.18	382	320	248.0	18.6	6.36	11.62
W_2	52.6	3.12	329	278	199.4	16.3	5.32	9.53
W_3	58.5	3.78	315	259	191.3	17.2	4.49	9.17
W_4	65.8	4.09	370	317	236.3	18.6	6.32	11.47
W_5	56.8	3.58	357	294	210.7	17.8	5.97	10.18
W_6	42.8	2.46	229	226	96.6	16.4	2.66	7.35
SEm±	1.1	0.07	6.0	5.0	5.8	0.65	0.13	0.17
CD (P=0.05)	2.7	0.17	14.0	13.0	14.2	NS	0.31	0.40

C_1, conventional planting; C_2, SRI marker planting; C_3, SRI machine planting; W_1, conoweeding 4 times at 10, 20, 30, 40 DAT; W_2, PE pretilachlor @ 0.75 kg/ha + 2 times conoweeding at 20 and 40 DAT; W_3, PE pretilachlor @ 0.75 kg/ha + EPOE bispyribac @ 20 g/ha; W_4, PE pretilachlor @ 0.75 kg/ha + EPOE bispyribac @ 20 g/ha + conoweeding at 40 DAT; W_5, EPOE bensulfuron + pretilachlor @ 0.66 kg/ha + 2 times conoweeding at 30 and 40 DAT; W_6, unweeded control tion of new roots and shoots, that resulted in production of more tillers on individual hill basis. Mechanical weeding increased the soil aeration by dissolved oxygen rather than deep part of soil thus encourages more tillers/hill. This is in line with the findings of Vijayakumar *et al.* (2006).

The SRI machine planting (C_3) produced distinctly higher yield attributes, viz. more number of panicles/m^2 and grains/panicle, however, it was comparable with SRI marker planting (C_2) than conventional transplanting. This was owing to the fact that all the treatments under SRI machine transplanting produced maximum crop growth and thereby increased accumulation of photosynthates in the reproductive parts, which ultimately brought about marked improvement in yield attributes. Gnanasambandan and Murthy (2000) also reported that treatments which had better growth and yield attributes had resulted in higher grain yield, accordingly.

In vertical strips, conoweeding 4 times at 10 days interval starting from 10 DAT (W_1) produced higher yield attributes, viz. more number of panicles/m^2, grains/panicle, 1,000-grain weight, this was corroborate with the findings of Anitha and Chellappan (2011) who revealed that incorporation of weed species by frequent conoweeder weeding enriched the nutrient content of soil thereby increased yield attributes. The treatment combination of SRI machine transplanting with conoweeding four times at 10 days interval starting from 10 DAT (C_3W_1) recorded significantly higher yield attributes and was on par with SRI machine transplanting pretilachlor (0.75 kg/ha PE) + bispyribac (20 g/ha EPOE) + conoweeding at 40 DAT (C_3W_4) compared to all other combination. This was in conformity with the findings of Dhiman *et al.* (2001).

Yield

Crop-establishment methods and weed management practices had significant influence on grain yield (kg/ha) of rice (Table 1). The SRI machine transplanting (C_3) produced distinctly more grain yield than conventional transplanting (CT), however, it was comparable with SRI marker planting (C_2). This might be due to less crop weed competition (Table 1), larger root system and crop canopy and higher microbial population which facilitated the enhanced nutrient uptake, photosynthetic activity and remobilization of photosynthates to grain which resulted in higher yield attributes and yield. Chandrapala *et al*. (2010) also reported increased grain yield with SRI which was attributed to lesser competition, enhanced solar radiation interception, nutrients uptake and higher yield attributes.

Conoweeding four times at 10 days interval starting from 10 DAT (W_1) attained its statistical supremacy by producing higher grain yield, which was on par with pretilachlor *fb* bispyribac + conoweeding on 40 DAT (W_4) than unweeded control (W_6). This is supported by the re-

Table 2. Effect of crop-establishment methods and weed management practices on total weed density and dry weight at 40 DAT and economics of rice (pooled data of 2 years)

Treatment	Total weed density (Nos/m^2)	Total weed dry weight (kg/ha)	Cost of cultivation (× 10^3 ₹/ha)	Gross returns (×10^3 ₹/ha)	Net returns (×10^3 ₹/ha)
Crop-establishment methods					
C_1	9.9 (105.0)	11.6 (139.3)	2.90	60.13	57.23
C_2	7.3 (74.3)	9.6 (102.6)	3.03	58.11	55.09
C_3	6.0 (56.2)	7.6 (70.1)	0.00	26.74	26.74
SEm±	0.5 0.8				
CD (P=0.05)	1.2	2.1			
Weed management					
W_1	3.1 (9.2)*	6.6 (44.6)	37.10	81.62	44.52
W_2	10.7 (107.1)	10.5 (109.1)	32.00	107.33	75.34
W_3	4.6 (19.2)	8.3 (67.5)	28.95	116.46	87.51
W_4	3.9 (13.6)	7.4 (52.8)	2.40	61.82	59.42
W_5	6.7 (42.3)	7.6 (56.3)	3.16	53.16	50.00
W_6	17.3 (279.7)	17.5 (298.7)	2.30	45.45	43.15
SEm±	0.6	0.5			
CD (P=0.05)	1.4	1.2			

*Data subjected to square root transformation. Figures in parentheses are means of original values

C_1, conventional planting; C_2, SRI marker planting; C_3, SRI machine planting; W_1, conoweeding 4 times at 10, 20, 30, 40 DAT; W_2, PE pretilachlor @ 0.75 kg/ha + 2 times conoweeding at 20 and 40 DAT; W_3, PE pretilachlor @ 0.75 kg/ha + EPOE bispyribac @ 20 g/ha; W_4, PE pretilachlor @ 0.75 kg/ha + EPOE bispyribac @ 20 g/ha + conoweeding at 40 DAT; W_5, EPOE bensulfuron + pretilachlor @ 0.66 kg/ha + 2 times conoweeding at 30 and 40 DAT; W_6, unweeded control sults of Thiyagarajan *et al.* (2002), who found that use of conoweeder resulted increased yield of rice.

Crop-establishment methods and weed management practices had significant interaction with each other at all the crop growth stages. The SRI machine transplanting with conoweeding four times at 10 days interval starting from 10 DAT (C_3W_1) registered higher grain yield than other combinations. This might be due to larger canopy with greater root development, less intra plant competition, improved remobilization of assimilates to grain. The least grain yield was recorded under conventional planting with unweeded check (C_1W_6). Almost similar results were recorded with straw yield of rice. This corroborates the findings of Revathi (2009) who reported that higher straw yield in SRI due to higher tillers and dry matter production.

Weed density

Crop-establishment methods exerted significant influence on the total weed count (no/m^2) and total weed dry weight (kg/ha). Total weed density recorded in machine planting was significantly lower and was on par with SRI marker planting compared to conventional transplanting which recorded higher weed density in horizontal strips (Table 2). This might be due to establishment of rice crop takes easier and compete with weed faster and thereby there was lower weed population during crop period.

In vertical strips, conoweeding four times at 10 days interval recorded lesser weed density than other treatments. This might be due to the incorporation of weed species by frequent cono weeder weeding and smothering effect of the larger canopy. This is in line with the findings of Anitha and Chellappan (2011). Among the herbicidal application, PE pretilachlor 0.75 kg a.i./ha fb EPOE bispyribac sodium 20g a.i./ha + conoweeding at 40 DAT recorded significantly lower weed population in comparison of all other herbicides applied. This may be attributed to more bioefficacy of pretilachlor fb bispyribac sodium which effectively controlled both the narrow and broad-leaved weeds, mainly grassy weeds which was contributed the maximum in total density of weeds. Alone application of herbicides were least effective in minimizing the density of weeds. This might be due to better control of weeds by pre-emergence herbicides in early stages and control of later emerging weeds, particularly sedges and broad-leaved weeds by sequential application of bispyribac sodium at later stages

Weed dry weight

Total weed dry weight recorded in SRI machine transplanting was significantly lower which was on par with SRI marker planting and conventional transplanting recorded higher weed dry weight in horizontal strips (Table 2). This might be due to suppression of initial emerging and emerged weeds on one hand and better crop growth on the other which thereby had minimum weed population that tends to reduced the dry weight of weeds. The results are in agreement with the findings of Navneet and Avtar (2015).

Among the vertical strips, considerable reduction in total weed dry weight was recorded with conoweeding four times at 10 days interval which was on par at PE pretilachlor fb EPOE bispyribac sodium. This might be attributed to the lesser number of total weeds with lower biomass during the cropping period (Table 2). Conoweeding four times at 10 days interval recorded lesser weed dry weight was due to the incorporation of weed species by frequent cono weeder weeding and smothering effect of the larger canopy reduces the dry matter accumulation of weeds. This is in line with the findings of Anitha and Chellappan (2011).

Economics

Crop-establishment methods and weed management practices showed variations on cost of cultivation, income obtained (Table 2). The SRI machine transplanting along with conoweeding 4 times at 10 days interval starting from 10 DAT (C_3W_1) incurred lesser cost of cultivation and higher net returns due to lesser labour requirement for transplanting and weeding. This was followed by SRI machine transplanting along with pretilachlor (0.75 kg a.i./ha pre-emergence) + bispyribac sodium (20 g a.i./ha early post-emergence) + conoweeding at 40 DAT (C_3W_4) and SRI machine transplanting.

The present findings indicated that SRI machine transplanting with conoweeding 4 times at 10, 20, 30, 40 DAT of rice was found to be the most effective in minimizing weed growth and enhancing crop growth characters, yield-attributing characters, grain and straw yields and profitability than all the other treatment combinations. Whereas, under labour shortage condition, machine planting with application of pretilachlor (0.75 kg/ha PE) + bispyribac (20 g/ha EPOE) + conoweeding at 40 DAT was most effective to enhance the rice productivity under lowland conditions.

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