



## Management of complex weed flora with herbicides in direct-seeded rice under lateritic soil

S.S. Pinjari\*, S.B. Gangawane, N.V. Mhaskar, S.A. Chavan, U.V. Mahadkar and V.A. Rajemahadik  
College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli 415 712

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### ABSTRACT

Efficient weed management, restricting weed growth and weed density particularly within the critical growth period, could induce essential growth dynamics with subsequent yield advantage. Field investigation on weed density and weed dry weight in drilled rice was conducted at the Agronomy Farm, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (Maharashtra) in *Kharif* season to evaluate the effect of different herbicide and herbicide combination during 2012 to 2015. The lowest weed population and dry weight of grasses, sedges and broad-leaved weeds were recorded in weed free check followed by pendimethalin *fb* manual weeding and pendimethalin *fb* bispyribac-Na *fb* manual weeding. The treatment weedy check recorded the highest dry weight of weeds. The highest weed control efficiency (89.5%) and weed control index (95.0%) were recorded by weed free check followed by pendimethalin *fb* manual weeding (84.4 and 92.8%) and pendimethalin *fb* bispyribac-Na *fb* manual weeding (76.6 and 89.9%).

**Key words:** Direct-seeded rice, Weed density, Weed growth, Weed management, Yield

Konkan region is one of the important rice growing belt of Maharashtra having the highest productivity of 2.75 t/ha milled and 3.83 t/ha unmilled rice (brown rice). The Konkan region produces of 15.26 lakh tones unmilled (brown rice) and 10.53 lakh tones milled rice from 3.83 lakh ha area (Anonymous 2014). The production and productivity of rice is affected by several biotic and abiotic stresses. Weed competition is one of the most important limiting factors in rice production. Weed can suppress the crop growth accounting 15-90% yield loss unless controlled efficiently (Jha *et al.* 1997). Manual weeding is considered as best method but it is time consuming and uneconomical. Therefore, it has given importance to the use of herbicides to get timely as well as effective weed control. In direct-seeded rice, it is important to keep the field weed free for first 30-45 DAS to avoid any loss in yield because dry weight of weeds increased greatly from 30 DAS in direct-seeded rice (Huh *et al.* 1995). Therefore, use of pre-emergence or early post-emergence herbicides is effective and economical at initial stages to prevent or inhibits the growth of weeds. There is need to combine different weed management techniques, not only to minimize the overall weed competition but also to reduce the total cost involved in weeding operations. Keeping these views into account, the present study was done to generate data regarding efficiency of herbicides in different combinations.

### MATERIALS AND METHODS

A field experiment was conducted during 2012 to 2015 at Department of Agronomy, College of Agriculture at Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (MS) to evaluate the effect of herbicide combination on weed density, weed dry matter and weed control efficiency in direct-seeded rice. The experiment was laid out in randomized block design with three replication consisted of ten treatments *i.e.* bispyribac-Na at 25 g/ha 20 DAS (3-4 leaf stage), pendimethalin (PE) at 1000 g/ha 0 to 2 DAS *fb* bispyribac-Na at 25 g/ha 20 DAS (3-4 leaf stage), oxadiargyl at 100 g/ha 0 to 2 DAS *fb* bispyribac-Na at 25 g/ha 25 DAS, pyrazosulfuron at 20 g/ha 0 to 3 DAS *fb* bispyribac-Na at 25 g/ha 25 DAS, pendimethalin (PRE) at 1000 g/ha 0 to 3 DAS *fb* bispyribac-Na at 25 g/ha. 25 DAS *fb* manual weeding at 45 DAS, pendimethalin (PRE) at 1000 g/ha 0 to 2 DAS *fb* manual weeding at 25 to 30 DAS, bispyribac-Na at 20 g/ha + chlorimuron + metsulfuron at 4 g/ha 20 DAS, three mechanical weeding (cono/rotary weeder) at 20, 40 and 60 DAS, weed free check (HW at 20, 40 and 60 DAS) and weedy check. The soil of the experimental plot was sandy clay loam in texture, acidic in pH (5.80) and medium in organic carbon content (1.38). It was low in available nitrogen (282.1 kg/ha), medium in available phosphorus (10.8 kg/ha), and high in available potassium (235.9 kg/ha).

The seed of rice variety 'Ratnagiri-1' treated with thiram at the rate of 3 g/kg of seed was used for

\*Corresponding author: pinjari94222@gmail.com

sowing. Sowing was done by opening small furrows of about 3 cm depth with the help of marker at a distance of 20 cm between the lines on onset of monsoon. The rice seed rate of 60 kg/ha was used and covered with the soil. The recommended dose of fertilizer was applied to all the plots. The uniform representative samples of weeds at 60 and 90 DAS were randomly collected from each plot and dried. Data were analyzed statistically harvesting and yield data using standard methods of Panse and Sukhatme (1984).

**RESULTS AND DISCUSSION**

The major weed flora observed during the experimentation were, viz. *Cyperus rotundus*, *Isachne globosa*, *Ludwigia octovalis*, *Cloem viscosa*, *Echinochloa colona*, *Ischemum rugosum*, *Amaranthus sessilis*, *Mimosa pudica*, *Physalis minima*, *Ageratum conyzoides* and *Celocia argentea*.

Application of pendimethalin fb manual weeding remained at par with weed free check and pendimethalin fb bispyribac-Na fb manual weeding recorded significantly lower density of monocots than the remaining treatments during the year 2013, 2014 and in pooled results. However, pendimethalin fb manual weeding showed the lowest weed density over rest of the weed control measures tried except weed free check, bispyribac-Na, pendimethalin fb bispyribac-Na, pyrazosulfuron fb bispyribac-Na and bispyribac-Na + (chlorimuron + metsulfuron), which were at par with each other during 2012 (Table 1) .

Weed density of broad-leaved weeds at 60 DAS was not significantly influenced due to different weed control measures during all individual years of experimentation except 2014 and in pooled means. Weed free check recorded significantly lowest weed density of broad-leaved weeds except pendimethalin fb manual weeding. The weed free check resulted in the highest weed control efficiency followed by pendimethalin fb manual weeding and pendimethalin fb bispyribac-Na fb manual weeding.

At 90 DAS, weed free check (3 HW) reduced the density of monocots significantly over all other weed control measures tried, except use of pendimethalin fb manual weeding and pendimethalin fb bispyribac-Na fb manual weeding during 1<sup>st</sup> year and in pooled results while, pendimethalin fb manual weeding during 2<sup>nd</sup> year (Table 2). However, during 3<sup>rd</sup> year, use of pendimethalin fb bispyribac-Na fb manual weeding recorded the lowest weed density of monocots than all other weed control measures, except weed free check and pendimethalin fb manual weeding. Similar effective lower density of grasses, sedges and broad leaved weeds in rice field was documented by Sharma *et al.* (2007) and Walia *et al.* (2012).

**Effect on weed dry weight**

During the first year (2012) of the experiment, use of pendimethalin fb manual weeding significantly reduced the growth of monocots as compared to use of bispyribac-Na, pendimethalin fb bispyribac-Na,

**Table 1. Effects of herbicide combinations on weed density (0.25/m<sup>2</sup>) and weed control efficiency (four year pooled mean) at 60 DAS**

Treatment	Grasses and Sedges					Broad-leaved weeds					WCE %				
	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled
Bispyribac-Na 25 g/ha at 20 DAS	33.00 (5.68)	29.00 (5.16)	44.33 (6.64)	19.67 (4.45)	15.71 (4.00)	00.00 (0.71)	00.00 (0.71)	15.00 (3.93)	1.33 (1.18)	3.46 (1.98)	52.9	41.2	58.4	50.0	35.9
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	53.00 (6.56)	21.33 (4.32)	23.33 (4.88)	21.33 (4.66)	14.02 (3.80)	1.67 (1.26)	3.00 (1.68)	11.00 (3.38)	4.00 (2.12)	2.73 (1.80)	21.9	50.7	75.9	39.7	44.0
Oxadiazargyl (PRE) 100 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	26.33 (4.64)	23.33 (4.41)	17.00 (4.13)	20.00 (4.52)	13.13 (3.67)	1.00 (1.10)	00.00 (0.71)	14.67 (3.89)	2.33 (1.57)	1.96 (1.57)	61.0	52.7	77.8	46.8	49.6
Pyrazosulfuron (PRE) 20 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	33.00 (5.68)	34.67 (5.88)	32.33 (5.70)	25.00 (5.03)	18.61 (4.34)	0.00 (0.71)	0.00 (0.71)	15.00 (3.91)	4.33 (2.18)	1.89 (1.54)	52.9	29.7	66.8	30.2	31.5
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS fb manual weeding at 45 DAS	57.00 (4.43)	2.67 (1.74)	15.67 (4.00)	9.33 (3.06)	6.36 (2.54)	4.00 (1.63)	1.00 (1.17)	9.33 (3.13)	3.67 (1.83)	1.61 (1.42)	12.9	92.6	82.5	69.0	73.4
Pendimethalin (PRE) 1000 g/ha fb manual weeding 25-30 DAS	76.67 (2.60)	0.67 (1.00)	16.00 (4.05)	8.67 (3.02)	4.07 (2.14)	3.00 (1.50)	3.33 (1.79)	6.67 (2.67)	0.67 (1.00)	1.38 (1.36)	86.2	91.9	84.1	77.8	81.8
Bispyribac-Na 20 g/ha + almix 4 g/ha at 20 DAS (chlorimuron + metsulfuron)	55.00 (7.41)	26.00 (5.02)	45.67 (6.78)	19.33 (4.42)	11.48 (3.46)	7.33 (2.04)	0.0 (0.71)	13.67 (3.76)	3.00 (1.72)	3.33 (1.93)	11.0	47.3	58.4	46.8	50.5
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	21.33 (4.45)	12.00 (2.88)	28.67 (5.37)	13.00 (3.57)	8.59 (2.95)	15.00 (3.59)	3.67 (1.85)	11.00 (3.37)	2.33 (1.68)	2.07 (1.60)	48.1	68.24	72.2	63.5	64.4
Weed free check (HW at 20,40 and 60 DAS)	87.67 (2.85)	3.00 (1.86)	16.00 (4.03)	4.67 (2.24)	3.48 (1.99)	0.67 (1.00)	0.0 (0.71)	5.33 (2.39)	0.67 (1.00)	0.78 (1.12)	88.1	93.9	85.0	87.3	85.8
Weedy check	57.00 (7.45)	47.67 (6.71)	116.00 (10.78)	34.00 (5.86)	23.74 (4.92)	12.67 (2.53)	1.67 (1.39)	26.67 (5.26)	8.00 (2.87)	6.18 (2.58)	-	-	-	-	-
LSD (P=0.05)	(2.20)	(1.86)	(0.78)	(0.89)	(0.79)	(N.S.)	(N.S.)	(0.55)	(N.S.)	(N.S.)	-	-	-	-	-

Figures in parentheses are  $\sqrt{x+0.5}$  transformed values; PE - pre-emergence; POE - post-emergence

pyrazosulfuron fb bispyribac-Na, weedy check and remained at par with rest of the treatments. However, during other years and in pooled results, the use of pendimethalin fb manual weeding recorded significantly lower weed growth than rest of the treatments except pendimethalin fb bispyribac-Na fb

manual weeding and weed free check. Various weed control measures tried did not significantly influence growth of broad-leaved weeds during individual years as well as in pooled results at 60 DAS (Table 3 and 4). Walia *et al.* (2012) also reported similar results in drilled rice.

**Table 2. Effects of herbicide combinations on weed density at 90 DAS (no. 0.25/m<sup>2</sup>) and weed control efficiency (four year pooled mean)**

Treatment	Grasses and sedges					Broad-leaved weeds					WCE %				
	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled
Bispyribac-Na 25 g/ha at 20 DAS	26.00	46.67	42.33	18.00	33.25	00.00	00.00	15.67	6.67	5.58	16.1	71.5	56.4	50.7	58.9
	(5.04)	(6.81)	(6.50)	(4.26)	(5.81)	(0.71)	(0.71)	(4.02)	(2.66)	(2.47)					
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	17.33	19.33	22.67	22.67	20.50	3.00	3.67	11.67	5.67	6.00	34.4	86.0	74.2	43.3	72.0
	(4.09)	(4.22)	(4.81)	(4.79)	(4.58)	(1.50)	(1.81)	(3.51)	(2.45)	(2.55)					
Oxadiargyl (PRE) 100 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	17.67	26.00	18.33	21.00	20.75	2.67	0.33	15.00	6.00	6.00	34.4	83.9	74.9	46.0	71.7
	(3.87)	(4.76)	(4.32)	(4.61)	(4.60)	(0.89)	(0.88)	(3.94)	(2.54)	(2.55)					
Pyrazosulfuron (PRE) 20 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	23.33	76.33	27.67	28.33	38.92	0.00	0.67	15.33	6.33	5.58	24.7	53.0	67.7	30.7	52.9
	(4.74)	(8.73)	(5.28)	(5.31)	(6.27)	(0.71)	(1.00)	(3.95)	(2.59)	(2.45)					
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS fb manual weeding at 45 DAS	1.00	32.33	15.67	9.00	14.50	8.67	4.00	12.00	5.67	7.58	68.8	77.8	79.2	70.7	76.6
	(1.17)	(5.32)	(4.00)	(3.07)	(3.83)	(2.98)	(2.02)	(3.53)	(2.47)	(2.84)					
Pendimethalin (PRE) 1000 g/ha fb manual weeding 25-30 DAS	3.00	5.33	17.67	7.33	8.33	7.33	6.67	7.67	4.00	6.42	66.7	92.7	80.9	77.3	84.4
	(1.71)	(2.06)	(4.26)	(2.79)	(2.96)	(2.65)	(2.58)	(2.83)	(2.09)	(2.61)					
Bispyribac-Na 20 g/ha + almix 4 g/ha at 20 DAS (chlorimuron + metsulfuron)	19.00	39.33	39.67	18.67	29.17	0.00	1.00	15.00	6.33	5.58	38.7	75.4	58.9	50.0	63.2
	(4.32)	(6.26)	(6.30)	(4.34)	(5.45)	(0.71)	(1.10)	(3.94)	(2.59)	(2.46)					
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	12.67	30.00	20.67	10.33	18.42	5.67	3.67	10.00	4.33	5.92	40.8	79.5	76.9	70.7	74.2
	(3.15)	(5.31)	(4.68)	(3.23)	(4.31)	(2.24)	(1.55)	(3.24)	(2.15)	(2.50)					
Weed free check (HW at 20,40 and 60 DAS)	0.67	3.00	18.00	4.33	6.50	1.00	1.00	9.00	2.67	3.42	94.6	97.6	79.7	86.0	89.5
	(1.00)	(1.82)	(4.10)	(2.18)	(1.96)	(1.10)	(1.10)	(3.08)	(1.76)	(1.96)					
Weedy check	21.00	156.67	105.67	40.33	80.92	10.00	7.33	27.33	9.67	13.58					
	(4.56)	(12.03)	(10.29)	(6.37)	(8.95)	(2.81)	(2.17)	(5.27)	(3.18)	(3.72)					
LSD (P=0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(1.46.)	(2.25)	(0.62)	(0.90)	(0.75)	(2.11)	(N.S.)	(0.40)	0.64	0.58					

Figures in parentheses are  $\sqrt{x+0.5}$  transformed values

**Table 3. Effects of herbicide combinations on weed dry weight (g) at 60 DAS (0.25/m<sup>2</sup>) and weed control index (four year pooled mean)**

Treatment	Grasses and Sedges					Broad-leaved weeds					WCI %				
	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled
Bispyribac-Na 25 g/ha at 20 DAS	24.67	3.84	14.67	6.31	12.37	00.00	00.00	12.50	0.25	3.19	30.2	65.7	12.8	59.2	33.7
	(4.74)	(1.97)	(3.88)	(2.58)	(3.55)	(0.71)	(0.71)	(3.59)	(0.85)	(1.91)					
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	19.67	2.75	12.33	6.67	10.35	0.33	0.27	6.33	1.51	2.11	43.4	73.0	40.1	49.2	46.9
	(4.34)	(1.79)	(3.56)	(2.67)	(3.28)	(0.88)	(0.87)	(2.61)	(1.41)	(1.61)					
Oxadiargyl (PRE) 100 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	15.00	3.53	14.00	8.45	10.25	0.33	0.00	5.17	0.98	1.62	56.6	68.5	38.5	41.4	49.4
	(3.40)	(2.00)	(3.80)	(2.99)	(3.24)	(0.88)	(0.71)	(2.37)	(1.16)	(1.45)					
Pyrazosulfuron (PRE) 20 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	27.33	4.09	10.00	8.61	14.51	0.00	0.00	3.23	2.37	1.40	22.7	63.5	57.6	29.9	32.2
	(4.83)	(2.13)	(3.30)	(2.98)	(3.83)	(0.71)	(0.71)	(1.92)	(1.69)	(1.38)					
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS fb manual weeding at 45 DAS	10.67	0.44	5.00	3.39	4.87	0.33	0.09	2.33	0.95	0.93	68.9	95.3	76.5	73.0	75.3
	(2.79)	(0.96)	(2.34)	(1.96)	(2.24)	(0.88)	(0.77)	(1.66)	(1.15)	(1.19)					
Pendimethalin (PRE) 1000 g/ha fb manual weeding 25-30 DAS	1.00	0.12	6.50	1.60	2.31	0.33	0.36	4.17	0.00	1.22	96.2	95.7	65.8	90.1	83.9
	(1.22)	(0.78)	(2.64)	(1.42)	(1.67)	(0.88)	(0.91)	(2.14)	(0.71)	(1.30)					
Bispyribac-Na 20 g/ha + almix 4 g/ha at 20 DAS (chlorimuron + metsulfuron)	10.33	2.42	13.83	6.23	8.20	3.33	0.00	7.00	1.31	2.91	61.3	78.4	33.2	53.2	52.6
	(3.18)	(1.57)	(3.78)	(2.55)	(2.94)	(1.53)	(0.71)	(2.73)	(1.31)	(1.83)					
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	4.33	4.37	12.67	4.13	6.38	1.33	0.44	4.17	0.87	1.70	84.0	57.0	46.0	68.9	65.6
	(2.09)	(2.00)	(3.61)	(2.14)	(2.59)	(1.34)	(0.96)	(2.13)	(1.17)	(1.48)					
Weed free check (HW at 20,40 and 60 DAS)	2.00	0.42	6.83	3.30	3.14	0.33	0.00	2.12	0.23	0.67	93.4	96.2	71.3	78.1	84.8
	(1.52)	(1.03)	(2.70)	(1.94)	(1.91)	(0.88)	(0.71)	(2.26)	(0.83)	(1.08)					
Weedy check	32.67	10.80	17.50	12.69	18.42	2.67	0.40	13.67	3.41	5.04	-	-	-	-	-
	(5.70)	(3.25)	(4.22)	(3.63)	(4.34)	(1.45)	(0.98)	(6.87)	(1.92)	(2.35)					
LSD (P=0.05)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(2.39)	(1.05)	(0.45)	0.70	(0.85)	(N.S.)	(N.S.)	(N.S.)	(N.S.)	(N.S.)					

Figures in parentheses are  $\sqrt{x+0.5}$  transformed values

The pooled data indicated that, the highest weed control index on the basis of weed dry weight was recorded under weed free check (84.8 and 95.0 at 60 and 90 DAS, respectively) followed by pendimethalin fb manual weeding and pendimethalin fb bispyribac-Na fb manual weeding at all the stages of observations. These results were in conformity with the findings of Walia *et al.* (2012) and Ganie *et al.* (2013).

**Effect on yield and yield attributes**

Weed free check (three hand weeding) recorded significantly higher plant height over all other

treatments followed by pendimethalin (PE) at 1000 g/ha 0 to 2 DAS fb manual weeding at 25 to 30 DAS while in respect of number of tillers, weed free check (HW at 20, 40, and 60 DAS) recorded significantly higher number of tillers except pendimethalin (PE) at 1000 g/ha 0 to 2 DAS fb manual weeding at 25 to 30 DAS. Weed free check (HW at 20, 40, and 60 DAS) also recorded significantly higher weight of filled grains per panicle as compared to bispyribac-Na at 25 g/ha 20 DAS, oxadiargyl at 100 g/ha 0 to 2 DAS fb bispyribac-Na at 25 g/ha 25 DAS, pendimethalin (PE) at 1000 g/ha 0 to 3 DAS fb bispyribac-Na at 25 g/ha

**Table 4. Effects of herbicide combinations on weed dry weight (g) at 90 DAS (0.25/m<sup>2</sup>) and weed control index (four year pooled mean)**

Treatment	Grasses and Sedges					Broad-leaved weeds					WCI %				
	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled
Bispyribac-Na 25 g/ha at 20 DAS	33.50 (5.76)	102.00 (9.87)	25.38 (5.08)	2.67 (1.77)	39.48 (6.32)	00.00 (0.71)	00.00 (0.71)	18.70 (4.36)	2.27 (1.66)	1.66 (1.47)	68.5	16.4	24.2	56.8	32.1
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	20.00 (4.30)	23.67 (4.00)	18.04 (4.29)	2.87 (1.83)	12.71 (3.53)	1.33 (1.39)	1.00 (1.17)	9.10 (3.06)	2.65 (1.77)	2.26 (1.65)	81.1	79.8	53.4	51.7	75.3
Oxadiargyl (PRE) 100 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	36.83 (6.02)	86.33 (8.27)	20.37 (4.56)	2.82 (1.81)	32.64 (5.45)	1.17 (1.22)	0.33 (0.88)	9.47 (3.14)	2.11 (1.61)	1.69 (1.48)	66.3	29.0	48.7	56.9	43.4
Pyrazosulfuron (PRE) 20 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	28.83 (5.13)	66.33 (7.98)	29.78 (5.50)	3.16 (1.91)	25.96 (5.04)	0.00 (0.71)	0.33 (0.71)	6.18 (2.56)	2.68 (1.78)	1.40 (1.37)	74.4	45.4	38.2	48.9	54.9
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS fb manual weeding at 45 DAS	1.00 (1.15)	12.33 (3.22)	10.81 (3.35)	1.08 (1.25)	4.44 (2.18)	1.67 (1.45)	1.00 (1.22)	3.70 (2.04)	2.08 (1.58)	1.70 (1.48)	97.6	89.1	75.1	72.4	89.9
Pendimethalin (PRE) 1000 g/ha fb manual weeding 25-30 DAS	2.50 (1.53)	1.33 (1.27)	12.90 (3.65)	2.18 (1.64)	2.41 (1.69)	1.50 (1.38)	1.33 (1.34)	6.19 (2.90)	1.99 (1.55)	1.93 (1.56)	96.4	97.8	67.2	63.5	92.8
Bispyribac-Na 20 g/ha + almix 4 g/ha at 20 DAS (chlorimuron + metsulfuron)	17.50 (4.16)	112.67 (10.43)	21.61 (4.68)	2.67 (2.67)	34.34 (5.84)	0.00 (0.71)	0.33 (0.88)	13.16 (3.64)	2.77 (1.81)	1.69 (1.48)	84.5	7.4	40.3	52.4	40.5
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	10.50 (3.24)	53.00 (6.51)	18.26 (4.31)	2.60 (1.76)	17.60 (4.11)	15.17 (3.36)	0.67 (1.05)	7.20 (2.75)	1.99 (1.54)	5.14 (2.28)	77.2	56.0	56.3	59.9	62.5
Weed free check (HW at 20,40 and 60 DAS)	1.67 (1.26)	1.00 (1.22)	11.32 (3.43)	2.31 (1.67)	2.10 (1.60)	0.17 (0.81)	0.33 (0.88)	3.48 (1.97)	1.24 (1.30)	0.93 (1.19)	98.4	98.9	74.6	69.0	95.0
Weedy check	74.50 (8.47)	116.67 (10.78)	32.90 (5.77)	5.59 (2.45)	46.96 (6.79)	38.33 (5.28)	5.33 (2.12)	25.32 (5.07)	5.85 (2.51)	13.65 (3.54)	-	-	-	-	-
LSD (P=0.05)	- (1.61)	- (1.52)	- (0.45)	- (0.42)	- (1.31)	- (3.42)	- (1.19)	- (0.70)	- (0.52)	- (1.25)	-	-	-	-	-

Figures in parentheses are  $\sqrt{x+0.5}$  transformed values

**Table 5. Effects of herbicide combinations on growth and yield attributes of rice (four year pooled mean)**

Treatment	Height (cm)					No. of tillers					Panicle length (cm)					Weight of filled grain /panicles				
	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled
Bispyribac-Na 25 g/ha at 20 DAS	52.40	65.7	83.3	69.9	67.8	37.3	96.0	62.0	40.3	58.9	18.4	19.3	19.3	18.8	18.9	1.03	2.97	1.98	2.07	2.07
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	57.0	71.5	89.7	75.0	73.3	31.0	64.0	61.7	44.3	46.6	18.1	21.5	20.2	19.4	19.8	1.47	3.70	2.52	2.19	2.19
Oxadiargyl (PRE) 100 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	59.7	63.5	88.2	74.7	71.5	50.0	72.7	64.0	43.3	57.5	19.7	20.3	20.3	19.7	20.0	2.01	4.18	2.40	2.06	2.06
Pyrazosulfuron (PRE) 20 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	51.4	66.9	86.8	73.9	69.8	47.0	56.0	63.0	44.7	52.7	18.5	19.3	18.4	18.9	18.8	2.11	2.64	2.00	2.23	2.23
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS fb manual weeding at 45 DAS	63.7	72.6	91.3	79.3	76.6	48.3	62.7	66.0	51.3	54.2	19.3	19.6	31.4	19.9	20.0	2.01	3.38	3.19	2.08	2.08
Pendimethalin (PRE) 1000 g/ha fb manual weeding 25-30 DAS	59.7	69.7	93.2	78.9	75.4	60.7	75.3	69.0	50.0	63.7	19.9	20.5	21.5	20.1	20.5	2.25	3.35	3.08	2.24	2.24
Bispyribac-Na 20 g/ha + almix 4 g/ha at 20 DAS (chlorimuron+metsulfuron)	49.5	76.1	83.3	72.2	70.3	35.3	60.0	60.7	46.3	50.6	18.9	21.4	19.0	18.9	19.6	2.09	3.17	2.48	2.26	2.26
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	55.7	71.5	89.5	74.4	73.0	36.7	76.0	62.0	47.0	53.6	18.2	20.7	20.4	19.4	19.7	1.52	3.52	2.48	2.21	2.21
Weed free check (HW at 20,40 and 60 DAS)	60.8	76.4	91.0	80.6	77.7	51.7	80.0	68.0	56.3	64.0	19.3	20.4	20.7	20.0	20.1	2.22	3.68	2.63	2.27	2.27
Weedy check	54.6	61.2	79.3	62.9	64.5	32.0	66.0	56.0	45.7	45.3	19.5	18.7	16.8	17.7	18.5	2.00	2.20	1.90	1.90	1.86
LSD (P=0.05)	NS	NS	1.01	1.75	0.77	N.S.	N.S.	0.80	0.63	2.62	N.S.	N.S.	0.33	N.S.	N.S.	N.S.	0.88	0.45	0.08	0.08

**Table 6. Effects of herbicide combinations on yield and yield attributes of rice (four year pooled mean) and weed index**

Treatment	Grain yield (t/ha)					Straw yield (t/ha)					WI (%)				
	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled	2012	2013	2014	2015	Pooled
Bispyribac-Na 25 g/ha at 20 DAS	1.95	2.31	2.86	2.78	2.23	2.04	2.42	4.91	3.35	2.93	33.6	56.1	27.7	17.1	42.6
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	1.79	5.04	3.52	2.78	3.04	2.00	5.30	5.47	3.39	3.79	38.9	4.2	11.2	16.9	21.8
Oxadiargyl (PRE) 100 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	1.80	4.06	3.68	2.89	3.10	1.91	4.30	5.29	3.54	3.76	38.9	22.9	7.3	13.7	20.0
Pyrazosulfuron (PRE) 20 g/ha fb bispyribac-Na 25 g/ha at 25 DAS	1.64	3.28	2.92	2.58	2.61	1.91	3.68	4.19	3.06	3.21	44.1	37.6	26.2	23.0	32.8
Pendimethalin (PRE) 1000 g/ha fb bispyribac-Na 25 g/ha at 25 DAS fb manual weeding at 45 DAS	2.57	4.64	3.92	3.20	3.58	2.89	5.01	5.82	3.86	4.40	12.5	11.9	1.1	4.4	7.7
Pendimethalin (PRE) 1000 g/ha fb manual weeding 25-30 DAS	2.32	5.23	3.94	3.21	3.68	2.41	5.65	5.55	3.88	4.38	21.0	0.6	0.5	4.3	5.3
Bispyribac-Na 20 g/ha + almix 4 g/ha at 20 DAS (chlorimuron + metsulfuron)	1.13	3.83	2.77	2.73	2.62	1.22	4.14	4.67	3.32	3.34	61.5	27.2	30.0	18.5	32.6
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	1.79	3.75	3.56	2.51	2.90	1.91	4.05	5.29	3.13	3.59	39.1	28.7	10.2	25.2	25.2
Weed free check (HW at 20,40 and 60 DAS)	2.94	5.26	3.96	3.35	3.88	3.04	5.68	5.96	4.02	4.68	-	-	-	-	-
Weedy check	0.33	1.09	2.0	2.49	1.48	0.38	1.18	3.43	2.92	1.98	88.7	79.1	49.6	25.8	61.9
LSD (P=0.05)	0.16	0.21	0.07	0.16	0.08	0.11	0.117	0.15	0.17	0.10	-	-	-	-	-

25 DAS fb manual weeding at 45 DAS and weedy check. Similar results of higher yield attributes of direct-seeded rice were reported by Veeraputhiran and Balasubramanian (2013) and Chauhan *et al.* (2013).

Consequently, weed free check (Table 6) (HW at 20,40, and 60 DAS) produced significantly higher grain and straw yield as 3.88 and 4.68 t/ha, respectively over rest of the treatments except pendimethalin (PRE) at 1000 g/ha 0 to 2 DAS fb manual weeding at 25 to 30 DAS (3.68 and 4.38 t/ha) and pendimethalin(PE) at 1000 g/ha 0 to 3 DAS fb bispyribac-Na at 25 g/ha 25 DAS fb manual weeding at 45 DAS (3.58 and 4.40 t/ha), which were at par with each other (Table 6). Weed free check (HW at 20, 40, and 60 DAS) also indicated higher per cent increment of grain yield (162.8%) over weedy check followed by pendimethalin (PE) at 1000 g/ha 0 to 2 DAS fb manual weeding at 25 to 30 DAS (148.9%). Compared to best treatment of weed free check (HW at 20, 40, and 60 DAS), the weed index (WI) which indicate the increase in grain yield was maximum under pendimethalin (PRE) at 1000 g/ha 0 to 2 DAS fb manual weeding at 25 to 30 DAS (5.26%) closely followed by pendimethalin (PRE) at 1000 g/ha 0 to 3 DAS fb bispyribac-Na at 25 g/ha. 25 DAS fb manual weeding at 45 DAS (7.70%). Similar results of higher yield attributes of direct-seeded rice was reported by Veeraputhiran and Balasubramanian (2013) and Naseeruddin and Subramanyam (2013).

The combination of chemical and cultural/physical control measures (pendimethalin fb manual weeding and pendimethalin fb bispyribac-Na fb manual weeding) were effective for weed control in drilled rice than the application of chemical herbicides, cultural or mechanical control alone.

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