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Herbicide combinations for weed management in direct-seeded rice

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ABSTRACT

Ten treatments were evaluated during *Kharif* 2013, 2014 and 2015 at Palampur (Himachal Pradesh) to study their impacts on weeds, crop and economics. *Echinochloa colona* was the most competitive weed followed by *Aeschynomene indica* and *Panicum dichotomiflorum*. Oxadiargyl *fb* bispyribac, pyrazosulfuron *fb* bispyribac, pendimethalin *fb* bispyribac *fb* manual weeding and bispyribac + chlorimuron + metsulfuron-methyl gave significantly lower count of *E. colona* and *Panicum dichotomiflorum*. The economic threshold levels (no/m^2) with the weed management practices studied varied between 2.5-17.8/m^2. With every 1 weed/m^2 increase in density, the grain yield of dry-seeded rice was reduce by 62.4 kg/ha. Manual weeding engaged more labour and had higher cost tending to increase the economic threshold over herbicidal treatments. Cost of weed control under herbicidal/integrated treatments was 14 - 49% of weed free and 19.9 - 69.3% of that under mechanical weeding. Oxadiargyl *fb* bispyribac resulted in highest net return due to weed control. Crop resistance index and efficiency index were highest and weed index was minimum under pendimethalin *fb* bispyribac *fb* manual weeding. Weed management index, agronomic management index and integrated weed management index were highest under pendimethalin *fb* manual weeding followed by bispyribac, pendimethalin *fb* bispyribac and mechanical weeding. The overall performance index (OP_i) was highest under pendimethalin *fb* bispyribac *fb* manual weeding (1.34) followed by oxadiargyl *fb* bispyribac (1.31), pyrazosulfuron *fb* bispyribac (1.18), bispyriac + chlorimuron + metsulfuron (1.14) and bisppyribac (1.12). Weeds reduced the grain yield of rice by 67.1%.

Key words: Chemical control, Direct-seeded rice, Impacts, Herbicide mixtures, Weeds, Weed management, Yield

Dry-seeded rice has been the most promising water saving method wherein the rice is established by direct seeding in non-puddled and non flooded fields. In addition, direct-seeded rice culture requires less labour and capital input with saving of 29% of the total rice production cost. In dry-seeded rice system, dry tillage and aerobic soil conditions are highly conducive for germination and higher growth of weeds which results in greater rice grain yield losses as compared to puddle transplanted rice. It is very often characterized by a complex plurispecific weed flora, composed of grasses, sedges and broad-leaved weeds (Angiras *et al.* 2010, Kumar and Rana 2013, Pavithra and Poonguzhalan 2015). Uncontrolled weeds reduce the yield by 96 to 100% in dry direct-seeded rice (Maity and Mukherjee 2008). Hence, developing an effective weed management approach has been a challenge for widespread adoption of direct-seeded rice cultivation. The rice herbicides used were mainly pre-emergence, which generally do not provide season-long effective weed control. Therefore, need for some alternative post-emergence herbicide which can provide broad-spectrum weed control without affecting direct-seeded rice growth and yield was felt. Post-emergence bispyribac-Na has been recommended as an effective alternative (Kumar and Rana 2013, Kumar *et al.* 2013), if pre-emergence herbicide application is not done. However, in the direct-seeded cultures, weed problem is more severe as they appear in several flushes. In order to optimize weed control efficacy and minimize the application costs, the use of combinations of pre-post-emergence herbicides, formulated or tank mix herbicide mixtures (Rana *et al.* 2015) as well as integrating herbicides with manual or mechanical means (Rana and Angiras 1999a and b) has become the rule rather than the exception. However, any new weed control measure is adopted only when its results are expected to be more economically beneficial than the existing control measure. Growers compare the cost of weed control to select weed control inputs that provide the desired degree of control at the lowest cost. Therefore, present

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investigation was carried out to assess the impacts of new herbicide mixtures in dry seeded rice under mid hill conditions of Himachal Pradesh.

MATERIALS AND METHODS

To study the impact of combinations of herbicides against weed complex in direct-seeded upland rice, a field experiment was conducted during *Kharif* 2013, 2014 and 2015 in randomized block design with 10 treatments and three replications. The treatments were, bispyribac-Na 25 g/ha (20 DAS), pendimethalin 1000 g/ha (pre) *fb* bispyribac 25 g/ha (25 DAS), oxadiargyl 100 g/ha (pre) *fb* bispyribac 25 g/ha (25 DAS), pyrazosulfuron 20 g/ha (pre) *fb* bispyribac 25 g/ha (25 DAS), pendimethalin 1000 g/ ha (pre) *fb* bispyribac 25 g/ha (20 DAS) *fb* manual weeding (45 DAS), pendimethalin 1000 g/ha (pre) *fb* manual weeding (25-30 DAS), bispyribac 25 + chlorimuron 20 g/ha + metsulfuron methyl 4 g/ha (20 DAS), cono/rotary weeding (15, 30 and 45 DAS), weed free (manual weeding 15, 30, 45 and 60 DAS) and weedy check. The experimental soil was silty clay loam in texture, acidic in reaction (pH 5.6), medium in available nitrogen (350 kg/ha), phosphorus (22.8 kg/ha) and high in available potassium (211 kg/ ha). Rice variety '*HPR 1156*' was sown on 01 June 2013, 20 May 2014 and 25 May 2015 keeping row to row spacing of 25 cm (approximately 80 kg/ha seed rate). The crop was fertilized with 90 kg N, 40 kg P_2O_5 and 40 kg K_2O/ha through urea, single super phosphate and muriate of potash, respectively. The required quantity of half N and whole P_2O_5 and 40 kg K_2O was drilled at sowing. The remaining half N was band placed at 55 DAS. Herbicides were applied with power sprayer using 600 L water per hectare. The rest of the management practices were in accordance with the recommended package of practices. Data on density of weeds was recorded at harvest of crop. The crop was harvested on 22 October 2013, 28 October 2014 and 24 October 2015.

The data obtained were subjected to statistical analysis by analysis of variance (ANOVA) for the randomized block design to test the significance of the overall differences among the treatments by the "F" test and conclusion was drawn at 5% probability level. Standard error of mean was calculated in each case. When the 'F' value from analysis of variance tables was found significant, the critical difference was computed to test the significance of the difference between the two treatments. The economic threshold (=economic injury levels), the weed density at which the cost of treatment equals the economic benefit obtained from that treatment, was calculated after Uygur and Mennan (1995) as well as those given by Stone and Pedigo (1972) as below:

Uygur and Mennan:

$$Y = [\{(100/He*Hc)+A_C\}/(Gp*Yg)]*100$$

Where, Y is per cent yield losses at a different weed density; He, herbicide efficiency; Hc, herbicide cost; Ac, application cost of herbicide; Gp, grain price and Yg, yield of weed free.

Stone and Pedigo:

Economic threshold = Gain threshold/ Regression coefficient

Where, gain threshold = Cost of weed control (Hc+Ac)/Price of produce (Gp), and regression coefficient (b) is the outcome of simple linear relationship between yield (Y) and weed density/ biomass (x), Y = a + bx.

The different impact indices were worked out after Rana and Kumar (2014) as follow:

Additionally, 'overall performance index' was determined, by calculating firstly the 'comparable unit value' where the value under a particular treatment of a parameter was divided by the respective arithmetic mean value of treatments for that parameter as given below:

$$U_{ij} = \frac{V_{ij}}{AM_j}$$

Where U_{ij} is the unit value for ith treatment corresponding to jth parameter, V_{ij} is the actual measured value for ith treatment and jth parameter and A_{Mj} is the arithmetic mean value for jth parameter.

Weed persistence index (WPI)

$$WPI = \frac{Weed\ weight\ in\ treated\ plot}{Weed\ weight\ in\ control\ plot}\ x\ \frac{Weed\ count\ in\ control\ plot}{Weed\ count\ in\ treated\ plot}$$

Crop resistance index (CRI)

$$CRI = \frac{Crop\ weight\ in\ treated\ plot}{Crop\ weight\ in\ control\ plot}\ x\ \frac{Weed\ weight\ in\ control\ plot}{Weed\ weight\ in\ treated\ plot}$$

Weed management index (WMI)

$$WMI = \frac{Percent\ yield\ over\ control}{Percent\ control\ of\ the\ pest}$$

Agronomic management index (AMI)

$$AMI = \frac{Percent\ yield\ over\ control - Percent\ control\ of\ the\ pest}{Percent\ control\ of\ the\ pest\ (weed)}$$

Integrated Management index (IWMI)

$$IWMI = \frac{WMI + AMI}{2}$$

Herbicide efficiency index (EI)

$$EI = \frac{\frac{Yield\ of\ treatment - Yield\ of\ control}{Yield\ of\ control}\ x\ 100}{\frac{Weed\ weight\ in\ treatment}{Weed\ weight\ in\ control}\ x\ 100}$$

Secondly, the overall performance index was calculated as an average of unit values (U_{ij}) of all the parameters under consideration:

$$OP_i = \frac{1}{N}\sum_{i=1}^{N} U_{ij}$$

where OP_i is the overall performance index for ith treatment and N is the number of parameters considered in deriving performance index.

RESULTS AND DISCUSSION

Effect on weeds

The major weeds of the experimental field were *Echinochloa colona* (50, 57.8 and 63.6%), *Digitaria sanguinalis* (5.0, 9.5 and 7.6%), *Panicum dichotomiflorum* (38.0, 12.6 and 14.2%), *Aeschynomene indica* (2.0, 9.7 and 4.1%), *Ageratum conyzoides* (5.0, 5.3 and 3.8%) and *Cyperus iria* (0.0, 5.3 and 6.6% during 2013, 2014 and 2015, respectively in the unweeded check). *Commelina benghalensis* showed its sporadic occurrence.

Weed control treatments brought about significant variation in the count of *Echinochloa colona* during all the three years (Table 1). All weed control treatments were significantly superior to weedy check in reducing *E. colona* in all the three years. Herbicidal treatments behaving similar with weed free resulted in significantly lower density of *E. colona* as compared to three mechanical weedings with cono/rotary weeder. The superiority of bispyribac (Kumar and Rana 2013, Kumar *et al.* 2013) and herbicide combinations (*Shekhar et al.* 2012, Rana *et al.* 2015) in controlling *E. colona* has been reported by several workers. Weed control treatments caused significant variation also in the count of *P. dichotomiflorum* during all the three years of experimentation. Oxadiargyl *fb* bispyribac, pyrazosulfuron *fb* bispyribac, pendimethalin *fb* bispyribac *fb* manual weeding and bispyribac + chlorimuron + metsulfuron-methyl behaving statistically similar resulted in significantly lower density of *P. dichotomiflorum* as compared to weedy check. The other treatments could not significantly curtail the population of *P. dichotomiflorum* over the unweeded check. Weed control treatments resulted in significant variation in the count of *D. sanguinalis* during 2014 and 2015. The population of the weed was completely eliminated under oxadiargyl *fb* bispyribac, pyrazosulfum *fb* bispyribac, pendimethalin *fb* bispyribac *fb* manual weeding, pendimethalin *fb* manual weeding and bispyribac + chlorimuron + metsulfuron methyl. The other treatments either had higher or equal population of this weed as under weedy check.

Weed control treatments encountered significant variation in the count of *A. indica* during 2014 and 2015 (Table 2). All treatments were significantly superior to weedy check in reducing the population of *A. indica* during 2014. All herbicidal treatments except pendimethalin *fb* bispyribac gave comparable control of this weed as weed free. *Ageratum* appeared late in the season by 75 DAS. Its population also varied significantly due to treatments during 2014 and 2015. Its complete elimination was noticed in the treatments bispyribac, pendimethalin *fb* bispyribac *fb* manual weeding and mechanical weeding. In the other treatments its population was

Table 1. Effect of treatments on species wise weed count (no./m²) at harvest in direct-seeded rice

Treatment	Dose (g/ha)	Time (DAS)	*Echinochloa*			*Digitaria*			*Panicum*		
			2013	2014	2015	2013	2014	2015	2013	2014	2015
Bispyribac-Na	*25*	*20*	3.2(9)	3.0(8)	2.6(6)	1.4(1)	1.5(1)	1.7(2)	3.6(12)	3.5(11)	3.39(11)
Pendimethalin *fb* bispyribac	1000, 25	0-2, 25	2.1(4)	2.0(3)	2.1(3)	2.6(6)	2.5(5)	2.7(6)	3.3(10)	3.1(9)	2.88(7)
Oxadiargyl *fb* bispyribac-Na	100, 25	0-2, 25	3.1(8)	3.0(8)	2.9(7)	1.0(0)	1.0(0)	1.0(0)	2.7(6)	1.8(2)	1.76(2)
Pyrazosulfum *fb* bispyribac-Na	20, 25	0-3, 25	2.8(7)	2.7(7)	2.8(7)	1.0(0)	1.0(0)	1.0(0)	2.7(6)	1.8(2)	1.76(2)
Pendimethalin *fb* bispyribac *fb* manual weeding	1000, 25	0-2, 20, 45	2.8(7)	2.7(6)	2.5(5)	1.0(0)	1.0(0)	1.0(0)	2.8(7)	1.8(2)	1.73(2)
Pendimethalin *fb* manual weeding	1000	0-2, 25-30	3.2(9)	2.8(7)	2.8(7)	1.0(0)	1.0(0)	1.0(0)	3.4(11)	3.3(10)	2.88(7)
Bispyribac-Na + (chlorimuron + metsulfuron methyl)	25+ 20+4	20	3.2(9)	3.0(8)	3.0(8)	1.0(0)	1.0(0)	1.0(0)	2.0(3)	1.6(2)	1.58(2)
Cono/ rotary weeding	-	15,30,45	3.7(13)	3.9(14)	3.6(12)	1.8(2)	1.7(2)	1.8 (2)	3.5(11)	1.9(2)	1.48(1)
Weed free	-		2.7(6)	2.7(6)	2.1(3)	1.8(2)	1.7(2)	1.9(3)	3.5(11)	2.0(3)	2.09(3)
Weedy check	-		5.1(25)	4.8(22)	5.1(25)	1.9(3)	2.1(4)	2.0(3)	4.5(19)	2.4(5)	2.56(6)
LSD (P=0.05)			1.7	0.5	0.4	NS	0.6	0.6	1.3	1.0	1.05

Values given in the parentheses are the original means DAS= after sowing *fb*= followed by either equal or more than the weedy check. Weed control treatments resulted in significant variation in the count of *C. iria*. *Cyperus* is sensitive to competition. Its appearance was noticed only under pyrazosulfuron *fb* bispyribac, weed free and weedy. In other treatments it was not noticed. Total weed count was significantly influenced by different weed control treatments (Table 3). All the weed control treatments except three mechanical weedings with cono/rotary weeder behaving statistically similar resulted in significantly lower total weed count. The superiority of herbicidal treatments in curtailing weed population has been presented in several scientific papers (Maity and Mukherjee 2008, Kumar *et al.* 2008, 2011, Shekhar *et al.* 2012, Angiras *et al.* 2010).

Impact of weed control

Rice grain yield was negatively associated with the count of *E. colona* (r= -0.883**, -0.832**, -0.950** and -0.910**, during 2013, 2014, 2015 and combined of all years, respectively; **significant at 1% level of significance), *A. indica* (r= - 0.827** and -0.769** during 2014 and the combined), *P. dichotomiflorum* (r= - 0.730* during 2013 only, *significant at 5% level of significance) and total weed count (r= -0.933**, -0.930**, -0.871** and -0.973**) showing their high competitiveness in rice. The count of rest of the weeds was not significantly associated with grain yield of rice. Weed control treatments resulted in significant variation in grain yield of rice (Table 3). Pendimethalin *fb* bispyribac *fb*

Table 2. Effect of treatments on species wise weed density (no./m^2) at harvest in direct-seeded rice

Treatment	Dose (g/ha)	Time (DAS)	*Aeschynomene*			*Ageratum*			*Cyperus*		
			2013	2014	2015	2013	2014	2015	2013	2014	2015
Bispyribac-Na	*25*	*20*	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)
Pendimethalin *fb* bispyribac	1000, 25	0-2, 25	1.5(1)	1.5(1)	1.4(1)	1.5(1)	1.4(1)	1.6(1)	1.0(0)	1.0(0)	1.0(0)
Oxadiargyl *fb* bispyribac-Na	100, 25	0-2, 25	1.0(0)	1.0(0)	1.0(0)	1.7(2)	1.7(2)	1.8(2)	1.0(0)	1.0(0)	1.0(0)
Pyrazosulfum *fb* bispyribac-Na	20, 25	0-3, 25	1.0(0)	1.0(0)	1.0(0)	1.8(2)	1.7(2)	1.7(2)	2.1(4)	2.3(4)	1.8(2)
Pendimethalin *fb* bispyribac *fb* manual weeding	1000, 25	0-2, 20, 45	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)
Pendimethalin *fb* manual weeding	1000	0-2, 25-30	1.5(1)	1.0(0)	1.0(0)	3.5(11)	3.2(9)	2.3(5)	1.0(0)	1.0(0)	1.0(0)
Bispyribac-Na + (chlorimuron + metsulfuron methyl)	25+ 20+4	20	1.0(0)	1.0(0)	1.0(0)	1.7(2)	1.6(2)	2.0(3)	1.0(0)	1.0(0)	1.0(0)
Cono/ rotary weeding	-	15,30,45	1.5(1)	1.4(1)	1.5(1)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.0(0)
Weed free	-		1.0(0)	1.0(0)	1.0(0)	1.0(0)	1.5(1)	1.5(1)	2.0(3)	1.9(3)	1.9(3)
Weedy check	-		1.4(1)	2.2(4)	1.61(2)	1.9(3)	1.7(2)	1.6(2)	1.0(0)	1.7(2)	1.9(3)
LSD (P=0.05)			NS	0.3	0.25	NS	0.4	0.3	0.7	0.5	0.5

Values given in the parentheses are the original means DAS=days after sowing *fb*= followed by

Table 3. Effect of different treatments on total weed count (no./m^2), grain yield, economic thresholds and economics in direct-seeded rice

Treatment	Dose (g/ha)	Time (DAS)	Weed count (no/m^2)			Grain yield (t/ha)			Gt	Et		CWC	NRwc	MBCR
			2013	2014	2015	2013	2014	2015		SP	UM			
Bispyribac-Na	*25*	*20*	4.8(22)	4.8(22)	4.4 (18)	2.79	2.68	2.61	156	2.5	5.9	2340	34036	14.55
Pendimethalin *fb* bispyribac-Na	1000, 25	0-2, 25	4.8(22)	4.6(20)	4.2(16)	3.03	2.80	2.68	301	4.8	11.0	4520	35002	7.74
Oxadiargyl *fb* bispyribac-Na	100, 25	0-2, 25	4.2(17)	3.8(14)	3.5 (11)	3.09	3.07	2.62	222	3.6	8.3	3326	38107	11.46
Pyrazosulfum *fb* bispyribac	20, 25	0-3, 25	4.4(19)	4.3(17)	3.8(13)	2.80	2.81	2.31	239	3.8	9.0	3580	31626	8.83
Pendimethalin *fb* bispyribac *fb* manual weeding	1000, 25	0-2, 20, 45	3.9(14)	3.2(10)	2.9 (7)	3.15	3.38	2.79	539	8.6	18.1	8090	37338	4.62
Pendimethalin *fb* manual weeding	1000	0-2, 25-30	5.7(32)	5.3(27)	4.4 (19)	1.96	2.21	2.39	542	8.7	18.5	8130	17203	2.12
Bispyribac-Na + chlorimuron + metsulfuron methyl	25+ 20+4	20	3.8(14)	5.3(27)	3.7(13)	2.65	2.60	2.32	271	4.3	9.4	4062	28609	7.04
Cono/rotary weeding	-	15, 30, 45	5.3(27)	4.2(16)	5.2 (27)	2.23	2.40	2.21	782	12.5	25.1	11730	15688	1.34
Weed free	-	-	4.8(22)	4.1(16)	4.3(17)	2.80	2.81	2.43	1111	17.8	35.7	16660	19411	1.17
Weedy check	-	-	7.1(50)	6.6(44)	6.1(37)	1.12	1.08	0.87	-	-	-	-	-	-
LSD (P=0.05)	-	-	2.0	2.1	2.0	0.37	0.31	0.25	-	-	-	-	-	-

Values given in the parentheses are the original means, DAS= Days after sowing, *fb*= Followed by; Gt= Gain threshold; Et= Economic threshold; SP= After Stone and Pedigo (1972); UM= After Uygur & Mennan (1995); CWC= Cost of weed control (INR/ha); NR_{WC} = net return due to weed control (INR/ha); MBCR= Marginal benefit cost ratio manual weeding 1000 *fb* 25g/ha (0-2 *fb* 20 DAS *fb* 45 DAS) behaving statistically alike with oxadiargyl *fb* bispyribac, pendimethalin *fb* bispyribac, bispyribac, pyrazosulfuron *fb* bispyribac and weed free during 2014 and 2015 resulted in significantly higher grain yield of rice over other treatments. The higher grain yield under these treatments was owed to superior weed control. These findings were in line with those of Angiras *et al*. (2010), Rana and Angiras (1999a&b), Kumar *et al.* (2008, 2011, 2013), Kumar and Rana (2013), Shekhar *et al*. 2012) and Maity and Mukherjee (2008). Weeds in unweeded check reduced the grain yield of paddy by 67.1% over pendimethalin *fb* bispyribac *fb* manual weeding.

The linear relationship between weed count (x) and grain yield (Y) of direct seeded rice is given here as under,

Y= 3799 – 62.4x (R^2= 0.947)…….(i)

The equation (i) explains that 94.7% of variation in grain yield of dry seeded rice due to weed count could be explained by the regression equation. With every 1 weed/m^2 increase in density, the grain yield of dry seeded rice was expected to fall by 62.4 kg/ha.

The economic threshold levels of weeds at the current prices of treatment application and the crop production on the basis of weed infestation in direct-seeded rice are given in Table 3. The economic threshold levels (no/m^2) with the weed management practices studied varied between 2.5-17.8/m^2 when determined after Pedigo and Stone (1972) and 5.9-35.7/m^2 after Uygur and Mennan (1995). Though the later method determined higher values of economic threshold than the former, the trend was almost similar under the methods of determination (r= 0.9995**, significant at 1% level of significance). It is clearly indicated that any increase in the cost of treatment would lead to higher values of economic threshold, whereas an increase in price of crop produce would result in lowering the economic threshold. Manual weeding engaged more labour and had higher cost tending to increase the economic threshold more than the herbicidal treatments.

Weed management cost was highest under weed free followed by mechanical weeding. Cost of weed control under herbicidal/integrated treatments was 14-48.8% of weed free and 19.9-69.3% of that under mechanical weeding. Bispyribac 25 g/ha had lowest cost of weed management followed by oxadiargyl *fb* bispyribac. Due to lower cost of weed management, all herbicidal treatments gave more net return due to weed control over mechanical weeding. Oxadiargy *fb* bispyribac resulted in highest net return due to weed control followed by pendimethalin *fb* bispyribac *fb* manual weeding, pendimethalin *fb* bispyribac, bispyribac and pyrazosulfuron *fb* bispyribac. All herbicidal/integrated weed management treatments resulted in higher MBCR over mechanical weeding and weed free. MBCR was highest under bispyribac followed by oxadiargyl *fb* bispyribac, pyrazosulfuron *fb* bispyribac, pendimethalin *fb* bispyribac and bispyribac + chlorimuron + metsulfuron methyl.

Weed free had highest weed control efficiency followed by pendimethalin *fb* bispyribac *fb* manual weeding and pendimethalin *fb* bispyribac. Weed persistence index was highest under weed free followed by pendimethalin *fb* bispyribac and pendimethalin *fb* manual weeding. Crop resistance index was highest under pendimethalin *fb* bispyribac *fb* manual weeding. This was followed by oxadiargyl *fb* bispyribac, pyrazosulfuron *fb* bispyribac, weed free and pendimethalin *fb* bispyribac. Efficiency index indicates weed killing potential and

Table 4. Impact assessment indices

Treatment	Dose (g/ha)	Time (DAS)	WCE	WPI	CRI	EI	WI	WMI	AMI	IWMI	OP_i
Bispyribac-Na	25	20	74.7	1.90	5.47	3.39	-0.5	5.07	4.07	4.57	1.12
Pendimethalin *fb* bispyribac	1000, 25	0-2, 25	82.2	2.50	6.20	3.97	-5.9	5.01	4.01	4.51	1.09
Oxadiargyl *fb* bispyribac-Na	100, 25	0-2, 25	74.6	1.25	8.97	5.83	-9.2	4.19	3.19	3.69	1.31
Pyrazosulfum *fb* bispyribac-Na	20, 25	0-3, 25	75.1	1.51	6.85	4.19	1.5	4.14	3.14	3.64	1.18
Pendimethalin *fb* bispyribac *fb* manual weeding	1000, 25	0-2, 20, 45	82.5	1.33	12.99	8.71	-16.0	3.96	2.96	3.46	1.34
Pendimethalin *fb* manual weeding	1000	0-2, 25-30	73.3	2.22	3.61	1.92	18.4	5.23	4.23	4.73	0.85
Bispyribac-Na + chlorimuron + metsulfuron methyl	25+ 20+4	20	75.5	1.66	6.05	3.60	5.8	4.16	3.16	3.66	1.14
Cono/rotary weeder	-	15,30,45	32.9	0.80	4.16	2.29	14.8	4.81	3.81	4.31	0.84
Weed free	-		84.5	2.70	6.23	3.85	0.0	4.51	3.51	4.01	1.03
Weedy check	-		74.7	1.00	1.00	0.00	61.8	0	0	0	0.10
LSD (P=0.05)			-	-	-	-	-	-	-	-	-

Values given in the parentheses are the original means, DAS= Days after sowing, *fb*= Followed by ; WCE= Weed control efficiency (%); WPI= Weed persistence index; CRI= Crop resistance index; EI= Efficiency index; WI= Weed index; WMI= Weed management index; AMI= Agronomic management index; IWMI= Integrated weed management index; OP_i = overall performance index phytotoxicity on crop followed the trend similar to crop resistance index and was highest under pendimethalin *fb* bispyribac *fb* manual weeding. This was followed by oxadiargyl *fb* bispyribac, pyrazosulfuron *fb* bispyribac and pendimethalin *fb* bispyribac. Weed index indicates fall in yield over a weed free was minimum under pendimethalin *fb* bispyribac *fb* manual weeding followed by oxadiargyl *fb* bispyribac, pendimethalin *fb* bispyribac and bispyribac. The other treatments had positive weed index indicating poor performance than the weed free. WMI, AMI and IWMI were highest under pendimethalin *fb* manual weeding followed by bispyribac, pendimethalin *fb* bispyribac and mechanical weeding. Since the treatments under the impact assessment indices discussed above were less consistent in performance, an overall 'performance index' considering various indices as well as percent control of major weeds, yield and economics was drawn to have a valid inference. The overall performance index (OP_i) was highest under pendimethalin *fb* bispyribac *fb* manual weeding (1.34) followed by oxadiargyl *fb* bispyribac (1.31), pyrazosulfuron *fb* bispyribac (1.18), bispyriac + chlorimuron + metsulfuron (1.14), bisppyribac (1.12), pendimethalin *fb* bispyribac (1.09) and weed free (1.03). Thus in order of preference, pendimethalin 1000 g/ha (pre) *fb* bispyribac 25 g/ha (25 DAS) *fb* manual weeding (45 DAS), oxadiargyl 100 g/ha (pre) *fb* bispyribac 25 g/ha (25 DAS), pyrazosulfuron 20 g/ha (pre) *fb* bispyribac 25 g/ha (25 DAS), bispyriac 25 g/ha + chlorimuron 20 g/ha + metsulfuron 4 g/ha (20 DAS), bisppyribac 25 g/ha (20 DAS), pendimethalin 1000 g/ha (pre) *fb* bispyribac 25 g/ha (25 DAS) may be recommended for an effective weed management in direct seeded rice.

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