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Efficacy of various herbicide combinations on yield, its attributes and economics of transplanted rice in Indo Gangetic plain zone (*Oryza sativa* L.)

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Abstract
A field experiment was conducted at Agronomy Research Farm, A.N.D. University of Agriculture & Technology, Kumarganj, Faizabad during the Kharif season of 2017-18. The experiment was conducted with Randomized Block Design and replicated three times and comprised with twelve treatments. The herbicides were used individually as well as in combinations viz. Butachlor, Pretilachlor, Bispyribac-Na and Almix. Total weed population and its dry weight, weed index were lowest with Pretilachlor @ 750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE). However, highest weed control efficiency was recorded with Pretilachlor @ 750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE). The growth parameters and yields increased significantly with Pretilachlor @ 750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) over rest of the treatments. Yield and yield attributes like number of effective shoots m^{-2}, length of panicle (cm), number of grain $panicle^{-1}$, test weight (g), Grain yield q ha^{-1}), and harvest index were significantly higher with Pretilachlor @ 750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE). Weed free upto 60th DAT gave the maximum gross returns (Rs. 94452 ha^{-1}), however, Net returns (60729.00 Rs. ha^{-1}) and maximum B:C ratio (1.84) recorded with Pretilachlor @ 750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE).

Keywords: Pre and Post-Emergence, Herbicides, Profitability, Transplanted, Test Weight, Harvest Index, Rice, Economics

Introduction
Rice (*Oryza sativa* L.) is a most important cereal crop, grown under aquatic condition and mostly under submergence or variable ponding conditions. It belongs to family Poaceae (Gramineae). It is a most important staple food of about more than 60% of total world population. Rice is cultivated world-wide over an area of about 160.68 million ha with an annual production of about 650.19 million tonnes and productivity 4.15 tonnes per hectare. About 90% of all rice grown in the world is produced and consumed in the Asian region. It accounts 43% of total food grain production and 55% of cereal production in the country. It is a high caloric food, which contain 75% starch, 6-7% protein, 2-2.5% fat, 0.8% cellulose and 5-9% ash. In India, rice is grown over an area of about 42.77 million ha which produces 110.40 million tonnes with an average productivity of 2490 kg/ha. In U.P., it is grown in an area of about 25.86 million ha with production of 13.83 million tonnes and productivity of 2358 kg/ha. (Anonymous, 2017-18) [1].

In 21st century there will be need of about 250 million tonnes of food grains to feed the rapidly increasing population. To meet the demand of increasing population and maintain self-sufficiency the present production level needs to be increase up to 14 million tonnes by 2025 which can be achieved only by increasing the rice production by over 2 million tonnes per year in coming decade (Subbaih, 2006) [7]. This has to be done against the backdrop of declining natural resources base such as land, water, labor and other input without adversely affecting the quality of environment.

The herbicidal treatments Almix 20 WP @ 4 g ha^{-1} applied 15 DAT as post emergence effectively control all categories of weeds resulted minimum biomass production of weeds (4.45 gm^{-2}) minimum weed index (1.37) and higher weed control efficiency (90.44%) which

ultimately produced higher grain yield (5.01 t/ha) and gave maximum monetary return (21801.98) and benefit: cost ratio (1.41) Pal *et al.* (2008) [6].

Keeping these facts in view, the present experiment was planned with single and sequential herbicide application to find out the economically viable and effective weed control methods in transplanted rice crop.

Materials and Methods

The experiment was conducted to evaluate the performance of different herbicides combinations on weeds, yield and economics of transplanted Rice (*Oryza sativa* L.) at Research Farm of Agronomy Department, A.N.D. University of Agriculture and Technology, Narendra Nagar (Kumarganj), Faizabad (U.P.) during *Kharif* season, 2017-18 (July to November). The experimental site is situated at a distance of about 42 km in south-east from Ayodhya on Raebareli road. Geographically, experimental site falls under sub-tropical zone in Indo-gangetic plains and lies between $26^0$47' North latitude, $82^0$12' East longitudes, at an altitude of about 113.0 meter from mean sea level. The soil of experimental field was low in available nitrogen (204.00 kg ha-1) and organic carbon (0.34%), medium in available phosphorus (15.35 kg ha-1) and high in potassium (267.00 kg ha-1). The reaction of the soil was slightly alkaline. The twelve treatments comprised of viz; Butachlor @1.5 kg a.i. ha^{-1} (PE), Pretilachlor @750 g a.i. ha^{-1} (PE), Bispyribac-Na @25 g a.i. ha^{-1} (POE), Almix @4 g a.i. ha^{-1} (POE), Butachlor @1.5 kg a.i. ha^{-1} (PE) *fb* Bispyribac-Na @25 g a.i. ha^{-1} (POE), Butachlor @1.5 kg a.i. ha^{-1} (PE) *fb* Almix @4 g a.i. ha^{-1} (POE), Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @25 g a.i. ha^{-1} (POE), Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Almix @4 g a.i. ha^{-1} (POE), Bispyribac-Na @25 g a.i. ha^{-1} (POE) *fb* Almix @4 g a.i. ha^{-1} (POE), Two Mechanical weeding (Cono-weeder) (20/40 DAT), Weed free (20/40/60 DAT), and Weedy check.Were laid out in Randomized Block Design with 3 replications. The twenty one days old seedling of rice variety SARJU-52 was transplanted in experimental field on July 26th, 2017, using 2-3 per hills seedling 20 x 10 cm. Recommended doses of fertilizer of 120:60:40 kg N, P_2O_5, K_2O ha^{-1} and Zinc sulphate @ 25 kg ha^{-1} was adopted.

The herbicides were applied as pre-emergence (2 DAT) and post emergence (25 DAT) at 3-4 leaf stage of weeds with the help of manually operated Knapsack sprayer fitted with flat fan nozzle using 250 liters of water per hectare. The unweeded control plots were kept undisturbed for the entire cropping period. The data on weed density and its dry weight of different weed flora m^{-2} were recorded at different growth stages of rice crop. Grain yield of rice along with yield components like effective panicles m^{-2} were recorded at harvest and statistically analyzed as per procedure (Gomez and Gomez, 1984).

Cost of cultivation of different treatments was worked out by considering all the expenses incurred in the cultivation of experimental crop and added with cost due to various operations and inputs used. Accordingly cost of cultivation was calculated for each treatment combinations. Gross return was worked out by multiplying grain and straw yield separately under various treatment combinations with their existing market price. The money value of grain and straw was added together in order to achieve gross return. Net return was calculated by deducting the cost of cultivation from the gross return of the individual treatment combination.

Net return = Gross return – Cost of cultivation

Benefit-cost ratio was worked out by dividing the net return to the cost of cultivation of the individual treatment combination.

$$\text{Benefit: cost ratio} = \frac{\text{Net return (Rs ha}^{-1})}{\text{Cost of cultivation (Rs ha}^{-1})}$$

Results and Discussion

Effect on Yield Attributes

All Sequential spray of herbicide treatments (T_5 to T_9) recorded significantly highest values of all growth parameter over herbicide applied alone either pre or post emergence. Application of Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) recorded significantly highest values of all yield attributes over rest of the treatments except T_5, T_6, T_8, T_9 T_{10} incase of number of effective shoots (m^{-2}) and length of panicle, T_9 incase of number of grain $panicle^{-1}$, and T_3 to T_{10} incase of test weight by crop where non-significant difference was observed.

Weedy check reduced significantly the all yield attributes like Number of Effective shoots (m^{-2}) and length of panicle, number of grain $panicle^{-1}$ and test weight as compare to rest of the treatment (table-1). Similar result was reported by Kumar *et al.* (2013) [5].

Effect on Yield

It is obvious from the data presented in table-2 that grain and straw yield was affected statistically due to different weed control treatment.

Weed free upto 60 days produced higher grain yield of 54.50 q ha^{-1} which was significantly superior over rest of the treatment, however being at par with T_7, T_8, T_9 and T_{10} treatments. Among the herbicide treatments, application of Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) produce significantly highest grain yield over rest of the treatments except treatment T_8, T_9 and T_{10} where non-significantly different was observed with regards to grain yield. Similar trends of results was observed in case straw yield, where Weed free upto 60 days produced significantly higher staraw yield over rest of the treatments except T_5, T_6, T_7, T_8, T_9 and T_{10}. Weed check produced the lowest grain yield (36.70 q ha^{-1}) and straw yield (49.05 q ha^{-1}).

The higher grain and straw yield with Weed free was mainly attributed to better growth and yield attributes due to lower population and dry weight of weeds resulted in higher nutrients availability. However, better Weed control with Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) resulted in higher nutrient availability to crop favoured the higher growth and yield attributes and higher grain and straw yield. Similar higher grain yield of rice was recorded by Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE). Similar result was reported by scientist like Jayadeva *et al.* (2010) [4] and Bhat *et al.* (2011) [2].

The values of harvest index was highest (45.03 %) followed by application of Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) i.e. 44.73. and lowest values of harvest index was registered with Weedy check (42.80 %).

The percent increase in yield with Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) was recorded to the tune of 20.26, 18.68, 15.38, 16.03, 13.34, 14.40, 6.29 and 4.44 per cent over Butachlor @ 1.5 kg a.i. ha^{-1}, Pretilachlor @ 750 g a.i. ha^{-1}, Bispyribac-Na @ 25 g a.i. ha^{-1}, Almix @ 4 g a.i. ha^{-1}, Butachlor @ 1.5 kg a.i. ha^{-1} *fb* Bispyribac-Na @ 25 g a.i. ha^{-1}, Butachlor @ 1.5 kg a.i. ha^{-1} *fb*

Almix @ 4 g a.i. ha^{-1}, Pretilachlor @ 750 g a.i. ha^{-1} *fb* Almix @ 4 g a.i. ha^{-1}, Bispyribac-Na @ 25 g a.i. ha^{-1} *fb* Almix @ 4 g a.i. ha^{-1} treatments, respectively.

It is concluded from the results that weed free upto 60th days recorded the highest grain yield, however application of Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) recorded significantly higher grain yield over rest of the herbicides treatments.

Effect on Economics

Among the different treatments, spray of Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) recorded the highest net profit (Rs. 60729 ha^{-1}) and benefit-cost ratio (1.84) followed by Bispyribac-Na *fb* Almix @25g/ 4 g ha^{-1} (Rs. 57632 ha^{-1} and 1.78). Weed free gave highest gross income as compared to rest of the treatments. However, minimum net return and B:C ratio was recorded with weedy check treatment (Table 3). Similar result was reported by Das *et al*. (2017) [3].

Conclusion

On the basis of results obtained it concluded that application of Pretilachlor @ 750 g a.i. ha^{-1} (Pre) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) gave highest values of yield attributes and yield, net income and B.C. Ratio followed by Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) *fb* Almix @4 g a.i. ha^{-1} (PE) with net income of (57632 Rs ha^{-1}) and B.C. Ratio (1.78).

Table 1: Effect of weed management treatments on yield attributes of rice

Treatment	No. of Effective shoots (m^{-2})	Length of Panicle (cm)	No. of Grains panicle^{-1}	Test Weight (g)
Butachlor @ 1.5 kg a.i. ha^{-1} (PE)	344.53	19.00	153.50	21.80
Pretilachlor @750 g a.i. ha^{-1} (PE)	356.06	19.30	155.80	22.00
Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	370.46	20.10	163.00	22.50
Almix @ 4 g a.i. ha^{-1} (POE)	364.40	19.70	161.30	22.30
Butachlor @ 1.5 kg a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	403.12	21.40	168.80	23.00
Butachlor @ 1.5 kg a.i. ha^{-1} (PE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	386.92	20.60	164.50	22.60
Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	428.21	23.00	186.20	23.40
Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	406.20	22.40	177.90	23.10
Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	419.57	22.70	181.40	23.20
Mechanical weeding (Conoweeder) Two (20/40 DAT)	404.55	21.90	174.50	23.05
Weed free (three hand weeding at 20/40/60 DAT)	439.58	23.60	198.60	23.50
Weedy check	305.04	18.40	149.50	20.70
SEm+-	12.63	0.93	6.91	0.68
C.D. at 5%	37.03	2.73	20.25	NS

Table 2: Effect of weed management treatments on grain yield, straw yield and harvest index of rice.

Treatment	Grain Yield q ha^{-1}	Straw yield q ha^{-1}	Harvest index (%)
Butachlor @ 1.5 kg a.i. ha^{-1} (PE)	44.90	58.56	43.40
Pretilachlor @750 g a.i. ha^{-1} (PE)	45.50	59.22	43.45
Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	46.80	60.66	43.55
Almix @ 4 g a.i. ha^{-1} (POE)	46.30	60.14	43.50
Butachlor @ 1.5 kg a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	48.50	62.48	43.70
Butachlor @ 1.5 kg a.i. ha^{-1} (PE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	47.20	61.06	43.60
Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	54.00	66.72	44.73
Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	50.80	64.39	44.10
Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	51.70	65.27	44.20
Mechanical weeding (Conoweeder) Two (20/40 DAT)	49.90	63.64	43.95
Weed free (three hand weeding at 20/40/60 DAT)	54.50	66.81	45.03
Weedy check	36.70	49.05	42.80
SEm+-	1.77	2.03	-
C.D. at 5%	5.15	5.95	-

Table 3: Effect of Various Treatments on Economics

Treatments	Cost of treatment (Rs. ha^{1})	Common cost of cultivation (Rs.ha^{-1})	Total cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{1})	Net return (Rs. ha^{-1})	BCR (Rs. $^{-1}$)
Butachlor @ 1.5 kg a.i. ha^{-1} (PE)	1335	28940	30275	78379	48104	1.59
Pretilachlor @750 g a.i. ha^{-1} (PE)	1239	28940	30179	79408	49229	1.63
Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	2800	28940	31740	81639	49899	1.57
Almix @ 4 g a.i. ha^{-1} (POE)	1050	28940	29990	80786	50796	1.69
Butachlor @ 1.5 kg a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	4135	28940	33075	84547	51472	1.56
Butachlor @ 1.5 kg a.i. ha^{-1} (PE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	2385	28940	31325	82319	50994	1.64
Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Bispyribac-Na @ 25 g a.i. ha^{-1} (POE)	4039	28940	32979	93708	60729	1.84
Pretilachlor @750 g a.i. ha^{-1} (PE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	2289	28940	31229	88399	57170	1.83
Bispyribac-Na @ 25 g a.i. ha^{-1} (POE) *fb* Almix @ 4 g a.i. ha^{-1} (POE)	3400	28940	32340	89972	57632	1.78
Mechanical weeding (Conoweeder) Two (20/40 DAT)	4500	28940	33440	86891	53451	1.59
Weed free (three hand weeding at 20/40/60 DAT)	13500	28940	42440	94452	52012	1.23
Weedy check	-	28940	28940	64243	35303	1.21

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