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Bio-Efficacy of Fenoxaprop-P-Ethyl Along with Bispyribac Sodium to Control Weed Flora in Direct Seeded Rice

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Abstract: A field experiment was conducted in order to evaluate the efficiency of Puma Super 69 EW (Fenoxaprop-P-ethyl) along with the use of Clover 10 SC (Bispyribac sodium) for the control of weed flora in direct seeded coarse rice. The herbicides viz. Clover 10 SC (Bispyribac sodium) at 30 g ha^{-1} and Puma Super 69 EW (Fenoxaprop-P-ethyl) was applied at 702, 937, 1171 and 1406 g ha^{-1} respectively as early post emergence spray. Results of the study showed that application of bispyribac sodium at 25 g ha^{-1} sequentially followed by fenoxaprop-p ethylat 1406 g ha^{-1} (T_5) proved more effective (>80%) in altering the population of weeds at 30 and 45 DAS. This treatment was comparable with T_4 (bispyribac sodium + fenoxaprop-p ethyl at 25 and 1171 g ha^{-1}), where 44 and 53.33 weeds were observed at 30 and 45 DAS, respectively. The maximum harvest index (32.23%) was recorded in T_3 (bispyribac sodium + fenoxaprop-p-ethyl at 25 and 937 g ha^{-1}, separately) treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g ha^{-1}, respectively. This treatment was comparable with T_4 (bispyribac sodium + fenoxaprop-p ethyl at 25 and 1171 g ha^{-1}) and T_5 (bispyribac sodium + fenoxaprop-p ethyl at 25 and 1406 g ha^{-1}) recorded as 31.160 and 31.203, individually. Economic analysis showed that treatment T_3 (bispyribac sodium + fenoxaprop-p-ethyl at 25 and 937 g ha^{-1}, respectively) gave maximum paddy yield (3.80 t ha^{-1}) and recorded highest net income Rs. 83006 ha^{-1}.

Key words: Weed flora · Direct seeded rice · Herbicides · Harvest index · Economic analysis

INTRODUCTION

Rice being an imperative food cash commodity holds a unique position in agriculture of Pakistan. It is the second essential staple food grain crop after wheat and major source of foreign exchange earnings after cotton. It accounts 3.1 percent of the value added in agriculture and 0.7 percent in GDP [1]. Transplanting of rice crop in the puddle soil (wet tillage), with continuous flooding, is the most common method in Southeast Asia. In Pakistan consumption of available fresh water for rice is 21%. It usually requires 9450 liters of water to produce one kg of rice whereas in India and China two and five kg of rice is produced, respectively from the same amount of water [2]. Water resources, both surface and underground are shrinking and may becoming a limiting factor in agricultural productivity [3]. Above mentioned scenario necessitates alternative methods of rice production and their feasibility needs to be explored under local agro-ecological conditions. A promising method of rice cultivation is aerobic direct seeding rather than puddling and transplanting rice seedlings [4]. Direct seeding of rice (DSR) is related to sowing pre-germinated seeds on a puddle soil surface (wet seeding) or into shallow standing water (water seeding), or dry seed into the already prepared seedbed (dry seeding) [5]. Less than 44% of water can be used in direct seeding as compared to conventional transplanted system by reducing leakage, seepage and evaporation losses, while maintaining an acceptable level of production or yield [6] but the need of hour is to diminish major obstacle i.e. heavy weed influx in aerobic rice cultures. Weeds infestation is a chief restriction in the acceptance of direct seeding rice in Asia. Weeds compete with crops for light, space, nutrients and water during the growth season of crop plant [7]. Contamination of rice grain with weeds

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seeds can reduce quality and cash value of crops. So, for a great success in direct seeding rice issues like weed management and poor establishment need serious attention [8]. Weeds are most successfully and cost-effectively controlled by a number of practices, including manual [9] and chemical [10, 11] control methods. Pre-emergence as well as post-emergence herbicides prove effective in aerobic rice fields if accurately used [12]. Sometimes use of single herbicides has been found to be unable to control a wide range of weeds. Thus application of more than one herbicide seems to be a better option. Keeping in view the above facts, present study is therefore intended to evaluate efficacy of Fenoxaprop-P-ethyl in combination with Bispyribac sodium against weed flora and to suggest an appropriate dose of Fenoxaprop-P-ethyl for effective weed control in direct seeded rice culture.

MATERIALS AND METHODS

This experiment was carried out at Agronomic Research Area, University of Agriculture, Faisalabad (31.25°N latitude, 73.09°E longitude and 184 m above sea level). Experimental treatments comprised of T_0= weedy check (control), T_1= Clover 10 SC (Bispyribac sodium) at 25 g a.i. ha^{-1} (12-15 DAS), T_2= Clover 10 SC at 25 g a.i. ha^{-1} (12-15 DAS) + Puma Super 69 EW (Fenoxaprop-P-ethyl) at 702 g a.i. ha^{-1} (15-20 DAS), T_3= Clover 10 SC at 25 g a.i. ha^{-1} (12-15 DAS) + Puma Super 69 EW at 937 g a.i. ha^{-1} (15-20 DAS), T_4= Clover 10 SC at 25 g a.i. ha^{-1} (12-15 DAS) + Puma Super 69 EW at 1171 g a.i. ha^{-1} (15-20 DAS), T_5= Clover 10 SC at 25 g a.i. ha^{-1} (12-15 DAS) + Puma Super 69 EW at 1406 g a.i. ha_{-1} (15-20 DAS). Weedy check plot was maintained to compare the other treatments. The experiment was planned in randomized complete block design (RCBD) arrangement and each treatment was replicated four times. The net plot size was 2.0 m × 6.0 m. KSK-133 (coarse rice cultivar) was used for experiment and seeds were collected from Rice Research Institute, Kala Shah Kaku. To get uniform germination and good stand establishment, seeds were hydro-primed [13] for 24 hours prior to seeding. Crop was directly sown in 20 cm apart rows using seed rate of 75 $kgha^{-1}$with a single row hand drill on June 15, 2012. To fulfill the requirement of nutrients, a fertilizer dose of 150 kg N, 90 kg P_2O_5, 70 kg K_2O and 10 kg $ZnSO_4$ was applied on the basis of per hectare. All the phosphorous, potash and 1/3rd of nitrogen was applied before seeding as basal dose while remaining nitrogen was applied in two equal splits at tillering (25 DAS) and at panicle initiation (65 DAS). Zinc was applied 35 days after sowing of rice crop. The crop was irrigated as and when required to meet consumptive use of water. Data related to the weed density, biomass (30 and 45 DAS) and yield components of rice were recorded by following standard procedures and statistically analyzed by following Fisher's analysis of variance technique. Least significant difference (LSD) test at 5% probability was used to compare the treatments' means.Economic analysis was also carried out to look into comparative benefits of different treatments.

RESULTS AND DISCUSSION

Weeds Observations

Total Weed Density (m^{-2}): Results indicated the significant effect of various weed control treatments on total weed population (Table 1). Application of herbicides resulted in lower weed density at 30 as well as 45 DAS over weedy check. Weed infestation was more at 45 DAS as compared to 30 DAS. The Maximum weeds density (235.25 and 327.11 plants m^{-2}) was documented in weedy check plots at 30 and 45 DAS, respectively. Application of bispyribac sodium at 25 g a.i. ha^{-1} sequentially followed by fenoxaprop-p ethyl at 1406 g a.i. ha^{-1} (T5) proved more effective (>80%) in altering the population of weeds at 30 and 45 DAS. Sequential application of herbicides was more detrimental for weeds, as >65% supression in weed density was recorded in all these treatments. Application of bispyribac sodium at 25 g a.i. ha^{-1} alone (T_1) was less effective, as these plots were infested with 161.75 and 272.63 weeds per m^2. These results are in agreement with Phuong *et al*. [14], Mann *et al.* [15] and Hussain *et al.* [16]. Mahajan *et al.* [16] and Khaliq *et al.* [17] also reported superior control of broad leaves weeds, grasses and sedges with the sequential application of herbicides.

Total Weed Dry Biomass (g m^{-2}): Various treatments significantly influenced total weed dry biomass (Table 1). Application of herbicides resulted in lower biomass at 30 and 45 DAS over weedy check. Inhibition in weed dry biomass was dose dependent and herbicide application at higher doses was more detrimental for weed. Weed biomass was more at 45 DAS as compared to 30 DAS. Maximum dry biomass (183.01 and 251.70 g m^{-2}) was verified in weedy check plots at 30 and 45 DAS, respectively. Application of bispyribac sodium at 25 g a.i. ha^{-1} sequentially trailed by fenoxaprop-p ethyl at 1406 g a.i. ha^{-1} (T5) proved more effective (>85%) in minimising the total dry biomass of weeds at 30 and 45 DAS.

Table 1: Influence of various weed control treatments on total weed density and dry biomass recorded at 30 and 45 DAS in direct seeded rice (m^{-2})

Treatment	Total weed density 30 DAS† (m^{-2})	Total weed density 45 DAS (m^{-2})	Total weed dry biomass 30 DAS ($g\ m^{-2}$)	Total weed dry biomass 45 DAS ($g\ m^{-2}$)
T_0	235.2 a	327.1 a	183.0 a	251.7 a
T_1	161.7 b	232.6 ab	117.6 b	159.3 b
T_2	81.5 c	108.2 c	57.9 c	77.8 c
T_3	54.2 d	69.3 d	35.5 d	48.4 d
T_4	44.0 de	53.3 e	27.4 de	37.1 e
T_5	38.7 e	47.7 e	23.5 e	31.7 e
LSD value (5%)	10.33	8.77	9.70	10.18

Table 2: Influence of various weed control treatments on individual weed density recorded at 30 and 45 DAS in direct seeded rice (m^{-2})

	Individual weeds											
	Crow foot grass		Purple nutsedge		Goose grass		Alligator weed		Jungle rice		Horse pursulane	
Treatment	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
T_0	40.7 a	48.5 a	96.2 a	105.7 a	8.75 a	10.5 a	9.25 a	11.25 a	35.75 a	41.5 a	21.5 a	28.75 a
T_1	31.7 b	37.5 b	75.7 b	84.5 b	4.25 b	5.75 b	5.25 b	7.50 b	19.50 b	22.2 b	2.25 b	5.25 b
T_2	9.00 c	12.7 c	29.7 c	34.7 c	3.50 bc	4.25 bc	4.75 b	6.0 bc	9.75 c	10.5 c	1.75 b	4.0 bc
T_3	5.75 cd	7.25 d	15.2 d	17.2 d	2.25 cd	3.0 cd	3.25 c	4.50 cd	3.50 d	4.75 d	1.25 b	3.25bcd
T_4	3.25 de	4.25 de	10.7 de	12.0 e	1.25 d	2.25 cd	2.50 c	3.75 d	2.50 d	3.75 d	0.75 b	1.5 cd
T_5	2.0 e	3.00 e	8.0 e	10.7 e	0.75 d	1.50 d	2.25 c	3.50 d	2.0 d	3.0 d	0.75 b	1.25 d
LSD ($P \leq 0.05$)	3.53	3.20	6.41	4.03	1.54	2.23	1.40	1.54	3.57	2.58	3.00	2.57

This treatment was comparable with T4 (bispyribac sodium + fenoxaprop-p ethyl at 25 and 1171 g a.i. ha-1), where 27.48 and 37.17 g m^{-2} dry biomass of weeds was observed at 30 and 45 DAS, respectively. Overall, sequential application of herbicides was more detrimental for weeds, as >68% supression in total weed dry biomass was observed in all these treatments. Lower weed dry biomass in herbicide treated plots is attributed to lower infestation of weeds resulting from detrimental effect of herbicides. Application of two herbicides gave better results than application of only single herbicide. These consequences are in line with Mann *et al*. [3] Hussain *et al*. [15], Mahajan *et al*. [16] and Khaliq *et al*. [4], who reported superior control of broad leaves weeds, grasses and sedges with the sequential application of herbicides.

Individual Weed Density (m^{-2}): Data pertaining individual weed density (m^{-2}) in direct seeded rice after 30 and 45 days of sowing (DAS) is presented in Table 2. Significant differences were recorded regarding crowfoot grass, purple nutsedge, goose grass, alligator weed, jungle rice and horse pursulane density among various weed control treatments. Application of herbicides resulted in less individual population at 30 as well as 45 DAS over weedy check (control). At 30 and 45 DAS, the maximum density of all individual weeds was recorded in weedy check plots. Application of bispyribac sodium at 25 g a.i. ha^{-1} sequentially followed by fenoxaprop-p ethyl at 1406 g a.i. ha^{-1} (T5) proved more effective in lowering the density of all individual weeds at 30 and 45 DAS. Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T1) was ineffective in reducing the individual weed density as compared to other herbicide treatments. Overall, comparatively higher weed density was recorded at 45 DAS as compared to that recorded at 30 DAS. These observations are alike with that of Mann *et al.* [3], who concluded that a combination of two post-emergence herbicides gives better results to control weeds in direct seeded rice. Khaliq *et al.* [4] also reported the good results by using combination of two herbicides.

Individual Weed Dry Biomass ($g\ m^{-2}$): Data pertaining dry biomass of individual weeds ($g\ m^2$) in direct seeded rice recorded at 30 and 45 DAS is presented in Table 3. Significant differences were recorded among various weed control treatments for dry biomass of crowfoot grass, purple nutsedge, goose grass, alligator weed, jungle rice and horse pursulane. Application of herbicides significantly reduced the dry biomass of all these weeds at 30 and 45 DAS over weedy check. At 30 and 45 DAS, the maximum dry biomass of individual weeds was recorded in weedy check plots. Application of bispyribac sodium at 25 g a.i. ha-1 sequentially followed by fenoxaprop-p ethyl at 1406 g a.i. ha^{-1} (T5) proved more effective in lowering the dry biomass of individual weeds at 30 and 45 DAS. Next best treatment was application of

Table 3: Influence of various weed control treatments on individual weed dry biomass recorded at 30 and 45 DAS in direct seeded rice (m^{-2})

	Individual weeds											
	Crow foot grass		Purple nutsedge		Goose grass		Alligator weed		Jungle rice		Horse pursulane	
Treatment	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS	30 DAS	45 DAS
T_0	52.16 a	69.35 a	20.21 a	31.72 a	11.55 a	16.59 a	6.84 a	9.11 a	70.7 a	93.7 a	9.46 a	20.12 a
T_1	40.64 b	53.62 b	15.90 b	25.35 b	5.61 b	9.08 b	3.88 b	6.07 b	38.6 b	50.2 b	0.99 b	3.92 b
T_2	11.52 c	18.23 c	6.24 c	10.42 c	4.63 bc	6.71 bc	3.51 b	4.86 bc	19.3 c	23.7 c	0.77 b	2.92 bc
T_3	7.36 cd	10.36 d	3.20 d	5.17 d	2.97 cd	4.80 cd	2.40 c	3.64 cd	6.93 d	10.9 d	0.63 b	2.50bcd
T_4	4.16 de	6.07de	2.45 de	3.77 e	1.65 d	3.55 cd	1.85 c	3.03 d	4.96 d	8.53 d	0.40 b	1.20 cd
T_5	2.56 e	4.29 e	1.76 e	3.47 e	0.99 d	2.37 d	1.66 c	2.83 d	4.23 d	6.70 d	0.33 b	1.07 d
LSD ($P \leq 0.05$)	4.52	4.57	1.38	1.28	2.03	3.51	1.04	1.25	7.09	5.78	1.33	1.84

Table 4: Influence of various weed control treatments on yield and yield components in aerobic direct seeded rice

Treatment	Plant height (cm)	Total number of tillers (m^{-2})	Panicle bearing tillers (m^{-2})	Branches per panicle	Kernels per panicle	1000 kernel weight	Paddy yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
T_0	64.2 e	248.7 e	216.2 f	8.70 d	75.0 e	15.7 d	2.33 d	8.57 e	27.2 b
T_1	72.2 d	306.2 d	278.2 e	9.12 c	83.7 d	16.5 cd	3.01 c	9.98 d	30.2 a
T_2	77.7 c	346.7 c	325.0 d	9.45 bc	91.7 c	18.1 bc	3.25 bc	10.5 cd	30.9 a
T_3	87.7 a	421.0 a	406.2 a	10.57 a	102.0 a	20.7 a	3.79 a	11.7 a	32.2 a
T_4	84.0 b	392.0 b	374.2 b	9.80 b	99.7 ab	19.7 ab	3.50 b	11.2 ab	31.1 a
T_5	81.7 b	370.7 bc	352.5 c	9.67 b	95.0 bc	18.6 b	3.42 b	10.9 bc	31.2 a
LSD ($P \leq 0.05$)	3.07	24.40	19.59	0.40	5.75	1.79	0.26	0.55	2.18

Means not sharing same letter differ significantly using LSD at 5% Probability level

bispyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} (T4). Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T1) was ineffective in reducing the individual weed dry biomass as compared to other herbicide treatments. These results are in agreement of those obtained by Mann *et al.* [3] and Khaliq *et al.* [4] who described that combination of two herbicides remained more effective for weed control than application of single herbicide.

Crop Related Attributes

Plant Height (cm): Plant height is an important character and although it is genetically controlled yet is greatly influenced by environmental factor, nutrient and water stresses. Data regarding plant height of direct seeded rice indicated that plant height varied significantly under the influence of various weed control treatments (Table 4). The tallest (87.75 cm) plants were observed in T3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. After this treatment, plots where bis-pyribac sodium at 25 g a.i. ha^{-1} sequentially followed by fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} (T4) recorded maximum plant height (84.0 cm) and was statistically similar to that (81.75 cm) observed for plots sprayed with bis-pyribac sodium at 25 g a.i. ha^{-1} and fenoxaprop-p-ethyl at 1406 g a.i. ha^{-1} (T5). Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone furnished plant height of 72.25 cm. Shortest (64.25 cm) plants were observed in weedy check plots. Less plant height in weedy check plot is because of weed competition with rice plants for growth resources. These consequences are similar with Mann *et al.* [3], who also reported less plant height in weed infested plots and taller plants in herbicide treated plots. Decrease in plant height at higher herbicide doses might be due to stress developed by herbicides. Improved plant height in weed control treatments than the control treatment showed the enhancement in crop growth due to herbicide usage.

Total Number of Tillers (m^{-2}): Total number of tillers is an important agronomic trait that represents extent of plant population. It significantly contributes to kernel yield of rice. Data regarding total number of tillers in direct seeded rice is presented in Table 4. Outcome discovered a helpful effect of various weed control treatments on this parameter so that more number of tillers was recorded in herbicide treated plots. Highest (421) number of total tillers was observed in T3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. After this treatment, plots where bis-pyribac sodium at 25 g a.i. ha^{-1} sequentially followed by fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} (T4) recorded maximum number of tillers (392 m^2) and was statistically similar to that (370.75 m2) observed for plots sprayed with bis-pyribac sodium at 25 g a.i. ha^{-1} and fenoxaprop-p-ethyl at 1406 g a.i. ha^{-1} (T5). Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T1) recorded 306.25 tillers m^{-2}. The minimum (248.75 m2) number of total tillers was observed in weed infested (T0) plots. This is because of weed dominance in these plots. So crop was unable to attain proper resources. More number of tillers in herbicide treated plots might be due to efficient control of weeds which facilitate crop to get abundant resources. Sandeep *et al.* [17] observed more number of tillers in herbicide treated plots than the weedy check. Khaliq *et al.* [4] also reported maximum tillers with sequential application of two herbicides.

Panicle Bearing Tillers (m^{-2}): Number of panicle bearing tillers is key factor in yield determination of rice crop. Results presented in Table 4 indicated that application of herbicides increased the number of panicle bearing tillers over weedy check. The maximum (406.25 m^2) number of panicle bearing tillers was observed in T_3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. Sequential use of bis-pyribac sodium at 25 g a.i. ha^{-1} followed by fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} (T_4) proved second best treatment by recording 374.25 tillers per m^2. Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T_1) recorded 278.25 panicle bearing tillers per m^2. The minimum (216.25 m^{-2}) number of panicle bearing tillers was observed in weedy check (T_0) plots. Several studies showed the positive influence of efficient weed control practices on panicle bearing tillers in rice [3, 16, 4]. The more number of panicle bearing tillers might be owing to better accessibility of growth resources to plants in the lack of weed-crop competition under the influence of different weed control measures [18].

Branches per Panicle: Number of branches per panicle is a significant parameter directly contributing to the production potential of rice. Data regarding number of branches per panicle in direct seeded rice is presented in Table 4. Comparison of means exposed an assertive impact of various weed control treatments on this parameter so that more number of branches per panicle was noted in herbicide treated plots. The highest (10.575) number of branches per panicle was observed in T_3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. After this treatment, plots where bis-pyribac sodium at 25 g a.i. ha^{-1} sequentially followed by fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} (T_4) recorded maximum number of branches (9.80) and was statistically similar to that (9.675) observed for plots sprayed with bis-pyribac sodium at 25 g a.i. ha^{-1} and fenoxaprop-p-ethyl at 1406 g a.i. ha^{-1} (T_5). Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T_1) furnished 9.125 branches per panicle. Minimum (8.70) number of branches was observed in weed infested (T_0) plots. Increased in number of branches per panicle seems an outcome of reduced weed-crop competition and improvement in this parameter over weedy check has been documented [19, 18].

Kernels per Panicle: Number of kernels per panicle is a vital agronomic parameter which contributes materially towards the final kernel yield of rice. Application of herbicides increased the number of kernels per panicle over weedy check (control). The maximum (102.0) number of kernels was observed in T_3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were used at 25 and 937 g a.i. ha^{-1}, respectively. This treatment was comparable with T_4 (99.75), where sequential usage of bis-pyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} was done. Application of bis-pyribac sodium at 25 g a.i. ha^{-1} (T_1) recorded 83.75 kernels per panicle. The minimum (75.0) number of kernels was witnessed in weedy check (T_0) plots. The increased number of kernels per panicles in herbicide treated plots might be attributed to better nutrient acquisition, fertilization and translocation of photo assimilates under the influence of efficient weed control treatments. These results are in line with those obtained by Mann *et al.* [3] who reported that sequential application of herbicides caused an increase in number of kernels per panicle in dry seeded rice.

1000 Kernels Weight (g): Kernel weight is an essential parameter which contributes to the final yield. It expresses the kernel size.Data regarding 1000-kernel weight of direct seeded rice indicated the variable response of this parameter to various weed control treatments (Table 4). Application of herbicides significantly increased 1000-kernel weight over weedy check. The highest (20.75 g) 1000-kernel weight was observed in T_3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. After this treatment, plots wherebis-pyribac sodium at 25 g a.i. ha^{-1} sequentially followed by fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} (T_4) recorded maximum 1000-kernel weight (19.75 g) and was statistically similar to that (18.68 g) observed for plots sprayed withbis-pyribac sodium at 25 g a.i. ha^{-1} and fenoxaprop-p-ethyl at 1406 g a.i. ha^{-1} (T_5). Use of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T_1) furnished 1000-kernel weight of 16.525 g. Minimum (15.75 g) 1000-kernel weight were observed in weedy check (T_0) plots. Khaliq *et al*. [4] produced similar results in which he mentioned maximum 1000-kernel weight by combination of herbicides among different weed control treatments.

Paddy Yield (t ha^{-1}): Paddy yield is cumulative effect of various yield components under particular set of environmental factors. Analysis of data revealed that paddy yield of rice was considerably affected by various weed control treatments (Table 4). Application of herbicides resulted in higher paddy yield as compared to weedy check. The maximum (3.797 t ha^{-1}) paddy yield was observed in T_3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. Treatments T_4 (bis-pyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1}) and T_5 (bis-pyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl at 1406 g a.i. ha^{-1}) were equally effective as these treatments recorded statically similar yield of 3.502 and 3.420 t ha^{-1}, correspondingly. Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T_1) furnished paddy yield of 3.017 t ha^{-1}. The upturn in paddy yield with effective weed control treatments may be credited to improved crop growth due to a lesser period of weed-crop competition for resources. Mahajan *et al*. [16] stated that herbicides are the best means of securing rice yields from weeds. These results are parallel with Mann *et al.* [3] and Khaliq *et al*. [4], who recorded maximum yield of rice in herbicide treated plots.

Biological Yield (t ha^{-1}): Results depicted a significant influence of all weed control treatments on biological yield of rice. Usage of herbicides resulted in higher biological yield as compared to weedy check (control). Maximum (11.78 t ha^{-1}) biological yield was recorded in T_3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. This treatment was comparable with T_4 (11.24 t ha^{-1}), where sequential application of bis-pyribac sodium at 25 g a.i. ha^{-1} followed by fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} was done. The minimum (8.57 t ha^{-1}) biological yield was observed in weedy check (T_0) plots. Higher biological yield in herbicide treated plots is due to higher plant height and number of tillers in these treatments. These attributes were negatively affected in the presence of weeds thus recorded less biological yield in weedy check plots. Sultana [20] and Mann *et al.* [3] also found similar results.

Harvest Index (%): The physiological efficiency of plants to convert total photosynthates into economic part is shown by harvest index. It is the ratio of grain and biological yield on pecentage basis. Data regarding harvest index of rice is presented in Table 4. Application of herbicide significantly improved harvest index as compared to weedy check. The maximum (32.23%) harvest index was calculated in T_3 treatment, where bispyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 937 g a.i. ha^{-1}, respectively. This treatment was comparable with T_4 (31.160%) and T_5 (31.203%), where

Table 5: Economic analysis of different weed control treatments in direct seeded rice

	T_0	T_1	T_2	T_3	T_4	T_5	Remarks
Grain yield (G.Y)	2335	3017.5	3255	3797.5	350.5	3420	kg ha^{-1}
10% loss (grain)	233.5	301.75	325.5	379.75	350.25	342	To bring at farmer level
Adjusted G.Y.	2101.5	2715.75	2929.5	3417.75	3152.25	3078	10% discount
Income from G.Y.	47284	61115	65914	76910	70936	69255	Rs. 22.5/kg
Straw yield (S.Y)	6237.5	6962.5	7275	7987.5	7737.5	7542.5	kg ha^{-1}
10% loss (straw)	623.75	696.25	727.5	798.75	773.75	754.25	To bring at farmer level
Adjusted S.Y.	5613.75	6266.25	6547.5	7188.75	6963.75	6788.25	10% discount
Income from S.Y	6736	7520	7857	8626	8357	81468	Rs. 1.2/kg
Gross income	54020	68635	73771	85536	79293	77401	
Cost of Clover	-	1200	1200	1200	1200	1200	Rs. 1200 ha^{-1}
Cost of Puma super	-	-	400	530	660	790	Rs. ha^{-1}
Spray application cost	-	300	600	600	600	600	Rs.300/man day^{-1} ha^{-1}
Spray rent	-	100	200	200	200	200	Rs. 100 per spray
Cost that varied	-	1600	2400	2530	2660	2790	
Net benefit	54020	67034	71371	83006	76632	74611	

T_0= Weedy check, T_1= bispyribac sodium at 25 g a.i. ha^{-1}, T_2= bispyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl) at 702 g a.i. ha^{-1}, T_3= bispyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl at 937 g a.i. ha^{-1}, T_4= bispyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1}, T_5= bispyribac sodium at 25 g a.i. ha^{-1} + fenoxaprop-p-ethyl at 1406 g a.i. ha^{-1}

DAS†= Days after sowing

fenoxaprop-p-ethyl was applied at 1171 and 1406 g a.i. ha^{-1}, respectively, along with bispyribac sodium. Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T_1) recorded harvest index of 30.233, which was statistically similar to T_2 (30.912%), where bis-pyribac sodium and fenoxaprop-p-ethyl were applied at 25 and 702 g a.i. ha^{-1}. The minimum value (27.214%) harvest index was observed in weedy check (T_0) plots. The less harvest index in weedy check treatment is attributed to low paddy yield in these plots. Higher paddy yield was recorded in plots, where herbicides were applied to control weeds. That's why harvest index was more. These effects are similar with Khaliq *et al.* [4].

Economic Analysis: Data regarding economic analysis of various weed control treatments is given in Table 5. All treatments caused in higher net benefits as compared to weedy check treatment. Among various treatments, T_3 (bispyribac sodium + fenoxaprop-p-ethyl at 25 and 937 g a.i. ha^{-1}, respectively) gave maximum paddy yield (3.80 t ha^{-1}) and recorded highest net income Rs. 83006 ha^{-1}. This treatment was followed by the application of bis-pyribac sodium at 25 g a.i. ha^{-1} sequentially followed by fenoxaprop-p-ethyl at 1171 g a.i. ha^{-1} with net benefits of Rs. 76632. The least (Rs. 54020 ha^{-1}) net benefit was recorded in weedy check treatment. Application of bis-pyribac sodium at 25 g a.i. ha^{-1} alone (T_1) recorded net benefit of Rs. 67034 ha^{-1}. Higher net benefit in herbicide treated plots is attributed to efficient weed control that led to higher paddy yield.

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