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Weed management in rice grown under System of Rice Intensification

Musthafa Kunnathadi*, C.T. Abraham and C. George Thomas
Department of Agronomy, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, Kerala 680 656

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ABSTRACT

An experiment was conducted to assess the efficacy of different weed management practices in rice grown under the System of Rice Intensification (SRI) in comparison with the conventional system. The study was carried out during 2007 and 2008 in the lateritic sandy clay loam soils at Pattambi, Kerala. Density and dry weight of weeds were higher in SRI especially when weed control was done through repeated cono weeding, while they were lower in the conventional system. Conventional system with cono weeding at 10 DAT followed by hand weeding at 30 DAT, and post-emergence herbicides alone reduced the weed dry weight significantly. Net returns and B:C ratio were also the highest in the conventional system with post-emergence application of cyhalofop-butyl 0.1 kg/ha followed by metsulfuron-methyl + chlorimuron-ethyl. In SRI, the weed density and dry weight were the lowest with pre-emergence herbicide followed by hand weeding at 30 DAT, and cono weeding at 10 DAT followed by post-emergence herbicides. However, weed control with post-emergence application of cyhalofop-butyl, followed by metsulfuron-methyl + chlorimuron-ethyl gave higher B:C ratio in both systems.

Key words: Cono weeding, Conventional system, Herbicides, System of Rice Intensification, Weed management

System of Rice Intensification (SRI) is reported as a sustainable low-cost alternative to the conventional rice farming. This system ensures high yields with less input, especially with respect to irrigation water and seed. Heavy weed growth is a major problem in SRI mainly because of the wider spacing and lack of flooding in the field. Therefore, SRI warrants repeated weeding either by hand or by machine weeders such as the cono weeder. Cono weeding is a tiresome job under non-flooding situation requiring more labour investment, and hence is not being adopted successfully leading to occasional crop loss. Latif *et al.* (2005) reported the effectiveness of using herbicides in SRI, which could reduce labour for weeding and thereby minimize economic loss in SRI. The present study aims at identifying the weed problems under SRI in comparison with the conventional system (CS) of rice cultivation and developing an economic weed management strategy in SRI.

MATERIALS AND METHODS

An experiment using the rice cultivar '*Jyothi*' (110 to 120 days) was conducted during the *Rabi* seasons of 2007 and 2008 in the lateritic sandy clay loam soils of Regional Agricultural Research Station, Pattambi in Palakkad district in Kerala. The soil was with pH 5.0 and medium fertility. The area enjoys tropical monsoon climate with >80% rainfall distributed through South-West and North-East monsoon showers. The experiment was laid out in randomized block design with 16 treatments, replicated thrice in plots of 20 m^2 gross area. Details of the treatments are given below:

T_1- SRI with four cono weedings at 10, 20, 30 and 40 days after transplanting (DAT)

T_2- SRI with pre-emergence herbicide followed by one hand weeding at 30 DAT

T_3- SRI with pre-emergence herbicide followed by one cono weeding at 30 DAT

T_4- SRI with two cono weedings at 10 and 30 DAT

T_5- SRI with one cono weeding at 10 DAT followed by one hand weeding at 30 DAT

T_6- SRI with one cono weeding at 10 DAT followed by post emergence herbicides

T_7- SRI with post emergence herbicides alone

T_8- SRI with four cono weeding at 10, 20, 30 and 40 DAT + organic manure alone (the typical SRI)

T_9- Conventional system (CS) with four cono weedings at 10, 20, 30 and 40 DAT

T_{10}- CS with pre-emergence herbicide followed by one hand weeding at 30 DAT

***Corresponding author:** musthaffa.k@kau.in

T_{11}- CS with pre-emergence herbicide followed by one cono weeding at 30 DAT

T_{12}- CS with two cono weedings at 10 and 30 DAT

T_{13}- CS with one cono weeding at 10 DAT followed by one hand weeding at 30 DAT

T_{14}- CS with one cono weeding at 10 DAT followed by post emergence herbicides

T_{15}- CS with post emergence herbicides alone

T_{16}- CS with two hand weedings at 20 and 40 DAT (Normal POP)

Pre-emergence herbicide butachlor 1.25 kg/ha was used. Post-emergence treatment included cyhalofop-butyl 0.1 kg/ha at 18 DAT followed by metsulfuron-methyl 10% + chlorimuron-ethyl 10% at 20 DAT.

In SRI, 10 days old single seedlings were transplanted at 30 x 30 cm spacing, while in the conventional system (CS), 20 days old seedlings (two each) were transplanted at 20 x 10 cm spacing. In the conventional system, water management was done as per the package of practices, whereas in SRI, irrigation was done just enough to get the soil saturated and subsequent irrigation was given as and when the soil developed fine cracks. This irrigation schedule was followed till the crop completed its tillering phase, and thereafter standing water of 2.5 cm depth was maintained in the field. Vermicompost (1.5% N, 0.4% P_2O_5, 1.8% K_2O) was used as the organic manure and chemical fertilizers, urea (46% N), phosphorus (20% P_2O_5) and muriate of potash (60% K_2O) were used to supply N, P and K, respectively.

The quantity of spray fluid used for both pre-emergence as well as post-emergence herbicides was 300 liter/ha. Cono weeding was done perpendicularly in two directions in the SRI, while in the conventional system, it was done between the rows only. Observations on growth parameters, yield attributes, and yield were recorded. Observations on weed density and weed dry weight were recorded from the sampling strip in each plot at 45 and 60 DAT, using a quadrat of size 0.5 m x 0.5 m.

The N, P and K contents of weeds at panicle initiation stage of the crop were estimated as per the standard procedures and calculated the nutrient uptake (kg/ha) by the weeds. Cost of cultivation was worked out taking into account the prevailing labour charge in the locality, cost of inputs and the extra treatment costs and expressed in `/ha. The gross return was calculated based on the local market prices of paddy and straw and expressed on per hectare basis.

RESULTS AND DISCUSSION

Major weeds in the experimental fields were: *Isachne miliacea* (grass), *Cyperus iria, Cyperus difformis*, *Fimbristylis miliacea*, and *Schoenoplectus lateriflorus* (sedges) and *Sphenoclea zeylanica*, *Ludwigia perennis* and *Dopatrium junce*um (broad-leaf weeds). Compared to sedges and broad-leaf weeds, grasses were less in SRI at 60 days after planting (Table 1). *Isachne miliacea, Cyperus iria, Fimbristylis miliacea* and *Sphenochlea zeylanica* grew taller than rice in the early growth phase of rice. Highest total weed density and weed dry weight at 45 days after planting were observed in SRI with two cono weedings at 10 and 30 days after transplanting (DAT) (T_4). At 60 days after planting also, the treatment T4 recorded the highest weed density, while the highest weed dry weight was recorded in SRI with four cono weedings at 10, 20, 30 and 40 DAT.

The results indicated higher occurrence of weeds in the System of Rice Intensification compared to the conventional system. In SRI, the practice of alternate wetting and drying created a congenial environment for proliferation of weeds and hence early and frequent weeding is essential (Singh *et al.* 2010). Increased spacing between or within rows increased light penetration to the soil surface which enhanced weed growth (Mertens and Jansen 2002). Higher weed competition under SRI compared to conventional system can be attributed to the congenial environment enjoyed by the weeds through wider plant spacing and aerobic soil condition.

Cono-weeding, either twice or four times could not check the growth of weeds even in the initial phases of crop growth in SRI as well as conventional system. The weed density at 60 days after transplanting was the highest in SRI with two cono-weeding at 10 and 30 DAT. Similarly, SRI with cono-weeding at 10, 20, 30 and 40 DAT recorded the highest weed dry weight at 60 DAT (Table 1). Further, the yield advantage in SRI through mechanical weeding as reported by Stoop *et. al.* (2002) was not observed in this study. Even though, SRI increased the number of productive tillers per hill, length of panicle as well as percentage of filled grains per panicle, the low yield in SRI, especially with twice or four times cono-weeding, was due to higher weed density and weed dry weight accompanied with lesser number of productive tillers per unit area.

Conventional system with cono weeding at 10 DAT followed by hand weeding at 30 DAT (T_{13}) recorded the lowest weed density and weed dry weight at 45 days after planting. At 60 days after planting, weed density was the lowest in the conventional system with pre-emergence herbicide followed by cono

Table 1. Density and dry weight of weeds at 60 days after planting in rice

Treatment	Weed density (no./m^2)				Weed dry weight (g/m^2)
	Grasses	Sedges	Broad-leaf weeds	Total weeds	
T_1	1.47^{cde} (2.00)	8.87^{ab} (78.33)	5.63^{b} (31.33)	10.57^{b} (111.7)	11.12^{a} (123.5)
T_2	2.53^{a} (6.00)	8.56^{bc} (73.00)	6.94^{a} (48.00)	11.27^{b} (127.0)	5.13^{d} (26.38)
T_3	1.94^{abcd} (3.33)	8.85^{ab} (78.67)	5.21^{bcd} (26.67)	10.43^{b} (108.67)	6.70^{c} (44.43)
T_4	1.29^{def} (1.33)	9.67^{a} (93.33)	7.81^{a} (60.67)	12.47^{a} (155.3)	9.44^{b} (89.84)
T_5	2.23^{ab} (4.67)	6.48^{d} (41.67)	4.90^{bcd} (23.67)	8.40^{cd} (70.00)	4.33^{de} (18.29)
T_6	2.08^{abc} (4.00)	4.52^{ef} (20.00)	3.42^{ef} (11.33)	5.97^{ef} (35.33)	3.75^{ef} (13.59)
T_7	1.94^{abcd} (3.33)	7.73^{c} (59.33)	3.38^{ef} (11.00)	8.61^{c} (73.67)	6.55^{c} (43.15)
T_8	1.29^{de} (1.33)	6.82^{d} (46.00)	3.06^{f} (9.33)	7.56^{d} (56.67)	7.16^{c} (50.75)
T_9	2.23^{ab} (4.67)	3.69^{fg} (13.33)	3.42^{ef} (11.33)	5.44^{ef} 29.33)	3.89^{e} (14.69)
T_{10}	2.08^{abc} (4.00)	3.23^{gh} (10.00)	3.80^{ef} (20.67)	5.34^{f} (28.00)	2.34^{gh} (5.05)
T_{11}	1.94^{bcde} (2.00)	2.44^{h} (5.647)	3.12^{f} (9.33)	4.16^{g} (17.00)	3.88^{e} (14.67)
T_{12}	1.29^{def} (1.33)	5.27^{e} (27.33)	5.19 ^{bcd} (27.33)	7.48^{d} (56.00)	4.99^{d} (24.43)
T_{13}	0.71^{f} (0.00)	3.62^{g} (12.67)	4.25^{cde} (17.67)	5.55^{ef} (30.33)	1.79^{h} (2.71)
T_{14}	1.76 ^{bcd} 2.67)	2.79^{gh} (7.33)	4.21^{de} (17.33)	5.27^{f} (27.33)	2.02^{gh} (3.630
T_{15}	1.00^{ef} (0.67)	3.32^{gh} (6.67)	5.24^{bc} (27.00)	6.23^{ef} (38.33)	1.54^{h} (1.88)
T_{16}	1.76^{bcd} (2.67)	4.96^{e} (24.33)	3.89^{ef} (14.67)	6.47^{e} (41.67)	2.81^{fg} (7.43)

Values are $\sqrt{x + 0.5}$ transformed, original values are in parentheses

The values followed by the same letters do not differ significantly in DMRT at 5% level

weeding at 30 DAT (T_{11}). Treatment (T_{13}) as well as conventional system with post-emergence herbicides (T_{15}) reduced the weed dry weight and nutrient removal by the weeds at 60 days after planting (Table 2). Treatment T_{15} increased the number of productive tillers per unit area, panicle length, number of filled grains/ panicle and 1000-grain weight, and produced the highest grain yield of 2.87 t/ha (Table 3). This was 32.7% higher than the grain yield in the typical SRI treatment. Conventional system with cono weeding at 10 DAT followed by hand weeding at 30 DAT (T_{13}) also produced yield at par with this, but the former recorded higher net returns and B:C ratio, which was significantly higher than the recommended practice of two hand weeding at 20 and 40 DAT.

Among the different weed control methods tried under SRI, pre-emergence herbicide combined with cono weeding at 30 DAT (T_3) recorded the lowest weed density at 45 days after planting. This was on par with pre-emergence herbicide combined with hand weeding at 30 DAT (T_2). The latter recorded the lowest weed dry weight at 45 days after planting. Pre-emergence herbicide combined with hand weeding at 30 DAT reduced densities of sedges and total weeds and the weed dry weight at 45 days after planting in SRI. At 60 DAT, cono weeding at 10 DAT combined with post-emergence herbicides (T_6) recorded the lowest densities of sedges, broad-leaf weeds and total weeds in SRI, and thereby reduced the dry weight and nutrient removal by the weeds (Table 1 and 2). SRI with pre-emergence herbicide followed by hand weeding at 30 DAT (T_2) increased the number of productive tillers/ hill, length of panicle and number of filled grains/ panicle and produced significantly higher grain yield which was 14.2% higher than the yield in the typical SRI treatment (Table 3).

Table 2. Nutrient removal by weeds at 60 days after planting in rice (kg/ha)

Treatment	N	P	K
T_1	24.05^{a}	3.88^{a}	1.52^{ab}
T_2	6.05^{de}	0.87^{d}	1.66^{a}
T_3	10.20^{c}	1.44^{c}	1.60^{ab}
T_4	16.59^{b}	2.78^{b}	1.48^{ab}
T_5	3.72^{efg}	0.56^{de}	1.64^{a}
T_6	2.94^{efg}	0.46^{def}	1.54^{ab}
T_7	7.65^{cd}	1.53^{c}	1.47^{abc}
T_8	10.12^{c}	1.51^{c}	1.39^{abc}
T_9	2.40^{fg}	0.41^{def}	1.29^{bc}
T_{10}	0.89^{g}	0.16^{ef}	0.57^{f}
T_{11}	3.12^{efg}	0.51^{def}	1.16^{cd}
T_{12}	5.00^{def}	0.74^{de}	0.66^{ef}
T_{13}	0.51^{g}	0.08^{f}	1.48^{abc}
T_{14}	0.71^{g}	0.11^{ef}	0.72^{abc}
T_{15}	0.36^{g}	0.06^{f}	0.94^{de}
T_{16}	1.19^{g}	0.25^{def}	0.71^{ef}

The values followed by the same letters do not differ significantly in DMRT at 5% level

Table 3. Effect of treatments on yield and economics of rice cultivation

Treatment	Productive tillers (no./hill)	Panicle length (cm)	Filled grains (%)	Grain yield (t/ha)	Straw yield (t/ha)	Net returns (x10^3 `/ha)	B:C ratio
T_1	21.9^{ab}	20.1^{ab}	87.3^{a}	1.88^{fg}	1.90^{cdef}	-11.01^{h}	0.72^{g}
T_2	23.5^{a}	20.4^{a}	82.0^{b}	2.47^{bcde}	2.29^{ab}	-3.84^{efg}	0.91^{def}
T_3	23.6^{a}	20.5^{a}	82.5^{ab}	1.60^{g}	1.94^{bcdef}	-11.76^{h}	0.68^{g}
T_4	18.5^{b}	20.0^{abc}	80.8^{b}	1.86^{fg}	2.26^{abc}	-8.04^{gh}	0.78^{fg}
T_5	22.1^{a}	20.5^{a}	82.1^{b}	2.51^{abcde}	2.23^{ab}	-4.34^{fg}	0.90^{ef}
T_6	23.2^{a}	20.3^{ab}	83.1^{ab}	2.33^{de}	2.51^{a}	-2.42^{cdef}	0.94^{de}
T_7	21.7^{ab}	20.3^{ab}	80.1^{b}	2.28^{de}	2.17^{abcde}	-1.05^{bcdef}	0.97^{cde}
T_8	21.3^{ab}	20.5^{a}	83.0^{ab}	2.16^{ef}	2.47^{a}	-3.26^{defg}	0.91^{def}
T_9	8.6^{c}	18.6^{de}	80.3^{b}	2.41^{cde}	2.00^{bcde}	1.86^{bcd}	1.05^{bcd}
T_{10}	10.3^{c}	18.7^{de}	81.9^{b}	2.81^{ab}	2.04^{bcdef}	4.43^{ab}	1.12^{b}
T_{11}	9.7^{c}	18.7^{de}	82.8^{ab}	2.35^{de}	1.97^{bcdef}	1.74^{bcde}	1.05^{bcd}
T_{12}	9.1^{c}	18.7^{de}	82.4^{ab}	2.85^{ab}	1.93^{bcdef}	9.35^{a}	1.29^{a}
T_{13}	8.9^{c}	19.8^{abc}	82.2^{b}	2.78^{abc}	1.87^{def}	4.19^{ab}	1.11^{bc}
T_{14}	9.5^{c}	19.0^{cde}	83.2^{ab}	2.56^{abcd}	1.82^{ef}	3.12^{bc}	1.09^{bc}
T_{15}	10.6^{c}	19.3^{bcd}	83.6^{ab}	2.87^{a}	2.04^{bcdef}	8.90^{a}	1.27^{a}
T_{16}	9.0^{c}	18.2^{e}	81.5^{b}	2.60^{abcd}	1.75^{f}	0.67^{bcdef}	1.02^{bcde}

The values followed by the same letters do not differ significantly in DMRT at 5% level

Economic analysis of the treatments showed that the net return and B:C ratio were the highest in the treatments where the weeds were controlled by post-emergence herbicides in the conventional (T_{15}) and SRI (T_7) systems of growing rice (Table 3). Cono weeding at 10 and 30 DAT (T_{12}) was at par with post-emergence herbicide treatment (T_{15}) in the conventional system but it could not repeat its performance in SRI.

It was concluded that weed control by post-emergence herbicides was superior in SRI as well as conventional system of rice cultivation. Even though hand weeding or cono weeding performed at par with post-emergence herbicides in reducing the weed dry weight, weed control with post-emergence application of cyhalofop-butyl followed by metsulfuron-methyl + chlorimuron-ethyl resulted in higher net returns and B:C ratio.

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