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Weed Management Practices on Weed Characters, Plant Growth and Yield of Rice Under System of Rice Intensification

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A field experiment was conducted during *Kharif* 2009 at Tamil Nadu Agricultural University, Coimbatore to evaluate weed management practices for System of Rice Intensification (SRI). The treatments comprised of different weed management practices *viz.*, recommended weed management practice *i.e.* 4 times conoweeding from 10 DAT at 10 days interval and conoweeding 3 times at 20, 30 and 40 DAT. These two treatments in single and in combination with three different herbicides *viz.*, almix @ 20 g a.i. ha^{-1}, butachlor @ 1 kg a.i. ha^{-1} and pretilachlor @ 0.75 kg a.i. ha^{-1} were tested along with unweeded control treatment. The weed flora of the experimental field were *Echinochloa crus-galli* (L.), *Cyperus difformis* (L.), *Eclipta alba* (L.) and *Ammania baccifera* (L.). The results revealed that application of pretilachlor as PE @ 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) was very effective in controlling the weeds and recorded the least weed density. The weed control efficiency (total and grassy weeds) as well as the plant growth components and yield were higher when rice was applied with Pretilachlor @ 0.75 kg a.i. ha^{-1} as pre-emergence + 4 times conoweeding from 10 DAT at 10 days interval, which was followed by the treatment of application of butachlor @ 1 kg a.i. ha^{-1} as pre-emergence + 4 times conoweeding from 10 DAT at 10 days interval.

Key words: SRI, weed management, Almix^{TM}, butachlor, pretilachlor, growth components, yield.

Rice (*Oryza sativa* L.) is one of the most important cereal crop as it is a staple food for more than 70 per cent of the world population. The System of Rice Intensification (SRI) developed in Madagascar follows a more comprehensive approach addressing various management practices at the same time with promising results (Uphoff, 2001; Stoop *et al.*, 2002). The SRI practices have been found to save inputs substantially and increase returns. Greater yield losses can occur at times when weed competition coincides with the critical periods of growth of crops (Carbonell and Moody, 1982). During early establishment, weeds make 20 to 30 per cent of their growth while crop makes only two to three per cent of its growth (Moody, 1990). Continuous use of these herbicides in transplanted rice resulted in the increased trend of non-grassy weeds (Upadhyay and Gogoi, 1993). Use of alternative herbicides that provide wide-spectrum weed control would be desirable for effective weed control. One of the most important classes of herbicides that have been used popularly all over the world is sulfonylurea group of herbicides. Among several sulfonylurea herbicides, Almix™ (*Metsulfuron Methyl 10% +Chlorimuron Ethyl 10%)* is a selective herbicide for rice at very low rate of 20 g *a.i.* ha^{-1}. Almix™ has a flexibility of application at pre-emergent stage (3-5 DAT) as well as at post emergent stage (21-25 DAT).

Materials and Methods

Field experiment was conducted during *Kharif,* 2009 at wetland farm of Tamil Nadu Agricultural University, Coimbatore to evaluate weed management practices for System of Rice Intensification (SRI). The soil was deep clay loam (vertic ustochrep) having P^H 8.0, EC 0.45 dS m^{-1}, organic carbon 0.68 per cent, available N, P_2O_5 and K_2O of 231.0, 18.6 and 458.0 kg ha^{-1}, respectively. Seeds of CO(R) 49 rice variety was sown on raised bed nursery on 19.08.2009 and transplanted on 01.09.2009 at a spacing of 25 cm × 25 cm. There were nine treatments including recommended weed management practice *i.e.* 4 times conoweeding from 10 DAT at 10 days interval and conoweeding 3 times at 20, 30 and 40 DAT either alone or in combination with three herbicides like almix @ 20 g a.i. ha^{-1}, butachlor @ 1 kg a.i. ha^{-1} and pretilachlor @ 0.75 kg a.i. ha^{-1} along with an unweeded control. The treatments were T_1: Recommended weed management practice *i.e.* 4 times conoweeding in both the directions from 10 DAT at 10 days interval with hand removal of left out weeds, T_2: Conoweeding 3 times at 20, 30 and 40 DAT in both the directions, T_3: Almix^{TM} @ 20 g a.i. ha^{-1} as POE herbicide + T_1, T_4: Butachlor 50 EC @ 1 kg a.i. ha^{-1} as PE herbicide + T_1, T_5: Pretilachlor 50 EC @ 0.75 kg a.i. ha^{-1} as PE herbicide + T_1, T_6: Almix^{TM} @ 20 g a.i. ha^{-1} as POE herbicide + T_2, T_7: Butachlor 50 EC

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@ 1 kg a.i. ha^{-1} as PE herbicide + T_2, T_8: Pretilachlor 50 EC at 0.75 kg a.i. ha^{-1} as PE herbicide + T_2 and T_9: Unweeded control. The experiment was laid out in randomized block design with three replication. As per treatment schedule, pre-emergence herbicide butachlor @1 kg a.i. ha^{-1} was applied on 3rd DAT (T_4 and T_7). The other pre-emergence herbicide pretilachlor was also applied @ 0.75 kg a.i. ha^{-1} on 3rd DAT (T_5 and T_8). The post-emergence herbicide almix @ 20 g a.i. ha^{-1} was applied on 15th DAT (T_3 and T_6). A thin film of water was maintained at the time of herbicide application. The unweeded check (T_9) was kept undisturbed for the entire cropping period. As per the treatment schedule, hand operated conoweeder was operated 4 times (T_1, T_3, T_4 and T_5) and 3 times (T_2, T_6, T_7 and T_8) between the rows in both the directions to incorporate weeds with simultaneous stirring up of soil. The left over weeds were taken out by hand weeding. The data on weed density, weed dry weight, plant height, leaf area index, number of tillers hill^{-1} and dry matter production (DMP) of rice was recorded at 30, 45 and 60 DAT.

Results and Discussion

Total weed density and total weed dry weight

Application of pretilachlor as PE @ 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) was very effective in controlling the weeds and reported the lowest weed density. This treatment caused a reduction in total weed density (Mean value of 30 DAT, 45 DAT and 60 DAT values) to the tune of 89 per cent over unweeded check (Table 1). With the use of herbicide like pretilachlor, the density of weeds was brought down significantly as compared to those under untreated check (Chin *et al.,* 2007). Application of butachlor as PE @ 1 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_4) also recorded lower weed density. Kabir *et al.* (2008) reported that the lowest weed density was observed in the treatment receiving

Table 1. Effect of weed management practices on total weed density, total weed dry weight, weed control efficiency (WCE) and weed index

Treatment	Total Weed Density			Total weed dry weight			Weed control efficiency (WCE)			Weed index
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	
T_1 - Recommended weed management practice i.e. 4 times conoweeding from 10 DAT at 10 days interval	2.61 (11.67)	2.43 (9.34)	2.20 (7.00)	2.21 (7.15)	1.61 (3.00)	2.12 (6.32)	90.88	97.93	98.61	11.98
T_2 - Conoweeding 3 times at 20, 30 and 40 DAT	3.06 (19.34)	3.08 (19.67)	2.89 (16.00)	2.88 (15.77)	2.30 (8.00)	2.68 (12.59)	79.87	94.49	97.24	29.22
T_3 - Almix^{TM} at 20 g a. i. ha^{-1} as POE + T_1	2.40 (9.00)	2.20 (7.00)	2.08 (6.01)	2.05 (5.80)	1.49 (2.44)	1.87 (4.50)	92.60	98.32	99.01	7.71
T_4 - Butachlor 50 EC at 1 kg a. i. ha^{-1} as PE + T_1	2.27 (7.67)	2.16 (6.67)	1.99 (5.34)	1.88 (4.58)	1.39 (2.00)	1.78 (3.92)	94.16	98.62	99.14	4.40
T_5 - Pretilachlor 50 EC at 0.75 kg a. i. ha^{-1} as PE + T_1	2.08 (6.00)	1.90 (4.67)	1.67 (3.33)	1.68 (3.36)	1.21 (1.35)	1.42 (2.14)	95.71	99.07	99.53	0.0
T_6 - Almix^{TM} at 20 g a. i. ha^{-1} as POE + T_2	2.85 (15.34)	2.89 (16.01)	2.69 (12.67)	2.60 (11.49)	2.07 (5.89)	2.49 (10.12)	85.34	95.94	97.78	21.74
T_7 - Butachlor 50 EC at 1 kg a. i. ha^{-1} as PE + T_2	2.81 (14.66)	2.85 (15.33)	2.59 (11.34)	2.56 (10.93)	2.02 (5.54)	2.27 (7.70)	86.05	96.18	98.31	20.60
T_8 - Pretilachlor 50 EC at 0.75 kg a. i. ha^{-1} as PE + T_2	2.64 (12.00)	2.69 (12.67)	2.43 (9.33)	2.39 (8.96)	1.79 (3.98)	2.14 (6.52)	88.57	97.26	98.57	17.81
T_9 - Unweeded control	3.67 (37.34)	4.16 (62.00)	3.65 (36.66)	4.39 (78.36)	4.99 (145.20)	6.13 (455.72)	0.00	0.00	0.00	69.15
SEd	**0.12**	**0.14**	**0.14**	**0.15**	**0.12**	**0.11**				
CD (P=0.05)	0.26	0.29	0.30	0.31	0.26	0.24				

PE - Pre-emergence POE - Post emergence
Log (x+2) transformation values. Figures in parenthesis are means of original values.

Butachlor 5G @ 2 kg ha^{-1} accompanied by one hand weeding at 40 DAT under good water management. The weed density was lower at 45 and 60 DAT compared to 30 DAT due to the control of late emerged weeds with subsequent conoweedings and in SRI due to wider spacing in early stage of the crop, weeds grow vigorously. Unweeded control registered the highest total weed density at all the stages of observation *viz.*, 30, 45 and 60 DAT. The unweeded control (T_9) has recorded significantly higher total weed density of 3.67, 4.16 and 3.65 m^{-2} at 30, 45 and 60 DAT, respectively.

Significant variations were observed on total weed dry weight at 30, 45 and 60 DAT, respectively (Table 1) due to the adoption of weed management practices. Application of pretilachlor as PE @ 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) registered the lowest total weed dry weight. This might be due to effective control of weeds by the integration of herbicides with

conoweeding. Similar finding was reported by Bhowmick (2002). Application of butachlor as PE @ 1 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_4) was comparable with treatment T_5 in respect of total weed dry weight. Butachlor @ of 1 kg a.i. ha^{-1} was very effective in controlling the grassy weeds when applied as PE as reported by Schillar and Indaphum (1979). Noticeable reduction in weed dry weight was observed with application of pretilachlor as PE @ 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) at 30, 45 and 60 DAT, respectively compared to unweeded check. This was due to the reduction of weed dry weight considerably with better weed control efficiency, and this is in line with the findings of Prabhakaran and Chinnusamy (2008).

Weed control efficiency (WEC) and weed index (WI)

Weed control efficiency indicates the comparative magnitude of reduction in weed dry weight by weed control treatments. Due to reduced weed density, the weed dry weight was very much reduced in the treatments. Weed control efficiency was highly influenced by different treatments throughout the crop period (Table 1). Weed control efficiency was higher with the application of pretilachlor as PE @ 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5). Balasubramanian *et al.* (1996) also reported that the higher weed control efficiency was obtained in pretilachlor (84.3%) compared to other herbicides. Application of

Table 2. Effect of weed management practices on plant height (cm), leaf area index (LAI) and number of tillers hill^{-1} of rice

Treatment	Plant height (cm)			Leaf Area index (LAI)			No. of tillers hill^{-1}		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
T_1 - Recommended weed management practice i.e. 4 times conoweeding from 10 DAT at 10 days interval	31.13	41.25	57.96	7.00	14.07	23.87	0.40	1.82	4.95
T_2 - Conoweeding 3 times at 20, 30 and 40 DAT	28.30	40.15	51.64	6.60	11.80	21.07	0.34	1.25	3.46
T_3 - Almix^{TM} at 20 g a. i. ha^{-1} as POE + T_1	31.47	42.32	58.03	7.93	14.93	24.33	0.42	2.03	5.08
T_4 - Butachlor 50 EC at 1 kg a. i. ha^{-1} asPE + T_1	32.40	43.04	58.64	8.00	15.80	24.67	0.42	2.18	5.44
T_5 - Pretilachlor 50 EC at 0.75 kg a. i. ha^{-1}as PE + T_1	33.43	44.57	59.32	8.33	16.60	25.07	0.43	2.28	5.71
T_6 - Almix^{TM} at 20 g a. i. ha^{-1} as POE + T_2	29.45	40.92	53.10	6.73	13.80	22.67	0.35	1.64	4.28
T_7 - Butachlor 50 EC at 1 kg a. i. ha^{-1} asPE + T_2	29.49	41.00	54.04	6.80	13.93	22.91	0.36	1.63	4.41
T_8 - Pretilachlor 50 EC at 0.75 kg a. i. ha^{-1}as PE + T_2	30.39	41.10	54.67	6.93	14.01	23.67	0.38	1.69	4.50
T_9 - Unweeded control	21.63	32.62	48.80	4.87	9.87	16.90	0.28	1.22	2.74
SEd	1.21	1.57	1.69	0.55	0.88	0.98	0.02	0.07	0.23
CD (P=0.05)	2.61	3.38	3.63	1.17	1.88	2.11	0.04	0.15	0.49

PE - Pre-emergence POE - Post emergence

butachlor as PE @ 1 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_4) was second in weed control efficiency. Butachlor @ 1.5 kg a.i. ha^{-1} was effective in controlling rice weeds in transplanted condition (Shahid *et al.,*1979).

Weed index is a measure of yield loss caused due to varying degree of weed competition compared to the relatively weed free condition throughout the crop period leading to higher productivity as shown in Table 1. In the present study, application of butachlor as PE @ 1 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_4) was the best treatment after T_5 as it resulted in 4.40 per cent yield reduction. It was followed by the application of almix as POE @ 20 g a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_3) which resulted in 7.71 per cent yield reduction. The largest yield reduction (69.15 per cent) was observed in unweeded control (T_9). Singh *et al.* (2000) reported a reduction in the grain yield of weedy check to the tune of 50.1 per cent.

Plant height (cm) and leaf area index (LAI)

Adoption of different weed management practices produced distinct variations on the height of plants at all the stages (Table 2). Application of pretilachlor as pre-emergence at 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) registered taller plants (33.43 cm at 30 DAT, 44.57 cm at 45 DAT and 59.32 cm at 60 DAT). It was comparable with application of butachlor as pre-emergence at 1 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_4) and application of almix as post-emergence at 20 g a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_3). This might be due to the better weed control at different growth stages of the crop. This resulted in the availability of all resources *viz.*, light, moisture, space and nutrients to the crop plants at different stages. Similar finding was reported by Ramana *et al.* (2007). Payman and Singh (2008) observed tallest rice plants with pretilachlor application at 0.75 kg ha^{-1}. Unweeded control (T_9) registered shorter plants.

LAI determines the total assimilating area available to the plant and quantum of source that would ultimately be available for translocation to the sink. At all the stages of observation *viz.*, 30, 45 and 60 DAT leaf area index was significantly influenced by different weed management practices. Application of pretilachlor as pre-emergence at 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days

interval (T_5) increased the leaf area index at all the stages of observation *viz.*, 30, 45 and 60 DAT. This might be due to better control of weeds and less competition by weeds. Umapathi (1998) also stated that leaf area index was higher in less weed competition treatments.

Number of tillers hill^{-1}and Dry matter production (DMP)

With regard to tiller production, application of pretilachlor as pre-emergence at 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) recorded higher number of tillers hill^{-1} which was comparable with the application of butachlor as pre-emergence at 1 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (Table 2). This might be due to less competition by weeds and good soil aeration by the use of cono weeder. Similar findings were reported by Misra and Sahoo (1971) and Shad (1986). Unweeded control (T_9) recorded the lowest number of tillers hill^{-1}. It might be due to severe weed competition from the early stage onwards. These findings were in conformity with the findings of Kalita and Gogoi (1994).

The dry matter production was significantly influenced by the different weed management practices (Table 3). Application of pretilachlor as pre-emergence at 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) registered higher dry matter production of 1170, 4082 and 7529 kg ha^{-1} at 30, 45 and 60 DAT, respectively. The increased growth and yield parameters might be due to broad spectrum of weed control and selectivity to rice crop. This result is in conformity with the results of Karuppiah (1995), who observed more dry matter production in minimum weed competition plots. The lowest dry matter production was recorded under unweeded control (T_9), which might be due to maximum utilization of resources by weeds and severe competition exerted by weeds throughout the growth period of rice. This observation is in conformity with the reports of Janardhan *et al.* (1999).

Table 3. Effect of weed management practices on crop dry matter production (DMP), grain yield (kg ha^{-1}), and straw yield (kg ha^{-1}) of rice

Treatment	Crop dry matter production (DMP) (Kg ha^{-1})			Grain yield and straw yield		
	30 DAT	45 DAT	60 DAT	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1 - Recommended weed management practice i.e. 4 times conoweeding from 10 DAT at 10 days interval	1110	3540	7054	5161	9011	0.36
T_2 - Conoweeding 3 times at 20, 30 and 40 DAT	1057	3105	6662	4150	8261	0.33
T_3 - Almix^{TM} at 20 g a. i. ha^{-1} as POE + T_1	1123	3716	7232	5411	9217	0.37
T_4 - Butachlor 50 EC at 1 kg a. i. ha^{-1} as PE + T_1	1149	3902	7348	5606	9500	0.37
T_5 - Pretilachlor 50 EC at 0.75 kg a. i. ha^{-1} as PE + T_1 **T_6 -** Almix^{TM} at 20 g a. i. ha^{-1} as POE + T_2	1170	4082	7529	5863	9772	0.38
T_7 - Butachlor 50 EC at 1 kg a. i. ha^{-1} as PE + T_2	1006	3301	6672	4589	8461	0.35
T_8 - Pretilachlor 50 EC at 0.75 kg a. i. ha^{-1} as PE + T_2 **T_9 -** Unweeded control	1066	3365	6704	4656	8522	0.35
SEd	1090	3416	6808	4819	8717	0.36
CD (P=0.05)	870	2256	4684	1808	3094	0.33
	39	155	275	297	291	0.02
	83	334	591	638	625	NS

PE - Pre-emergence POE - Post emergence

Grain and straw yield

Among the different weed control treatments, application of pretilachlor as PE @ 0.75 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_5) registered higher grain yield of 5863 kg ha^{-1} and straw yield of 9772 kg ha^{-1} (Table 3). This treatment was comparable with application of butachlor as PE @ 1 kg a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_4) and application of almix as POE @ 20 g a.i. ha^{-1} + 4 times conoweeding from 10 DAT at 10 days interval (T_3). This might be due to weed free environment created from the early stage up to harvest, leading to the production of effective tillers, longer panicles and more number of grains panicle^{-1} compared to all other treatments. However, unweeded control (T_9) recorded 69.15 per cent lesser yield due to higher weed competition and lower availability of nutrients to the crops resulted in lower grain and straw yield in control plot and this was conformity with the findings of Vinod Kumar *et al.* (1998).

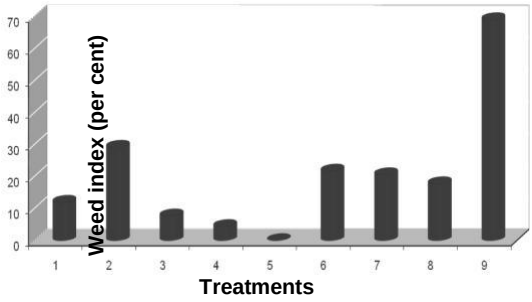

Fig1. Effect of weed management practices on weed index

Conclusion

The common weeds of the experimental field consisted of grasses, sedges and broad leaved weeds (BLW) from unweeded check at flowering stage of the crop. The major grass weed was *Echinochloa crus-galli* (L.) and the major sedge weed was *Cyperus difformis* (L.). Among the broad leaved weeds *Eclipta alba* (L.) and *Ammania baccifera* (L.) were the dominant species. Pretilachlor application at 0.75 kg a.i. ha^{-1} as pre-emergence + 4 times conoweeding from 10 DAT at 10 days interval has registered higher total weed and grass weed control efficiency and proved better in terms of growth attributes of rice *viz.*, plant height, number of tillers $hill^{-1}$, LAI and DMP throughout the crop period.

Among the weed control treatments, application of pretilachlor at 0.75 kg a.i. ha^{-1} as pre-emergence + 4 times conoweeding from 10 DAT at 10 days interval registered higher grain yield of 5863 kg ha^{-1} followed by application of butachlor at the rate of 1 kg a.i. ha^{-1} as pre-emergence + 4 times cono weeding from 10 DAT at 10 days interval, application of almix at 20 g a.i. ha^{-1} as post-emergence + 4 times conoweeding from 10 DAT at 10 days interval. All these three treatments are comparable with each other. The highest straw yield of 9772 kg ha^{-1} was registered with application of pretilachlor at 0.75 kg a.i. ha^{-1} as pre-emergence + 4 times conoweeding from 10 DAT at 10 days interval and it was comparable with application of butachlor at 1 kg a.i. ha^{-1} as pre-emergence + 4 times conoweeding from 10 DAT at 10 days interval and application of almix at 20 g a.i. ha^{-1} as post-emergence + 4 times conoweeding from 10 DAT at 10 days interval.

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