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Studies on effective herbicidal weed management practice in direct seeded rice under western Ghat zone

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Abstract
In direct seeded rice (DSR) cultivation, weed is the major constraint mainly due to absence of puddling in field. The yield loss due to weed interference is huge, may be up to 100%. In this perspective, the present experiment was conducted to study the "Studies on effective herbicidal weed management practice in direct seeded rice under western ghat zone". The dry weight and density of weeds were recorded at different growth stages and consequently herbicide efficacy was evaluated. Experimental results revealed that pre-emergence (PRE) herbicide effectively controlled the germination of grassy weeds. Application bispyribac-sodium as post-emergence (POST) following PRE herbicides (Pyrazosulfuron ethyl or oxyflourfen) or as tank-mixture with metsulfuron methyl 10% + chlorimuronethyl effectively reduced the density and biomass accumulation of diverse weed flora in DSR. Herbicidal treatments improved the plant height, yield attributes and grain yield (2.7 to 4.2 times) over weedy check. Differences in sensitivity values of weed dry matter and WCE across the crop growth stages also suggest that at 15, 30 and 60 days after sowing, herbicides most effectively controlled sedges, broad leaves and grasses, respectively. Based on the grain yield and herbicidal WCE, it can be concluded that the combined application of PRE application (EPOST) of Pyrazosulfuron ethyl 10% WP0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS or PRE application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ POST application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS. as PRE followed by bispyribac-sodium as POST or tank-mixture of Pyrazosulfuron ethyl + bispyribac sodium can effectively control different weed flushes throughout the crop growth period in DSR.

Keywords: Direct-seeded rice, weed, herbicide

Introduction
Rice is the most important staple crop for more than half of the population in India. The most common growing method of rice is manual transplanting of seedlings in puddled soils, creating a hard pan below the plough layer. This practice involves both water (3000-5000 L of water to produce 1 kg rice) and human labour resource both of which are becoming increasingly meager. The natural resource management under changing climate situation leads to direct seeded rice to reduce the losses and improve crop productivity. The real constraint in DSR is the weed competition due to slow early growth of rice plants is less competitive than transplants. The flooding will not reduce the weed flush as well as less reliance on limited chemicals. This will leads to more than 20-25 per cent yield loss on sustainable basis. It influences soil health owing to dispersion of soil particles and consequent compaction of the soil. These above situations have compelled scientists and researchers towards direct-seeded rice (DSR) cultivation, as it does not need puddling and transplanting and is a feasible alternative to save water and labour. When farmers shift to DSR from TPR, the weed flora changes drastically. Yield loss in DSR due to weed interference may be up to 100% (Singh *et al.*, 2014) [9]. Different weed control measures have been practiced previously to minimize weed pressure in DSR. Among them, chemical control is the most commonly used, and has been proved reliable by several workers for controlling weeds in DSR (De Datta & Baltazar, 1996). Application of herbicides effectively suppresses weeds and provides DSR with a weed-free environment. So, to effectively control the weed problem and also to harness the fullest benefit of DSR system, the use of herbicides at a right application rate and time is very important at this time. Several pre-emergence or PRE and post-emergence or POST herbicides are now available and being used by farmers in various Asian countries (Ahmed & Chauhan, 2014) [1]. Among them, pendimethalin is a soil applied pre-emergence herbicide. It is absorbed by roots and coleoptiles and inhibits cell division and cell elongation.

As a post-emergence herbicide, azimsulfuron is absorbed by roots and leaves, and also inhibits the enzyme acetolactate sysnthase in susceptible weed plants similar mode of action has also been reported for another two post emergence herbicides *viz.* pyrazosulfuron and bispyribac-sodium.

Pre-emergence application of pendimethalin followed by post-emergence application of bispyribac-sodium at 15 days after sowing (DAS) was most effective for controlling weeds in DSR (Mahajan *et al.*, 2009) [6]. Tank mix applications of azimsulfuron +fenoxaprop, or azimsulfuron + bispyribac sodium + fenoxaprop have been reported to effectively control weed and help crop to yield better than single herbicide application in DSR (Mahajan & Chauhan, 2015) [5].

Material and methods

The field experiment was conducted during *Kharif* 2019 at the Zonal Agricultural Research Sation, Westrn Ghat Zone, Igatpuri Dist. Nashik Farm, situated at Western Ghat Zone of Maharashtra. Zonal Agricultural Research Station, Igatpuri, Dist- Nashik received the total rainfall in 2019 was 5239.2 mm in 111 rainy days, which was 90 per cent more over the average rainfall of 2750 mm in 96 rainy days. The soil at the study site had a clay loam soil texture with pH of 7.4, low in organic carbon (0.42%), available N (221 kg/ha) and available P (41 kg P_2O_5/ha), and medium in available K (223 kg K_2O/ha).

Experimental design and treatment

The field trial was arranged as a randomized complete block design with tent weed control treatments replicated three times, the area of gross plot and net plot size was 4.00 x 3.00 m^2, 3.60 x 2.60 m^2 Treatments included different rate of oxyflourfen , Pyrazosulfuron ethyl as pre-emergence (PRE), tank mixture application of metsulfuron methyl 10% + chlorimuronethyl 10% in combination with bispyribac-sodium as early post-emergence (EPOST) and sequential application of Pyrazosulfuron ethyl and pendimethalin as PRE followed by bispyribac-sodium application as post-emergence. The herbicides were applied with a knapsack sprayer that delivered ~ 500 L/ha spray solution through flat fan nozzles. For the weed-free treatment, two hand-weedings were done to maintain a weed-free situation. In the weedy control, no weeding was done.

Table 1: Treatment details

Tr. No.	Treatment Details
T_1	PRE application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.
T_2	PRE application (EPOST) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS .
T_3	POST application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kg a.i../ha at 20 DAS.
T_4	POST application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS.
T_5	PE application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ POST application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kg a.i../ha at 20 DAS.
T_6	PRE application (EPOST) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + POST application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kg a.i../ha at 20 DAS.
T_7	PRE application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ POST application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS.
T_8	PRE application (EPOST) of Pyrazosulfuron ethyl 10% WP0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS.
T_9	Unweeded check.
T_{10}	Weed free.

Crop management

The field was prepared by giving two plowings, one with cultivator and another with rotavator. Rice (*cv*. Indrayani) was dry-seeded at 30 kg/ha with tractor-mounted seed-cum-fertilizer drill. Each year, rice was sown in rows 20 cm apart at a depth of 2-3 cm on June and harvested manually with sickle at a height of 25-30 cm from ground level in early November. The field was surface-irrigated after the rice seeding for uniform germination, and visited regularly to check the required irrigation demand of the crop according to the crop and soil conditions. After a week stand crop application of Urea-DAP Briquettes per two hills @ 170 kg ha^{-1} (56 kg N and 30kg P_2O_5).

The weed control efficiency (WCE) and weed control index (WCI) were calculated using the following formula

$$WCE = \frac{WD_c - WD_T}{WD_c} \times 100 \qquad [1]$$

Where WD_C and WD_T are weed density in control and herbicide-treated plots, respectively.

Results

Growth and Yield Attributes

The growth attributing characters *viz*. plant height and number of tillers differ significantly. Treatment T_{10} i.e. weed free check and T_1 i.e. PE Oxyflurofen @0.150 kg a.i/ha @ 2-3 DAS recorded significantly higher value of plant height (94.32 cm) as compared to rest of the treatments (Table 2).

The number of tillers (16.00), length of panicle (24.15 cm) and number of grains /panicle (134.10) was significantly higher in the treatment T_8 i.e. Pre emergence application (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS which was at par with treatment T_{10} i.e. weed free check except No. of grains per panicle. While, the number of panicles (18.18) was recorded higher in treatment T_{10} i.e. weed free check.

The significantly higher grain yield (44.70 q/ha) was recorded in weed free check (T_{10}) which was at par with treatment T_8 i.e. Pre emergence application (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS (42.00 q/ ha). The same trend was observed in straw yield.

Weed Study

From the Table 3, it is reveals that the weed control efficiency, lowest weed dry matter was recorded in treatment T_{10} i.e. weed free check, This was closely followed by the treatment T_8 and T_7. i.e. T_8- Pre emergence application (early post emergence) of Pyrazosulfuron ethyl 10% WP0.030 kg

a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS (1.92 q ha-[1]and 85.90%) and T_7 - Pre emergence application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Post emergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS ((2.41 q ha^{-1}and 83.12%) than rest of the treatments.

Economics: Amongst the different treatments, T_{10} weed free check has highest gross and net returns, and B:C ratio (RS. 100575, RS62368 and 1.63, respectively) than rest of the treatments. This treatment was followed by application of T_8. i.e. - Pre emergence application (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS (Rs. 94500,Rs.57459 and 1.55) and T_7 i.e.- Pre emergence application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Post emergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS (Rs. 86423,Rs.51009 and 1.44) than rest of the treatments.

Rice emergence and yield-related traits

Rice plant stands differed significantly among the weed control treatments. The PRE herbicides had negative effect on rice emergence. Among the PRE herbicides Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS and PE oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Postemergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS had more detrimental effect on germination of rice as compared to Pre emergence application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS , PE oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Post emergence application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kga.i../ha at 20 DAS but the EPOST application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @0.004 kg a.i../ha at 20 DAS did not show any negative impact on crop stand. The dry matter accumulated by the rice plant during the maximum tillering stage (45 DAS) was significantly higher in all the herbicide treatments as compared to the zero-herbicide plot (weedy). The height of the rice plant did not differ statistically among the weed control measures at 45 and 60 DAS, but during the final crop growth stage a wide variation was found among the herbicide treatments. At harvest the maximum plant height was recorded higher when Pre emergence application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS followed by PE oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Post emergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS. was applied as EPOST in combination with bispyribac-sodium as a tank mixture.

Rice panicles per unit area, grains per panicle and test weight (1000 grain weight) were influenced by the herbicide application, and the weedy plots had the lowest number of panicles among the treatments. The sequential and tank-mixture application of herbicides produced higher panicles per unit area, grains per panicle and test weight among different weed control measures.

A wide variation in rice grain yield was observed among different the weed management practices. There was 50-52% grain yield loss in the weedy check due to severe weed infestation as compared to the weed-free plots. Moreover, the application of different herbicides rectified the damaging effects of the weed infestation on the productivity of direct-seeded rice. The herbicide-treated plots produced significantly higher rice grain yield as compared to weedy situation. The weed free plots recorded maximum grain yield and none of the herbicide-treated plots was at par with it. Among the herbicides when PE (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS was applied as POST following the PRE herbicides as tank mixture recorded significantly higher rice grain yield.

Discussion

Weeds are important biotic constrict if not controlled timely by adopting proper management practices in zero-till direct seeded rice, and it can impose a serious threat to the productivity and sustainability of DSR (Rao *et al.*, 2007) [8]. In our study under the un-weeded situation *E. colona*, *E. crus-galli* and *C. iria* were the main dominant weeds, comprising 89% of total weed density. From this study it is comprehensible that only PRE herbicide application was not adequate to manage the weed flora in direct seeded rice. In DSR, due to favorable situation, weeds show several cohorts. Thus when bispyribac-sodium was applied as POST following PRE herbicides or as tank-mix with Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS as EPOST effectively controlled the subsequent weed cohorts and provided a better environment for crop growth. Application of herbicides in sequence (PRE followed by POST) or as tank-mixture performed better against diverse weed flora as compared to single herbicide by providing more than one technical molecule against a diverse group of weeds (Chauhan, 2013) [4]. In direct-seeded rice the control of different weed cohorts is largely dependent on the performance and persistence of herbicides in active form (Mahajan & Chauhan, 2013) [4].

The PRE herbicides, mainly Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS, had some inhibitory effect on rice seedling emergence. The adoption of proper weed management practices in DSR can provide a better environment for crop growth and productivity. The application of PRE herbicides Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS followed by bispyribac-sodium tank-mixture of contributed to a sizeable improvement in plant growth (plant height and biomass accumulation) and all other yield traits, like the number of productive tillers, grains per panicle and the test weight. The improvement in the crop growth and yield attributes was positively associated with reduced weed density and biomass because of efficient weed control. Reduction in weed density vis-à-vis weed biomass provides more utilization of space, water, light and nutrients by the crop, and thus ultimately results in escalated crop yield through better photosynthesis and overall growth and metabolic activities of the crop. Walia (2006) [11] opined, in similar manner, that the greatest loss caused by the weeds resulted from their competition with crop for growth factors *viz*., nutrients, soil moisture, light, or space.

In summary, in direct-seeded rice cultivation, the problem of weed infestation causes drastic yield reduction; and the situation needs a suitable solution with efficient weed management strategy. The present experiment had an intention to discern the effectiveness of herbicides of various modes of action either alone or in combination.

Conclusion

The significantly higher grain yield (44.70 q/ha) was recorded in weed free check (T_{10}) which was at par with treatment T_8 i.e. Pre emergence application (early post emergence) of

Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS (42.00 q/ ha). The same trend was observed in straw yield. Amongst the different treatments, T_{10} weed free check has highest gross and net returns, and B:C ratio (RS. 100575,RS. 62368 and 1.63, respectively) than rest of the treatments.

Table 1: Effect of weed management options of herbicide combination on growth and yield of direct seeded rice.

Sr. No.	Treatment	Plant height (cm)	Number of tillers	No. of Panicles	Length of panicle (cm)	No of grains/ panicle	Grain yield (q/ha)	Straw yield (q/ha)
T_{1}-	Pre emergence application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS	90.24	8.48	12.12	16.30	105.75	36.12	40.82
T_2	PE (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS .	83.30	9.70	13.40	15.00	98.20	35.90	40.10
T_3	Post emergence metsulfuron methyl 10% + chlorimuronethyl 10% WP @0.004 kg a.i../ha at 20 DAS.	76.42	11.15	15.30	14.70	96.12	34.00	38.50
T_4	Post emergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS	73.33	9.18	12.10	15.42	102.70	33.50	37.90
T_5	PE oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Post emergence application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kga.i../ha at 20 DAS.	81.52	14.00	15.40	17.70	104.45	37.70	42.40
T_6	PE (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + Post emergence application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kg a.i../ha at 20 DAS.	77.85	12.12	14.24	17.95	106.16	37.90	42.10
T_7	PE oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Post emergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS.	88.87	13.24	13.33	18.30	99.82	38.41	43.15
T_8	PE (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS.	87.65	16.26	16.85	24.15	134.10	42.00	46.30
T_9	Unweeded check.	84.45	9.58	10.92	17.17	90.25	30.10	34.80
T_{10}	Weed free.	94.32	15.36	18.18	24.00	127.97	44.70	48.75
	S.Em	1.17	1.69	1.17	1.60	1.28	1.70	1.26
	C.D. at 5%	3.47	5.01	3.47	4.75	3.81	5.05	3.75
	C.V. %	9.32	10.54	10.27	11.13	9.08	7.97	5.27

Table 2: Effect of weed management options of herbicide combination on growth and yield of direct seeded rice.

Sr. No	Treatment	Grain yield (q/ha)	Straw yield (q/ha)	Wt. of dry matter (q/ha)	WCE (%)	Gross Returns (Rs/ha.)	Cost of culti. (Rs./ha.)	Net Returns (Rs/ha.)	B:C Ratio
T_{1}-	Pre emergence application of oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS	36.12	40.82	3.42	77.10	81270	36554	44716	1.22
T_2	PE (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS .	35.90	40.10	3.50	76.42	80775	40014	40761	1.08
T_3	Post emergence metsulfuron methyl 10% + chlorimuronethyl 10% WP @0.004 kg a.i../ha at 20 DAS.	34.00	38.50	5.21	65.60	76500	37074	39426	1.06
T_4	Post emergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS	33.50	37.90	5.14	65.82	75375	37169	38206	1.03
T_5	PE oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Post emergence application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kga.i../ha at 20 DAS.	37.70	42.40	3.28	78.55	84825	36855	47970	1.30
T_6	PE (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + Post emergence application of metsulfuron methyl 10% + chlorimuronethyl 10% WP @ 0.004 kg a.i../ha at 20 DAS.	37.30	42.10	2.83	81.53	83925	37644	46281	1.23
T_7	PE oxyflourfen 23.5% EC @ 0.150 kg a.i/ha at 2-3 DAS.+ Postemergence application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS.	38.41	43.15	2.41	83.12	86423	35414	51009	1.44
T_8	PE (early post emergence) of Pyrazosulfuron ethyl 10% WP 0.030 kg a.i./ha at 8 DAS + application of Byspribic sodium 10% SC @ 0.030 kg a.i. /ha at 20 DAS.	42.00	46.30	1.92	85.90	94500	37041	57459	1.55
T_9	Unweeded check.	30.10	34.80	16.08	0	67725	37986	29739	0.78
T_{10}	Weed free.	44.70	48.75	0	100	100575	38207	62368	1.63
	S.Em	1.70	1.26	0.059	-	-	-	-	-
	C.D. at 5%	5.05	3.75	0.177	-	-	-	-	-
	C.V. %	7.97	5.27	12.35	-	-	-	-	-

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