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Sequential application of pre- and post-emergence herbicides for control of complex weed flora in dry direct-seeded rice under Cauvery command area of Karnataka

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ABSTRACT

A field experiment was conducted during rainy *(Kharif)* season of 2014 and 2015 at Zonal Agricultural Research Station, V. C. Farm, Mandya, Karnataka to study the efficacy of sequential application of herbicides on weed density, weed dry weight, yield and economics of dry direct-seeded rice. The results revealed that pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha *fb* post-emergence application of bispyribac-sodium at 25 g/ha at 20 days after sowing (DAS) recorded significantly lower total weed population (39.4 and 43.1/m^2) and weed dry weight (8.2 and 9.0 g/m^2) with weed control efficiency of 77.8 and 77.2% during 2014 and 2015, respectively. As a consequence of effective weed control the same treatment recorded significantly higher grain yield (4.60 and 4.42 t/ha), net monetary returns (` 39,340 and 36,710/ha) and B: C ratio (2.32 and 2.23) during 2014 and 2015, respectively. This treatment was statistically comparable to hand weeding thrice at 20, 40 and 60 DAS. Uncontrolled weed growth caused 56% reduction in grain yield of dry direct-seeded rice.

INTRODUCTION

Rice (*Oryza sativa* L.) is a major cereal crop and staple food for more than half of the world's population. About 90% of the world's rice is produced and consumed in Asia (FAO 2014). India is the second largest rice producing country in the world with an area of 43.7 mha and produced 112.7 Mt of rice with a productivity of 2576 kg/ha (Anonoymus 2017). In Karnataka paddy is mainly grown in command areas under transplanted submerged condition. Recent years, transplanted rice with submerged condition as become economical due to escalating labor cost, non-availability of timely labor and shortage of irrigation water due to recurrent droughts. Dry Direct-seeded rice is one of the viable options for rice production under shrinking water resources and scarcity of labors. Direct-seeded rice (DSR) is a cost effective rice establishment method where dry seed is drilled into the non-puddled soil. This provides opportunities of saving irrigation water by 12-35%, labor up to 60% and provides higher net returns (US$ 30-50/ha) with similar or slightly lower yield of rice (Kumar and Ladha 2011). However, the good harvest of crop yield under direct-seeded rice is mainly depends on effective weed management practices.

An effective early weed management tactic is imperative for any DSR production technology aiming at achieving higher productivity and profitability (Jaya Suria *et al.* 2011). Aerobic edaphic conditions under non-flooded conditions in DSR stimulate germination of diverse weed species. Weeds in DSR compete for moisture, nutrients, light and space and reduce the grain yield by 75 to 85% (Rao *et al.* 2007 and Dhanapal *et al.* 2018a). Weed problem in DSR can be managed by implementing integrated weed management. Chemical weed control by using pre-emergence herbicides being cost effective and less labour dependent is recommended to overcome weed menace in DSR. Broad-spectrum of weed flora, however, may not be controlled by spraying pre-emergence herbicides alone, as several flushes of weeds come up at different growth stages. Hence, use of sequential application of pre- *fb* post-emergence herbicides or pre-emergence herbicides *fb* manual weeding could be more convenient in containing the weed menace. The present investigation was carried out to study the efficacy of

sequential application of herbicides to control complex weed flora observed in dry direct-seeded rice in Cauvery Command Area of Karnataka.

MATERIAL AND METHODS

A field experiment was conducted during *Kharif* season of 2014 and 2015 at the Zonal Agricultural Research Station, Mandya to know the influence of sequential application of herbicides on weed flora and their effect on growth and yield of dry direct-seeded rice under Cauvery Command Area of Karnataka. The farm is geo graphically situated between 11^0 30' to 13^0 05' N latitude and 76^0 05 to 77^0 45' East longitude with an altitude of 697 meters above MSL. The soil of experimental site was red sandy loams with bulk density and particle density of 1.15 g/cc and 2.65 g/ cc, respectively with soil pH of 6.5. It was low in available nitrogen (225 kg/ha) and phosphorus (28 kg/ha) and potassium (126 kg/ha). Eight treatments, *viz.* bensulfuron-methyl 0.6% + pretilachlor 6% GR (Londax Power) at 10 kg/ha (PE) + one HW, pendimethalin (30 EC) at 1.0 kg/ha (PE) + one HW, bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha (PE) *fb* bispyribac-sodium at 25 g/ha (PoE), pendimethalin at 1.0 kg/ha (PE) *fb* bispyribac-sodium at 25 g/ha (PoE), bispyribac-sodium at 25 g/ha (early PoE), hand weeding thrice at 20, 40 and 60 DAS, weedy and weed free check. These treatments were replicated thrice in a complete randomized block design.

Pre-germinated seeds of medium duration rice variety '*IR-30864*' were sown on well puddled and leveled field in June 2014 and 2015 with a seed rate of 62.5 kg/ha with a spacing of 20 x 10 cm. The crop was fertilized with 100:50:50 kg N:P_2O_5: K_2O/ha. The 50% of recommended nitrogen, entire dose of phosphorous and potassium was applied as basal in addition to zinc sulphate at 25 kg/ha. The remaining 50% of the nitrogen was top dressed at two equal splits at tillering and panicle initiation stage. The gross plot size was 5.0 x 3.0 m. Pre-emergence herbicides were mixed with sand at 100 kg/ha and applied uniformly in the field on 5 DAS. A thin film of water was maintained at the time of pre-emergence herbicide application. The post-emergence herbicides were sprayed at 3-4 leaf stage of weeds by using knap-sack sprayer fitted with deflector nozzle mixed with water 750 liter/ha. Hand weeding was carried out as per the treatment schedule.

The data on weed density and weed dry weight at 60 DAS were recorded with the help of quadrate (0.5 x 0.5 m). The normality of distribution was not seen in case of observation on weeds hence, the values were subjected to square root transformation ($\sqrt{x+0.5}$) prior to statistical analysis to normalize their distribution. Data on plant height and number of tillers at harvest and yield attributes, *viz.* grain weight/ panicle, 100-seed weight and percent choppiness and grain and straw yield were recorded. The per cent choppiness was worked out by using the following formula.

$$\text{Per cent choppiness} = \frac{\text{No. of unfilled grains per panicle}}{\text{Total no. of grains per panicle}} \text{ x } 100$$

The weed control efficiency was worked out on the basis of weed dry matter production using the formula suggested by Mani *et al.* (1973) and weed index was calculated by using the formula suggested by Gill and Vijayakumar (1966). All the data obtained in the study were statistically analyzed using F-test, the procedure given by Gomez and Gomez (1984), Critical difference values at P=0.05 were used to determine the significance of differences between means.

RESULTS AND DISCUSSION

Weed flora

The predominant weed flora associated with dry direct-seeded rice in experimental field were in association with the direct-seeded dry sown rice, *viz. Cynodon dactylon* L. (Bermuda grass), *Dinebra retroflexa* (Vahl) Panz. (Viper grass), *Echinochloa colonum* L. (barnyard grass), *Panicum repens* L. (quack grass) and *Digiteria sanguinalis* L. (large crab grass) among grasses; *Ageratum conyzoides* L. (Billygoat weed), *Digera arvensis* L. (false amaranth), *Physalis minima* L. (native gooseberry), *Commelina Benghalensis* L. (benghal dayflower), *Abutilon indicum* L. (Indian mallow), *Portulaca oleracea* L. (common purslane), *Parthenium hysterophorus* L. (congress grasss) and *Trianthema portulacastrum* L. (desert horse purslane) among broad-leaved weeds (BLW); and *Cyperus rotundus* L. (purple nut sedge) and *Cyperus iria* L. (rice flat sedge) among sedges**.**

Weed density and dry weight

All the weed control treatments found effective in reducing the density and dry weight of grasses, BLW, sedges and total weeds as compared to unweeded check **(Table 1** and **2)**. At 60 DAS among the weed control treatments, hand weeding thrice at 20, 40 and 60 DAS recorded significantly lower density and dry matter of grasses, Sedges, BLW and Total weeds. However, it was at par with pre-emergence application of bensulfuron-methyl 0.6% +

pretilachlor 6% GR 10 kg/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha. The pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha found to control the all the three categories of weeds effectively upto 20-25 days after its application. While, later emerging weeds were effectively controlled by post-emergence application of bispyribac-sodium at 25 g/ha. Among the three categories of weeds BLW were dominant and post-emergence application of bispyribac sodium at 25 g/ha found effective in control of BLW. Hence the statement recorded significantly lower density of weeds and its dry matter production. These results are in conformity with (Pratik and Manoj 2017). While, the lowest weed density and dry weight of weeds were observed in weed free check due to season long weed removal and the highest was recorded in weedy check due to uncontrolled weed growth. The crop yield is directly proportional to weed control efficiency. The weed control efficiency at 60 DAS was maximum in hand weeding thrice at 20, 40 and 60 DAS (83.70% and 82.60% in 2014 and 2015, respectively) and this was closely followed by pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha *fb* post-emergence application of bispyribac-sodium 25 g/ha (77.80% and 77.20% in 2014 and 2015, respectively) and this was the best treatment among the herbicides in terms of higher WCE. The similar results are reported by Dhanapal *et al*. 2018b and Ramesha *et al*. 2019. The pre-emergence application of herbicides followed by one hand weeding at 40 DAS were failed to control the all types of weeds due to weed growth during critical period.

Table 1. Density of weeds (no./m^2) as influenced by weed management practices in dry direct-seeded rice at 60 DAS

Treatment	2014				2015			
	Grasses	BLW	Sedges	Total	Grasses	BLW	Sedges	Total
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) + one HW	4.30 (18.0)	4.74 (22.0)	1.94 (3.3)	6.62 (43.3)	4.57 (20.6)	4.87 (23.2)	2.14 (4.1)	6.95 (48.0)
Pendimethalin (30 EC) 1.0 kg/ha (PE) + one HW	4.34 (18.3)	4.77 (22.2)	2.30 (4.8)	6.77 (45.4)	4.53 (20.1)	4.91 (23.7)	2.42 (5.4)	7.04 (49.1)
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE)	4.10 (16.3)	4.51 (19.9)	1.92 (3.2)	6.31 (39.4)	4.36 (18.6)	4.64 (21.0)	1.99 (3.5)	6.60 (43.1)
Pendimethalin 1.0 kg/ha(PE) *fb* bispyribac-sodium 25 g/ha (PoE)	4.89 (23.4)	4.90 (23.6)	2.14 (4.1)	7.18 (51.1)	5.05 (25.1)	5.06 (25.2)	2.28 (4.7)	7.44 (55.0)
Bispyribac-sodium 25 g/ha (early PoE)	5.41 (28.8)	6.57 (42.8)	2.56 (6.1)	8.84 (77.8)	5.54 (30.4)	6.39 (40.4)	2.66 (6.7)	8.82 (77.4)
Hand weeding thrice at 20, 40 and 60 DAS	3.07 (8.9)	3.83 (14.2)	1.45 (1.6)	5.02 (24.8)	3.25 (10.1)	3.97 (15.3)	1.53 (1.9)	5.26 (27.2)
Weed free check	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)
Weedy check	6.93 (47.8)	8.91 (78.9)	3.07 (9.0)	11.66 (135.6)	7.07 (49.6)	9.02 (80.8)	3.14 (9.4)	11.84 (139.8)
LSD (p=0.05)	0.50	0.38	0.29	0.53	0.66	0.33	0.32	0.59

Square root $\sqrt{x+0.5}$ transformed values. Values in the parentheses are original values

Table 2. Dry weight of weeds (g/m^2) and weed control efficiency as influenced by weed management practices in dry direct-seeded rice at 60 DAS

Treatment	2014				2015				WCE (%)	
	Grasses	BLW	Sedges	Total	Grasses	BLW	Sedges	Total	2014	2015
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) + one HW	2.06 (3.75)	2.07 (3.77)	1.79 (2.70)	3.27 (10.2)	2.12 (4.02)	2.08 (3.82)	1.91 (3.20)	3.39 (11.0)	72.4	72.0
Pendimethalin (30 EC) 1.0 kg/ha (PE) + one HW	2.26 (4.63)	2.35 (5.03)	1.87 (3.00)	3.63 (12.7)	2.36 (5.09)	2.41 (5.31)	1.94 (3.27)	3.76 (13.7)	65.9	65.4
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE)	2.05 (3.70)	1.86 (2.95)	1.44 (1.58)	2.95 (8.2)	2.16 (4.18)	1.91 (3.15)	1.46 (1.62)	3.07 (9.0)	77.8	77.2
Pendimethalin 1.0 kg/ha(PE) *fb* bispyribac-sodium 25 g/ha (PoE)	2.12 (3.99)	2.22 (4.43)	1.51 (1.79)	3.27 (10.2)	2.21 (4.40)	2.29 (4.77)	1.56 (1.93)	3.40 (11.1)	72.5	71.9
Bispyribac-sodium 25 g/ha (early PoE)	2.52 (5.86)	3.30 (10.62)	2.33 (4.96)	4.67 (21.4)	2.59 (6.21)	3.33 (10.86)	2.40 (5.28)	4.76 (22.4)	42.3	43.4
Hand weeding thrice at 20, 40 and 60 DAS	1.64 (2.19)	1.48 (1.68)	1.63 (2.16)	2.56 (6.0)	1.69 (2.37)	1.58 (2.00)	1.73 (2.54)	2.71 (6.9)	83.7	82.6
Weed free check	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	0.71 (0)	100.0	100.0
Weedy check	3.54 (12.06)	3.95 (15.14)	3.24 (10.00)	6.14 (37.2)	3.66 (12.96)	4.03 (15.84)	3.35 (10.83)	6.32 (39.6)	0.0	0.0
LSD (p=0.05)	0.18	0.44	0.19	0.30	0.21	0.45	0.26	0.36	-	-

Square root $\sqrt{x+0.5}$ transformed values. Values in the parentheses are original values

Phytotoxicity

Among the herbicides tested, pendimethalin was found toxic with phytotoxic value of 5 and hindered the germination of rice seeds leading to reduced plant population. A similar phytotoxic effect caused by pendimethalin on rice crop was observed by Rana *et al.* (2016).

Growth, yield and yield attributing characters

The rice growth attributes, *viz.* plant height (cm) and no. of tillers at harvest and yield attributes, *viz.* grain weight/panicle (g), 100-seed weight (g), percent choppiness were influenced significantly due to weed control treatments. Among the weed control treatments, hand weeding thrice at 20, 40 and 60 DAS found excellent in recording significantly higher growth and yield attributes as compared to others. However, it was at par with herbicide treatment pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha *fb* post-emergence application of bispyribac-sodium at 25 g/ha. This increases yield in herbicide treatment is mainly due to considerable reduction in weed emergence at the initial crop growth stage lead to establishment of rice seedlings vigorously and resulted in higher number of tillers per hill and consequently significantly yield attributing characters, *viz.* number of panicles/m^2 and 100-seed weight (g). The accurance of choffy grains is one of the main yield limiting factors in dry direct-seeded rice and the percent choffyness was significantly influenced by weed control practices. Among them, pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha *fb* post-emergence application of bispyribac-sodium at 25 g/ha recorded significantly lower percentage of choffyness (15%) and was statistically comparable with hand weeding thrice at 20, 40 and 60 DAS (12%). This lower percent choffyness is mainly due to increased number of filled grains per panicle due to uptake of more nutrients by the crop and more photosynthetic activity especially during grain filling period due to season long control of weeds in these treatments.

As a consequence of significantly higher growth and yield attributes the pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha *fb* post-emergence application of bispyribac-sodium at 25 g/ha recorded significantly higher grain yield (4.60 t/ha and 4.42 t/ha) as compared to others and was statistically comparable with hand weeding thrice at 20, 40 and 60 DAS (4.98 t/ha and 4.65 t/ha) and weed free check (5.04 t/ha and 4.82 t/ha) during both the years of experimentation, respectively. This increased yield in the above treatment is mainly attributed to reduced competition for moisture, space, light and nutrients between crop and weeds along with effective suppression of weeds by combination of herbicides. The same results also reported by Dhanapal *et al.* 2018b and Ramesha *et al.* 2019. Unweeded control gave the lowest paddy grain yield (2.21 and 2.12 t/ha) due to severe competition from all types of weeds. The season long uncontrolled weed growth reduced the dry direct seeded rice to an extent of 56%.

Economics

Among different weed management practice, the higher net returns (` 36705-39,337/ha) and B:C ratio (2.32-2.23) were recorded with pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha *fb* post-emergence application of bispyribac-sodium at 25 g/ha during 2014 and 2015, respectively. While, the lowest net returns (` 8200/ha and ` 6935/ha) and B:C ratio (1.33 and 1.28) were

Table 3. Growth and yield attributes in dry DSR as influenced by weed management practices

Treatment	Plant height at harvest (cm)		No. of tillers at harvest		Grain weight/panicle (g)		100-seed weight (g)		Percent choppiness	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) + one HW	54.59	53.56	14.00	13.55	2.49	2.25	1.44	1.33	17.85	18.78
Pendimethalin (30 EC) 1.0 kg/ha (PE) + one HW	49.97	49.11	11.81	12.91	1.54	2.18	1.14	1.31	25.23	19.37
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE)	58.91	58.24	14.83	14.07	2.56	2.26	1.48	1.44	14.95	16.23
Pendimethalin 1.0 kg/ha(PE) *fb* bispyribac-sodium 25 g/ha (PoE)	49.64	48.83	14.12	11.66	2.47	1.52	1.45	1.09	17.25	26.30
Bispyribac-sodium 25 g/ha (early PoE)	46.57	45.94	10.82	10.38	1.43	1.4	1.06	1.08	28.12	19.08
Hand weeding thrice at 20, 40 and 60 DAS	60.76	60.07	14.89	14.95	2.57	2.45	1.69	1.64	11.64	12.39
Weed free check	61.09	60.26	15.49	14-98	2.64	2.52	1.71	1.67	10.54	11.83
Weedy check	43.94	43.94	8.66	7.94	1.4	1.35	1.04	1.02	57.18	60.53
LSD (p=0.05)	5.25	5.25	1.80	2.05	0.19	0.29	0.13	0.17	4.97	5.02

Table 4. Grain yield, weed index and economics of dry DSR as influenced by weed management practices

Treatment	Grain yield (t/ha)		Weed index (%)		Net returns (x 10^3 `/ha)		B:C ratio	
	2014	2015	2014	2015	2014	2015	2014	2015
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) + one HW	4.57	4.37	9.2	9.3	37.80	34.81	2.23	2.13
Pendimethalin (30 EC) 1.0 kg/ha (PE) + one HW	2.86	4.39	43.3	8.9	13.28	36.32	1.45	2.23
Bensulfuron-methyl 0.6% + pretilachlor 6% GR 10 kg/ha (PE) *fb* bispyribac-sodium 25 g/ha (PoE)	4.60	4.42	8.6	8.2	39.34	36.71	2.32	2.23
Pendimethalin 1.0 kg/ha(PE) *fb* bispyribac-sodium 25 g/ha (PoE)	4.57	2.80	9.2	42.0	38.87	12.20	2.30	1.41
Bispyribac-sodium 25 g/ha (early PoE)	2.56	2.42	49.2	49.8	11.53	9.43	1.43	1.35
Hand weeding thrice at 20, 40 and 60 DAS	4.98	4.65	1.0	3.5	37.83	32.84	2.02	1.89
Weed free check	5.04	4.82	0.0	0.0	32.60	29.41	1.76	1.68
Weedy check	2.21	2.12	56.1	55.9	8.20	6.94	1.33	1.28
LSD (p=0.05)	0.436	0.498	8.9	10.4	-	-	-	-

observed in un weeded check **(Table 4)**. The increased monetary benefits in this treatment was mainly attributed to higher grain yield and reduced labour cost due to effective control of all types of weeds. Similar findings have been also reported by Prameela *et al.* 2015, Dhanapal *et al.* 2018b and Nagarjun *et al.* 2019.

It was concluded that pre-emergence application of bensulfuron-methyl 0.6% + pretilachlor 6% GR at 10 kg/ha *fb* post-emergence application of bispyribac-sodium at 25 g/ha found most effective and economical in controlling the weeds in direct-seeded dry sown rice in Cauvery command area of Karnataka.

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