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Labour-saving weed management practices in transplanted rice

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Abstract
Field research was conducted during *rabi* season of 2011-2012 at Agricultural College and Research Institute, Killikulam, Tamil Nadu to evolve the labour-saving weed management practice in transplanted rice. The experiment was consisted of 12 treatments laid out in randomized block design with three replications. The treatments comprised of application of pre-emergence herbicides *viz.,* oxadiargyl 80% WP @ 70 g ha^{-1}, butachlor 50% EC @ 1.25 kg ha^{-1}, metsulfuron methyl 10% + chlorimuron ethyl 10% WP @ 4 g ha^{-1}, bensulfuron methyl 0.6% + pretilachlor 6% GR @ 660 g ha^{-1} on 3 DAT along with post-emergence herbicide 2, 4-D Na salt @ 1.25 kg ha^{-1} or hand weeding on 35 DAT. In addition, the rotary weeding and hand weeding twice on 15 and 35 DAT and weed free conditions were tested with unweeded check. The results revealed that pre-emergence application of bensulfuron methyl + pretilachlor at 660 g a.i. ha^{-1} on 3 DAT with one hand weeding on 35 DAT recorded significantly lower weed dry weight (37.80 kg ha^{-1}) and nutrient removal by weeds (1.25 N, 0.13 P_2O_5 and 0.87 K_2O kg ha^{-1}, respectively). This treatment also recorded higher grain and straw yield (6710 and 7717 kg ha^{-1}, respectively) with higher number of productive tillers m^{-2} (427), dry matter production (14668 kg ha^{-1}) and N, P_2O_5 and K_2O uptake of 93.88, 35.20 and 108.54 kg ha^{-1}, respectively. Further the gross return, net return and B:C ratio were also higher with this treatment.

Keywords: bensulfuron methyl, butachlor, chlorimuron ethyl, metsulfuron methyl, oxadiargyl, pretilachlor, rice, Weed management.

Introduction
In India, rice is cultivated in an area of 44 million hectares annually with a production of 103 million tonnes, with an average productivity of 2.3 t ha^{-1}. The average yield of rice in India is very low due to several constrains. Among them, weeds pose a major threat for increasing rice productivity. Uncontrolled weed growth caused 33-45% reduction in grain yield of rice (Manhas *et al*., 2012) [5].

Unlike other cereal crops, rice suffers more from weed competition. Weeds grow profusely in the rice fields and reduce crop yields drastically. Manual weeding although effective and most common practice of weed control in transplanted rice, these have several limitations particularly scarcity of labour at peak season, difficult to differentiate and remove the grassy weeds especially *Echinochloa colona* and *Echinochloa crus-galli*, due to phenotypical similarities between weeds and rice seedlings in the early stages. Raising cost of labour and their non-availability also lead to the search for alternative methods such as herbicide use either alone or in combination with hand weeding (Rao and Nagamani, 2007) [7] and herbicides offer the most effective, economical and practical way of weed management (Hussain *et al*., 2008) [3]. The present study was undertaken to evaluate the effective and economic weed management practice in transplanted rice during *rabi* season.

Materials and Methods
A field experiment was conducted during *rabi* season of 2011 to 2012 at Agricultural College and Research Institute, Killikulam, Tamil Nadu. The soil of the experimental site was sandy clay loam in texture and pH was normal (7.02). The soil was low in nitrogen (245.0 kg ha^{-1}), medium in phosphorus (18.5 kg ha^{-1}) and potassium (234.0 kg ha^{-1}). The organic content was medium (0.58 %) in range. Rice variety ADT (R) 47 with the duration of 118 days was used as test variety, transplanted with a spacing of 25 cm x 25 cm. Experiments consisting 12 treatments *i.e*., T_1- PE Bensulfuron methyl 0.6% + Pretilachlor 6% GR @ 660 g ha^{-1} on 3 DAT + PoE 2, 4-D Sodium salt @ 1.25 kg ha^{-1} on 35 DAT, T_2- PE Metsulfuron methyl 10% +

Chlorimuron ethyl 10% WP @ 4 g ha^{-1} on 3 DAT + PoE 2,4-D Sodium salt @ 1.25 kg ha^{-1} on 35 DAT, T_3- PE Oxadiargyl 80% WP @ 70 g ha^{-1} on 3 DAT + PoE 2,4-D Sodium salt @ 1.25 kg ha^{-1} on 35 DAT, T_4- PE Butachlor 50% EC @ 1.25 kg ha^{-1} on 3 DAT + PoE 2,4-D Sodium salt @ 1.25 kg ha^{-1} on 35 DAT, T_5- PE Bensulfuron methyl 0.6% +Pretilachlor 6% GR @ 660 g ha^{-1} on 3 DAT + Hand weeding on 35 DAT, T_6- PE Metsulfuron methyl 10% + Chlorimuron ethyl 10% WP @ 4 g ha^{-1} on 3 DAT + Hand weeding on 35 DAT, T_7- PE Oxadiargyl 80% WP @ 70 g ha^{-1} on 3 DAT + Hand weeding on 35 DAT, T_8- PE Butachlor 50% EC @ 1.25 kg ha^{-1} on 3 DAT + Hand weeding on 35 DAT, T_9- Hand weeding on 15 and 35 DAT, T_{10}- Rotary weeding on 15 and 35 DAT, T_{11}- Weed free plot, T_{12}- Control was laid out in randomized block design with three replications.

Irrigation was given to a depth of 2 cm was maintained upto 7 DAT for proper establishment of seedlings. After seedling establishment, irrigation was given to a 5 cm depth, one day after disappearance of previously ponded water and continued 10 days before harvest of the crop. Five plants were randomly selected from sampling area and they were cut close to the ground level at harvest stage. These samples were chopped, air-dried in the shade and then oven dried at 70 ºC for 72 hours till the attainment of constant weight. The dry weight was recorded using an electronic top pan balance and the dry matter was expressed in kg ha^{-1}. The ear bearing tillers per quadrat (0.25 m^2) were counted randomly at four places in each net plot pooled and expressed as No. m^{-2}. The border rows all around the plots were harvested first and then the net plot of each treatment was harvested and threshed, cleaned and the grain weight was recorded treatment wise. Grain yields were adjusted to 14 per cent moisture and expressed in kg ha^{-1}. The straw yield was computed based on the dry weight of the straw sun dried for three days and expressed in kg ha^{-1}. Plant and weed samples collected for dry matter estimation at harvest stage and 55 DAT, respectively from the respective treatments were oven dried and finely ground in Willey mill and used for estimating N, P_2O_5 and K_2O content using following methods and uptake of nutrients was calculated by multiplying the nutrient content and dry matter and expressed in kg ha^{-1}.

Table 1

Particulars	Method adopted	Reference
1. Nitrogen (kg ha^{-1})	Microkjeldahl method	Humphries (1956)
2. Phosphorus (kg ha^{-1})	Triple acid digestion with colorimetric estimation	Jackson (1973)
3. Potassium (kg ha^{-1})	Triple acid digestion with flame photometric method	Jackson (1973)

The data of weed dry weight was recorded from 0.5 X 0.5 m^2 quadrat at 55 DAT. Since the data on weed dry weight showed high variation, the data were subjected to square root transformation using the formula $\sqrt{x} + 0.5$ and the statistical analysis was done as per the procedures given by Gomez and Gomez (1984). The treatment differences were worked out at 5% probability level. The non-significant treatment differences were denoted as NS. Weed control index (WCI) (Mishra and Tosh, 1979) [6] was calculated as per the standard formulae.

$$WCI\ (\%) = \frac{Wdc - Wdt}{Wdc} \times 100 \ldots\ldots\ldots\ldots (1)$$

Where,

Wdc = Dry weight of weeds in control plot (kg ha^{-1})

Wdt = Dry weight of weeds in treated plot (kg ha^{-1})

Results and Discussion

Effect on Weed

Pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT with one hand weeding on 35 DAT recorded lower weed dry weight. Whereas unweeded check recorded significantly higher weed dry weight (Table 2). Higher weed control index was recorded with pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT with one hand weeding on 35 DAT. This might be due to the control of weeds at germination phase by the pre emergence application of herbicides and significant reduction at later growth stage as late germinating weeds were removed by hand weeding. The results were in agreement with the findings of Sunil *et al.* (2010) [9] and Sanjoy Saha and Rao (2010) [8].

Among various weed control treatments, pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT with one hand weeding on 35 DAT registered lower nutrient removal by weeds (1.25, 0.13 and 0.87 kg ha^{-1} N, P_2O_5 and K_2O, respectively). Sunil *et al.* (2010) [9] stated the reasons clearly that this was due to less weed competition and low weed biomass production.

Effect on Crop

The weed free treatment recorded higher dry matter production and productive tillers of 15082 kg ha^{-1} and 439 m^{-2}, which was on par with pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT *fb* one hand weeding on 35 DAT (14668 kg ha^{-1} and 427 m^{-2}, respectively). This might be due to the lesser weed competition as weeds might have been killed from their germination phase and keeping weeds at lower densities.

Among various weed management practices higher nutrient uptake recorded with pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT with one hand weeding on 35 DAT. The nutrient uptake in this treatment was 93.88, 35.20 and 108.54 kg NPK ha^{-1}. The reduced weed growth and consequently decreased nutrient depletion enabled more nutrient uptake by the rice in the above promising weed management practice.

Weed free treatment registered higher grain and straw yield. Among the herbicidal treatments pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT with one hand weeding on 35 DAT recorded higher grain yield (6710 kg ha^{-1}) and straw yield (7717 kg ha^{-1}) (Table 3). This was achieved by way of effective, early weed control through herbicide and a hand weeding later which prevented the crop-weed competition and increased NPK uptake by crop which inturn increased the growth and yield attributes. Earlier findings by Sunil *et al.* (2010) [9] and Sanjoy Saha and Rao (2010) [8] corroborate the present findings.

Effect on Economics

Higher cost of cultivation (₹ 35,300 ha^{-1}) was realized due to frequent hand weeding in weed free plot, followed by hand weeding twice on 15 and 35 DAT (₹ 27,800 ha^{-1}). maximum gross return (₹ 91,460 ha^{-1}) was obtained with weed free treatment followed by pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT *fb* one hand weeding on 35 DAT (₹ 90,250 ha^{-1}). Among various treatments, pre-emergence application of bensulfuron methyl

+ pretilachlor at 660 g ha^{-1} on 3 DAT *fb* one hand weeding on 35 DAT recorded the highest net return of ₹ 63,025 ha^{-1} and B:C ratio of 3.31 (Table 4). Though higher grain yield and gross return were obtained with weed free treatment, the net return and B: C ratio were less because of higher cost of cultivation.

Table 1: Effect of weed management practices on weed dry weight (kg ha^{-1}), weed control index (%) and nutrient removal by weeds (kg ha^{-1}) on 55 DAT.

Treatments	Weed dry weight (kg ha^{-1})	WCI (%)	Nutrient removal by weeds (kg ha^{-1})		
			N	P_2O_5	K_2O
T_1	761.63 (27.60)	81.04	25.90	2.67	19.04
T_2	1811.19 (42.56)	54.90	59.77	6.16	41.66
T_3	776.04 (27.86)	80.68	27.16	2.56	19.40
T_4	975.00 (31.22)	75.72	34.13	3.41	23.40
T_5	37.80 (6.15)	99.06	1.25	0.13	0.87
T_6	57.94 (7.61)	98.56	1.97	0.20	1.45
T_7	39.50 (6.28)	99.02	1.34	0.13	0.99
T_8	76.38 (8.74)	98.10	2.52	0.25	1.76
T_9	37.20 (6.10)	99.07	1.30	0.13	0.93
T_{10}	56.52 (7.52)	98.59	1.98	0.19	1.36
T_{11}	0.00 (0.71)	100.00	0.00	0.00	0.00
T_{12}	4016.28 (63.37)	-	136.55	13.86	100.41
SEd	1.13	NA	1.06	0.17	1.06
CD (p=0.05)	2.34	NA	2.10	0.22	2.19

* Figures in parentheses are square root transformed values. NA- Not Analyzed

Table 2: Effect of weed management practices on growth, yield and nutrient uptake of rice

Treatments	No. of productive tillers m^{-2}	DMP at harvest (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Nutrient uptake by crop at harvest (kg ha^{-1})		
					N	P_2O_5	K_2O
T_1	361	12453	5670	6577	78.45	29.89	92.15
T_2	270	9275	4235	4870	58.43	23.19	67.71
T_3	344	11592	5405	6000	70.71	27.82	83.46
T_4	329	11028	5165	5682	69.48	27.57	80.50
T_5	427	14668	6710	7717	93.88	35.20	108.54
T_6	356	12147	5585	6367	77.74	30.37	89.89
T_7	388	13503	6200	7068	85.07	32.41	98.57
T_8	377	13124	5915	6980	81.37	32.81	94.49
T_9	382	13060	6000	6840	82.28	32.65	95.34
T_{10}	340	11597	5345	6040	73.06	28.99	85.82
T_{11}	439	15082	6800	7820	93.51	36.20	108.59
T_{12}	198	7404	3450	3795	46.65	17.77	54.79
SEd	18	498	272	314	2.40	0.97	2.90
CD (p=0.05)	37	1034	565	653	5.18	2.02	6.00

Table 3: Effect of weed management practices on economics of rice

Treatments	Cost of cultivation (₹ ha^{-1})	Gross Return (₹ ha^{-1})	Net Return (₹ ha^{-1})	B:C ratio
T_1	25428	76432	51004	3.01
T_2	24100	56961	32861	2.36
T_3	24300	72049	47749	2.96
T_4	24200	68695	44495	2.84
T_5	27225	90250	63025	3.31
T_6	25900	74951	49051	2.89
T_7	26100	83204	57104	3.19
T_8	26000	80089	54089	3.08

T_9	27800	80520	52720	2.90
T_{10}	25800	71570	45770	2.77
T_{11}	35300	91460	56160	2.59
T_{12}	22800	45885	23085	2.01

Conclusion

Pre-emergence application of bensulfuron methyl + pretilachlor at 660 g ha^{-1} on 3 DAT with one hand weeding on 35 DAT is a viable labour-saving integrated weed management package to get higher net return for transplanted rice and would play an important role in areas where labour is too expensive and time is a constraint.

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