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Herbicide sequence for weed management in direct seeded rice

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Abstract: An experiment was conducted during *Kharif* 2014 and 2015 at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences, Raichur, Karnataka, India, to know the herbicide sequence for weed management in direct seeded rice. The dominant weeds in direct seeded rice were *Echinochloa sp, Panicum repens, Cynodon doctylon, Leptochloa chinensis, Bracharia sp. Ludwigia parviflora, Commelena sp. and Cyperus sp.* Pooled data revealed that, application of pyrazosulfuron ethyl 10 % WP at 20 g a.i./ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha at 20 to 25 days after sowing as post-emergent herbicide in direct seeded rice was most effective in controlling of grasses, broad leaf weeds and sedges and increased the rice grain yield (5583 kg/ha) without any phytotoxic effect and which was onpar with the application of Pendimethalin 30 EC @ 1 kg a.i. /ha as pre-emergent herbicide followed by one hand weeding at 30 days after sowing and weed free check .Therefore, the application of pre emergent herbicides followed by the post emergent herbicide application can reduce the weed problem in direct seeded rice. .

Keywords: Grain yield, Weed control efficiency, Weed dry weight, Weeds

INTRODUCTION

Agriculture has been a forefront agenda at national and international level for food security and management of natural resources. Cereals are the most important part of our diet throughout the world and thus, play a major role in our food security. Among cereals, rice has been staple food for more than 60 per cent of the world population, providing energy for about 40% of the world population where every third person on earth consumes rice every day in one form or other. Therefore, paddy (*Oryza sativa* L.) is an important crop which is extensively grown in tropical and subtropical regions of the world. It is cultivated in area of 44.0 million hectares with an annual production of 104.3 million tons in India. Its production has been found to be distributed as 91.5 million tons in *kharif* and 12.8 million tons in *rabi* season. However, its productivity in India is very low (2.37 t ha^{-1}) as compared to other rice growing countries like Japan (6.35 t ha^{-1}), Australia (6.22t ha^{-1}), Spain (6.16 t ha^{-1}), Egypt (5.0 t ha^{-1}) and China (5.2 t ha^{-1}) (Annonymous, 2015).

Weeds are the major cause of yield reduction in rice. Hand weeding is the traditional weed control measure and still being the most popular in rice. However, due to high labour cost, non-availability of labour and huge time requirement for manual weeding, farmers are inevitable to go for other alternative measures like chemical weed control. Many herbicides are being used successfully for weed control in transplanted rice as pre -emergence spray. New herbicides are available in the market and use of herbicides of different composition is desirable to reduce the problem of residue buildup, shift in weed problem (Rajkhowa *et al.,* 2006) and development of herbicide resistance in weeds (Rao, 1999, Saha *et al.,* 2006). The recent trend of herbicide use is to find out an effective weed control measure by using low dose high efficiency herbicides which will not only reduce the total volume of herbicide use but also the application become easier and economical (Pal and Banerjee, 2007). The herbicide pyrazosulfuron ethyl 10 % WP has both foliar and soil activity (Rajkhowa *et al.,* 2006). It is generally recommended as a pre-emergence herbicide in transplanted rice (Angiras and Kumar, 2005). Studies on bio-efficacy and phytotoxicity of pyrazosulfuron ethyl 10 % WP and Pendimethalin 30 EC for pre-emergence weed control and Bispyribac sodium 10 % SC, Penoxsulam 24 % SC, Metsulfuron methyl 10 % + chlorimuron 10 % and Azimsulfuron 50 DF in direct seeded rice are scanty. The present experiment was therefore undertaken to study the bio-efficacy and phytotoxicity of pre-emergent followed by post emergent herbicides for control of major weeds in direct seeded rice.

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MATERIALS AND METHODS

An experiment was conducted during *Kharif* 2014 and 2015 at Agricultural Research Station, Dhadesugur, University of Agricultural Sciences (UAS), Raichur, Karnataka, India, (situated at 15.6' N latitude and 76.8' E longitude with an altitude of 358 m above mean sea level). The soil was deep black clay in texture having a pH of 8.1, organic Carbon 0.21%, total N 160 kg/ha, available P 26.0 kg/ha and available K 486 kg/ha. The experiment was laid out in a randomized block design with ten treatments, *viz.* T_1- Pendimethalin 30 EC @ 1 kg a.i. /ha followed by Bispyribac sodium 10 % SC @ 250 ml/ha, T_2- Pendimethalin 30 EC @ 1 kg a.i. /ha followed by 2,4 D sodium salt 80 WP @ 600 g a.i./ha, T_3- Pendimethalin 30 EC @ 1 kg a.i. /ha followed by Azimsulfuron 50 DF @ 17.5 g a.i /ha, T_4- Pendimethalin 30 EC @ 1 kg a.i. /ha followed by Metsulfuron methyl 10 % + chlorimuron 10 % @ 4 g a.i. /ha, T_5- Pyrazosulfuron ethyl 10 WP @ 20 g a.i. /ha followed by Metsulfuron methyl 10 % + chlorimuron 10 % @ 4 g a.i. /ha, T_6- Oxodiagil 80 % @ 100 g a.i. /ha followed by Penoxsulam 24 % SC @ 25 g a.i./ha, T_7- Pyrazosulfuron ethyl 10 WP @ 20 g a.i. /ha followed by Bispyribac sodium 10 % SC @ 250 ml/ha, T_8- Pendimethalin 30 EC @ 1 kg a.i. /ha followed by one hand weeding at 30 days after sowing T_9- weed free check (weeding at 15 and 30 days after sowing) and T_{10}- weedy check (Untreated check) and replicated thrice. Pre-emergent herbicides were applied with in three days after sowing and post emergent herbicides were applied at 20-25 days after sowing as per the treatment. The rice variety used was Gangavathi sona of 135 days duration. The crop was sown during 1st week of July in both the years. The herbicides were sprayed with the spray volume of 500 l/ha using knapsack sprayer with flat fan nozzle. An area was selected randomly at three spots by making a quadrat of 0.25 m^2. Weed species were counted from that area and density was expressed in number per square meter. The collected weeds were first sun-dried and then kept in an electric oven at 70 ^{0}C till the weight became constant and weed dry weight was expressed as g/m^2. As wide variation existed in data, number and biomass of weeds were transformed through square-root method before analysis of variance. Comparison of treatment means for significance at five per cent level was done using the critical differences as suggested by Gomez and Gomez (1984). Weed control efficiency (WCE) was worked out using the formula as suggested by Mani *et al.,* 1973 and Gill and Vijayakumar, 1969. In direct seeded rice, five plants were randomly selected in each plot of each replication and were tagged for the purpose of recording observations on growth parameters *viz.,* plant height and number of productive tillers per hill at harvest. Yield parameters *viz.,* grain and straw yield. Similarly, rice from each net plot in each replication was harvested and dried. The grains after threshing were weighed and recorded as grain yield per net plot. Further, this net plot grain yield was converted to grain yield per hectare.

RESULTS AND DISCUSSION

Weed density and weed control efficiency: In the experimental plots, the dominant weeds were *Echinochloa sp, Panicum repens, Cynodon doctylon, Leptochloa chinensis, Bracharia sp. Ludwigia parviflora, Commelena sp.* All the herbicides (both pre and post emergent) showed effective control of all categories of dominant weeds resulting in less weed numbers per square meter, weed dry matter (g) and higher weed

Table 1. Effect of weed control treatments on weed counts (No./m^2) in direct seeded rice at 15 days after sowing.

Treatment	Weed population (Count/m^2)										
	Grasses (No./m^2)			Broad leaf weeds (No./m^2)			Sedges (No./m^2)			Total weed dry weight (g/m^2)	Weed control efficiency (%)
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	Pooled	Pooled
T_1: Pendimethalin fb Bispyribac sodium	2.41 (4.80)	2.41 (4.82)	2.41 (4.81)	2.12 (3.50)	2.13 (3.52)	2.12 (3.51)	1.84 (2.40)	1.85 (2.42)	1.85 (2.41)	3.42 (10.7)	57.0
T_2: Pendimethalin fb 2,4 D sodium salt	2.43 (4.90)	2.43 (4.91)	2.43 (4.91)	2.15 (3.62)	2.15 (3.64)	2.15 (3.63)	1.90 (2.61)	1.93 (2.71)	1.91 (2.66)	3.49 (11.2)	55.2
T_3: Pendimethalin fb Azimsulfuron	2.43 (4.92)	2.44 (4.94)	2.44 (4.93)	2.17 (3.71)	2.17 (3.73)	2.17 (3.72)	1.93 (2.71)	1.96 (2.84)	1.94 (2.78)	3.52 (11.4)	54.3
T_4: Pendimethalin fb Metsulfuron methyl	2.35 (4.50)	2.35 (4.52)	2.35 (4.51)	2.17 (3.72)	2.18 (3.75)	2.18 (3.74)	1.93 (2.74)	1.96 (2.83)	1.95 (2.79)	3.47 (11.0)	55.8
T_5: Pyrazosulfuron ethyl fb Metsulfuron methyl	2.29 (4.26)	2.30 (4.28)	2.30 (4.27)	2.20 (3.86)	2.08 (3.32)	2.14 (3.59)	1.77 (2.12)	1.80 (2.24)	1.78 (2.18)	3.32 (10.0)	59.8
T_6: Oxodiagil fb Penoxsulam	2.49 (5.21)	2.50 (5.24)	2.49 (5.23)	2.18 (3.74)	2.19 (3.81)	2.19 (3.78)	1.98 (2.94)	1.99 (2.95)	1.99 (2.95)	3.60 (11.9)	52.2
T_7: Pyrazosulfuron ethyl fb Bispyribac sodium	2.29 (4.25)	2.29 (4.26)	2.29 (4.26)	2.06 (3.24)	2.08 (3.34)	2.07 (3.29)	1.80 (2.24)	1.83 (2.34)	1.81 (2.29)	3.29 (9.84)	60.6
T_8: Pendimethalin + HW at 30 DAP	2.43 (4.91)	2.43 (4.92)	2.43 (4.92)	2.15 (3.62)	2.17 (3.71)	2.16 (3.67)	1.98 (2.92)	1.99 (2.95)	1.98 (2.94)	3.54 (11.5)	53.9
T_9: Weed free check	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.0)	100
T_{10}: Weedy check	3.66 (12.4)	3.69 (12.6)	3.67 (12.5)	3.03 (8.20)	3.05 (8.32)	3.04 (8.26)	2.26 (4.12)	2.31 (4.32)	2.28 (4.22)	5.10 (25.0)	-
p=0.05	**0.35**	**0.26**	**0.38**	**0.52**	**0.56**	**0.54**	**0.65**	**0.42**	**0.51**	**1.82**	**3.65**

Figures in the parenthesis are square root transformed values (sq. root of x+1) fb: followed by

Table 2. Effect of weed control treatments on weed counts (No./m^2) in direct seeded rice at 30 days after sowing.

Treatment	Weed population (Count/m^2)										
	Grasses (No./m^2)			Broad leaf weeds (No./m^2)			Sedges (No./m^2)			Total weed dry weight (g/m^2)	Weed control efficiency (%)
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	Pooled	Pooled
T_1: Pendimethalin fb Bispyribac sodium	1.98 (2.92)	1.99 (2.95)	1.98 (2.94)	1.12 (0.26)	1.13 (0.28)	1.13 (0.27)	1.82 (2.32)	1.83 (2.35)	1.83 (2.34)	2.56 (5.5)	87.2
T_2: Pendimethalin fb 2,4 D sodium salt	2.05 (3.21)	2.14 (3.56)	2.09 (3.39)	1.49 (1.21)	1.50 (1.26)	1.49 (1.24)	1.91 (2.65)	1.92 (2.69)	1.92 (2.67)	2.88 (7.3)	83.2
T_3: Pendimethalin fb Azimsulfuron	2.02 (3.10)	2.08 (3.31)	2.05 (3.21)	2.20 (3.84)	2.23 (3.98)	2.22 (3.91)	2.40 (4.78)	2.43 (4.92)	2.42 (4.85)	3.60 (12.0)	72.5
T_4: Pendimethalin fb Metsulfuron methyl	2.07 (3.28)	2.08 (3.31)	2.07 (3.30)	2.22 (3.92)	2.26 (4.12)	2.24 (4.02)	2.42 (4.85)	2.43 (4.89)	2.42 (4.87)	3.63 (12.2)	72.0
T_5: Pyrazosulfuron ethyl fb Metsulfuron methyl	2.06 (3.25)	2.14 (3.56)	2.10 (3.41)	2.21 (3.89)	2.22 (3.92)	2.21 (3.91)	2.42 (4.86)	2.43 (4.92)	2.43 (4.89)	3.63 (12.2)	71.9
T_6: Oxodiagil fb Penoxsulam	2.07 (3.29)	2.08 (3.32)	2.07 (3.31)	2.20 (3.86)	2.21 (3.89)	2.21 (3.88)	2.49 (5.21)	2.50 (5.24)	2.49 (5.23)	3.66 (12.4)	71.4
T_7: Pyrazosulfuron ethyl fb Bispyribac sodium	1.97 (2.89)	1.98 (2.91)	1.97 (2.90)	1.11 (0.24)	1.12 (0.25)	1.12 (0.25)	1.50 (1.26)	1.51 (1.29)	1.51 (1.28)	2.33 (4.42)	89.8
T_8: Pendimethalin + HW at 30 DAP	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.0)	100
T_9: Weed free check	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.0)	100
T_{10}: Weedy check	4.40 (18.4)	4.49 (19.2)	4.45 (18.8)	4.05 (15.4)	4.15 (16.2)	4.10 (15.8)	3.08 (8.48)	3.20 (9.25)	3.14 (8.87)	6.67 (43.5)	
p=0.05	**0.38**	**0.32**	**0.69**	**0.52**	**0.24**	**0.52**	**0.63**	**0.54**	**0.58**	**3.21**	**6.72**

Figures in the parenthesis are square root transformed values (sq. root of x+1), fb: followed by

Table 3. Effect of weed control treatments on weed counts (No./m^2) in direct seeded rice at 60 days after sowing.

Treatment	Weed population (Count/m^2)										
	Grasses (No./m^2)			Broad leaf weeds (No./m^2)			Sedges (No./m^2)			Total weed dry weight (g/m^2)	Weed control efficiency (%)
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	Pooled	Pooled
T_1: Pendimethalin fb Bispyribac sodium	2.03 (3.12)	2.06 (3.25)	2.05 (3.19)	1.52 (1.32)	1.53 (1.35)	1.53 (1.34)	2.03 (3.12)	2.06 (3.25)	2.05 (3.19)	2.95 (7.7)	84.3
T_2: Pendimethalin fb 2,4 D sodium salt	2.06 (3.26)	2.07 (3.27)	2.07 (3.27)	1.91 (2.65)	1.92 (2.67)	1.91 (2.66)	2.05 (3.21)	2.14 (3.56)	2.09 (3.39)	3.21 (9.3)	81.0
T_3: Pendimethalin fb Azimsulfuron	2.29 (4.25)	2.30 (4.28)	2.29 (4.27)	2.42 (4.85)	2.43 (4.89)	2.42 (4.87)	2.58 (5.65)	2.60 (5.74)	2.59 (5.70)	3.98 (14.8)	69.7
T_4: Pendimethalin fb Metsulfuron methyl	2.36 (4.56)	2.36 (4.57)	2.36 (4.57)	2.38 (4.65)	2.39 (4.69)	2.38 (4.67)	2.49 (5.21)	2.51 (5.32)	2.50 (5.27)	3.94 (14.5)	70.4
T_5: Pyrazosulfuron ethyl fb Metsulfuron methyl	2.28 (4.21)	2.29 (4.23)	2.28 (4.22)	2.29 (4.26)	2.30 (4.28)	2.30 (4.27)	2.54 (5.45)	2.55 (5.48)	2.54 (5.47)	3.87 (13.9)	71.5
T_6: Oxodiagil fb Penoxsulam	2.29 (4.26)	2.30 (4.29)	2.30 (4.28)	2.28 (4.21)	2.29 (4.26)	2.29 (4.24)	2.67 (6.12)	2.74 (6.51)	2.70 (6.32)	3.98 (14.8)	69.7
T_7: Pyrazosulfuron ethyl fb Bispyribac sodium	2.06 (3.25)	2.06 (3.26)	2.06 (3.26)	1.46 (1.12)	1.47 (1.15)	1.46 (1.14)	1.50 (1.25)	1.51 (1.29)	1.51 (1.27)	2.58 (5.66)	88.4
T_8: Pendimethalin + HW at 30 DAP	2.02 (3.10)	2.05 (3.21)	2.04 (3.16)	1.50 (1.26)	1.51 (1.27)	1.50 (1.27)	1.87 (2.50)	1.87 (2.51)	1.87 (2.51)	2.82 (6.9)	85.9
T_9: Weed free check	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.0)	100
T_{10}: Weedy check	4.72 (21.3)	4.85 (22.5)	4.79 (21.9)	4.31 (17.6)	4.37 (18.1)	4.34 (17.8)	3.20 (9.21)	3.20 (9.26)	3.20 (9.24)	7.07 (49.0)	
p=0.05	**0.42**	**0.54**	**0.56**	**0.48**	**0.65**	**0.62**	**0.48**	**0.32**	**0.35**	**1.17**	**4.21**

Figures in the parenthesis are square root transformed values (sq. root of x+1), fb: followed by

control efficiency (%) at 15, 30 and 60 days after sowing compared to untreated check (Tables 1-3). The number of dominant broad-leaved, grass and sedge weeds were gradually decreased with the application of pre emergent herbicides followed by the application of post emergent herbicides in all the observations (15, 30 and 60 DAS). Significantly better weed control was observed with the application of Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. /ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha as post emergent herbicide and which was onpar with the application of Pendimethalin 30 EC @ 1 kg a.i. /ha as pre-emergent herbicide followed by hand weeding at 30 days after sowing and weed free check. Significantly lower weed biomass/numbers at 15 days after herbicide application was recorded with pyrazosulfuron ethyl 10 % WP at 20 g a.i./ha compared to pendimethalin 30 % EC @ 1 kg a.i./ha and Oxodiagil 80 % @ 100 g a.i. /ha. Angiras and Kumar (2005) also found that application of pyrazosulfuron-ethyl at 15 g/ha mixed with sand at 150 kg/ha was effective to control weeds in rice which resulted in significantly lower weed density and biomass without any phytotoxic effect on rice plant. Pyrazosulfuron-ethyl at

Table 4. Effect of weed control treatments on growth and yield parameters of direct seeded rice.

Treatment	Plant height (cm)			Productive tillers (No./m^2)			Grain yield (kg/ha)			Straw yield (kg/ha)		
	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled	2014	2015	Pooled
T_1: Pendimethalin fb Bispyribac sodium	101	104	103	202	205	204	5426	5526	5476	5842	5982	5912
T_2: Pendimethalin fb 2,4 D sodium salt	100	102	101	200	202	201	5010	5142	5076	5421	5521	5471
T_3: Pendimethalin fb Azimsulfuron	99.6	101	100.5	199	200	200	4625	4812	4719	5121	5124	5123
T_4: Pendimethalin fb Metsulfuron methyl	99.4	100	99.8	199	201	200	4765	4978	4872	5267	5365	5316
T_5: Pyrazosulfuron ethyl fb Metsulfuron methyl	98.5	99.5	99.0	197	198	198	4925	4989	4957	5265	5312	5289
T_6: Oxodiagil fb Penoxsulam	98.0	99.4	98.7	196	197	197	4900	4952	4926	5214	5321	5268
T_7: Pyrazosulfuron ethyl fb Bispyribac sodium	104	105	105	208	212	210	5545	5621	5583	6051	6112	6082
T_8: Pendimethalin + HW at 30 DAP	105	107	106	211	215	213	5624	5742	5683	6012	6124	6068
T_9: Weed free check	110	113	111	220	221	220	5894	5924	5909	6254	6325	6290
T_{10}: Weedy check	94.0	96.2	95.1	188	186	187	2980	3256	3118	2995	3312	3154
p=0.05	**17.2**	**15.92**	**16.2**	**19.2**	**15.8**	**16.2**	**471.5**	**401.2**	**435.0**	**415.0**	**345.0**	**382.0**

fb- followed by

Table 5. Effect of weed control treatments on Economics of direct seeded rice (Pooled data).

Treatment	Cost of cultivation (`/ha)	Gross returns (`/ ha)	Net returns (`/ha)	B: C ratio
T_1: Pendimethalin fb Bispyribac sodium	34480	115432	80952	3.35
T_2: Pendimethalin fb 2,4 D sodium salt	32860	106991	74131	3.26
T_3: Pendimethalin fb Azimsulfuron	33355	99493	66137	2.98
T_4: Pendimethalin fb Metsulfuron methyl	32755	102746	69991	3.14
T_5: Pyrazosulfuron ethyl fb Metsulfuron methyl	31910	104429	72519	3.27
T_6: Oxodiagil fb Penoxsulam	34111	103788	69677	3.04
T_7: Pyrazosulfuron ethyl fb Bispyribac sodium	33635	117742	84107	3.50
T_8: Pendimethalin + HW at 30 DAP	35605	119728	84123	3.36
T_9: Weed free check	37000	124470	87470	3.36
T_{10}: Weedy check	31000	65514	34514	2.11
p=0.05	**NA**	**NA**	**6529**	**0.25**

Mtls	Pendimethalin	Bispyribac Na	2 4 D Na salt	Azimsulfuron	Metsulfuron	Penoxsulum	Pyrazosulfuron	Top star	Grain	Straw
Rs/ ha	1605	1875	255	750	150	2188	760	923	Rs 20/kg	Rs. 1/kg

20 and 25 g/ha significantly reduced weed density and total weed biomass of *Cyperus iria, Echinochloa colona etc.* when applied at 3 to 10 days after transplanting (Chopra and Chopra 2003). There was no phyto-toxic effect was observed in direct seeded rice when applied pre and post emergent herbicides.

Further, application of Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. /ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha as post emergent herbicide recorded significantly lower weed dry weight (9.84, 4.42 and 5.66 g/m^2 at 15, 30 and 60 days after sowing, respectively) and which was onpar with the application of Pendimethalin 30 % EC @ 1 kg a.i./ha as pre-emergent herbicide followed by hand weeding at 30 days after sowing (11.5, 0.00 and 2.51 g/m^2 at 15, 30 and 60 days after sowing, respectively) and weed free check. The overall result showed that, Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. /ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ ha as post emergent herbicide was comparatively more effective against broad-leaved, grassy and sedge weeds in direct seeded rice.

Similarly, Weed control efficiency (100 %) was higher in weed free check at all three dates of observation (15, 30 and 60 DAS) compared to other treatments. Application of Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. / ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha as post emergent herbicide recorded significantly higher weed control efficiency (60.6, 89.8 and 88.4 % at 15, 30 and 60 days after sowing, respectively) and which was onpar with the application of Pendimethalin 30 % EC @ 1 kg a.i./ha as pre-emergent herbicide followed by hand weeding at 30 days after sowing (53.9, 100 and 85.9 % at 15, 30 and 60 days after sowing, respectively).

Growth of direct seeded rice: Significantly taller plants and more number of productive tillers per hill were observed in weed free treatment (111 cm and 220) and which was onpar with the application of Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. /ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha as post emergent herbicide (105 cm and 210) and the application of Pendimethalin 30 % EC @ 1 kg a.i./ha as pre-

emergent herbicide followed by hand weeding at 30 days after sowing (105 cm and 213) compared to other weed control treatments. Whereas, shorter plants and less number of productive tillers per hill were recorded in the weedy check (Table 4).

Grain and straw yield: Significantly higher grain and straw yield were recorded in weed free treatment (5909 and 6290 kg/ha, respectively) and which was onpar in the treatment with the application of Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. /ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha as post emergent herbicide (5583 and 6082 kg/ha, respectively) and the application of Pendimethalin 30 % EC @ 1 kg a.i./ha as pre-emergent herbicide followed by hand weeding at 30 days after sowing (5683 and 6068 kg/ha, respectively) compared to other weed control treatments (Table 4). Similar trend was recorded with respect to yield parameters of paddy. Pyrazosulfuron-ethyl at 20 and 25 g/ha provided grain yield statistically similar to weed free treatment (Chopra and Chopra, 2003, Pal and Banerjee, 2007).Whereas, lower grain and straw yield were recorded in weedy check plot. This was due to the higher infestation of weeds.

Economics of direct seeded rice: Application of Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. /ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha as post emergent herbicide recorded significantly higher benefit cost ratio (3.50) and which was onpar with the application of Pendimethalin 30 % EC @ 1 kg a.i./ha as pre-emergent herbicide followed by hand weeding at 30 days after sowing (3.36) and weed free treatment (3.36) compared to other weed control treatments (Table 5). This might be due to higher grain yield. Application of pyrazosulfuron ethyl 10 % WP @ 20 g a.i./ ha reduced grasses, broad leaf weeds and sedges in transplanted paddy (Chopra and Chopra, 2003). Whereas, significantly lower benefit cost ratio (2.11) was reported in weedy check plot. This might be due to the higher infestation (100 %) of weeds.

Conclusion

Results are concluded that, application of Pyrazosulfuron ethyl 10 % WP @ 20 g a.i. /ha as pre-emergent herbicide followed by the application of Bispyribac sodium 10 % SC @ 250 ml/ha as post emergent herbicide or application of Pendimethalin 30 % EC @ 1 kg a.i./ha as pre-emergent herbicide followed by hand weeding at 30 days after sowing was effectively controlled the broad leaved, grasses and sedges and led to higher grain yield in direct seeded rice.

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