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RESEARCH ARTICLE

Chemical weed management in transplanted rice and its residual effect on follow up lathyrus (*Lathyrus sativus* L.)

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ABSTRACT

A field experiment was conducted at Central Research Farm, Gayeshpur, Nadia, West Bengal, India during the *Kharif* (rainy) seasons of 2019-20 and 2020-21 to evaluate bio-efficacy and phytotoxicity of herbicide pretilachlor 50% EC in transplanted rice and its residual effect on *utera*/*paira* (follow up) crop lathyrus. The experiment was placed in randomized complete block design comprising 10 treatments (pretilachlor 50% EC 375, 500, 625, 750, 875 g/ha, pendimethalin 30% EC 1000, 1500 g/ha, Butachlor 50% EC 1250 g/ha, hand weeding at 15 and 30 days after transplanting and unweeded control) and replicated thrice. Pooled results revealed that application of pretilachlor 50% EC 625 g/ha was superior over pendimethalin and butachlor remained equally effective as hand weeding in ensuring high weed control efficiency. Consequently, 4.38 and 4.98 t/ha of grains and straw yields, respectively were obtained at pretilachlor 50% EC 625 g/ha. Further, no phytotoxic effect on crop as well as on soil health was observed under application of that herbicide. Performance of *paira* crop lathyrus did not get hampered due to herbicidal applications in rice due to dissipation of toxicity from soil. Therefore, early post-emergence application of pretilachlor 50% EC 625 g/ha can be safely recommended for transplanted *Kharif* rice cultivation in Gangetic plains of West Bengal.

Keywords: Chemical weed management, Follow up lathyrus crop, *Lathyrus sativus,* Rice, Weed control efficiency, Yield

INTRODUCTION

Rice (*Oryza sativa* L.) plays a vital role in food and livelihood security for almost every household. It is a principal source of food for more than half of the world's population and also an important cereal crop next to wheat which accounts for the major dietary energy requirement of Asian rural people as more than 90 % of rice is grown and consumed in Asia.

About 56% of gross cropped area of Bengal has been occupied by rice and ranks first in cultivated area providing livelihood for about 120-150 million rural households. It contributes about 43% of whole food grain production and 46 % of total cereal production in India (Anonymous 2021). Out of 782 million tonnes of global rice production from 167.1 million hectares, India produced 116.4 mt in 44.5 mha (rainy season: 102.1 mt from 39.27 mha) (FAO, 2020; GOI, 2020). Weeds are most severe and widespread biological constraints to crop production in India and weeds alone cause 33% of losses out of total losses due to pests (Verma *et al.* 2015). Weeds are considered as a major contributors of rice yield loss generally ranged between 18-20% in transplanted rice, 30-35% in direct sown puddled rice and more than 50% in direct seeded upland rice. Weed problem is now a major concern of rice growers throughout the world which claimed to reduce 45-55% yield of rice (Bouman *et al*. 2005). Therefore, proper management of weeds is the fundamental requisite for ensuring quality rice production. In general, weeds problem in transplanted paddy is lower than that of direct-seeded rice (Rao *et al.* 2007). But, in situations where continuous standing water cannot be maintained particularly during the first 45 days, weed infestation in transplanted rice may be as high as direct-seeded rice. Weeds can reduce the grain yield of dry direct-seeded rice (DSR) by 75.8%, wet-seeded rice (WSR) by 70.6% and transplanted rice (TPR) by 62.6% (Singh *et al.*, 2004). The pre-emergence herbicide protects the crop with early and effective control of weeds that assists in maximizing yields, regardless of the production potential that can minimize the application of post-emergence herbicide

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and protect against early-season weed competition. Among the winter growing annual pulse crops, *Lathyrus sativus* (Lathyrus or Khesari) is considered as an 'insurance crop' due to its remarkable drought tolerating ability with minimal external inputs which can easily be grown as a relay crop under rice fallow situation (Bhowmick *et al.*, 2014). Basically, lathyrus is a protein-rich pulse crop (28%) containing considerable proportions of essential minerals like calcium, phosphorus and iron with reliable yields and therefore, believed to be an ideal legume for resource-poor farmers. Considering all these facts, the present experiment was planned to evaluate the weed management through application of chemical herbicide in transplanted *Kharif* rice and its residual effect on performance of *paira* (follow up) crop lathyrus in lower Gangetic plains of West Bengal, India.

MATERIALS AND METHODS

The field experiment was carried out at Central Research Farm, Gayeshpur, Nadia, West Bengal, India during 2019-20 and 2020-21 under randomized complete block design (RCBD) comprising 10 treatments: pretilachlor 50% EC 375 g/ha, pretilachlor 50% EC 500 g/ha, pretilachlor 50% EC 625 g/ha, pretilachlor 50% EC 750 g/ha, pretilachlor 50% EC 875 g/ha, pendimethalin 30% EC 1000 g/ha, butachlor 50% EC 1250 g/ha, hand weeding at 15 and 30 days after transplanting (DAT), unweeded control, pendimethalin 30% EC 1500 g/ha), replicated thrice. Rice variety *'IET-4786'* was sown in nursery and then transplanted on the main field at a spacing of 20 × 15 cm with 2 seedlings /hill. Gap filling was done at 7 DAT. Individual plot size was 4 × 3 m. To test herbicides pretilachlor 50% EC and two standard check herbicides, pendimethalin 30% EC and butachlor 50% EC at various doses were applied with the spray volume of 500 L/ha through knapsack sprayer under standing water of rice field at early post-emergence stage (4 DAT). Recommended doses of fertilizers (60:30:30 N:P:K kg/ha) was applied through urea, S.S.P. and M.O.P. (1/4th N, full P and 3/4th K as basal during final land preparation and ½ N at active tillering stage *i.e*. 21 DAT and 1/4th N and K at panicle initiation stage *i.e*. 42 DAT). 2-3 cm standing water from 2-30 DAT and 4-5 cm standing water for next 7-10 days were maintained, after which soil was allowed to saturate under no application of water for 4-5 days. After heading to hard dough stage intermittent irrigation (2 cm water application at 2 days interval) was done up to 30 days after heading. Water supply was stopped at 12-15 days before harvesting. Before harvesting of *Kharif* rice, *paira* (follow up) crop lathyrus (cv. *Nirmal*) was sown on the experimental field to evaluate residual toxic effect of applied herbicide on succeeding crop lathyrus.

Observations included weed density, weed dry weight and weed control efficiency (WCE) of dominant weed flora in rice field at 30, 45 and 60 days after application of herbicide as well as yield and yield attributes *i.e*. grain yield, straw yield, biological yield and harvest index of transplanted *Kharif* rice. Production economics of rice was also estimated. Furthermore, germination percentage, plant height, pods/plant, seeds/pod and seed yield of *paira* crop lathyrus at harvest were noted. Soil samples of 0-15 cm depth were collected from experimental plots at different interval and toxicity on soil rhizospheric micro-organisms (bacteria, fungi and actinomycetes) was analyzed by counting on agar plates as number of viable cells per gram of soil using Thronton's agar medium, Martin-Rose Bengal Streptomycin agar medium and Jensen's agar medium respectively through serial dilution technique, pour plate method (Pramer and Schmidt, 1965) followed by incubation at 28±1°C. The counts were taken at 5th day of incubation. Phytoxicity study involved visual symptoms (epinasty, hyponasty, vein clearing, wilting and leaf injury) noted at 1, 3, 5, 7, 15, 30 DAA and represented as per phytotoxicity rating scale (0, 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90 and 91-100% crop injury were represented by 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 scales, respectively).

Data recorded from the field as well as the laboratory were statistically analyzed through analysis of variance (ANOVA) method as prescribed by Panse and Sukhatme (1985) in online OP-stat portal (Sheoran *et al.*, 1998) and treatment means were compared through least significant difference (LSD) at 5% level of significance. As wide variation existed in the original data sets of weed densities and dry weights, they were subjected to square root transformation ($\sqrt{x+0.5}$) for improving the homogeneity.

RESULTS AND DISCUSSION

Dominant weed flora

Observations during both the years of experiment expressed that rice field was mostly dominated by grasses like *Echinochloa crus-galli*, *Echinochloa colona*, sedges like *Cyperus difformis*, *Fimbristylis miliacea* and broad leaf weeds like *Ludwigia parviflora*, *Monochoria vaginalis*, *Alternanthera philoxeroides*, *Marsilea quadrifolia*. Other noticeable weed floras were *Leersia hexandra*, *Ammania baccifera*, *Echinochloa formosensis*, *Cyperus rotundus*, *Cyperus iria*, *Commelina benghalensis*, *Oxalis corniculate etc*. Shahabuddin *et al.* (2016) and Mondal *et al.* (2019) also noticed similar types of weed flora in transplanted rice field.

Weed density

Weed density (no./m^2) at 30, 45 and 60 days after application (DAA) of herbicides represent the efficacy of various weed management practices on suppression of weeds. Pooled value stated that hand weeding at 15 and 30 DAT significantly reduced weed density of rice field over unweeded control, which was followed by various herbicidal applications. Among chemical treatments, pretilachlor 50% EC 625 g/ha recorded lowest population in all three categories of weed biomass during 30, 45 and 60 DAA (**Table 1**). It was also noted that pretilachlor 50% EC at various doses were superior over butachlor 50% EC and pendimethalin 30% EC in suppression of dominant weed floras of rice field. Application of selective herbicide, pretilachlor effectively reduced weed density from rice field, which might be due to its inhibitory effect on cell division of weeds (Challam and Thabah, 2018). Moreover, blocking of protein, nucleic acid and gibberelic acid synthesis by pretilachlor might be another reason for suppression of weeds in rice field (Das 2008).

Weed dry weight

Weed dry weight (g/m^2) is most appropriate measure of various weed management practices. Pooled results depicted maximum dry weights of all the categories of weeds under unweeded control as no measure was incorporated there to suppress weeds. Among various weed management practices, hand weeding at 15 and 30 DAT mostly reduced dry weights of grass, sedges and broad leaf weeds indicating its efficacy of suppressing weeds of rice field, whereas among herbicidal application, pretilachlor 50% EC 625 g/ha also significantly reduced weed dry weights at 30, 45 and 60 DAA and these values were statistically at par (**Table 2**). The result was in agreement with the finding of Mondal *et al.* (2019) who similarly noticed that pretilachlor 50% EC reduced weed biomass better than other herbicidal applications like butachlor in transplanted rice.

Table 1. Weed density (no./m^2) of transplanted *Kharif* rice as influenced by different weed control measures (pooled value of two years)

Treatment	Weed density (no./m^2) 30 DAA			45 DAA			60 DAA		
	Grass	Sedges	Broad-leaf	Grass	Sedges	Broad-leaf	Grass	Sedges	Broad-leaf
Pretilachlor 375 g/ha	1.46(1.4)	1.98(1.57)	2.51 (1.73)	3.02(1.88)	3.76(2.06)	4.08(2.14)	3.68(2.04)	3.94(2.10)	4.32(2.19)
Pretilachlor 500 g/ha	1.43(1.39)	1.92(1.56)	2.42(1.71)	2.74(1.8)	2.49(1.73)	3.84(2.08)	3.46(1.98)	3.71(2.05)	4.05(2.13)
Pretilachlor 625 g/ha	1.34(1.36)	1.81(1.52)	2.11(1.62)	2.21(1.65)	2.14(1.62)	3.35(1.96)	3.12 (1.9)	3.18(1.91)	3.13(1.90)
Pretilachlor 750 g/ha	1.42(1.39)	1.82(1.52)	2.34(1.69)	2.31(1.68)	2.32(1.68)	3.41(1.98)	3.34(1.95)	3.25(1.93)	3.39(1.97)
Pretilachlor 875 g/ha	1.40(1.38)	1.84(1.53)	2.20(1.64)	2.26(1.66)	2.28(1.67)	3.54(2.01)	3.24(1.93)	3.45(1.98)	3.32(1.94)
Pendimethalin 1000 g/ha	1.52(1.42)	2.24(1.66)	2.76(1.81)	3.83(2.08)	4.41(2.22)	4.51(2.24)	3.87(2.09)	4.29(2.18)	4.87(2.31)
Butachlor 1250 g/ha	1.67(1.47)	2.43(1.71)	2.87(1.84)	3.88(2.09)	4.62(2.26)	4.83(2.31)	3.98(2.11)	4.56(2.24)	5.36(2.42)
Hand weeding at 15&30 DAT	1.28(1.33)	1.78(1.51)	1.98(1.57)	2.18(1.64)	2.11(1.62)	3.28(1.94)	3.04(1.88)	3.08(1.89)	3.08(1.89)
Unweeded Control	2.57(1.75)	4.13(2.15)	3.54(2.01)	4.62(2.26)	5.78(2.51)	5.41(2.43)	4.74(2.28)	4.96(2.33)	6.17(2.58)
Pendimethalin 1500 g/ha	1.49(1.41)	2.02(1.59)	2.63(1.77)	3.72(2.05)	4.36(2.2)	4.35(2.2)	3.64(2.03)	4.17(2.16)	5.09(2.36)
LSD (p=0.05)	0.24	0.64	0.38	0.31	0.54	0.37	0.26	0.22	0.24

*Data presented in the table indicated square root transformed value ($\sqrt{x+0.5}$) of original data set

Table 2. Weed dry weight (g/m^2) of transplanted *Kharif* rice as influenced by different weed control measures (pooled value of two years)

Treatment	Weed dry weight(g/m^2) 30 DAA			45 DAA			60 DAA		
	Grass	Sedges	Broad leaf	Grass	Sedges	Broad-leaf	Grass	Sedges	Broad-leaf
Pretilachlor 375 g/ha	15.84(4.0)	17.82(4.3)	20.17(4.5)	16.29(4.1)	18.23(4.3)	21.24(4.7)	16.31(4.1)	18.54(4.4)	23.78(4.9)
Pretilachlor 500 g/ha	14.58(3.8)	17.12(4.2)	19.12(4.4)	15.58(4.0)	17.42(4.2)	20.42(4.6)	16.05(4.1)	17.62(4.2)	22.13(4.7)
Pretilachlor 625 g/ha	11.36(3.4)	15.12(3.9)	16.14(4.1)	12.18(3.6)	13.16 (3.7)	17.35(4.2)	12.52(3.6)	14.23(3.8)	18.52(4.4)
Pretilachlor 750 g/ha	13.89(3.7)	17.05(4.2)	16.24(4.1)	13.68(3.8)	17.23(4.2)	18.25(4.3)	14.26(3.8)	15.41(4.0)	19.47(4.5)
Pretilachlor 875 g/ha	14.24(3.8)	16.89(4.2)	18.43(4.3)	14.82(3.9)	17.27(4.2)	19.57(4.5)	16.21(4.1)	16.52(4.1)	21.21(4.6)
Pendimethalin 1000 g/ha	18.37(4.3)	17.92(4.3)	21.45(4.7)	17.08(4.2)	21.37(4.7)	23.54(4.9)	16.51(4.1)	20.12(4.5)	24.73(5.0)
Butachlor 1250 g/ha	17.69(4.2)	18.24(4.3)	20.42(4.6)	16.81(4.2)	22.42(4.8)	22.87(4.8)	17.42(4.2)	19.13(4.4)	23.58(4.9)
Hand weeding at 15&30 DAT	11.04(3.3)	14.67(3.9)	14.56(3.9)	11.95(3.5)	13.05(3.7)	17.08(4.2)	12.12(3.5)	13.37(3.7)	17.85(4.3)
Unweeded Control	19.89(4.4)	23.74(4.9)	25.28(5.1)	20.39(4.6)	28.21(5.4)	28.67(4.5)	20.24(4.5)	25.48(5.1)	28.23(5.4)
Pendimethalin 1500 g/ha	17.62(4.5)	16.45(4.1)	20.34 (4.6)	15.45(4.0)	20.82(4.6)	22.25 (4.7)	16.32(4.1)	19.23(4.4)	23.56(4.9)
LSD (p=0.05)	1.22	0.81	2.54	0.72	1.12	0.53	0.72	0.48	0.62

*Data presented in the table indicated square root transformed value ($\sqrt{x+0.5}$) of original data set

Weed control efficiency

Weed control efficiency also similarly varied according to various weed management practices. Pooled results (**Table 3**) showed that hand weeding at 15 and 30 DAT ensured best value of weed control efficiency at 30, 45 and 60 DAA. However, among the various herbicidal measures, pretilachlor 50% EC 625 g/ha was almost equally effective as that of hand weeding during the 30, 45 and 60 DAA period of observations. pretilachlor 50% EC 625 g/ha ensured the best results of weed control efficiency at 30, 45 and 60 DAA which was followed by same herbicide 750 g/ha, 875 g/ha, 500 g/ha and 375 g/ha (**Table 3**). Further, impairment of growth and cell division by the herbicidal mode of action led to death of weed flora of rice field. These facts might be there behind the high WCE in rice field by the test herbicide pretilachlor 50% EC as observed in the present experiment.

Yield and yield attributes

Pooled results revealed that yield of transplanted *Kharif* rice varied significantly in response to various weed management practices. Pooled results showed that hand weeding at 15 and 30 DAT recorded maximum numbers of productive tillers/m^2 and number of filled grains/panicle, whereas among chemical treatments, pretilachlor 50% EC 625 g/ha reported the best value which was better than other doses of Pretilachlor, Butachlor and pendimethalin applications. The maximum grain and straw yields of transplanted *Kharif* rice were achieved when hand weeding was done at 15 and 30 DAT. However, among chemical measures, maximum grain and straw yields were attained under application of pretilachlor 50% EC 625 g/ha which remained almost equally effective as hand weeding at 15 and 30 DAT. Consequently, biological yield of transplanted *Kharif* rice also followed the similar trend. Harvest index of transplanted *Kharif* rice was dependent on economic (grain) and biological yields. Pooled results on harvest index (**Table 4**) however explored slightly different trends of grain, straw and biological yields of transplanted *Kharif* rice. Highest harvest index of transplanted *Kharif* rice was observed when pretilachlor 50% EC 750 g/ha was applied which was closely followed by application of pretilachlor 50% EC 625 g/ha and hand weeding at 15 and 30 DAT. The lowest grain, straw, biological yields and harvest index of transplanted *Kharif* rice were obtained from unweeded control (**Table 4**).

Effect on *paira* crop lathyrus

Experimental results (**Table 5**) explored that there was no residual effect of herbicidal application

Table 3. Weed control efficiency (%) of transplanted *Kharif* rice as influenced by different weed control measures (pooled value of two years)

Treatment	Weed control efficiency (%)								
	30 DAA			45 DAA			60 DAA		
	Grass	Sedges	Broad-leaf	Grass	Sedges	Broad-leaf	Grass	Sedges	Broad-leaf
Pretilachlor 375 g/ha	72.69	75.14	73.65	73.59	72.43	75.32	7311	72.48	75.26
Pretilachlor 500 g/ha	71.61	77.60	81.89	65.70	71.03	78.83	64.38	70.08	77.56
Pretilachlor 625 g/ha	78.98	76.82	76.94	78.28	76.59	80.21	76.23	76.22	81.21
Pretilachlor 750 g/ha	75.04	73.33	74.42	74.27	73.30	72.34	73.26	72.98	73.19
Pretilachlor 875 g/ha	76.12	77.64	76.03	75.41	79.27	78.59	72.23	80.18	79.23
Pendimethalin 1000 g/ha	67.92	66.44	71.51	71.82	63.73	65.04	71.01	63.29	64.27
Butachlor 1250 g/ha	84.59	83.87	87.92	75.37	77.19	78.12	74.49	76.62	78.17
Hand weeding at 15&30 DAT	89.23	88.23	92.54	88.72	91.22	91.39	88.65	90.89	91.89
Unweeded control	76.54	76.17	78.38	72.32	74.15	73.25	73.21	73.63	72.19
Pendimethalin 1500 g/ha	79.85	78.62	78.83	76.62	75.19	74.19	76.32	74.23	73.96
LSD (p=0.05)	--	--	--	--	--	--	--	---	---

Table 4. Effect of different weed control measures on yield and yield attributes of transplanted *Kharif* rice (pooled of two years)

Treatment	No. of productive tillers/m^2	No. of filled grains/ panicle	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (%)
Pretilachlor 375 g/ha	316	80.11	3.89	4.71	45.06
Pretilachlor 500 g/ha	328	82.64	4.02	4.78	45.71
Pretilachlor 625 g/ha	336	83.12	4.39	4.98	46.52
Pretilachlor 750 g/ha	320	81.58	3.97	4.52	47.00
Pretilachlor 875 g/ha	312	76.82	3.82	4.72	44.57
Pendimethalin 1000 g/ha	284	72.76	3.54	4.46	44.14
Butachlor 1250 g/ha	299	74.10	3.68	4.30	46.09
Hand weeding at 15&30 DAT	345	84.18	4.46	5.08	46.60
Unweeded control	237	65.21	2.12	4.84	30.35
Pendimethalin 1500 g/ha	290	73.46	3.59	4.77	42.48
LSD (p=0.05)	1.88	0.74	0.02	0.03	0.21

in transplanted *Kharif* rice on *paira* (follow up) crop lathyrus. Germination % at 10 DAS, plant height, pods/plant, seeds/pod and seed yield of lathyrus did not significantly vary under herbicidal application in previous crop rice. However, among various herbicides applied in transplanted *Kharif* rice, performance of *paira* crop lathyrus was better observed under pretilachlor 50% EC at various doses. The plant height, pods/plant, seeds/pod, seed yield of lathyrus and germination % at 10 DAS were noticed best where previously herbicide, pretilachlor 50% EC 625 g/ha was applied in transplanted *Kharif* rice as weed control measures (**Table 5**). Hand weeding in transplanted *Kharif* rice at 15 and 30 DAT closely followed the results obtained from application of herbicide, pretilachlor 50% EC 625 g/ha in transplanted *Kharif* rice since hand weeding in rice can preserve the soil nutrient and moisture for next crop (lathyrus) as it was devoid of any toxic effect. No residual toxic effects of herbicides on *paira* crop lathyrus might be due to the degradation of herbicidal molecules by the microorganisms for their own nourishment (Bera and Ghosh 2013).

Soil microbial population

Pooled results (**Table 6**) showed that initially there were no statistically significant variations of bacterial, fungal and actinomycetes populations in the rhizosphere regions of rice in experimental plots. However, after application of herbicides, the microbial populations in the experimental soil varied significantly. There were drastic reductions of bacterial, fungal and actinomycetes populations in soil soon after application of herbicides. Bera and Ghosh (2013) also reported sudden declines of microbial populations soon after application of herbicides in rice field as concentrations of toxic chemicals were high on soil at the time of application which affected physiological process of the microbial community. However, among different herbicides, reduction of microbial populations was comparatively less in pretilachlor 50% EC. At 30 DAA, slight recoveries of microbial populations from 10 days after application were found, which continued up to 60 DAA. It might be due to gradual fading of herbicidal efficacy as days progressed. However, from 30 DAA onwards, increments in microbial populations were noticed as bacteria, fungi and actinomycetes population continued their recovery considerably and at 60 DAA, bacterial, fungal and actinomycetes population exceed the initial microbial populations. The result might be due to the fact that soil micro-organisms undergone effective degradation of herbicidal molecule to obtain carbon-based products for their own nourishment and multiplication (Biswas and Dutta 2019).

Table 5. Germination (%), seed yield and ancillary characters of *paira* crop lathyrus as influenced by different weed control measures applied in transplanted *Kharif* rice (pooled of two years)

Treatment	Germination % at 10 DAS	Plant height (cm)	Pods/plant	Seeds/pod	Seed yield (kg/ha)
Pretilachlor 375 g/ha	82	86.5	32	3.2	880
Pretilachlor 500 g/ha	81	88.3	31	3.1	865
Pretilachlor 625 g/ha	85	92.2	33	3.4	898
Pretilachlor 750 g/ha	80	85.2	30	3.1	872
Pretilachlor 875 g/ha	83	85.3	31	3.2	859
Pendimethalin 1000 g/ha	82	82.2	32	2.9	862
Butachlor 1250 g/ha	81	84.5	30	3.1	873
Hand weeding at 15&30 DAT	85	90.1	32	3.3	882
Unweeded control	82	89.2	31	3.2	876
Pendimethalin 1500 g/ha	84	83.5	29	2.8	862
LSD (p=0.05)	NS	NS	NS	NS	NS

Table 6. Microbial population of the experimental soil at various days after herbicide application (pooled of two years)

Treatment	Bacteria (CFU x 10^6 /gm of soil)				Fungi (CFU x 10^4 /gm of soil)				Actinomycetes (CFU x 10^5 /gm soil)			
	Initial	10 DAA	30 DAA	60 DAA	Initial	10 DAA	30 DAA	60 DAA	Initial	10 DAA	30 DAA	60 DAA
Pretilachlor 375 g/ha	35.52	32.74	34.54	85.62	55.31	36.52	45.53	88.45	55.34	37.72	43.41	89.57
Pretilachlor 500 g/ha	35.75	30.42	35.85	88.23	56.85	32.35	42.64	96.68	56.68	33.52	41.55	99.38
Pretilachlor 625 g/ha	34.66	29.56	36.35	96.82	54.68	30.84	44.38	108.47	54.29	33.59	44.52	102.17
Pretilachlor 750 g/ha	35.54	31.82	35.23	99.71	55.82	28.78	42.89	108.42	55.75	32.87	42.68	98.73
Pretilachlor 875 g/ha	36.72	30.24	35.21	102.57	55.93	27.37	43.47	107.23	56.83	32.18	43.75	95.96
Pendimethalin 1000 g/ha	35.57	24.23	32.72	84.56	56.57	22.98	40.12	81.46	53.12	28.18	40.85	91.43
Butachlor 1250 g/ha	35.38	22.82	34.51	80.41	55.41	21.42	38.45	78.67	54.58	27.54	38.12	88.64
Hand weeding at 15&30 DAT	36.32	56.18	59.64	112.52	54.34	58.72	59.56	108.65	56.24	62.57	65.92	101.95
Unweeded control	35.62	55.27	57.14	107.26	55.57	56.23	57.24	82.57	54.32	61.29	64.58	93.57
Pendimethalin 1500 g/ha	36.74	22.58	34.25	76.41	54.28	20.45	37.89	74.58	53.47	25.87	36.87	84.34
LSD (p=0.05)	NS	3.21	4.22	6.21	NS	3.22	5.21	6.23	NS	2.26	3.23	3.51

Phytotoxicity

Phytotoxicity study (**Table 7**) revealed that apart from pendimethalin 30% EC 1500 g/ha, no other herbicide application showed phytotoxicity symptoms such as epinasty, hyponasty, vein clearing, wilting and leaf injury on rice. The observation was in line with the finding of Mondal *et al.* (2019) in transplanted winter rice. Selective nature of the herbicide might be the reason behind the observation. pendimethalin 30% EC at high dose *i.e.* 1500 g/ha showed 1-20% phytotoxic symptoms which were visible mostly from 5 DAA and those slightly increased as days progressed up to 30 DAA on rice. Bandopadhyay and Choudhury (2009) also similarly reported phytotoxic effects of pendimethalin at higher doses on mustard.

Economics

Production economics of transplanted *Kharif* rice showed variations under different weed control measures (**Table 8**). The maximum cost of cultivation (₹ 51709/ha) was incurred when hand weeding was done due to high labour involvement to remove weeds from the field, while unweeded control fetched lowest cost of cultivation (₹ 44209/ha) due to no weed control measure. Based on the market price and quantity required for weed control, cost of cultivation varied among chemical herbicide treated plot. Yet, less cost of cultivation was required for pretilachlor treated plots over other herbicides. Due to better positive impact on yield of rice, hand weeded plot showed maximum gross return (₹ 90780/ha), while unweeded control made lowest gross and net returns (₹ 44970 and ₹ 761/ha) as well as B:C (1.02) due to negative impact of weeds on growth and yield of crop. pretilachlor 50% EC 625 g/ha recorded highest net return (₹ 42994/ha) and B:C (1.93) among all the treatments due to its greater weed control efficiency at less cost, which reflected positively on growth, yield and economics of transplanted *Kharif* rice. Similar observation was noted by Biswas *et al.* (2021) in cotton.

Conclusion

The present investigation confirms the greater efficacy of pretilachlor 50% EC in controlling weeds from transplanted *Kharif* rice field than butachlor and pendimethalin. Further, it has proved its equal effectiveness and emerged as a potential alternative of uneconomical, labour-intensive hand weeding. pretilachlor 50% EC has also confirmed the safety of

Table 7. Visual observations on phytotoxicity in different doses of herbicides (Scale 1 - 10)

Treatment	Epinasty						Hyponasty						Vein clearing						Wilting						Leaf injury					
	1 DAA	3 DAA	5 DAA	7 DAA	15 DAA	30 DAA	1 DAA	3 DAA	5 DAA	7 DAA	15 DAA	30 DAA	1 DAA	3 DAA	5 DAA	7 DAA	15 DAA	30 DAA	1 DAA	3 DAA	5 DAA	7 DAA	15 DAA	30 DAA	1 DAA	3 DAA	5 DAA	7 DAA	15 DAA	30 DAA
Pretilachlor 375 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pretilachlor 500 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pretilachlor 625 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pretilachlor 750 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pretilachlor 875 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pendimethalin 1000 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Butachlor 1250 g/ha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pendimethalin 1500 g/ha	0	0	1	1	2	2	0	0	1	2	2	2	0	0	1	1	1	2	0	0	1	1	2	2	0	0	1	1	2	2

Table 8. Effect of different weed control measures on economics of transplanted *Kharif* rice (pooled of two years)

Treatment	Cost of cultivation (₹/ha)	Gross return* (₹/ha)	Net return (₹/ha)	B:C
Pretilachlor 375 g/ha	46171	79388	33216	1.72
Pretilachlor 500 g/ha	46259	81975	35716	1.77
Pretilachlor 625 g/ha	46346	89340	42994	1.93
Pretilachlor 750 g/ha	46434	80805	34371	1.74
Pretilachlor 875 g/ha	46521	78030	31509	1.68
Pendimethalin 1000 g/ha	47242	72375	25133	1.53
Butachlor 1250 g/ha	46659	74985	28326	1.61
Hand weeding at 15 and 30 DAT	51709	90780	39071	1.76
Unweeded control	44209	44970	761	1.02
Pendimethalin 1500 g/ha	47909	73583	25674	1.54
LSD (p=0.05)				

*Price of rice grain and straw: ₹ 19.5/kg and ₹ 0.75/kg, respectively its use by ensuring no phytotoxic effect on crop as well as on soil health and negligible residual toxicity persistence on soil. Based on the results, post-emergence application of pretilachlor 50% EC 625 g/ ha can be recommended to rice growers of Gangetic plains of West Bengal, India for achieving high suppression of dominant weed flora and ensuring high productivity of rice as well as its follow up (*paira*) crop lathyrus.

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