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Efficacy of weed management through herbicide efficiency and crop resistance indexin direct seeded rice

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Abstract
A field experiment was carried out at the Agricultural Research Farm, Rajendra Agricultural University, Pusa, Samastipur, Bihar (India), during *kharif* season of 2014 to evaluate the efficiency of herbicidesand crop resistance in direct seeded rice.The factors under study comprised of 12 weed management treatments on direct seeded rice. T_1-Weedy check, T_2-Weed free (3 hand weedings at 20, 40 and 60 DAS), T_3-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS), T_4-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS), T_5-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 15 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS), T_6-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 15 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS), T_7-Pendimethalin 1 l/ha (2 DAS) *fb* Pendimethalin 1 l/ha + Bispyribac-Na 30 g/ha in tank mix (20 DAS), T_8-Pendimethalin 1 l/ha (2 DAS) *fb* Pendimethalin 1 l/ha + Bispyribac-Na 15 g/ha in tank mix (20 DAS), T_9-Bispyribac-Na 30 g/ha + Pyrazosulfuron 25 g/ha in tank mix (20 DAS), T_{10}-Bispyribac-Na 30 g/ha + Ethoxysulfuron 18.5 g/ha in tank mix (20 DAS), T_{11}-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha (20 DAS) + Hand weeding (40 DAS), T_{12}-Brown manuring with *Sesbenia aculeate* at 35 DAS. The experiment was conducted in RBD design and was replicated thrice taking rice variety Swarna Sub-1 as a test crop with RDF- 80-40-20 kg N-P_2O_5-K_2O per ha, respectively. Other crop management practices were performed as per standard package of practices.Themajor weed species dominant in the experimental field were *Echinochloa* spp. among the grasses, *Cyperus* spp. among the sedge and *Caesuliaaxillaris, Ammanicabaccifera, Ecliptaalba and Phyllanthuniruri* among the broad leaf weeds. Combined application of herbicides as Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS)effectively curtailed the density and dry weight of grasses, sedges and broad-leaved weeds and attained superior values of weed indices (herbicide efficiency index and crop resistance index), crop yields comparable to hand weeding thrice (20, 40 and 60 DAS). But found in weedy checkwhich attained the inferior values of weed indices due to poor weed control.
Thus, among different herbicidal treatments applied on direct seeded rice, T_3-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS) had efficiently control the complex weed flora.

Keywords: herbicides, weed indices, direct seeded rice

Introduction
Rice (*Oryza sativa* L.) is the leading cereal of the world (Ashraf *et al*., 2006), India is the pioneer country for the cultivation of rice cropand the second largest rice producing country in the world. However, heavy weed infestation is the major constraint to the production of direct seeded rice.Weeds cause heavy damage to direct-seeded rice (DSR) crop which can be to 5-100% yield loss. (Kohle 1989).Weeds compete for light, nutrients and water from the crop. This can be lead to the simultaneous emergence of weeds and crops and less availability of efficient selective herbicides for control of weeds during initial stages of crop weed competition. Most of the herbicides that are recommended for direct seeded rice are applied as pre-emergence to crop to control weeds during the initial period. The weeds that emerge during the later periods of crop growth cycle are not suppressed by any herbicides.Therefore, it is imperative to evaluate the efficacy of suitable post-emergence herbicides in mixture for effective control of dominant and diversified weed flora in direct seeded rice crop. Competitive ability of any crop cultivar can be judged by its ability to prosper and thrive under weedy conditions (Mahajan and Chauhan, 2011). As a rule of thumb, weed density and biomass will be less in a weed competitive crop cultivar (Mahajan *et al*., 2004). A cultivar that is competitive against weeds can have definite yield advantage over less competitive cultivars especially under weedy conditions. The degree of competition offered by a crop cultivar can also influence the level of weed control that can be achieved with herbicides (Lemerle*et al*., 1996).

Morpho-physiological differences among crop cultivars might account for this variation.
Keeping the above facts in view, the present investigation was carried out to evaluate the efficiency of Pre and post-emergence herbicidal mixture on weed indices of crop.

Materials and Methods
The field experiment was conducted at the Agricultural Research Farm, Rajendra Agricultural University, Pusa, Samastipur, Bihar (India), during *kharif* season of 2014. The climate of this region is sub- tropical. The soil of experimental site was sandy loam in texture with pH 8.43, low in organic carbon 0.46 %, available nitrogen (242 kg/ha), phosphorus (18.38 kg/ha) andpotassium (111 kg/ha). The factors under study comprised of 12 weed management treatments on direct seeded rice. T_1-Weedy check, T_2-Weed free (3 hand weedings at 20, 40 and 60 DAS), T_3-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS), T_4-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS), T_5-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 15 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS), T_6-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 15 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS), T_7-Pendimethalin 1 l/ha (2 DAS) *fb* Pendimethalin 1 l/ha + Bispyribac-Na 30 g/ha in tank mix (20 DAS), T_8-Pendimethalin 1 l/ha (2 DAS) *fb* Pendimethalin 1 l/ha + Bispyribac-Na 15 g/ha in tank mix (20 DAS), T_9-Bispyribac-Na 30 g/ha + Pyrazosulfuron 25 g/ha in tank mix (20 DAS), T_{10}-Bispyribac-Na 30 g/ha + Ethoxysulfuron 18.5 g/ha in tank mix (20 DAS), T_{11}-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha (20 DAS) + Hand weeding (40 DAS), T_{12}-Brown manuring with *Sesbenia aculeate* at 35 DASwere laidout in randomized block design with three replications.
Rice variety Swarna sub-1 was sown on 26thJune 2014 with broadcasting and a plant to plant spacing of nearly 20 cm. The recommended dose of fertilizers for rice was 80 kg N, 40 kg P_2O_5 and 20 kg K_2O/ha. The whole quantity of P, and K was applied through DAP and muriate of potash respectively at the time of sowing of crop and nitrogen was applied in three equal split doses i.e. basal, tillering and panicle initiation stages through urea fertilizer. The crop samples were collected at regular intervals of 30 days and also at harvest stage. Plants of one metre row length were uprooted from each plot from sampling row and then it converted into g /m^2. Weeds were cut at ground level, washed, sun dried and then kept in oven at 70 ^{0}C $\pm$ 1 till constant weight reached. Then dry weight was taken with digital electronic balance. The weed density (No./m^2) was worked out by counting number of weeds from randomly thrown of quadrate (1.0 m^2) at two place in each plot and average of two reading was done and after counting number of weeds, they are uproot from the plot for dry weight recording. They are sun-dried subsequently oven drying was done at 60ºC till constant weight reached. Thereafter weighing was done and average of two reading was recorded. Data on weed density and weed biomass were transformed using square root transformation. Herbicide efficiency index and Crop resistance index were computed using the standard procedure as following details:

Herbicide efficiency index (HEI): (Krishnamurthy *et al*., 1975)
This index indicates the weed killing potential of herbicides treatments for and their phytotoxicity on the crop and was computed using the following formula:

$$\text{Herbicide efficiency index (HEI)} = \frac{\frac{(Yt-Yc)}{Yt}\times 100}{\frac{WDMt}{WDMc}\times 100}$$

Where,
Yt- crop yield from treated plot
Yc- crop yield from weedy check plot
WDMt-weed dry matter in treated plot
WDMc-weed dry matter in weedy check plot

Crop resistance index (CRI): (Mishra and Mishra, 1997)
It indicates the relationship between a proportionate increase in crop biomass in treated plots and a proportionate reduction in weed biomass in the treated plots.

$$\text{CRI} = \frac{\text{Dry matter of crop in treated plot}}{\text{Dry matter of crop in control plot}} X \frac{\text{Dry matter of weed in control plot}}{\text{Dry matter of weed in treated plot}}$$

Results and Discussion
Weed density and biomass
The major weed flora observed in the experimental field were *Echinochloa*spp. among grasses, *Cyperus*spp. Among sedges, *Caesuliaaxillaris, Ammanicabaccifera, Ecliptaalba*and *Phyllanthusniruri* among broad leaved weeds. The total weed density and biomass differed significantly at 60 DAS due to weed control treatments (Table 1). The total density and biomass of weeds was maximum (57.67 /m^2 and 17.30g/ m^2) under weedy check plots, where weeds were not controlled by any means. Hand weeding thrice at 20, 40 and 60 DAS excelled to all the herbicidal treatments as it curtailed the density of grassy, sedge and dicot weeds to a larger extent (11.33 /m^2).This result was similar to that of the experiment at findings of Singh *et al*., (2017).weed biomass was also registered significantly lower under Weed free treatment(5.33 g/m2) at 60DAS and it was statistically at par with T_{11}-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha (20 DAS) + Hand Weeding (40 DAS).Therefore, Hand weeding thrice at 20, 40 and 60 DAS reduced the density including biomass of weeds to the maximum extent over herbicidal treatments due to elimination of all sort of weeds during the course of hand weeding (Das, 2008, Lal, *et al* 2017). Among the herbicide treatments, weed density /m^2 and weed biomass (g /m^2) was registered significantly lowest under T_3-Pendimethalin 1 l/ha (2 DAS) fb Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS), at 60 DAS. This may be attributed due to earlier and effective control of weeds by Pendimethalinand subsequently flushes of weeds were controlled by Bispyribac-sodium and Azimsulfuronefficiently. This result was similar to that of the experiment at findings of Narolia *et al*., (2014) and singh *et al*., (2014).

Dry matter production and yield of crop
The dry matter production with weedy plots were significantly lowest among all the treatments at 60 DAS it may be due to when multiple weed problems. Dry matter accumulation by rice plants was influenced significantly by weed management treatments
The highest dry matter (485.67 g/m^2) was recorded under treatment T_2-Weed free (3 hand weedings at 20, 40 and 60 DAS), which was statistically at par with treatment T_{11}-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha (20 DAS) + Hand Weeding (40 DAS)-(473.67 g/m^2), T_3-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS)-(468.00 g/m^2),

T_5-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 15 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS)-(464.00 g/m^2), and T_4-Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS)-(462.00 g/m^2) –(Table-2)while remains significantly superior to rest of the treatments. Therefore, it becomes advantageous to use a mixture of herbicides to control complex weed flora which comprises of grassy, sedges and broad leaved weeds. Similar result was found by Dadsena *et al.*, (2014)

The highest total crop yield (93.13q /ha) was recorded under treatment T_2-Weed free (3 hand weedings at 20, 40 and 60 DAS) and lowest grain yield obtained under weedy check T_1-(63.14q/ha). The higher grain yield under hand weeding and herbicidal treatments which were attributed to better utilization of applied nutrients by crop as compared to weedy check crop. The results were similar to that of the experiment at findings of Amarjeet *et al*, (2006) and Singh *et al*. (2010).

Various weed indices in crop

The values of weed indices like herbicide efficiency index (HEI) and crop resistance index (CRI) at 60 DAS were inferior in plots receiving no any weed control treatment. And recorded superior values to that of hand weeding thrice (20, 40 and 60 DAS) and these proved better than combined application of herbicides. Highest value of herbicide efficiency index (2.81) and crop resistance index (5.33) under combined application of herbicides in Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS) including hand weeding plots could be assigned the reason for superior weed indices as in Pendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha (20 DAS) + Hand Weeding (40 DAS)(Table-2) and lower the values of weed indices in case of rest of the herbicidal treatments. Similar results have also been reportedly Krishnamurthy *et al.*, 1975, Ramamurthy, 1999 and Lal, 2017.

Table 1: Weed density and weed biomass at 60 days after application of herbicidal treatments

Treatments	Weed density at 60 DAS(No./m^2)				Weed biomass at 60 DAS(g/m^2)			
	Grasses	Sedges	Broad leaves	Total	Grasses	Sedges	Broad leaves	Total
Weedy Check	33.67(5.84)	15.00(3.94)	9.00(3.07)	7.63(57.67)*	10.10(3.25)	4.70(2.28)	2.50(1.73)	4.22(17.30)*
Weed free (3 hand weedings at 20, 40 and 60 DAS)	5.18(2.27)	3.65(2.02)	2.50(1.72)	3.44(11.33)	1.90(1.55)	1.10(1.26)	0.58(1.04)	2.01(3.58)
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS)	6.80(2.70)	4.80(2.29)	3.40(1.92)	3.92(15.00)	2.56(1.75)	1.23(1.28)	0.83(1.15)	2.27(4.62)
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 30 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS)	9.65(3.18)	5.35(2.41)	4.00(2.08)	4.40(19.00)	3.49(1.99)	1.41(1.36)	1.20(1.30)	2.57(6.10)
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 15 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS)	7.07(2.74)	5.50(2.44)	4.10(2.09)	4.13(16.67)	2.81(1.81)	1.46(1.40)	1.23(1.32)	2.45(5.50)
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 15 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS)	16.27(4.07)	7.00(2.74)	5.40(2.41)	5.40(28.67)	5.83(2.51)	1.65(1.44)	1.38(1.37)	3.06(8.86)
Pendimethalin 1 l/ha (2 DAS) *fb*Pendimethalin 1 l/ha + Bispyribac-Na 30 g/ha in tank mix (20 DAS)	11.80(3.50)	7.30(2.78)	5.90(2.52)	5.05(25.00)	4.59(2.22)	1.72(1.49)	1.41(1.38)	2.87(7.72)
Pendimethalin 1 l/ha (2 DAS) *fb*Pendimethalin 1 l/ha + Bispyribac-Na 15 g/ha in tank mix (20 DAS)	14.20(3.83)	8.50(3.00)	6.30(2.60)	5.43(29.00)	5.68(2.48)	1.96(1.57)	1.59(1.44)	3.12(9.23)
Bispyribac-Na 30 g/ha + Pyrazosulfuron 25 g/ha in tank mix (20 DAS)	16.80(4.14)	5.30(2.39)	3.90(2.09)	5.14(26.00)	6.27(2.60)	1.38(1.37)	0.99(1.21)	3.02(8.64)
Bispyribac-Na 30 g/ha + Ethoxysulfuron 18.5 g/ha in tank mix (20 DAS)	21.73(4.17)	5.10(2.35)	3.50(1.99)	5.55(30.33)	7.15(2.76)	1.29(1.34)	0.89(1.18)	3.13(9.33)
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 30 g/ha (20 DAS) + Hand Weeding (40 DAS)	5.37(2.40)	3.88(2.08)	2.75(1.79)	3.52(12.00)	1.94(1.56)	1.14(1.28)	0.66(1.06)	2.06(3.74)
Brown manuring with *Sesbenia aculeate* at 35 DAS	8.53(2.99)	6.80(2.69)	5.00(2.34)	4.56(20.33)	3.29(1.94)	1.51(1.42)	1.31(1.34)	2.57(6.11)
SEm±	1.18(0.19)	0.73(0.15)	0.68(0.16)	0.18(1.60)	0.47(0.11)	0.27(0.09)	0.19(0.08)	0.09(0.45)
C.D. (P=0.05)	3.47(0.57)	2.15(0.45)	2.00(0.48)	0.52(4.72)	1.40(0.31)	0.80(0.28)	0.56(0.23)	0.26(1.32)

*Figure in parenthesis shows the original value

Table 2: Influence of weed control treatments on dry matter at 60 DAS, yield of crop and weed indices (HEI and CRI)

Treatments	YIELD (q/ha)			Crop dry weight(g/m^2)	HEI	CRI
	Grain yield	Straw yield	Total yield			
Weedy Check	22.33	40.80	63.14	328.67	0.00	1.00
Weed free (3 hand weedings at 20, 40 and 60 DAS)	41.73	51.40	93.13	485.67	2.30	7.15
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS)	39.80	49.87	89.67	468.00	1.57	5.33
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 30 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS)	38.40	49.20	87.60	462.00	1.10	3.99
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 15 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS)	39.47	49.25	88.72	464.00	1.27	4.44
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 15 g/ha + Azimsulfuron 15 g/ha in tank mix (20 DAS)	36.97	47.96	84.93	414.00	0.67	2.46
Pendimethalin 1 l/ha (2 DAS) *fb*Pendimethalin 1 l/ha + Bispyribac-Na 30 g/ha in tank mix (20 DAS)	37.23	48.17	85.41	457.00	0.79	3.11
Pendimethalin 1 l/ha (2 DAS) *fb*Pendimethalin 1 l/ha + Bispyribac-Na 15 g/ha in tank mix (20 DAS)	36.07	46.96	83.02	447.00	0.59	2.55
Bispyribac-Na 30 g/ha + Pyrazosulfuron 25 g/ha in tank mix (20 DAS)	37.14	48.04	85.18	453.00	0.70	2.76
Bispyribac-Na 30 g/ha + Ethoxysulfuron 18.5 g/ha in tank mix (20 DAS)	35.73	46.90	82.64	390.00	0.57	2.20
Pendimethalin 1 l/ha (2 DAS) *fb*Bispyribac-Na 30 g/ha (20 DAS) + Hand Weeding (40 DAS)	41.07	50.80	91.87	473.67	2.10	6.67
Brown manuring with *Sesbenia aculeate* at 35 DAS	37.87	48.34	86.20	455.67	1.03	3.93
SEm±	1.32	0.82	1.63	9.33	-	-
C.D. (P=0.05)	3.91	2.42	4.81	27.55	-	-

Conclusion

The present study concluded thatPendimethalin 1 l/ha (2 DAS) *fb* Bispyribac-Na 30 g/ha + Azimsulfuron 30 g/ha in tank mix (20 DAS) was an effective weed control treatment due to the higher value of weed indices.It is therefore suggested that combined application of pre and post-emergence herbicides to the crop that can tackle recalcitrant weed flora much efficiently, thus securing crop yields against weed infestation.

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