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Effect of Different Integrative Weed Management Tactics on Paddy (*Oryza sativa* L.) during *Kharif* in *Terai* Region of West Bengal

Pratonu Bandyopadhyay[1], Triptesh Mondal[2], Parthendu Poddar[3], Md. Wasim Reza[4] 10.18805/IJARe.A-6156

ABSTRACT

Background: Now a days chemical control measures alone develop resistance in different weed species. Integrative weed management techniques are more effective and sustainable than chemical management. Based on these facts, a field experiment was conducted during *kharif,* 2019 and 2020 at Uttar Banga Krishi Viswavidyalaya to investigate the impact of integrative weed management treatments on growth attributes, yield attributes, yield, weed indices and economics of paddy.

Methods: The experiment was laid out in randomized block design with four replications. In each replication, five integrated weed management treatments were done namely, pretilachlor followed by paddy weeder (P_1), pyrazosulfuron ethyl followed by metsulfuron methyl + chlorimuron ethyl (P_2), bispyribac sodium followed by paddy weeder (P_3), completely no weed (P_4) and weedy check (P_5).

Result: Among the chemical and integrative weed control options, bispyribac sodium + paddy weeder *i.e.*, treatment P_3 showed significantly better results than others in case of all the growth attributes and yield attributes except 1000-grain weight. Significantly higher grain yield than all other treatments were recorded in treatment P_4 *i.e.*, complete weed free (6.68 t ha^{-1}) followed by treatment P_3 *i.e.*, bispyribac sodium + paddy weeder (6.54 t ha^{-1}). Among all the treatments, weed indices like weed control index (80.17, 72.30 and 82.51% at 30, 45 and 60 DAT, respectively) and weed control efficiency (76.48, 79.01 and 80.79% at 30, 45 and 60 DAT, respectively) showed highest results on all the dates whereas weed persistence index at 90 DAT (0.91) and weed index (2.10%) were calculated lowest in treatment P_3 *i.e.*, bispyribac sodium + paddy weeder after treatment P_4 *i.e.*, completely no weed treatment. This study also indicated rice treated with P_4 *i.e.*, weed free showed highest gross return (₹ 116700 ha^{-1}) and rice treated with P_3 *i.e.*, bispyribac sodium at 15 DAT + paddy weeder at 30 DAT showed highest net return (₹ 59269 ha^{-1}) and benefit:cost (2.07).

Key words: Bispyribac sodium, Integrative weed management, Paddy weeder.

INTRODUCTION

Paddy (*Oryza sativa* L.) is one of the vital crops in Asian countries, the staple cereal of over 50% of the people worldwide and provides about 20% of the world's dietary energy supply (FAO International Year of Rice, 2004). Paddy is a preliminary source of foodgrain for greater than one third of the world's population, basically in Asia, Africa and Latin America (Hasamuzzaman *et al*., 2009). The second most common cereal consumed by people is paddy next to wheat.

Worldwide, 530 million tonnes of paddy are obtained from 150 million hectares of land annually, providing an average yield of 3.5 t ha^{-1} and 21% of the food calorie of world's population. Almost 9/10th of paddy is grown in the continent, Asia (Zimdahl, 1988 and McDonald, 1994). The current yield of paddy in our country is lesser than mean grain yield of paddy in the world. One of the major factors responsible for low productivity of paddy is weed because of its multiple harmful impacts. Uncontrolled weed population decreased the grain productivity by 75.8, 70.6 and 62.6% under dry direct-seeded paddy, wet direct-seeded paddy and puddled transplanted paddy, respectively (Singh *et al*., 2005).

Paddy production in our country faced loss of 15 million tonnes every year only because of weed competition in the 20th century (Chattarjee and Maity, 1981). In upland ecosystem of paddy, yield reduction calculated from the weed density and dry weight, varies from 30-100% (Jensen *et al*., 2001). In the world, 10% deterioration in agricultural

[1]Department of Agronomy, Faculty of Agriculture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar-736 165, West Bengal, India.
[2]Department of Agronomy and Agroforestry, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Gajapati-761 211, Odisha, India.
[3]Regional Research Station Terai Zone, Uttar Banga Krishi Viswavidyalaya, Pundibari, Coochbehar-736 165, West Bengal, India.
[4]Regional Research Station Terai Zone, Uttar Banga Krishi Viswavidyalaya, Kharibari, Darjeeling-734 427, West Bengal, India.

Corresponding Author: Triptesh Mondal, Department of Agronomy and Agroforestry, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Gajapati-761 211, Odisha, India. Email: mtriptesh@gmail.com

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production is often allotted to the competitive nature of weeds in the situation of following proper control measures. Direct-seeded paddy is extensively grown by the farmers to cut back the cost of cultivation but the jungle rice drastically diminishes the yield of cultivated rice (Lee *et al*., 2004 and Seal *et al*., 2005). The upland crop of paddy faces a tremendous crop-weed competition upto 40 days followed by sowing operation and if the weeds are not controlled then the decrement in productivity is also 50% or higher relying on the composition and intensity of weeds. Losses because of weeds differ among countries; relying on the major weed species and also their suppressing techniques followed by regional growers. Weeds are the main factor of biotic stress in the production of paddy in Srilanka which showed 30-40% losses in economic yield (Abeyskera and Anwudhika, 2001). The overall cultivated area of paddy in Bangladesh is about 105.0 lakh hectares with a production of 250.9 lakh tonnes where transplanted winter paddy alone occupies 55.6 lakh hectares of land with a production of 112.5 lakh tonnes (Anonymous, 2001). But the paddy productivity of Bangladesh is lesser than the productivity of other paddy growing countries due to the heavy infestation of weeds (Mamun, 1988). Weed infestation can even create problem in the operation of combine harvester and significantly enrich the costs of harvesting, threshing and drying. Contamination of weed seeds lowers the quality of paddy grains and ultimately the cash value of grains. The yield loss due to weed problem in paddy was observed about 15-66 per cent in direct-seeded paddy and 6-30 per cent in puddled transplanted paddy in India (Gharde *et al*., 2018). Popularization of integrative tactics of weed control with the application of herbicides by ensuring safe use is required to avoid ill impact on human health, environment and avoid weeds building resistance against herbicides (Rao *et al*., 2020). Location specific integrative weed management tactics can be developed based on weed ecology and biology and fine tuning of the accessible technologies to handle the weed problem with no harm (Rao *et al*., 2020).

MATERIALS AND METHODS

The current experiment was performed during *Kharif*, 2019 and 2020 in the experimental farm of Uttar Banga Krishi Viswavidyalaya, Coochbehar, West Bengal, India. The soil of the experimental site was sandy loam textured and slightly acidic in reaction (soil pH 6.15). Soil organic carbon content was high (1.07%), medium available nitrogen (290.4 kg ha^{-1}), phosphorus (19.4 kg ha^{-1}) and potassium (118 kg ha^{-1}) was the initial fertility status of experimental soil. Paddy cultivar, Maudamani (CR Dhan 307) was taken in this experiment. The experiment was designed in randomized blocks with four replications and five treatments viz. pretilachlor @ 0.75 kg ha^{-1} at 3 DAT with paddy weeder at 30 DAT (P_1), pyrazosulfuron ethyl @ 20 g ha^{-1} at 3 DAT with metsulfuron methyl 10% WP + chlorimuron ethyl 10% WP (ready mix) @ 20 g ha^{-1} at 25 DAT (P_2), bispyribac sodium @ 25 g ha^{-1} at 15 DAT with paddy weeder at 30 DAT (P_3), complete weed free (P_4) and weedy check (P_5).

Plant samples were taken at 30 DAT, 60 DAT, 90 DAT and harvest in both of the years. The samples are taken using 1 m^2 quadrate whereas, weed samples were taken at 15 DAT, 30 DAT, 45 DAT and 60 DAT from five places using 1 m^2 quadrate. Weed samples were collected, oven dried at 65°C until constant sample weight observed and then dry weight was noted down.

B:C ratio and weed indices *i.e*., weed control efficiency and weed control index, weed persistence index and weed index were evaluated through the following formulas:

$$\text{B:C ratio} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

Weed control efficiency (WCE%) =

$$\frac{\text{Weed count in untreated plot} - \text{Weed count in treated plot}}{\text{Weed count in untreated plot}} \times 100$$

Weed control index (WCI%) =

$$\frac{\text{Dry weight of weeds in control plot} - \text{Dry weight of weeds in treated plot}}{\text{Dry weight of weeds in control plot}} \times 100$$

Weed persistence index (WPI) =

$$\frac{\text{Weed biomass of treated plot}}{\text{Weed biomass of control plot}} \times \frac{\text{Weed density of control plot}}{\text{Weed density of treated plot}}$$

Weed index (WI%) =

$$\frac{\text{Yield in weed-free plot - Yield in treated plot}}{\text{Yield in weed-free plot}}$$

Data from both the years were calculated and made average for analysis. The data regarding weeds found from the samples were transformed using square root transformation ($\sqrt{X+0.5}$) for treatment comparison through ANOVA. Effect of the treatments was statistically compared by Fisher's least significant difference method at 5% level of significance (Gomez and Gomez, 1984). All statistical analyses were completed by SPSS 24.0 software package created by IBM Corp. (2016).

RESULTS AND DISCUSSION

This experiment revealed (Table 1) that growth attributes like height of plants and accumulation of dry matter at 60 and 90 DAT and at harvest were significantly influenced by the weed management treatments in rice. The treatment, bispyribac sodium @ 25 g ha^{-1} at 15 DAT + paddy weeder at 30 DAT treatment (P_3) recorded the maximum plant height at harvest (117.62 cm) except the complete weed free treatment which had also significantly taller plants than all the chemical and integrative weed management treatments in both years. The paddy crop with complete weed free (P_4) treatment registered highest accumulation of dry matter (1288.40 g m^{-2} at 90 DAT and 1531.80 g m^{-2} at harvest) at 90 DAT and harvest which differed significantly with other treatments in both years. This was might be due to no competition of paddy with weeds during the later period of crop growth. This weed free treatment was closely followed by bispyribac sodium + paddy weeder treatment (P_3) at 90 DAT (1262.30 g m^{-2}) and harvest (1511.80 g m^{-2}). Adilakshmi *et al.* (2022) found that the treatment combination with bispyribac sodium showed better growth attributes of paddy. At 30 DAT, bispyribac sodium + paddy weeder treatment (P_3) achieved shortest plants and minimum dry matter accumulation due to some phytotoxic effect of bispyribac sodium though insignificant variation was found. Paddy crop under P_5 *i.e.*, weedy check treatment recorded the shortest plants with lowest dry matter accumulation at all the stages of crop growth except 30 DAT. Paddy grown in complete weed free plots *i.e.*, P_4 option registered the maximum number of tillers m^{-2} (179.81 m^{-2} at 30 DAT, 287.90 m^{-2} at 60 DAT, 245.40 m^{-2} at 90 DAT and 228.74 m^{-2} at harvest) on all the dates of observation followed by bispyribac sodium + paddy weeder *i.e.*, P_3 option (175.56 m^{-2} at 30 DAT, 286.60 m^{-2} at 60 DAT, 242.40 m^{-2} at 90 DAT and 225.61 m^{-2} at harvest) which varied significantly with other chemical and integrative weed management treatments. This was mainly due to lower crop-weed competition under these treatments than others.

Yield attributing characters (Table 2) such as number of panicles m^{-2}, number of filled grains $panicle^{-1}$ varied significantly under different weed management treatments for both the years. The treatment, completely weed free *i.e.*, P_4 noted down the maximum number of panicles m^{-2} and number of filled grains $panicle^{-1}$ followed by bispyribac sodium + paddy weeder *i.e.*, P_3 treatment and they were statistically *at par*. This was due to higher dry matter accumulation under these treatments than others during the later period of crop growth. Paddy crop under P_5 *i.e.*, weedy check recorded the lowest number of panicles m^{-2} as well as number of filled grains $panicle^{-1}$ due to maximum weed density during the crop growing period. The test weight was not significantly influenced by various weed controlling options.

Among weed management treatments, paddy crop under no weed *i.e.*, P_4 treatment exhibited the maximum productivity of grains (6.68 t ha^{-1}) trailed by P_3 *i.e.*, bispyribac sodium + paddy weeder treatment (6.54 t ha^{-1}) (Table 2). Crop remained under weedy check *i.e.*, P_5 treatment noted down the minimum yield of grains (5.79 t ha^{-1}). The crop treated with pretilachlor @ 0.75 kg ha^{-1} at 3 DAT + paddy weeder at 30 DAT *i.e.*, P_1 the exhibited the highest straw yield (8.26 t ha^{-1}) followed by weed free *i.e.*, P_4 (8.25 t ha^{-1}) and P_3 *i.e.*, bispyribac sodium + paddy weeder treatment (8.19 t ha^{-1}). These three treatments had also been found statistically *at par*. Crop treated as weedy check *i.e.*, P_5 recorded the lowest straw yield of paddy (7.91 t ha^{-1}) on pooled basis (Table 2). Maximum harvest index was recorded to weed free *i.e.*, P_4 (45.06%) followed by P_3 *i.e.*, bispyribac sodium + paddy weeder treatment (44.39%) and the lowest harvest index was recorded with weedy check treatment *i.e.*, P_5 (42.29%).

Table 1: Growth attributing parameters of paddy as influenced by various weed management options (pooled data of two years).

Treatments	Plant height (cm)				Dry matter accumulation (g m^{-2})				Number of tillers m^{-2}			
	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest	30 DAT	60 DAT	90 DAT	Harvest
P_1	77.88	111.00	116.20	114.96	420.66	808.40	1161.80	1407.50	159.39	265.00	229.00	213.35
P_2	77.63	113.30	117.60	116.94	418.80	817.20	1181.20	1437.30	166.57	269.40	235.10	214.18
P_3	76.02	113.30	118.70	117.62	412.63	827.80	1262.30	1511.80	175.56	286.60	242.40	225.61
P_4	78.41	113.60	120.60	118.24	421.53	831.70	1288.40	1531.80	179.81	287.90	245.40	228.74
P_5	77.66	108.60	114.70	113.66	416.73	804.60	1092.90	1393.60	151.08	261.00	220.50	210.31
SEm±	0.18	0.32	0.42	0.22	1.30	1.47	5.81	4.48	0.85	0.98	0.69	0.91
CD ($P \leq 0.05$)	0.54	0.99	1.30	0.67	NS	4.53	17.92	13.86	2.61	3.02	2.13	2.79

DAT- Days after transplanting.

Table 2: Influence of various weed management options on yield attributes, yield and harvest index of paddy (pooled data of two years).

Treatments	Number of panicles m^{-2}	Number of filled grains $panicle^{-1}$	1000-grain weight (g)	Yield (t ha^{-1})		Harvest index (%)
				Grain	Straw	
P_1	191.11	174.70	21.19	6.07	8.26	42.35
P_2	194.75	176.89	21.53	6.25	8.04	43.74
P_3	201.08	179.07	21.96	6.54	8.19	44.39
P_4	202.34	180.69	21.52	6.68	8.25	45.06
P_5	188.05	171.19	21.62	5.79	7.91	42.29
SEm±	0.62	0.62	0.25	0.04	0.05	-
CD ($P \leq 0.05$)	1.90	1.90	NS	0.11	0.16	-

NS- Non-significant at $P \leq 0.05$.

The weed species were identified in both the years. From initial stage to 45 DAT, there was maximum number of broad-leaved weeds. The occurrence of grasses was thereafter 45 DAT. The Common broadleaved weeds were *Ottelia alismoides*, *Sphenoclea zeylanica*, *Marsilea quadrifolia*, *Alternanthera sessilis*. However, two types of grasses *i.e.*, *Panicum repens*, *Echinochloa crusgalli* and one type of sedge *i.e.*, *Scirpus articulate* were found.

The data presented in Table 3 revealed irrespective of different levels of weed control treatment, the first date of observation (15 DAT) regarding weed population did not appear in any categories of weeds might be due to preparation of weed free puddled beds with proper depth of water submergence.

The total weed population and weed dry weight were recorded under different weed management treatments on 30 DAT, 45 DAT and 60 DAT. Lowest weed population (0.71 m^{-2} on all the dates) and weed dry weight (0.71 g m^{-2} on all the dates) were recorded in completely weed free *i.e.*, P_4 treatment followed by P_3 treatment *i.e.*, bispyribac sodium + paddy weeder at all the dates of observation (weed population and weed biomass were 2.34 m^{-2} and 2.95 g m^{-2} at 30 DAT, 2.75 m^{-2} and 3.94 g m^{-2} at 45 DAT and 2.82 m^{-2} and 3.88 g m^{-2} at 60 DAT, respectively). Highest weed population and weed biomass were recorded in weedy check *i.e.*, P_5 treatment on all the dates.

The best efficiency in controlling weeds (WCE) and weed control index (WCI) were recorded (Table 4) in pooled data to those paddy crops which were treated with complete weed free treatment *i.e.*, P_4 (100.00% in both WCE and WCI on all the dates) followed by P_3 *i.e.*, bispyribac sodium + paddy weeder treatment (WCE was 76.48% at 30 DAT, 79.01% at 45 DAT and 80.79% at 60 DAT and WCI was 80.17% at 30 DAT, 72.30% at 45 DAT and 82.51% at 60 DAT) and the lowest weed control index and lowest efficiency in controlling weeds was obtained with the crop under weedy check *i.e.*, P_5 on the different dates of observations (0.00% in both WCE and WCI at 30 DAT, 45 DAT and 60 DAT) as no weed control measures had been followed there. Maurya *et al.* (2023) reported that bispyribac sodium provided better result among the chemicals used in terms of efficient control of weeds.

Weed persistence index indicating relative gathering of dry matter of weeds in every count with compared to control, which confirmed the effectiveness of used herbicide (Table 5). This index indicated that pyrazosulfuron ethyl @ 20 g ha^{-1} at 3 DAT followed by metsulfuron methyl 10% WP + chlorimuron ethyl 10% WP (ready mix) @ 20 g ha^{-1} at 25 DAT (P_2) treatment resulted in highest value of weed persistence index at 60 DAT (1.88) and 90 DAT (1.03) whereas, it was lowest at 30 DAT (0.93). This finding strengthened the fact that application of herbicides alone initially controlled the weeds but weed infestation was again reached to maximum during the later period of crop growth. Gupta *et al.* (2023) observed that the combination of other herbicide with pyrazosulfuron ethyl was capable to show lowest weed persistence index. However, complete weed free treatment (P_4) always recorded the lowest weed persistence index.

Table 3: Influence of various weed management options on density and dry weight of weeds (pooled data of two years).

Treatments	Weed density (no. of weeds m^{-2})			Weed dry weight (g m^{-2})		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
P_1	3.22 (9.95)	3.43 (11.27)	4.63 (20.93)	4.95 (23.99)	4.66 (21.35)	6.54 (42.23)
P_2	2.92 (8.05)	3.52 (11.88)	4.04 (15.91)	3.88 (14.68)	6.03 (35.89)	5.94 (34.80)
P_3	2.34 (2.75)	2.75 (7.08)	2.82 (7.55)	2.95 (8.22)	3.94 (15.04)	3.88 (14.63)
P_4	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)
P_5	4.66 (21.24)	5.85 (33.70)	6.30 (39.23)	6.47 (41.44)	7.40 (54.25)	9.17 (83.56)
SEm±	0.10	0.07	0.33	0.11	0.12	0.08
CD (P≤0.05)	0.30	0.20	0.99	0.32	0.36	0.24

*Values are √X+0.5 transformed and actual values are in parentheses. DAT- days after transplanting.

Table 4: Influence of various weed management options on WCE (%) and WCI (%) (pooled data of two years).

Treatments	Weed control efficiency (%)			Weed control index (%)		
	30 DAT	45 DAT	60 DAT	30 DAT	45 DAT	60 DAT
P_1	! 53.14	! 66.60	! 46.65	! 42.11	! 60.66	! 49.43
P_2	! 62.08	! 64.81	! 59.50	! 64.57	! 33.90	! 58.36
P_3	✓76.48	✓79.01	✓80.79	✓80.17	✓72.30	✓82.51
P_4	✓100.00	✓100.00	✓100.00	✓100.00	✓100.00	✓100.00
P_5	X 0.00	X 0.00	X 0.00	X 0.00	X 0.00	X 0.00

✓Represented good control of weeds.

! Represented moderate control of weeds.

X Represented no control of weeds. DAT- days after transplanting.

Table 5: Influence of various weed management options on weed persistence index and weed index (mean data of two years).

Treatments	Weed persistence index			Weed
	30 DAT	60 DAT	90 DAT	index (%)
P_1	1.18	1.18	0.95	9.13
P_2	0.93	1.88	1.03	6.44
P_3	1.53	1.32	0.91	2.10
P_4	0.00	0.00	0.00	0.00
P_5	1.00	1.00	1.00	13.32

DAT- Days after transplanting.

Table 6: Influence of various weed management options on economics of paddy cultivation (mean data of two years).

Treatments	Total cost of production (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Benefit: Cost
P_1	55026	107570	52544	1.95
P_2	54571	109830	55259	2.01
P_3	55211	114480	59269	2.07
P_4	61721	116700	54979	1.89
P_5	51221	102670	51449	2.00

However, the lowest weed index recorded to those paddy plots which were considered as completely weed free (0.00%) followed by treated with bispyribac sodium @ 25 g ha^{-1} at 15 DAT + paddy weeder at 30 DAT (2.10%) and the highest weed index was recorded in un-weeded control (13.32%) plots (Table 5).

The above table (Table 6) showed that the highest gross return was recorded in completely weed free *i.e.*, P_4 treatment (₹ 116700 ha^{-1}) followed by bispyribac sodium + paddy weeder *i.e.*, P_3 treatment (₹ 114480 ha^{-1}) whereas, the highest net return was obtained from bispyribac sodium + paddy weeder *i.e.*, P_3 treatment (₹ 59269 ha^{-1}). However, there were no crop-weed competition and results related to crop growth and yield were found best in completely weed free treatment (P_4), but the profit was reduced due to higher cost of cultivation in case of P_4 than others. Highest benefit-cost ratio was also obtained in bispyribac sodium @ 25 g ha^{-1} at 15 DAT + paddy weeder at 30 DAT *i.e.*, P_3 treatment (2.07). Proportionately higher yield with respect to cost of cultivation was obtained in the treatment, bispyribac sodium + paddy weeder (P_3) as compared to other treatments. Swain *et al.* (2023) discovered that the application of bispyribac sodium provided maximum net return from paddy among the chemical weed control options.

CONCLUSION

Following the above results, it might be concluded that combination of mechanical and chemical weed management had direct effect on reducing weed infestation, increasing crop productivity and economic return. Thus, application of bispyribac sodium @ 25 g ha^{-1} at 15 DAT + paddy weeder operation at 30 DAT could be recommended for rice farmers during *kharif* season to achieve highest yield and profit as well as best weed control in *terai* region of West Bengal.

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Ethics and conflict of interest

This research is conducted ethically and in compliance with relevant guidelines and regulations. We, all the authors have declared that no conflict of interest exists that could have appeared to influence the work reported in this paper.

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