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Herbicide combinations for weed control in direct-seeded rice

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Abstract
A field experiment was conducted during *Kharif* season of 2018-19 at Agriculture Research Farm, Bihar Agriculture University, Sabour, Bhagalpur to assess the bioefficacy of different herbicides and their combinations for weed control as well as their relative influence on profitability in direct dry-seeded rice cultivation. The minimum weed index (1.69%) was recorded under herbicidal treatment T_5 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE) whereas, the maximum weed index (36.39%) was recorded under T_2 (Pendimethalin @ 1000 g *a.i.* ha^{-1} PE). Among different herbicidal treatments, the maximum weed control efficiency was recorded under T_5 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE) treatment at 45 and 60 days after sowing, the minimum weed control efficiency (69.00%) was observed in treatment T_2 (Pendimethalin @ 1000 g *a.i.* ha^{-1} PE). Maximum net return (Rs. 62401 ha^{-1}) and benefit: cost ratio (1.95) were obtained from the treatment T_5 (Pyrazosulfuron @ 25 g *a.i.*ha^{-1} PE *fb*Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE). T_{10} (Hand weeding) treatment though significantly reduced weeds dry weight and improved the grain yield and gave less benefit: cost ratio owing to higher cost of farm labour.

Keywords: Direct-seeded rice, herbicides, herbicide combinations, weed index, weed control efficiency

Introduction
Direct-seeded rice (DSR) has potential for attaining better water as well as other resources utilization. Heavy weed infestation and shifts in weed population are major constraints in the sustainability of DSR. An appropriate weed management strategy has always been a major focus and key element to make DSR a success. Such a strategy is of utmost significance to improve rice yield, quality and to minimize production costs as well. Traditionally, weeds are controlled through cultural/chemical methods. Manual weeding, though effective is getting increasingly impractical due to labour scarcity, rising wages and its dependence on weather conditions. Moreover, allowing weeds to reach sufficient size to be pulled out and the presence of perennial weeds that fragment/break on pulling are other related concerns (Rao *et al.* 2007). Thus, herbicide usage seems essential for weed management in DSR. Although DSR has been under practice in many regions of the world, yet its adoption has been limited by the unavailability of a successful local weed control strategy. The present study was designed to assess the bio-efficacy and economics of sole and sequential application of pre and post-emergence herbicides and their integration herbicide combinations for weed control in DSR.

Materials and Methods
A field experiment was conducted at Agriculture Research Farm, Bihar Agricultural University, Sabour, Bhagalpur, Bihar (longitude 87°2'42" East and latitude 25°15′40″ North at altitude of 46 meters above *mean* sea level in the heart of the vast Indo-Gangetic plains of North India) during *Kharif* Season of 2018-19. The soil of the experimental site was loamy sand in texture having normal soil reaction (pH 7.27) and electrical conductivity (0.27 dSm^{-1}), low in organic carbon (0.46%) & available N (180.61 kg ha^{-1}) and medium in available P (22.65 kg ha^{-1}) and K (206.88 kg ha^{-1}). The experiment comprised of 11 weed management practices, *viz.*, alone application of Pendimethalin and Pyrazosulfuron as pre-emergence herbicides while other herbicides as post-emergence at 20 days after sowing of crop (DAS) *i.e.* treatments T_1 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE), T_2 (Pendimethalin @1000 g *a.i.* ha^{-1} PE), T_3 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE fb 2,4-DEE @ 750 g *a.i.*ha^{-1} POE), T_4 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE fb Bispyribac sodium @ 25 g *a.i.* ha^{-1} POE), T_5 (Pyrazosulfuron @ 25 g

Same findings were reported by Singh *et al*. (2012) [3] Thippeswamy, (2001) [5] and Singh *et al.* (2006) [4] Hosamani *et al.* (2008) [1] and Jindal *et al.* (2009) [2].

The crosses L3 x T2 and L4 X T1 were identified as the good specific combiner for marketable yield per plot in order of merit. The crosses L2 x T3 for days to first flowering, L5 X T1 for days to 50 per cent flowering, L2 X T2 total number of *a.i.* ha^{-1} PE fb Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE), T_6 (Bispyribac sodium @ 25 g *a.i.* ha^{-1} POE), T_7 (Bispyribac sodium@ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE), T_8 (Ethoxysulfuron @ 15 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.*ha^{-1} POE), T_9 (Halosulfuron @ 67.5 g *a.i.* ha^{-1} + Azimsulfuron @ 30 g *a.i.* ha^{-1} POE), T_{10} (Hand weeding 15, 30 and 45 DAS) and T_{11} (Weedy check). The experiment was laid out in randomized block design (RBD) with three replications. Rice variety 'Sabour Sampannadhan' (BRR0059) was sown on 16th June 2018 using tractor drawn conventional drill with seed rate of 30 kg ha^{-1} in rows spaced at 20 cm. The recommended dose of fertilizers and plant protection measures for insect-pest and disease control were applied. Herbicides were sprayed by knapsack sprayer fitted with flat fan nozzle using 500 litres of water per hectare.The weed control efficiency of different treatments was calculated along the basis of diminution in weight in the treated plot in comparison to weedy check and expressed as a percent. It was calculated by adopting the formula given by Mani *et al.* (1976)

Weed control efficiency was estimated along a dry weight basis

$$WCE = \frac{\text{Dry matter of weeds in weedy check} - \text{Dry matter of weeds in treated check}}{\text{Dry matter of weeds in weedy check}} \times 100$$

Weed index is a reduction in yield due to weed infestation. It is figured by applying the pattern given by Gill and Kumar (1969).

$$WI = \frac{X\text{-}Y}{X} \times 100$$

Where
X- Yield of weed free plot
Y-Yield of treated plot

Result and Discussion

Weed Index (%)

The minimum weed index% was recorded in T_{10} (Hand weeding) and the highest weed index (50.95 per cent) was obtained in weedy check (T_{11}) which is significantly inferior compared to remaining treatments.

Among the different herbicidal treatments, the lowest weed index (1.69 per cent) was observed in the T_5 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac-Na @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE) followed by T_4 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb*Bispyribac-Na @ 25 g *a.i.* ha^{-1} POE) (7.58 per cent) weed management practices. Improved weed control efficiency and season long broad-spectrum control of these weed management practices bring about in reduced weed index significantly. These results were supported by (Maity and Mukherjee, 2008).

Table 1: Effect of chemical weed management practices on weed index and weed control efficiency of DSR

Treatments	Description	Weed index	Weed control efficiency (%)	
			45 DAS	60 DAS
T_1	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE	34.48	64.83	70.25
T_2	Pendimethalin @ 1000 g *a.i.* ha^{-1} PE	36.39	61.94	69.00
T_3	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* 2,4-DEE @ 750 g *a.i.* ha^{-1} POE	29.13	70.55	75.02
T_4	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb*Bispyribac sodium @ 25 g *a.i.* ha^{-1} POE	7.58	81.54	84.27
T_5	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb*Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE	1.69	84.88	87.09
T_6	Bispyribac sodium @ 25 g *a.i.* ha^{-1} POE	22.75	74.20	78.06
T_7	Bispyribac sodium@ 20 g *a.i.* ha^{-1}. + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE	18.06	75.65	78.56
T_8	Ethoxsulfuron @ 15 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE	28.42	71.28	75.83
T_9	Halosulfuron @ 67.5 g *a.i.* ha^{-1} + Azimsulfuron @ 30 g *a.i.* ha^{-1} POE	15.06	78.55	81.84
T_{10}	Hand weeding (15,30 and 45 DAS)	0.00	100.00	100.00
T_{11}	Weed check	50.95	0.00	0.00

PE-Pre-emergence, POE-Post-emergence, *a.i.* Active ingredient, *fb* followed by

4.2.5 Weed control efficiency (%)

Weed control efficiency was calculated at 45 and 60 DAS on the basis of weed density and the data related to weed control efficiency as influenced by crop weed management treatments have been presented in Table 1.

Among different herbicidal treatments, the maximum weed control efficiency was recorded (84.88%) in T_5 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac-Na @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE) treatment at 45 DAS whereas minimum weed control efficiency (61.94%) was obtained in treatment T_2 (Pendimethalin @ 1000 g *a.i.* ha^{-1} PE).

The maximum weed control efficiency was obtained (87.09%) in T_5 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac-Na @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE) treatment at 60 DAS and minimum weed control efficiency (69.00 per cent) was recorded in T_2 (Pendimethalin @ 1000 g *a.i.* ha^{-1} PE). The highest weed control efficiency with hand weeding was also observed by Singh *et al*. (2014).

Economics

Among all the treatments, the highest gross returns (Rs. 96688 ha^{-1}) were obtained in hand weeding (T_{10}) and lowest gross returns (Rs. 47469 ha^{-1}) were obtained in weedy check (T_{11}). Among all the herbicidal treatments, highest gross returns (Rs. 95073 ha^{-1}) were obtained in T_5 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac-Na @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE) which is statistically at par with T_4 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb*Bispyribac-Na @ 25 g *a.i.*ha^{-1} POE) (Rs. 89369 ha^{-1}) and T_9 (Halosulfuron @ 67.5 g *a.i.* ha^{-1} + Azimsulfuron @ 30 g *a.i.*ha^{-1} POE) (Rs. 82194 ha^{-1}). Among the herbicidal treatments, highest net returns (Rs. 62401 ha^{-1}) were obtained in T_5 which is statistically at par with T_4 (Rs. 57066 ha^{-1}), T_9 (Rs. 49865 ha^{-1}) and T_{10} (Rs. 57429 ha^{-1}) and the lowest net returns of (Rs. 17462 ha^{-1}) were obtained in T_{11} (weedy check). The highest B: C ratio was obtained in T_5 (1.9) which is statistically at par with T_4 (1.8), T_6 (1.4), T_7 (1.5), T_9 (1.5) and T_{10} (1.5) and the lowest B:C ratio (0.6) was observed in

T_{11} (weedy check). These results are in conformity with findings of Upasani *et al*. (2010).

Table 2: Effect of chemical weed management practices on Cost of cultivation, Gross return, Net return and Benefit: Cost ratio of DSR

Treatments	Description	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Benefit: cost ratio
T_1	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE	30843	63394	32551	1.1
T_2	Pendimethalin @ 1000 g *a.i.* ha^{-1} PE	31372	61536	30164	1.0
T_3	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* 2,4-DEE @ 750 g *a.i.* ha^{-1} POE	31423	68557	37134	1.2
T_4	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac sodium @ 25 g *a.i.* ha^{-1} POE	32303	89369	57066	1.8
T_5	Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE	32672	95073	62401	1.9
T_6	Bispyribac sodium @ 25 g *a.i.* ha^{-1} POE	31467	74744	43277	1.4
T_7	Bispyribac sodium@ 20 g *a.i.* ha^{-1}. + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE	31836	79275	47439	1.5
T_8	Ethoxsulfuron @ 15 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE	31190	69219	38029	1.2
T_9	Halosulfuron @ 67.5 g *a.i.* ha^{-1} + Azimsulfuron @ 30 g *a.i.* ha POE	32329	82194	49865	1.5
T_{10}	Hand weeding (15,30 and 45 DAS)	39259	96688	57429	1.5
T_{11}	Weed check	30007	47469	17462	0.6
	SEm ±	-	**4892**	**4892**	**0.2**
	CD (P=0.05)	-	**14432**	**14432**	**0.5**

Maximum net returns of Rs. 62401 ha^{-1} and B: C ratio of (1.95) were obtained from the treatment T_5 (Pyrazosulfuron @ 25 g *a.i.*ha^{-1} PE *fb* Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE). T_{10} (Hand weeding) treatment though significantly reduced weeds dry weight and improved the grain yield and gave less B: C ratio owing to higher cost of farm labour.

Based on findings of investigation for one year, it may be concluded that application of T_5 (Pyrazosulfuron @ 25 g *a.i.* ha^{-1} PE *fb* Bispyribac sodium @ 20 g *a.i.* ha^{-1} + Pyrazosulfuron @ 20 g *a.i.* ha^{-1} POE) was equally effective to hand weeding thrice in terms of weed control, greater yield and economic viability in DSR.

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