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Studies on bio efficacy of different herbicide molecules against weeds in dry direct seeded rice (*Oryza sativa* L.)

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Abstract: A field experiment was conducted during kharif, 2015 at Agricultural Research Station, Gangavathi, Karnataka to study the bio efficacy of different herbicide molecules against weeds in dry direct seeded rice (*Oryza sativa* L.). The experiment comprised of 11 sequential applications of herbicides in randomized block design and replicated thrice. The study revealed that hand weeding at 30 and 60 days after sowing recorded significantly lower weed density (2.39 0.25m^{-2}), weed dry weight (3.02 g 0.25 m^{-2}) and high weed control efficiency (80 %) and resulted in higher grain yield and net returns. Among herbicidal treatments pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds proved most effective in controlling weeds and recorded higher yield, net returns and BC ratio. In contrast weedy check treatment recorded significantly lower grain yield, net returns and BC ratio.

Key words: Herbicides, Weed control, Weed index, Weed density, Yield

Introduction

Rice (*Oryza sativa* L.) is the world's most important staple food crop and primary source of food for more than half of the world's population. More than 90 per cent of the world's rice is produced and consumed in Asia, where 60 per cent of the earth's population lives (Anon., 2014). In the world, rice occupies 147 m ha with a production of 525 m t. India is second largest producer of rice next to china with an area of 43.95 m ha and a production of 106.54 m t and with a productivity of 2424 kg ha^{-1}. In Karnataka, rice is grown in an area of 1.33 m ha with a production of 3.76 m ha and productivity of 2828 kg ha^{-1} (Anon., 2014).

In the Tungabhadra irrigation command area of Karnataka in mid and tail end regions, farmers are opting for direct-seeded rice (DSR) because of its advantages, such as water and labour savings, reduced costs and early crop maturity by 8 to 9 days than the transplanted rice. In direct seeded rice, weed infestation is more severe than transplanted rice mainly due to simultaneous emergence of both rice and weed species; land exposure during initial crop growth stage; aerobic soil conditions; dry tillage practices and alternate wetting and drying. Due to germination of weeds in flushes single application of either pre.em or post.em application may not give effective control of weeds and hence need sequential application to ensure weed free condition for longer time. Use of pre and post emergence herbicides help to keep the crop free of weed at critical stages and maintain better crop growth. Weed flora changes with place and time, method of land preparation and crop establishment method. Many new herbicide molecules are arriving into market which needs to be evaluated for their bio efficacy and phyto toxicity on paddy. With this background the present an experiment was conducted.

Material and methods

The field experiment was conducted during *kharif* 2015 at Agricultural Research Station, Gangavathi, University of Agricultural Sciences, Raichur, Karnataka. The soil of the experimental field was medium deep black clay in texture. The experiment comprised of 11 weed management practices (sequential applications) *viz.,* T_1 : pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE), T_2 - butachlor 50 EC @ 1.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE), T_3 - penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g.a.i. ha^{-1}(POE), T_4 - bensulfuron methyl + pretilachlor 6.6 % G @ 12.5 kg ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE), T_5 - pyrazosulfuron ethyl 10 % WP @ 20 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE), T_6 - pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE), T_7 - pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb hand weeding at 60 days after sowing(DAS), T_8 - penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (Early POE) (15-20 DAS) fb hand weeding at 60 days after sowing (DAS), T_9 - penoxsulam + cyhalofop butyl 6 % OD @135 g a.i. ha^{-1} (POE) (15 DAS) with hand weeding at 60 DAS, T_{10} - Hand weeding at 30 DAS and 60 DAS, T_{11} – weedy check, These treatments were laid out in randomized block design with three replications. Pre em herbicides were applied at one day after sowing the crop, post.em herbicides were applied at 2-4 leaf stage of weeds and early post em herbicides were applied at 15 DAS using a hand operated knapsack sprayer fitted with flat fan nozzle and at a spray volume of 500 l/ha. Rice crop (IET 19251) was sown on 1st September 2015 at a spacing of 22.5 x 10 cm. The recommended fertilizer dose of 150 kg N, 75 kg P_20_5 and 75 kg K_20 per ha was applied as per package of practices. Weed density was recorded by putting a quadrate of 0.25 m^2 at random in each plot and converted to m^2. The weed data was subjected to $\sqrt{x+0.5}$ transformation.

Results and discussion

The major weed flora observed in the weedy check plot of dry direct seeded rice (DSR)includes grassy weeds *viz.,*

Echinochloa colona, Panicum repens, Dinebra retroflexa, Chloris barbata and *Leptochloa chinensis.* Among the sedges *Cyperus difformis, Cyperus iria* and *Fimbristylis miliaceae and among broad leaf weeds Ammania baccifera, Amaranthus viridis, Cyanotis axillaris, Eclipta alba, Phyllanthus niruri.*were present. Similar weed flora in dry direct seeded rice was reported by Gopinath *et al.* (2012), Nikhil and Singh (2014) and Kashid *et al.* (2015).

The data revealed that different weed control treatments significantly influenced the total weed density at harvest. Hand weeding twice @ 30 and 60 DAS had recorded significantly the lower total weed density at harvest (2.39 / 0.25 m^2). In the case of herbicides pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} had recorded significantly lower total density of weeds (2.54 / 0.25 m^2) as compared to weedy check (4.66 / 0.25 m^2) and check herbicide (3.62 / 0.25 m^2). However, it remained on par with penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (3.13 / 0.25 m^2) and pyrazosulfuron ethyl 10 % WP @ 20 g a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (2.90 / 0.25 m^2). Weedy check recorded significantly higher total density of weeds (4.66 / 0.25 m^2). The total weed population was significantly the lowest in the case of pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i.ha^{-1} (POE) indicating that it is effective against all type of weeds. Earlier Dileep and Bazaya, (2011) also reported effective control of weeds by pretilachlor in dry DSR.

The dry weight of the weeds at all growth stages differed significantly due to herbicidal treatments. The data revealed that significantly lower weed dry weight was recorded in two hand weeding (3.02 / 0.25 m^2).Among the herbicides, pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) recorded lower total weed dry weight (3.15 / 0.25 m^2) as compared to all other treatments but remained on par with penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) (3.45 / 0.25 m^2) and pyrazosulfuron ethyl 10 % WP @ 20 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) (3.51 / 0.25 m^2). Significantly higher total weed dry weight was recorded in weedy check (5.64 / 0.25 m^2). The results are in conformation with findings of Chandra Prakash *et al.* (2013) who reported better control of weeds by post emergent application of bispyribac sodium.

Hand weeding two times at 30 and 60 DAS recorded significantly higher weed control efficiency (WCE)(80 %). Among the herbicidal treatments, significantly higher WCE was recorded with application of pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) (73 %) than other treatments including check herbicide treatment of pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1}(POE) (46 %). However, it remained on par with penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) (64 %) and pyrazosulfuron ethyl 10 % WP @ 20 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) (63 %). The results confirms the earlier findings by Rohitashav singh *et al.* (2014).

Among the herbicides, significantly lower weed index was recorded in pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} fb bispyribac

Table 1. Weed density, weed dry weight, weed control efficiency and weed index as influenced by herbicides in dry DSR

Treatment		Weed density	Weed dry weight (g/0.25m^2)	Weed control efficiency (%)	Weed index
T_1:	Pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1}(POE) at 2- 4 leaf stage of weeds	3.62 (12.67)	4.03 (15.82)	46	20.17
T_2:	Butachlor 50 EC @ 1.5 kg a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	3.43 (11.33)	3.74 (13.56)	57	15.55
T_3:	Penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	3.13 (9.33)	3.45 (11.39)	64	4.92
T_4:	Bensulfuron methyl + Pretilachlor 6.6 % G @ 12.5 kg ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) at 2-4 leaf stage of weeds	3.57 (12.33)	4.06 (16.02)	48	25.13
T_5:	Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	2.90 (8.00)	3.51 (11.83)	64	14.34
T_6:	Pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	2.54 (6.00)	3.15 (9.44)	73	1.35
T_7:	Pendimethalin 38.7 CS @ 0.78 kg a.i.ha^{-1} (PRE) fb hand weeding at 60 DAS	3.33 (10.67)	4.12 (16.49)	41	35.13
T_8	Penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (Early POE) (15-20 DAS) fb hand weeding at 60 DAS	2.85 (7.67)	3.69 (13.15)	58	13.72
T_9:	Penoxsulam + Cyhalofop butyl 6 % OD @135 g a.i. ha^{-1} (POE) (15-20 DAS) at 2-4 leaf stage of weeds with hand weeding at 60 DAS	3.53 (12.00)	3.98 (15.36)	51	22.64
T_{10}:	Hand weeding at 30 DAS and 60 DAS	2.39 (5.33)	3.02 (8.69)	80	0.00
T_{11}:	Weedy check	4.66 (21.33)	5.64 (31.35)	0.00	48.25
	S.Em±	0.15	0.15	3.86	2.56
	C.D. (P=0.05)	0.45	0.42	11	7.47

Table 2. Plant height, number of panicles, grain yield, net return and B:C ratio as influenced by herbicides in dry DSR

	Treatments	Plant height (cm)	Number of panicles m^{-2}	Grain yield (kg ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1:	Pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1}(POE) at 2- 4 leaf stage of weeds	84.97	295	3420	23102	1.71
T_2:	Butachlor 50 EC @ 1.5 kg a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	86.20	325	3589	26307	1.82
T_3:	Penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	87.20	339	4080	34204	2.07
T_4:	Bensulfuron methyl + Pretilachlor 6.6 % G @ 12.5 kg ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) at 2-4 leaf stage of weeds	80.53	252	3203	19086	1.57
T_5:	Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	87.00	337	3642	28970	1.93
T_6:	Pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb Bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds	90.33	345	4187	36250	2.16
T_7:	Pendimethalin 38.7 CS @ 0.78 kg a.i.ha^{-1} (PRE) fb hand weeding at 60 DAS	83.60	242	2756	13899	1.43
T_8	Penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (Early POE) (15-20 DAS) fb hand weeding at 60 DAS	86.13	337	3675	26599	1.80
T_9:	Penoxsulam + Cyhalofop butyl 6 % OD @135 g a.i. ha^{-1} (POE) (15-20 DAS) at 2-4 leaf stage of weeds with hand weeding at 60 DAS	83.07	289	3297	21994	1.67
T_{10}:	Hand weeding at 30 DAS and 60 DAS	91.67	378	4273	31381	1.84
T_{11}:	Weedy check	77.33	238	2246	10435	1.37
	S.Em±	2.26	14.76	188	1795	0.09
	C.D. (P=0.05)	7.58	43.08	549	5387	0.26

sodium 10 % SC @ 35g a.i. ha^{-1} (1.35) as compared to all other treatments except penoxsulam 24 % SC @ 22.5g a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (4.92). Significantly higher weed index was recorded in weedy check (48.25). Similar findings of high WCE by pretilachlor was reported by Ghanshyam and Surjith (2008) and Ramachandiran and Balasubramanian,(2012).

At harvest higher plant height (92.67 cm) was recorded in hand weeding two times @ 30 and 60 DAS. Among the herbicides, pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (POE) recorded significantly higher plant height (90.33 cm) as compared to bensulfuron methyl+ pretilachlor 6.6 % G @ 12.5 kg ha^{-1} PRE fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) (80.53 cm) and weedy check treatment. However, plant height remained on par with other treatments including recommended herbicide of pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1}(POE) (84.97 cm).

The numbers of panicles were significantly higher with hand weeding two times @ 30 and 60 DAS (378 panicles m^{-2}) as compared to weedy check treatment (238 panicles m^{-2}). Among the herbicidal treatments, higher number of panicles were recorded in pretilachlor 50 % EC @ 0.50 kg a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (345 panicles m^{-2}) as compared check herbicide (295 panicles m^{-2}), bensulfuron methyl + pretilachlor 6.6 % G @ 12.5 kg ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) (252 panicles m^{-2}), penoxsulam +cyhalofop butyl 6 % OD @135 g a.i.ha^{-1} (POE) (15-20 DAS) with hand weeding at 60 DAS (289 panicles m^{-2}), pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb hand weeding at 60 DAS (242 panicles m^{-2}).

Rice grain yield was significantly higher in hand weeding two times at 30 and 60 DAS (4273 kg ha^{-1}). Among herbicidal treatments, higher grain yield was recorded by pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1} (4187 kg ha^{-1}) as compared to the check herbicide pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35 g a.i ha^{-1} (3420 kg ha^{-1}) representing 18.32%higher yield. However, it remained on par with hand weeding two times at 30 and 60 DAS (4273 kg ha^{-1}), penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (4080 kg ha^{-1}), penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1}(15-20 DAS) fb hand weeding at 60 DAS (3675 kg ha^{-1}) and pyrazosulfuron ethyl 10 % WP @ 20 g a.i.ha^{-1} fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (3642 kg ha^{-1}). Effective control of weeds by a combination of pre.em pretilachlor fb post.em bispyribac sodium resulted in weed free environment since from the early stage of crop growth that finally reflected in improved yield parameters and higher grain yield. Earlier Mandhata and Singh (2010) reported that the application of pretilachlor (0.75 kg a.i. ha^{-1} as PRE) followed by 2, 4-D (0.50 kg a.i. ha^{-1} as POE) proved to be most effective in minimizing the density and dry weight of weeds and enhancing WCE, grain yield. Similar results of better performance of pre.em pretilachlor were reported in aerobic rice by Kusuma, (2007) and Dilip and Bajaya (2011).While Manjunath *et al.* (2012) and Kumar and Rana (2013) reported better performance of bispyribac sodium in direct seeded rice.

Significantly lower net returns were recorded in weedy check (₹ 10435 ha^{-1}) as compared to all other treatments. Among herbicidal treatments significantly higher net returns were recorded in pretilachlor 50 % EC @ 0.5 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) (₹ 36250 ha^{-1}) as compared to check herbicide treatment pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i ha^{-1}(POE) (₹ 23102 ha^{-1}) except penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) (₹ 34204 ha^{-1}) and hand weeding twice (₹ 31381 ha^{-1}) where in it remained on par. Earlier Mandhata Singh and Singh (2010) reported higher net returns and benefit cost ratio due to pre.em application of pretilachlor.

The data revealed that significantly higher BC ratio was recorded in pretilachlor 50 % EC @ 0.50 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) (2.16) as compared to all other treatments including the check treatment pendimethalin 38.7 CS @ 0.78 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i. ha^{-1}(POE) (1.71) but remained on par with penoxsulam 24 % SC @ 22.5 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g ha^{-1} (POE) (2.07) and pyrazosulfuron ethyl 10 % WP @ 20 g a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35 g a.i .ha^{-1} (POE) (1.93). Narolia *et al.* (2014) reported higher BC ratio with pre.em pretilachlor in direct seeded rice.

From the present investigation it can be concluded that sequential application of pretilachlor 50 % EC @ 0.50 kg a.i. ha^{-1} (PRE) fb bispyribac sodium 10 % SC @ 35g a.i. ha^{-1} (POE) at 2-4 leaf stage of weeds was found the most effective in controlling weeds in dry direct seeded rice and resulted in higher grain yield and net returns and can be recommended to farmers for field adoption.

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