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Effect of sequential application of herbicides on productivity and profitability of transplanted rice

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ABSTRACT

Field experiments were conducted during *Rabi* (winter season) 2018-19 and 2019-20 to study the effect of sequential application of herbicides on productivity and profitability of transplanted rice. Pre-emergence (PE) application of pretilachlor 750 g/ha *fb* ready-mix post-emergence (PoE) application of triafamone + ethoxysulfuron 60 g/ha recorded significantly higher grain yield which was found to be at par with two hand weedings. Sequential application of pretilachlor 750 g/ha *fb* triafamone + ethoxysulfuron 60 g/ha proved to be more effective in minimising total weed biomass (5 g/m^2), weed index (4%) and enhancing weed control efficiency (96%), grain yield (5.4 t/ha), net returns (47.0 x10^3 ₹/ha) and benefit cost ratio (1.9) than weedy check. Tank-mix application of fenoxaprop-p-ethyl 60 g/ha with ethoxysulfuron 18.75 g/ha or chlorimuron + metsulfuron 4 g/ha after pretilachlor 750 g/ha showed phytotoxicity at 5 days after application (DAA) of herbicide, which got recovered at 30 DAA.

INTRODUCTION

Rice crop suffers from various biotic and abiotic production constraints. Weed infestation has been established as one of the important factors responsible for lower productivity. Weed competition under transplanted conditions caused yield reductions up to 45% (Manhas *et al.* 2012). Generally, water management, mechanical and manual weeding and herbicides are used for weed control in rice field (Juraimi *et al.* 2013). The traditional method of weed control in Odisha is manual weeding. Usually, hand weeding is conducted two or three times during the planting season. Although it is effective, but becoming difficult due to labour scarcity, increasing cost. The effectiveness depends on the moisture content of soil at operation date. Although a number of pre-emergence herbicides provide good control of grassy weeds, but due to continuous use of such herbicides, a shift in weed flora and evolution of herbicide resistant weeds has been observed (Rajkhowa *et al.* 2006). Herbicide rotation and herbicide mixtures are two major strategies to prevent development of herbicide resistance in weeds. Herbicides with different mode of actions when mixed together, bind to different target site in weed and prevent the probability of target site resistance in susceptible species (Paswan *et al.* 2012). Technological developments on mixing herbicides with different active ingredients aiming to get a broad-spectrum control are expected to slow the emergence of weeds resistant to herbicides, reduce production costs and reduce herbicide residues (Guntoro *et al.* 2013). Therefore, the present study was undertaken with different post-emergence herbicide mixtures applied after pretilachlor (PE) to observe the effectiveness in weed control, yield improvement and economics of transplanted rice in irrigated commands.

MATERIALS AND METHODS

A field experiment was conducted during *Rabi* (winter season) 2018-19 and 2019-20 at the Regional Research and Technology Transfer Station, Chiplima (21.3^0 N latitude and 83.9^0 E longitude), Odisha University of Agriculture and Technology, Bhubaneshwar, India. The soil of experimental field was clay loam with porosity 39.28%, infiltration rate 0.26 cm/hr, water holding capacity 25.56% on weight basis, field capacity 19.7% on weight basis, permanent wilting point 10%, acidic (pH 5.65), low in organic carbon (4.7 g/kg) and available N (242 kg/ha), P (9.2 kg/ha) and medium in available K (155 kg/ha). The experiment was laid out in a randomized block design with 3 replications. The treatments comprised of ten weed management practices, *viz*. Pretilachlor750 g/ha as PE, pretilachlor 750 g/ha as PE *fb* chlorimuron ethyl + metsulfuron methyl 4g/ha as PoE, pretilachlor 750 g/ha as PE *fb* flucetosulfuron 25 g/ha as PoE, pretilachlor 750 g/ha as PE *fb* penoxsulam + cyhalofop butyl 135 g/ha as PoE, pretilachlor 750 g/ha as PE *fb* fenoxaprop-p-ethyl 60 g/ha + chlorimuron-ethyl + metsulfuron-methyl 4 g/ ha as PoE, pretilachlor 750 g/ha as PE *fb* fenoxaprop-p-ethyl 60 g/ha+ ethoxysulfuron 18.75 g/ha as PoE, pretilachlor 750 g/ha as PE *fb* bispyribac-sodium 25 g/ha as PoE, pretilachlor 750 g/ha as PE *fb* triafamone + ethoxysulfuron 60 g/ha as PoE, hand weeding at 20 and 40 DAT (weed free) and weedy check.

Pre-emergence (PE) herbicides were broadcasted by mixing with 50 kg sand/ha at 3 days after transplanting and post-emergence herbicides were sprayed at 20 DAT. Post-emergence (PoE) herbicides were applied with knapsack sprayer fitted with flat fan nozzle using 375 L/ha of water. A thin film of water was maintained in the field at the time of application of pre and post-emergence herbicides. Rice variety '*MTU 1001'*was transplanted in February and harvested in May. The land was prepared by giving two ploughings each followed by planking with the help of a tractor – drawn cultivator. The puddling was done one day before transplanting. Rice crop was fertilized with N, P and K at 80, 40 and 40 kg/ha, respectively. Full dose of P and K along with half dose of N were applied as basal and remaining half dose of N was applied in two equal splits at tillering and panicle-initiation stage of the crop. Two seedlings of rice were transplanted at a spacing of 20 ×10 cm. Plant protection measures and irrigation was provided as and when required.

Data on crop phytotoxicity was assessed visually on a scale of 1-5 (Okafor 1986) at 5 and 30 DAA of herbicide. Plant chlorophyll content was measured in the flag leaf at 5 DAA and 30 DAA of herbicide using chlorophyll meter (SPAD-502, Minolta Camera Co, Osaka, Japan) as SPAD values of intact leaves (Peng *et al*. 1993). Data on weed density (number/m^2), weed biomass (g/m^2), yield attributes and yield were recorded. A quadrate of 0.5 m^2 was placed at two places in each plot to determine the density and dry weight of different weeds. Weed dry weight was recorded after drying the weed samples at 85^0C for 16 hour in hot air circulating oven (Klingman 1971). The data on weeds were subjected to square root transformation $(\sqrt{x+1})$ to normalise their distribution. weed control efficiency and weed index was calculated as per standard formula.

Economics was computed using the prevailing market prices for inputs and outputs such as rice grain (₹ 17.5 X 10^3/t), rice straw (₹ 0.8 X 10^3 /t), manual labour (₹ 0.28 X 10^3 /day), fenoxaprop-p-ethyl 9 EC (₹ 585/250 ml), flucetosulfuron 10 WG (₹ 750/100g), chlorimuron + metsulfuron 20 WP (₹ 207/8g), ethoxysulfuron15 WDG (₹ 370/50g), cyhalofop + penoxsulam 6 OD (₹ 900/l), triafamone + ethoxysulfuron 30 WG (₹ 800/45g), pretilachlor 50 EC (₹ 300/1L.), bispyribac-sodium 10 EC (₹ 835/100 ml). The net returns were computed by deducting the total cost of cultivation from the gross returns and benefit: cost ratio was calculated by dividing the net returns with the cost of cultivation. The data obtained on various parameters, *viz*. weed density, weed dry matter, yield attributes and yield were tabulated and subjected to analysis of variance techniques as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on weeds

Major weed species infesting the field were; *Echinochloa crus-galli* L., *Echinochloa colona* L., *Paspalum distichum* L., *Cyperus iria* L., *Cyperus difformis* L., *Fimbristylis miliacea* L., *Scirpus acutus* L., *Marsilea quadrifolia* L., *Ammania baccifera* L., *Alternanthera sessilis* L., *Ludwigia parviflora* L. On an average of two years, weed density of 104/m^2 was observed in weedy plots at 40 DAT which corresponds to 30.6, 33.1 and 36.6 % of grasses, sedges and broad-leaved weeds, respectively (**Table 1**).

Sedges and broad-leaved weeds were predominant at 40 DAT in all other treatments except pretilachlor 750 g/ha PE *fb* bispyribac 25 g/ha PoE and pretilachlor 750 g/ha PE *fb* triafamone + ethoxysulfuron 60 g/ha PoE. Pooled data of two years study showed that pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of triafamone + ethoxysulfuron 60 g/ha resulted in the lowest weed density with 2 grasses, 1 sedge/m^2 and no broad-leaved weed (**Table 1**). The better performance of this treatment might be attributed to the effective control of grasses at initial stage by pretilachlor and control of broad-leaved weeds and sedges at later stages by triafamone + ethoxysulfuron, which was found to be statistically at par with pretilachlor 750 g/ha *fb* bispyribac-sodium 25 g/ha and pretilachlor 750 g/ha *fb* fenoxaprop -p-ethyl 60 g/ha + ethoxysulfuron 18.75 g/ha. Similar results were also reported by Hossain and Mondal (2014).

Among herbicide treatments the lowest weed biomass (5.0 g/m^2) was found in pretilachlor 750 g/ha *fb* post-emergence application of triafamone + ethoxysulfuron 60 g/ha, which was at par with pretilachlor 750 g/ha *fb* bispyribac-sodium 25 g/ha (**Table 2**). Post-emergence application of ready-mix triafamone + ethoxysulfuron recorded complete reduction in biomass of broad-leaf weeds. The high selectivity of herbicides to rice and non-selectivity to weeds was the reason of better control of weeds. Pretilachlor caused reduction in germination of emerging weed during initial period of growth, further post-emergence application of triafamone + ethoxysulfuron has controlled the late emerging sedges and broad-leaved weeds. Besides this treatment, pre-emergence application of pretilachlor 750 g/ha *fb* fenoxaprop-p-ethyl 60 g/ha + ethoxysulfuron 18.75 g/ha PoE also recorded low biomass of broad-leaved weeds (1.1 g/m^2). The lower biomass of broad-leaved weeds recorded in these treatments might be due to efficiency of ethoxysulfuron in the mixtures Kumar *et al.* (2013). The sedges were much problematic in the rice field of this zone. The dry matter of sedges was reduced in most of the treatments where combinations of herbicides were used. The lower biomasses of sedges were recorded with application of pretilachlor 750 g/ha *fb* post-emergence application of triafamone + ethoxysulfuron 60 g/ha, which was at par with pretilachlor 750 g/ha *fb* bispyribac-sodium 25 g/ha, pretilachlor 750 g/ha *fb* fenoxaprop-p-ethyl 60 g/ha + chlorimuron + metsulfuron 4 g/ha and pretilachlor 750 g/ha *fb* flucetosulfuron 25 g/ha. The lowest weed biomass of sedges was also found in pretilachlor *fb* flucetosulfuron (0.3g/m^2). Arya and Syriac (2018) reported that flucetosulfuron provided 24-32% reduction in sedge population over bispyribac-sodium.

Among the herbicide treatments, the highest weed control efficiency (96%) and lowest weed index (4%) was recorded with pretilachlor 750 g/ha *fb* post-emergence application of triafamone + ethoxysulfuron 60 g/ha, which was closely followed by pretilachlor 750 g/ha *fb* bispyribac-sodium 25 g/ha, pretilachlor 750 g/ha *fb* fenoxaprop -p-ethyl 60 g/ha + ethoxysulfuron 18.75 g/ha (**Table 2** and **3**). The better performance of post-emergence treatments with herbicide combinations indicates their superiority over sole application. The lowest weed control efficiency (56%) and highest weed index (30%) was found in pre-emergence application of pretilachlor 750 g/ha without application of any post-emergence herbicides.

Yield attributes and yield

Pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of triafamone + ethoxysulfuron 60 g/ha recorded significantly higher number of tillers/hill (9.7) and grains/panicle (148), which was at par with pretilachlor 750 g/ha *fb* bispyribac-sodium 25 g/ha (9.3 and 141). Sole application of pretilachlor 750 g/ha as pre-emergence recorded lower tillers/hill (7.3) and grains/panicle

Table 1. Effect of weed control treatments on weed density at 40 DAT in transplanted rice

Treatment	Weed density (no./m^2) at 40 DAT											
	2018-19				2019-20				Pooled			
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total
Pretilachlor 750 g/ha PE	4.2 (17.0)	4.6 (20.0)	5.4 (28.0)	8.1 (65.0)	2.6 (6.0)	4.2 (17.0)	4.9 (23.0)	6.9 (46.0)	3.5 (11.3)	4.4 (18.7)	5.2 (25.7)	7.5 (55.7)
Pretilachlor 750 g/ha PE *fb* chlorimuron + metsulfuron 4 g/ha PoE	5.1 (25.0)	2.6 (6.0)	4.1 (16.0)	6.9 (47.0)	3.0 (8.0)	2.2 (4.0)	3.7 (13.0)	5.1 (25.0)	4.2 (16.3)	2.4 (5.0)	3.9 (14.6)	6.1 (35.9)
Pretilachlor 750 g/ha PE *fb* flucetosulfuron 25 g/ha PoE	4.4 (18.0)	1.2 (0.4)	4.7 (21.0)	6.4 (39.4)	2.8 (7.0)	1.4 (1.0)	4.0 (15.0)	4.9 (23.0)	3.7 (12.7)	1.3 (0.7)	4.4 (18.2)	5.7 (31.6)
Pretilachlor 750 g/ha PE *fb* penoxsulam + cyhalofop-butyl 135 g/ha PoE	2.2 (4.0)	2.8 (7.0)	3.3 (10.0)	4.7 (21.0)	2.2 (4.0)	2.2 (4.0)	3.5 (11.0)	4.5 (19.0)	2.2 (4.0)	2.5 (5.3)	3.4 (10.7)	4.6 (20.0)
Pretilachlor 750 g/ha PE *fb* fenoxaprop 60 g/ha + chlorimuron + metsulfuron 4 g/ha PoE	1.0 (0.0)	1.7 (2.0)	3.5 (11.0)	3.7 (13.0)	1.0 (0.0)	1.7 (2.0)	3.3 (10.0)	3.6 (12.0)	1.0 (0.0)	1.7 (2.0)	3.4 (10.3)	3.6 (12.3)
Pretilachlor 750 g/ha PE *fb* fenoxaprop 60 g/ha + ethoxysulfuron 18.75 g/ha PoE	1.0 (0.0)	2.6 (6.0)	1.4 (1.0)	2.8 (7.0)	1.0 (0.0)	2.4 (5.0)	2.0 (3.0)	3.0 (8.0)	1.0 (0.0)	2.5 (5.3)	1.7 (2.0)	2.9 (7.3)
Pretilachlor 750 g/ha PE *fb* bispyribac 25 g/ha PoE	2.2 (4.0)	1.7 (2.0)	1.0 (0.0)	2.6 (6.0)	2.0 (3.0)	1.7 (2.0)	1.0 (0.0)	2.4 (5.0)	2.1 (3.3)	1.7 (1.9)	1.0 (0.0)	2.5 (5.2)
Pretilachlor 750 g/ha PE *fb* triafamone + ethoxysulfuron 60 g/ha PoE	1.7 (2.0)	1.4 (1.0)	1.0 (0.0)	2.0 (3.0)	1.7 (2.0)	1.4 (1.0)	1.0 (0.0)	2.0 (3.0)	1.7 (2.0)	1.4 (1.1)	1.0 (0.0)	2.0 (3.1)
Hand weeding at 20 and 40 DAT	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)
Weedy check	7.2 (51.0)	6.2 (37.0)	6.3 (39.0)	11.3 (127.0)	3.7 (13.0)	5.7 (32.0)	6.2 (38.0)	9.2 (83.0)	5.7 (32.0)	5.9 (34.4)	6.3 (38.3)	10.3 (104.7)
LSD (p=0.05)	0.9	0.3	1.0	1.6	0.3	0.6	0.4	1.1	0.9	0.8	1.0	1.4

Square root ($\sqrt{x+1}$) transformed value, values in the parentheses is original values, *fb*: followed by

(116). Application of PoE herbicides increased the tiller number by 5.5 to 32.9% and grains/panicle by 2.6 to 27.6% (**Table 3**). Higher grains/panicle is the indication of higher photosynthetic efficiency of plants resulting in higher yield (Channappagoudar *et al.* 2008).

Two hand weedings recorded 93.1% increase in grain yield of rice over weedy check (2.9 t/ha). Among the herbicide treatments sequential application of pretilachlor 750 g/ha *fb* PoE application of triafamone + ethoxysulfuron 60 g/ha recorded higher grain yield (5.4 t/ha), which was at par with two hand weedings treatment and with pretilachlor 750 g/ha *fb* bispyribac-sodium 25 g/ha and pretilachlor 750 g/ha *fb* fenoxaprop-p-ethyl 60 g/ha + ethoxysulfuron 18.75 g/ha. This might have happened due to fact that competition between crops and weeds become less due to effective weed control in the treated plots. It could reduce competition between rice plant and weeds for nutrient, water, solar radiation and space. Thus, on optimal soil nutrient availability, nutrient uptake will be increased so that the needs for optimal growth and production levels will be elevated. Increasing of growth components and yield components will be followed by an increase in the grain production per hectare. The lowest grain yield (2.9 t/ha) was recorded in weedy check. This might be due to severe crop weed competition, as evident from higher weed density and biomass. Similar results were also reported by Prakash *et al.* (2011) and Bhat *et al.* (2013).

Correlation analysis

The linear relationships between weed biomass (w) at 40 DAT and grain yield (Y) of rice is given here as under, eq. (i)

$$Y = 5.245 - 0.068\ w \qquad (R^2 = 0.789) \text{ —— (i)}$$

The equation (i) explains that 78.9% variation in yield due to total weed biomass at 40 DAT could be explained by the regression. The further analysis indicated that with every unit increase in weed biomass, the grain yield of rice was expected to fall by 0.07 t/ha.

Crop injury

The phytotoxic effect on the crop was recorded at 5 and 30 DAA of herbicide (**Table 4**). Crop injury from pretilachlor 750 g/ha *fb* post-emergence application of fenoxaprop-p-ethyl 60 g/ha + chlorimuron + metsulfuron 4 g/ha and pretilachlor 750 g/ha *fb* fenoxaprop-p-ethyl 60 g/ha + ethoxysulfuron18.75 g/ha were characterised by a change in flag leaf colour to yellow, rating crop toxicity 2. Plants treated with herbicides exhibited slight phytotoxic effect at 5 DAA and recovered at 30 DAA. The grain yield was not much affected due to this phytotoxicity.

The lowest chlorophyll content was obtained in pretilachlor 750 g/ha *fb* fenoxaprop-p-ethyl 60 g/ha + chlorimuron + metsulfuron 4 g/ha (6.83) treated plants at 5 DAA of herbicide (**Table 4**). In pretilachlor

Table 2. Effect of weed control treatments on weed biomass and weed control efficiency at 40 DAT in transplanted rice

Treatment	Weed biomass (g/m^2) at 40 DAT														
	2018-19				2019-20				Pooled				WCE (%)		
	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total	Grasses	Sedges	BLW	Total	2018-19	2019-20	Pooled
Pretilachlor 750 g/ha PE	5.5 (29.1)	5.4 (28.5)	3.5 (11.4)	8.4 (68.9)	3.4 (10.5)	5.0 (23.7)	3.2 (9.2)	6.7 (43.5)	4.6 (19.8)	5.2 (26.1)	3.4 (10.3)	7.6 (56.2)	59	49	54
Pretilachlor 750 g/ha PE *fb* chlorimuron + metsulfuron 4 g/ha PoE	7.0 (47.5)	3.5 (11.2)	3.1 (8.7)	8.3 (67.4)	4.1 (15.5)	2.9 (7.4)	2.8 (6.9)	5.6 (29.8)	5.7 (31.5)	3.2 (9.3)	3.0 (7.8)	7.0 (48.6)	60	65	63
Pretilachlor 750 g/ha PE *fb* flucetosulfuron 25 g/ha PoE	5.1 (25.5)	1.1 (0.2)	5.6 (29.9)	7.5 (55.5)	3.3 (9.7)	1.2 (0.4)	4.7 (20.9)	5.7 (31.1)	4.3 (17.6)	1.1 (0.3)	5.1 (25.4)	6.7 (43.3)	67	64	66
Pretilachlor 750 g/ha PE *fb* penoxsulam + cyhalofop-butyl 135 g/ha PoE	3.2 (9.1)	1.9 (2.6)	3.9 (14.5)	5.2 (26.2)	3.2 (9.1)	1.6 (1.6)	4.0 (15.3)	5.2 (26.0)	3.2 (9.1)	1.8 (2.1)	4.0 (14.9)	5.2 (26.1)	84	70	77
Pretilachlor 750 g/ha PE *fb* fenoxaprop 60 g/ha + chlorimuron + metsulfuron 4 g/ha PoE	1.0 (0.0)	2.7 (6.1)	3.2 (9.1)	4.0 (15.2)	1.0 (0.0)	2.7 (6.1)	3.1 (8.5)	4.0 (14.6)	1.0 (0.0)	2.7 (6.1)	3.1 (8.8)	4.0 (14.9)	91	83	87
Pretilachlor 750 g/ha PE *fb* fenoxaprop 60 g/ha + ethoxysulfuron 18.75 g/ha PoE	1.0 (0.0)	3.4 (10.4)	1.4 (1.1)	3.5 (11.4)	1.0 (0.0)	3.2 (9.2)	2.0 (3.2)	3.7 (12.4)	1.0 (0.0)	3.3 (9.8)	1.8 (2.1)	3.6 (11.9)	93	86	90
Pretilachlor 750 g/ha PE *fb* bispyribac 25 g/ha PoE	2.7 (6.2)	1.9 (2.5)	1.0 (0.0)	3.1 (8.7)	2.5 (5.2)	1.9 (2.7)	1.0 (0.0)	3.0 (7.9)	2.6 (5.7)	1.9 (2.6)	1.0 (0.0)	3.0 (8.3)	95	91	93
Pretilachlor 750 g/ha PE *fb* triafamone + ethoxysulfuron 60 g/ha PoE	2.1 (3.4)	1.7 (1.7)	1.0 (0.0)	2.5 (5.1)	2.1 (3.4)	1.6 (1.5)	1.0 (0.0)	2.4 (4.9)	2.1 (3.4)	1.6 (1.6)	1.0 (0.0)	2.4 (5.0)	97	94	96
Hand weeding at 20 and 40 DAT	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	1.0 (0.0)	100	100	100
Weedy check	10.1 (101.2)	7.3 (51.6)	4.1 (15.4)	13.0 (168.2)	5.2 (25.8)	6.8 (44.8)	4.0 (15.2)	9.3 (85.8)	8.0 (63.5)	7.0 (48.2)	4.0 (15.3)	11.3 (127.0)	0	0	0
LSD (p=0.05)	1.3	0.3	0.1	0.2	0.6	0.7	1.2	1.4	1.0	2.3	0.8	1.7	-	-	-

Square root ($\sqrt{x+1}$) transformed value, values in the parentheses are original values, *fb*: followed by

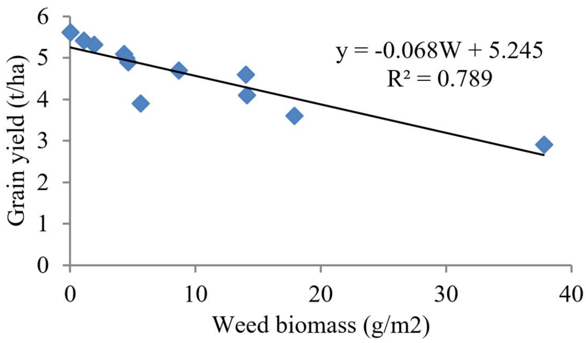

Figure 1. Weed biomass affected by weed control method on grain yield of rice

750 g/ha *fb* fenoxaprop-p-ethyl 60 g/ha + chlorimuron + metsulfuron4 g/ha treated plot, the lower chlorophyll content was due to fenoxaprop-p-ethyl as it was not affected in chlorimuron + metsulfuron (9.43) treated plots after pretilachlor. The lower chlorophyll in weedy check was probably due to crop-weed competition and lack of nutrients. Smith (1988) observed that fenoxaprop-p-ethyl in tank mixtures with bentazone applied at 4 leaf stage of grasses caused moderate (30-69%) plant chlorosis and stunting during 5 to 10 DAA. However, the crop recovered from the toxic effects after 2 to 4 weeks. In the present study slight phytotoxic effect was found in tank mixture containing fenoxaprop-p-ethyl.

Some weed control treatments manifested significant effects on plant height at harvest (**Table 4**). Significantly higher plant height was recorded in weed free treatment, which was statistically at par with pretilachlor 750 g/ha *fb* penoxsulam + cyhalofop butyl 135 g/ha (95.8 cm), pretilachlor 750 g/ha *fb* triafamone + ethoxysulfuron 60 g/ha (95.6 cm) and pretilachlor 750 g/ha *fb* bispyribac-sodium 25 g/ha (95.2 cm). Significantly the lowest plant height was observed with pretilachlor 750 g/ha *fb* fenoxaprop-p-ethyl 60 g/ha + chlorimuron + metsulfuron 4 g/ha (87.4 cm), which was at par with pretilachlor 750 g/ ha *fb* fenoxaprop -p-ethyl 60 g/ha + ethoxysulfuron 18.75 g/ha (85.7 cm) and weedy check plot (89 cm). In weedy check plot, plant height was affected by heavy weed infestation, while in fenoxaprop-p-ethyl + chlorimuron + metsulfuron and fenoxaprop-p-ethyl + ethoxysulfuron, had adverse effect on plant height probably due to some physiological effect. Similar results were reported by Mohapatra *et al.* **(**2018).

Economics

Sequential application of herbicides proved superior as compared to single application of herbicide of pretilachlor as pre-emergence. The highest net return (47.20× 10^3 ₹/ha) was realized from pre-emergence application of pretilachlor 750 g/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha with benefit: cost ratio of 1.9. It recorded 18.2% more net return than two hand weedings plot (**Table 3**). Though weeds were controlled more effectively and grain yield was highest in hand weeding treatment net return was lower due to its higher cost of cultivation (58.6 x10^3 /ha) involving more human labour engagement and increasing labour wage. The engagement of human labours for controlling weeds was reduced with application of post-emergence herbicide, which was responsible for reduction in total cost of cultivation, resulting higher B: C ratio than weed free treatment. Only sole pretilachlor treated plot had lower B: C ratio due to less weed control efficiency as

Table 3. Effect of different weed control methods on yield attributing character and yield of rice (pooled data of two years)

Treatment	Tillers/ hill	Grains/ panicle	1000 grain weight (g)	Grain yield (t/ha)			Straw yield (t/ha)	Weed index (%)	Cost (x10^3 `/ha)	Net returns (x10^3 `/ha)	B:C ratio
				2018-19	2019-20	Pooled					
Pretilachlor 750 g/ha PE	7.3	116	23.0	4.1	3.7	3.9	4.6	30	45.46	23.37	1.4
Pretilachlor 750 g/ha PE *fb* chlorimuron + metsulfuron 4 g/ha PoE	7.7	119	22.1	4.2	4	4.1	4.9	26	44.06	28.26	1.6
Pretilachlor 750 g/ha PE *fb* flucetosulfuron 25 g/ha PoE	8.0	123	22.3	5	4.2	4.6	5.4	18	44.47	36.02	1.7
Pretilachlor 750 g/ha PE *fb* penoxsulam + cyhalofop-butyl 135 g/ha PoE	8.0	126	22.0	4.9	4.5	4.7	5.6	16	45.01	37.23	1.8
Pretilachlor 750 g/ha PE *fb* fenoxaprop 60 g/ha + chlorimuron + metsulfuron 4 g/ha PoE	8.3	129	22.4	4.7	5.1	4.9	5.8	13	45.52	40.22	1.8
Pretilachlor 750 g/ha PE *fb* fenoxaprop 60 g/ha + ethoxysulfuron 18.75 g/ha PoE	8.7	133	22.3	4.9	5.3	5.1	6.0	9	45.93	43.89	1.9
Pretilachlor 750 g/ha PE *fb* bispyribac 25 g/ha PoE	9.3	141	22.3	5.1	5.5	5.3	6.3	5	45.55	47.20	1.9
Pretilachlor 750 g/ha PE *fb* triafamone + ethoxysulfuron 60 g/ha PoE	9.7	148	23.6	5.1	5.7	5.4	6.4	4	47.45	47.04	1.9
Hand weeding at 20 and 40 DAT	10.0	150	23.8	5.3	5.9	5.6	6.6	0	58.65	39.93	1.6
Weedy check	5.3	101	22.2	2.6	3.2	2.9	3.5	47	43.55	7.78	1.1
LSD (p=0.05)	1.0	6.8	NS	0.4	0.9	0.6	0.4			29.79	0.1

Table 4. Effect of herbicide on crop toxicity rating, chlorophyll content and plant height of rice (pooled data of two years)

Treatment	Crop toxicity rating		Chlorophyll content in crop (SPAD)		Plant height at harvest (cm)
	Initial (5 DAA of herbicide)	30 DAA of herbicide	Initial (5 DAA of herbicide)	30 DAA of herbicide	
Pretilachlor750 g/ha PE	1	1	9.42	12.2	91.4
Pretilachlor750 g/ha PE *fb* chlorimuron + metsulfuron 4 g/ha PoE	1	1	9.43	12.0	91.3
Pretilachlor750 g/ha PE *fb* flucetosulfuron 25 g/ha PoE	1	1	9.42	11.5	90.6
Pretilachlor750 g/ha PE *fb* penoxsulam + cyhalofop-butyl 135 g/ha PoE	1	1	9.44	12.1	95.8
Pretilachlor750 g/ha PE *fb* fenoxaprop 60 g/ha + chlorimuron+ metsulfuron 4 g/ha PoE	2	1	6.83	10.1	85.7
Pretilachlor750 g/ha PE *fb* fenoxaprop 60 g/ha +ethoxysulfuron 18.75 g/ha PoE	2	1	7.24	10.3	87.4
Pretilachlor750 g/ha PE *fb* bispyribac 25g/ha PoE	1	1	9.47	11.1	95.2
Pretilachlor 750 g/ha PE *fb* triafamone + ethoxysulfuron 60 g/ha PoE	1	1	9.46	11.0	95.6
Hand weeding at 20 and 40 DAT	1	1	9.45	12.5	96.2
Weedy check	1	1	7.41	10.6	89.0
LSD (p=0.05)			0.8	0.4	1.2

DAA: Days after application, Crop injury is measured on a Scale 1-5, 1= No crop injury and 5 = complete crop destruction

compared to combination of pre and post-emergence herbicide treatments.

Weed control with post-emergence herbicides that contain active triafamone + ethoxysulfuron, bispyribac-sodium and fenoxaprop-p-ethyl + ethoxysulfuron after pretilachlor showed similar results with that of manual weed control. Therefore, controlling weed by the use of these herbicides was able to replace manual weeding. Although weed control with tank mix application of fenoxaprop-p-ethyl + ethoxysulfuron was similar to above herbicide, but phytotoxicity was noticed with this herbicide.

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