A-5919
[1-7]

RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume Issue : ()

Response of Rice (*Oryza sativa* L.) to Weed Management Methods in the Lower Gangetic Plain Zone

Urjashi Bhattacharya, Alindip Ghosh, Smritikana Sarkar, Shrabanti Maity

10.18805/IJARe.A-5919

ABSTRACT

Background: In India, rice covers largest area under cultivation. Among the biotic stresses weeds pose serious threat to rice if not controlled in its critical crop-weed competition period, reducing yield by 50%, in case of transplanted rice. The experiment was carried out to evaluate effectiveness of different herbicides and its combination with mechanical weed control methods in checking weed population in transplanted rice so as to maintain sustained production.

Methods: The experiment was carried out in lower Gangetic plain zone during *kharif* season of 2018. It was laid out in randomized block design with seven treatments replicated thrice. The treatments were pretilachlor 50% EC@ 1500 ml ha^{-1} (0-4 DAT), butachlor 50% EC @ 4000 ml ha^{-1} (0-4 DAT), bispyribac Na 10% SC @ 200 ml ha^{-1} (Post-emergence), Sesbania intercrop @ 25 kg ha^{-1} up to 30 DAT followed by mechanical incorporation followed by 1 hand weeding @ 50 DAT, pretilachlor 50% EC @ 1500 ml ha^{-1} (0-4 DAT) followed by bispyribac Na 10% SC @ 2000 ml ha^{-1} (25 DAT), two hand weedings at 25 DAT and 50 DAT and untreated control.

Result: *Cyperus rotundus, Cyperus difformis, Alternanthera philoxeroides, Ludwigia octovalvis, Echinochloa colona, Fimbristyslis sp.* were the dominating weed species as per experimental findings. Among all treatments two hand weedings at 25 DAT and 50 DAT significantly reduced the total weed density (no.m^{-2}) while total weed biomass (g m^{-2}) as was found to be lowest in treatment of pretilachlor 50% EC @ 1500 ml ha^{-1} (0-4 DAT) followed by bispyribac Na 10% SC @ 2000 ml ha^{-1} (25 DAT). Highest growth characteristics in rice was observed in treatment of two hand weedings at 25 DAT and 50 DAT. Pre- emergence and post-emergence application of pretilachlor and bispyribac sodium, respectively, was successful in achieving highest yield attributes, yield (4.12 t ha^{-1}) and economic return (Rs. 47438 ha^{-1}).

Key words: Economic return, Herbicides, Rice, Weeds, Yield.

INTRODUCTION

India is second largest rice (*Oryza sativa*) producer in the world, producing 118.43 mt in 2019-2020 (Pocket book of Agricultural Statistics, 2020). In eastern India, 51.5% (14.0 m/ha) is rainfed low land area among total rice cultivated areas (Mahapatra *et al*. 2012). Weeds being one of the major biological constraints for yields, reduces 50% of production in transplanted rice and (Ananya, 1999). Weeds compete with the crop aggressively because of their high growth rate, high potential to acclimatize changing environment and more efficient seed production (Kim and Moody, 1989). In order to control weeds effectively, knowledge on the critical period of crop weed competition is crucial before application of any weed control practice. During early establishment, weeds make 20-30% of their growth while the crop makes 2-3% of its growth (Moody, 1980); if weeds are not controlled before 50 days after transplanting, the farmers may lose one-third of their total expected yield. Shortage of labour, increased wages and lack of suitable weed control implements have compelled farmers to think for alternative strategies of weed management. Herbicides have been the obvious choice for the farmers, but most of them are specific and work against narrow range of weed species (Mukherjee and Singh, 2005) besides leading several problems in long run. Therefore for wide spectrum weed control with limited ecological footprint, appropriate and economic weed management technology involving mechanical, cultural and chemical methods have been developed for sustainable rice cultivation. Pre-emergence herbicides which are applied to the soil, control weeds before they emerge, while post-emergence is applied to weeds after they emerge. For long term weed control, combination of direct weed control methods, such as herbicides or hand weeding, with indirect methods such as land preparation, flooding and a competitive crop might act as a solution, to restrain build up of certain dominant species, in lowland rice ecosystem. Keeping in view, of the biological stress and probable yield reduction due to weeds, an experiment was taken up to evaluate weed management measures, in realising highest economic return while maintaining weed population below the threshold level.

Department of Agronomy, Bidhan Chandra Krishi Vishwavidyalaya, Nadia-741 252, West Bengal, India.

Corresponding Author: Smritikana Sarkar, Department of Agronomy, Bidhan Chandra Krishi Vishwavidyalaya, Nadia-741 252, West Bengal, India. Email: smritikanasarkar12@gmail.com

How to cite this article: Bhattacharya, U., Ghosh, A., Sarkar, S. and Maity, S. (2022). Response of Rice (*Oryza sativa* L.) to Weed Management Methods in the Lower Gangetic Plain Zone. Indian Journal of Agricultural Research. DOI: 10.18805/IJARe.A-5919.

Submitted: 24-09-2021 **Accepted:** 14-12-2021 **Online:** 15-03-2022

MATERIALS AND METHODS

The experiment was conducted during *kharif* season of 2018-2019, to assess the relative effectiveness of different weed control measures, in Bidhan Chandra Krishi Viswavidyalaya, Nadia, located at 22° 58′ N latitude and 88° 25′ E longitudes with an elevation of 9 m above mean sea level. The experimental soil was sandy clay loam in texture with a pH of 7.06, medium in organic carbon (0.72%), phosphorus (7.67 kg/ha^{-1}), potassium (148.60 kg/ha^{-1}) and lower in available nitrogen (192.06 kg/ha^{-1}). The experiment was laid out in randomized block design, with seven weed control treatments and three replications. The treatments were pretilachlor 50% EC@ 1500 ml/ha^{-1} (0-4 DAT), butachlor 50% EC @ 4000 ml ha^{-1} (0-4 DAT), bispyribac Na 10% SC @ 200 ml/ha^{-1} (Post-emergence), Sesbania aculeata intercropped every two rows of rice @ 25 kg/ha^{-1} up to 30 DAT followed by mechanical incorporation followed by one hand weeding @ 50 DAT, Pretilachlor 50% EC @ 1500 ml/ha^{-1} (0-4 DAT) followed by bispyribac Na 10% SC @ 2000 ml/ha^{-1} (25 DAT), 2 hand weeding at 25 DAT and 50 DAT and untreated control. The plot size was 5 m × 4 m. Shatabdi (IET-4786) was used as rice variety. Seedlings were raised by wet bed method in the nursery. The experimental field was ploughed twice with cultivator followed by power tiller in standing water to make the land well puddled. Laddering was done at last to get a uniform surface. Row planting of 21 days old seedling at 3-4 cm depth was done at a spacing of 20 cm×20 cm with 3 seedlings hill^{-1}. The recommended fertilizer dose was 80:40:40 kg N:P:K ha^{-1}. Half dose of N and full dose of P and K were applied as basal at the time of final land preparation. One fourth of the N was applied at active tillering stage and rest ¼ is at panicle initiation stage. The field was maintained with 2 to 5 cm depth of standing water throughout the growing season. Water was drained out if required and finally from the field seven days before harvesting. For accounting the general weed flora of the experimental field, category wise species identification was carried out and recorded. Species wise weed count was recorded using 50 cm × 50 cm (0.25 m^2) quadrant from three randomly selected places in each plot outside the area from where the grain yield of rice was recorded and the recorded mean values were expressed in numbers m^{-2}. The densities of grasses, sedges and broad leaf weeds were recorded at 30, 60 and 90 DAT. In order to get weed dry weight, the weeds collected from each plot using quadrant, were oven dried at 60±2°C till a constant weight was obtained and expressed in g m^{-2}.

Weed control efficiency (WCE) was calculated using the following formula (Agronomic Terminology, 2009):

$$WCE\ (\%) = \frac{WD_C - WD_T}{WD_C} \times 100$$

Where,

WD_C= Weed density (no./m^2) in unweed plot.

WD_T= Weed density (no./m^2) in treated plot.

The growth and yield parameters were recorded periodically and yield was calculated according to net plot basis and expressed in t/ha^{-1}. Economics was estimated based on the yield and prevailing market price of that year. Statistical analysis was conducted by analysis of variance method and significance of sources of variation was tested by F test at 5% probability level. Weed data has been presented after square root transformation.

RESULTS AND DISCUSSION

Weed density, biomass and weed control efficiency

Among the various categories of weed flora like grass, sedge and broad leaf weeds (Table 1) observed in the experimental field during *kharif* season of 2018, the dominant weeds were *Echinochloa colona, Leersia hexandra, Cyperus difformis, Fimbristylis dichotoma*, *Cynodon dactylon*, *Alternanthera philoxeroides*, *Cyperus iria*, *Fimbristylis dichotoma, Ludwigia octovalvis*, *Ammania baccifera, Eclipta alba etc.* Saha *et al.* (2003), Singh *et al.* (2004), Ezung *et al.* (2018), Bhimwal *et al.* (2018) observed similar dominant weed species in transplanted rice. Density and biomass of the dominant weeds differed significantly due to the effect of different weed management treatments at 30, 60 and 90 DAT. Highest density and biomass of weeds was observed in untreated

Table 1: Weed flora observed in experimental plots of *kharif* transplanted rice.

Grass weeds	Sedge weeds	Broad leave weeds
Echinochloa colona	*Cyperus iria*	*Alternanthera philoxeroides*
Echinochloa crus-galli	*Cyperus difformis*	*Eclipta alba*
Panicum repens	*Fimbristylis dichotoma*	*Ludwigia octovalvis*
Brachiaria mutica		*Ammania baccifera*
		Oldenlandia corymbosa
Leersia hexandra		*Spenoclea zeylanica*
Leptochloa chinensis		*Stellaria media*
		Bergia capensis
Paspalum distichum		*Physalis minima*
		Ageratum conyzoides
Paspalum conjugatum		
Cynodon dactylon		

control. Lowest density of grassy weed throughout the growth period was observed with two hand weedings were given, except at 90 DAT wherein the treatment receiving pretilachlor followed by bispyribac Na recorded the lowest density (Fig 1). Treatment having pretilachlor followed by bispyribac Na was superior throughout the growth period by maintaining minimum density of sedges and broadleaf weeds (Fig 2 and Fig 3). Total weed density (Table 2) was regulated to its lowest during entire growth period when two hand weeding was given, though at 60 DAT (14.81 nos. m^{-2}) and 90 DAT (33.72 nos. m^{-2}) of observation it was statistically similar with treatment receiving Pretilachlor followed by bispyribac Na. Application of pretilachlor followed by bispyribac Na was successful in recording lowest total weed

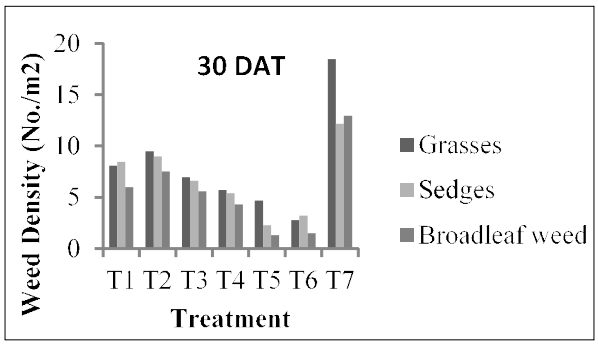

Fig 1: Effect of different weed management practices on weed density at 30 DAT in transplanted rice during *Kharif*, 2018.

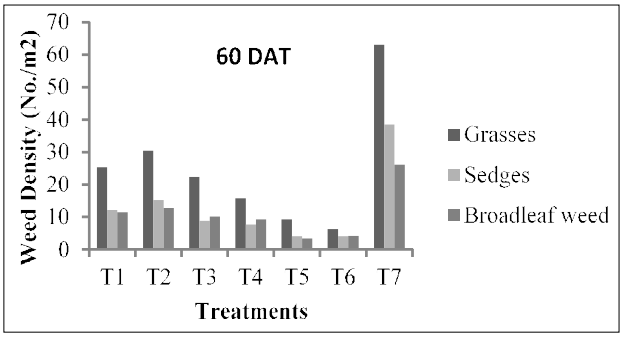

Fig 2: Effect of different weed management practices on weed density at 60 DAT in transplanted rice during *Kharif*, 2018.

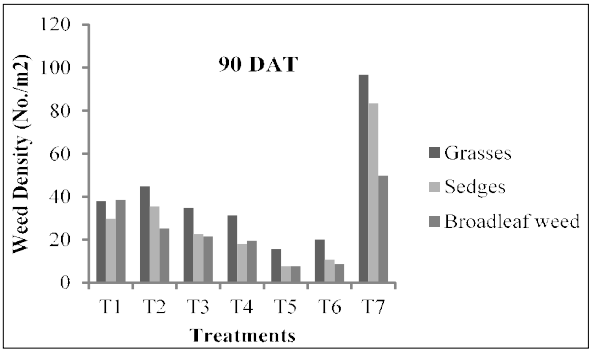

Fig 3: Effect of different weed management practices on weed density at 90 DAT in transplanted rice during *Kharif*, 2018.

biomass throughout the growing period of rice with a total weed biomass of 17.5 g m^{-2} at 90 DAT and was most efficient in controlling weeds throughout the growth period, achieving 82.28% weed control efficiency at 90 DAT. Prakash *et al.* (2017), in his experiment reported highest weed control efficiency of 86.15% when transplanted rice was treated with pretilachlor followed by almix at 30 DAT, which was probably due to systematic control of early emerging and late emerging weeds. Combined application of pretilachlor (pre-emergence herbicide) and butachlor (post emergence herbicide), was found more efficient in reducing total weed density and total weed biomass than single application of butachlor (pre-emergence herbicide) or bispyribac sodium (post-emergence herbicide) as it decimated weeds during the critical crop weed competition period of transplanted rice *i.e.* 20-40 DAT. Hossain *et al.* (2014) also observed similar results that indicated, application of pre-emergence and post-emergence herbicides was more effective than single application of pretilachlor, bispyribac sodium and pyrazosulfuron in suppressing total weed density and total weed biomass. Pretilachlor affected grass weeds, broadleaf weeds and sedges by combining with acetyl CoA and sulfhydryl molecules which in turn restricted the long chain fatty acid molecules during early emergence of seedlings (Sherwani *et al.* 2015). Whereas, being systemic herbicide bispyribac sodium inhibited branched amino acid synthesis and was effective in controlling wide range of weeds by interfering with acetolactate synthase (ALS) responsible for growth.

Growth attributes

Various growth attributes were significantly influenced by different weed management practices. Plant height (98.57 cm) and dry matter accumulation (815.34 g/m^{-2}) at 90 DAT were highest with two hand weeding, which was 18.30% and 59.93% more than untreated control, respectively (Table 3). Weeds compete with rice plant for nutrients, space, carbon di-oxide, water and when they grow taller than the rice plant they compete for sunlight, this might be the reason for poor growth attributes in the untreated control (Smith, 1970). Treatment receiving combined application of pretilachlor and bispyribac sodium noted statistically similar values for plant height and in case of dry matter accumulation it recorded second highest value (752.16 g/m^{-2}) at 90 DAT, with respect to treatment of two hand weeding. Parthipan *et al.* (2013), recorded tallest plant (125.1 cm) of rice at harvest in treatment which received two handing weeding at 25 DAT and 45 DAT. Controlling weeds during the critical crop weed competition period might have conferred competitive advantage for rice plants over weeds and resulted in efficient utilization of the available resources. This might be the reason for better crop growth characters. Mandi *et al.* (2016) noticed that hand weeding promoted various growth attributes of rice as compared to other weed management treatments. Crop growth rate decreased with increase in age of crop due to senescence.

Table 2: Effect of different weed management practices on total weed density, total weed biomass and weed control efficiency in transplanted rice during *Kharif*, 2018.

Treatments	Total weed density (No./ m^2)			Total weed biomass (g/ m^2)			Weed control efficiency (%)		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
T_1: Pretilachlor 50% EC @1500 ml/ha	4.65 (21.18)	7.15 (50.72)	10.31 (105.89)	3.55 (12.15)	4.90 (23.52)	6.22 (38.20)	63.15	64.76	61.15
T_2: Butachlor 50% EC @4000 ml/ha	5.37 (23.93)	7.57 (56.91)	10.29 (105.56)	3.75 (13.58)	4.70 (21.6)	6.63 (43.53)	58.82	67.61	55.73
T_3: Bispyribac Na 10% SC @200 ml/ha	4.58 (20.54)	6.89 (47.07)	9.06 (81.67)	3.46 (11.53)	4.86 (23.15)	6.15 (37.43)	65.03	65.28	61.93
T_4: Sesbania intercrop @25 kg/ha up to 30 DAT followed by mechanical incorporation, followed by 1 hand weeding at 50 DAT	4.17 (16.93)	6.75 (45.07)	8.42 (70.42)	3.30 (10.45)	4.69 (21.58)	6.06 (36.34)	68.16	67.64	63.04
T_5: Pretilachlor 50% EC @1500 ml/ha followed by Bispyribac Na 10% SC @ 200 ml/ha	3.2 (9.70)	4.18 (17.02)	6.12 (37.0)	2.44 (5.5)	3.45 (11.43)	4.2 (17.5)	83.32	82.86	82.28
T_6: 2 Hand weedings at 25 DAT and 50 DAT	2.63 (6.42)	3.91 (14.81)	5.84 (33.72)	2.64 (6.47)	3.70 (13.22)	4.64 (21.09)	80.38	80.17	78.55
T_7: Untreated control	7.51 (55.98)	10.73 (114.71)	15.19 (230.43)	5.78 (32.98)	8.19 (66.69)	9.94 (98.33)	0.00	0.00	0.00
S.Em(±)	0.62	1.32	2.95	0.17	0.85	0.95	-	-	-
CD at 5%	1.93	4.10	9.19	0.53	2.66	2.97	-	-	-

Square root transformed data are presented; original data are in parenthesis.

At 60-90 DAT, treatment in which Sesbania was incorporated manually at 30 DAT followed by one hand weeding at 50 DAT, showed maximum crop growth rate of 9.83 g/m^{-2} day, though it was statistically at par with the treatment which received two hand weedings (Table 3). Any treatment where weeding was done twice exhibited better performance as compared to unweeded control and those receiving one weed control practice. Lowering of weed population in inter-row and intra-row spacing might have resulted in better photosynthetic efficiency of crop which further led to more dry matter accumulation and higher crop growth rate.

Yield attributes, yield and economics

Yield parameters like number of number of panicles m^{-2} differed significantly with various weed treatments (Table 4). Plots treated twice with pretilachlor and bispyribac sodium exhibited highest number of panicles m^{-2} (324) though it was statistically at par with treatment having two hand weeding. Data from (Table 4) showed that treatment receiving twice application of pretilachlor and bispyribac sodium was 32.24% superior over untreated weed treatment with regard to number of panicles m^{-2}, respectively. The increase in number of grains $panicle^{-1}$ was 39.36% in plots treated with pretilachlor and bispyribac sodium as compared to untreated weed control, though the values were found to be statistically similar to plots receiving two hand weeding and plots in which Sesbania as an intercrop was incorporated followed by one hand weeding. Singh *et al.*(2016) reported significantly higher effective tillers m^{-2} and grains per panicle in plots treated with pre and post emergence herbicide as compared to untreated weedy control. There was no significant difference among different weed treatments with respect to panicle length and test weight. Maximum grain yield (4.12 t/ha^{-1}) and straw yield (6.18 t/ha^{-1}) (Table 5) was noted in treatment in which pretilachlor and bispyribac sodium was applied as pre and post emergence herbicides respectively, though being on par with treatment receiving two hand weeding and treatment in which Sesbania was incorporated followed by one hand weeding. The results were similar with those of Channabasavanna *et al.* (2017) and Kailkhura *et al.* (2015); who suggested pre-emergence and post emergence application of pendimethalin and bispyribac sodium showed highest rice grain yield (6.42 t/ha^{-1}) which was at par with

Table 3: Effect of different weed management practices on plant height, dry matter accumulation and crop growth rate in transplanted rice during *Kharif*, 2018.

Treatments	Plant height (cm)	Dry matter accumulation (g/m^2)			Crop growth rate (g/m^2/day)	
	90 DAT	30 DAT	60 DAT	90 DAT	30-60 DAT	60-90 DAT
T_1 : Pretilachlor 50% EC @ 1500 ml/ha	91.54	174.69	443.54	612.6	8.96	5.63
T_2 : Butachlor 50% EC @ 4000 ml/ha	86.09	172.95	430.02	611.09	8.56	6.03
T_3: Bispyribac Na 10% SC @200 ml/ha	92.88	202.3	460.69	730.13	10.83	6.75
T_4: Sesbania intercrop @25 kg/ha up to 30 DAT followed by mechanical incorporation, followed by 1 hand weeding at 50 DAT	95.27	175.21	436.43	731.43	8.7	9.83
T_5 : Pretilachlor 50% EC @1500 ml/ha followed by Bispyribac Na 10% SC @ 200 ml/ha	96.84	192.31	525.54	752.16	11.1	7.55
T_6 : 2 hand weedings at 25 DAT and 50 DAT	98.57	205.92	560.19	815.34	11.8	8.5
T_7: Untreated control	83.32	167.19	317.17	509.78	5	6.22
S.Em (±) 1.96	6.66	12.6	14.723	0.56	0.43	
CD at 5%	6.02	20.76	39.25	45.86	1.75	1.36

Table 4: Effect of different weed management practices on effective tillers/$m^2$and yield parameters of transplanted rice during *Kharif*, 2018.

Treatments	Number of panicles/m^2	Number of grains/panicle	Panicle length (cm)
T_1 : Pretilachlor 50% EC @ 1500 ml/ha	285	110.63	23.41
T_2 : Butachlor 50% EC @ 4000 ml/ha	276	107.38	23.13
T_3: Bispyribac Na 10% SC @200 ml/ha	291	113.27	24.08
T_4: Sesbania intercrop @25 kg/ha up to 30 DAT followed by mechanical incorporation, followed by 1 hand weeding at 50 DAT	306	125.3	24.76
T_5 : Pretilachlor 50% EC @1500 ml/ha followed by Bispyribac Na 10% SC @ 200 ml/ha	324	138.28	25.1
T_6 : 2 hand weedings at 25 DAT and 50 DAT	315	127.67	25.68
T_7: Untreated control	245	99.22	22.96
S.Em (±)	12.78	4.36	0.70
CD at 5%	39.83	13.59	NS

Table 5: Effect of different weed management practices on yield and test weight of transplanted rice during *Kharif*, 2018.

Treatments	Grain yield(t ha^{-1})	Straw yield (t ha^{-1})	Test weight (g)
T_1 : Pretilachlor 50% EC @ 1500 ml/ha	3.51	5.46	19.43
T_2 : Butachlor 50% EC @ 4000 ml/ha	3.37	5.23	19.27
T_3: Bispyribac Na 10% SC @200 ml/ha	3.69	5.81	19.56
T_4: Sesbania intercrop @25 kg/ha up to 30 DAT followed by mechanical incorporation, followed by 1 hand weeding at 50 DAT	3.85	5.86	20.03
T_5 : Pretilachlor 50% EC @1500 ml/ha followed by Bispyribac Na 10% SC @ 200 ml/ha	4.12	6.18	20.65
T_6 : 2 hand weeding at 25 DAT and 50 DAT	4.03	6.10	20.28
T_7: Untreated control	3.15	5.08	19.16
S.Em (±)	0.07	0.22	0.62
CD at 5%	0.20	0.68	NS

Table 6: Effect of different weed management practices on economics of transplanted rice during *Kharif*, 2018.

Treatments	Net return (Rs. ha^{-1})	B:C
T_1 : Pretilachlor 50% EC @ 1500 ml/ha	36952.33	1.85
T_2 : Butachlor 50% EC @ 4000 ml/ha	33614.33	1.77
T_3: Bispyribac Na 10% SC @200 ml/ha	41262.00	1.95
T_4: Sesbania intercrop @25 kg/ha up to 30 DAT followed by mechanical incorporation, followed by 1 hand weeding at 50 DAT	40327.33	1.85
T_5 : Pretilachlor 50% EC @1500 ml/ha followed by Bispyribac Na 10% SC @ 200 ml/ha	47438.33	2.03
T_6 : 2 hand weedings at 25 DAT and 50 DAT	43006.67	1.88
T_7: Untreated control	32369.33	1.80
S.Em (±)	81.49	0.001
CD at 5%	251.07	0.004

hand weeding twice at 25 DAT and 45 DAT. Pre and post emergence herbicide of pretilachlor and byspyribac sodium together at initial growth stages of the crop, resulted in lower weed density as well as weed biomass creating a conducive environment for robust crop growth and yield attributes which finally culminated in higher yield compared to plots having one weed treatment or no weed treatment. De Datta *et al.* (1983) indicated that timely and early weed control is highly critical in obtaining satisfactory crop yield. Data from Table 6 showed highest net return (Rs. 47438.33 ha^{-1}) and B:C (2.03) was gained in those plots in which pretilachlor was applied followed by bispyribac sodium. Significantly higher net return was observed in those treatments in which weed control measures were adopted twice during the crop growth period. Highest yield achieved in the said treatment contributed to the highest net return and B:C. This was followed by treatment receiving two hand weedings at 25 DAT and 50 DAT with the untreated control treatment recording lowest net return (Rs. 32369.33 ha^{-1}).

Experimental results concluded that plots treated with Pretilachlor 50% EC @1500 ml/ha followed by Bispyribac Na 10% SC @ 200 ml/ha recorded highest yield and net return with better control over weeds. There was no phytotoxicity effect on crop seen with the application of this treatment. Therefore, for getting better productivity along with remunerative return beside controlled weed population under threshold level, application of Pretilachlor 50% EC @1500 ml/ha followed by Bispyribac Na 10% SC @ 200 ml/ha can be suggested in rice.

Conflict of interest: None.

REFERENCES

Ananya, A.L. (1999). Allelopathy as a tool in the management of biotic resources. Critical Reviews. Plant Sci. 19: 697-739.

Bhimwal, J.P., Verma, A., Gupta. V., Meena, S.K. (2018). Performance of different tank mix herbicides for broad-spectrum weed control in soybean [*Glycine max* (L.) Merrill]. Indian Journal of Agricultural Research. 52(6): 681-685.

Channabasavanna, A.S., Talwar, A.M., Rajakumar, K.H. (2017). Evaluation of post emergence herbicides on grass weeds in pigeon pea and its bioassay on following crop. Indian Journal of Agricultural Research. 51(2): 188-190.

De Datta, S.K. and Herdt, R.W. (1983). Alternative Technology and Economic Assessment of Weed Control in Wet Land Rice. In: Pesticide Chemistry; Human Welfare and The Environment. vol. 2. National Products. [Miyamoto, J., Keamey, P.C., Takahashi, N., Yoshioka, H., Misato, T., Matsunaka, S. (Eds.)]. Oxford, U.K. Pergamon Press, 359-365.

Ezung, N.K., Choudhary, J.K., Das, J.C., Kikon, N., Koutsu, R. (2018). Weed growth and nutrient uptake in organically managed rice and maize as affected by nitrogen management and live mulching with cowpea. Indian Journal of Agricultural Research. 52(6):631-636.

Hossain, A., Mondal, D.C. (2014). Weed management by herbicide combinations in transplanted rice. Indian Journal of Weed Science. 46(3): 220-223.

Kailkhura, S., Pratap, T., Singh, V.P., Guru, S.K. and Singh, S.P. (2015). Herbicide combinations for control of complex weed flora in transplanted rice. Indian Journal of Weed Science. 47(4): 414-416.

Kim, S.C. and Moody, K. (1989). Growth dynamics of rice and several weed species under density and fertilizer stresses. In: Proc. of the 1989 Asian Pacific Weed Sci. Conf. 47-56.

Mahapatra, I.C., Rao, K.S., Panda, B.B. and Shivay, Y.S. (2012). Agronomic research on rice (*Oryza sativa* L.) in India. Indian Journal of Agronomy. 57 (3rd IAC Special issue): 9-31.

Mandi, S., Dar, E.A., Datta, A., Singh, R.P., Singh, M.K. (2016). Growth and yield of transplanted rice as affected by different cultivars and weed management practices. Journal of Applied and Natural Science. 8(3): 1462-1466.

Moody, K. (1980). Weed Science Research at IRRI and its role in weed science in Asian region. Weed Science. 28(4): 461-463.

Mukherjee, D.and Singh., R.P. (2005). Effect of micro-herbicides on weed dynamics, yieldand economics of transplanted rice. Institute of Agricultural Science, Varanasi, UP. Indian J. Agron. 50: 292-295.

Parthipan, T., Ravi, V., Subramanian, E. and Ramesh, T. (2013). Integrated weed management on growth and yield of transplanted rice and its residual effect on succeeding black gram. Journal of Agronomy. 12: 99-103.

Pocket Book of Agricultural Statistics. (2020). Government of India. Ministry of Agriculture and Farmers Welfare Department of Agriculture, Cooperation and Farmers Welfare. Directorate of Economics and Statistics.

Prakash, J., Singh, R., Yadav, R.S., Vivek, Yadav, R.V. Dyani, B.P., Sengar, R.S. (2017). Effect of different herbicide and their combination on weed dynamics in transplanted rice Research Journal of Chemical and Environmental Sciences. 5(4): 71-75.

Rao, V.P. (2009). Agronomic Terminology. Indian Society of Agronomy. New Delhi.

Saha, S., Moorthy, B.T.S. and Behra, J. (2003). Performance of herbicide in puddle rice during summer. Indian Journal of Weed Science. 33(3 and 4): 208-210.

Sherwani, S.I., Arif, I.A. and Khan, H.A. (2015). Modes of Action of Different Classes of Herbicides. Herbicides, Physiology of Action and Safety.

Singh, R.K. and Namdeo, K.N. (2004). Effect of fertility levels and herbicides on growth, yield and nutrient uptake of direct-seeded rice (*Oryza saliva*). Indian Journal of Agronomy. 49(1): 34-36.

Smith, R.J. (1970). Molinate for barnyard grass control in rice. Weed Sci. 18(4): 467- 469.

Singh, V., Jat, M.L., Ganie, Z.A., Chauhan, B.S., Gupta, R.K. (2016). Herbicide options for effective weed management in dry direct-seeded rice under scented rice-wheat rotation of western Indo-Gangetic Plains.Herbicide options for effective weed management in dry direct seeded rice under scented rice-wheat rotation of western Indo-Gangetic Plains. Crop Protection. 81:168-176.