Indian Journal of Weed Science **48**(3): 279–283, 2016
DOI: 10.5958/0974-8164.2016.00068.X

Integrated use of herbicides to enhance yield and economics of direct-seeded rice

S.S. Pinjari*, S.B. Gangawane, N.V. Mhaskar, S.A. Chavan, V.G. Chavan and D.N. Jagtap
Department of Agronomy, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra 415 712

Received: 2 July 2016; Revised: 24 August 2016

ABSTRACT

A field study was conducted at Dr. B.S. KKV, Dapoli (Maharashtra) farm in *Kharif* seasons (2012 to 2015) on rice to evaluate the effect of different herbicide and herbicide combination on yield attributes, yield and economics. Based on pooled analysis, significantly lower dry weight of grasses, sedges and broad-leaved weeds and higher yield attributes and yield were recorded in weed free check (HW at 20, 40, and 60 DAS) followed by pendimethalin as pre-emergence (PE) 1000 g/ha at 0 to 2 DAS *fb* manual weeding at 25-30 DAS and pendimethalin 1000 g/ha at 0 to 2 DAS (PE) *fb* bispyribac-Na 25 g/ha at 20 DAS (3 to 4 leaf stage) *fb* manual weeding (45 DAS). The highest weed control index (95.00%) was recorded by weed free check (HW at 20, 40, and 60 DAS) followed by pendimethalin 1000 g/ha at 0 to 2 DAS *fb* manual weeding at 25-30 DAS (92.84%) and pendimethalin 1000 g/ha at 0 to2 DAS *fb* bispyribac-Na 25 g/ha at 20 DAS *fb* manual weeding at 45 DAS (89.87%). The lowest weed index was recorded with the application of pendimethalin 1000 g/ha at 0 to 2 DAS *fb* manual weeding (25-30 DAS) and pendimethalin 1000 g/ha at 0 to 2 DAS *fb* bispyribac-Na 25 g/ha at 20 DAS (3 to 4 leaf stage) *fb* manual weeding at 45 DAS. The highest net returns with B-C ratio of 1.28 was obtained in the application of pendimethalin 1000 g/ha at 0 to 2 DAS (PE) *fb* manual weeding (25-30 DAS) followed by weed free check (HW at 20, 40 and 60 DAS).

Key words: Direct-seeded rice, Economics, Herbicides, Weed control, Yield attributes, Yield

In India, rice is cultivated under various ecosystems *viz.* transplanted and direct sown under irrigated and rainfed situations. Rice is generally established through transplanting method and this practice has been widely adopted by the farmers in Konkan region of Maharashtra. However, with increasing scarcity and cost of human labour, direct seeding of rice through drum seeder is one of the technological options which will not only address this problem but also increase the rice productivity. Direct sowing of rice offers the advantage of quicker, easier sowing, reduce labour requirement, hastens crop maturity and more economical. However, the weed infestation is the main problem in this method. Weed pressure is often two to three times more in direct-seeded rice as compared to transplanted one. The yield losses due to weeds are 36% in transplanted rice but as high as 84% in direct sown rice (Ravichandran 1991). The extent of yield reduction due to weed infestation was worked out at 15-20% under transplanted system and more than 50% in direct-seeded system (Pillai and Rao 1974). Infestation of heterogeneous weed flora becomes the biggest biological constraints in direct-seeded rice. The success of direct-seeded rice is dependent upon efficient weed control. For direct-seeded rice, it is important to keep field weed free for at least first 30 days. Therefore, use of pre-emergence or early post-emergence herbicides is effective and economical at initial stages. The pre-emergence or early post-emergence herbicide either prevents weed seeds to emerge or inhibits the growth of seedlings. Use of these herbicides along with post-emergence herbicides or cultural, mechanical and agronomic methods of weed control gives effective control of weeds. Thus, the present study was undertaken to explore the possibility of use of herbicides under such situations for efficient and economic weed management to increase the yield level in direct seeded rice.

***Corresponding author:** pinjari94222@gmail.com

MATERIALS AND METHODS

A field experiment was conducted during 2012 to 2015 at Research Farm of Department of Agronomy, College of Agriculture, Dapoli (Maharashtra). The experimental site was located at west coast 250 meter height from mean sea level having annual average rainfall 3500 mm with 95 to 100 rainy days throughout *Kharif* season. The experiment was laid out in randomized block design with three replications. The ten treatment comprised; bispyribac-Na 25 g/ha at 20 DAS (3-4 leaf stage), pendimethalin as pre-emergence (PE) 1000 g/ha at 0

to 2 DAS *fb* bispyribac-Na 25 g/ha at 20 DAS (3-4 leaf stage), oxadiargyl 100 g/ha at 0 to 2 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS, pyrazosulfuron 20 g/ha at 0 to 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS, pendimethalin 1000 g/ha at 0 to 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS *fb* manual weeding at 45 DAS, pendimethalin 1000 g/ha at 0 to 2 DAS *fb* manual weeding at 25 to 30 DAS, bispyribac-Na 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 and medium in organic carbon content. It was low in available nitrogen (282 kg/ha), medium in available phosphorus (10.8 kg/ha) and high in available potassium (236 kg/ha).

The gross plot size was 5.0 x 3.0 m. The seed of rice variety *'Ratnagiri-1'* was treated with thiram at the rate of 3 g/kg of seed used for 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. The rice seed was sown about 3 cm deep manually at the rate of 60 kg/ha and covered with the soil. The recommended dose of fertilizer (100:50:50 NPK kg/ha) was applied to all the plots. Half dose of nitrogen and full dose of phosphorus and potassium was applied at the time of sowing while remaining half dose of nitrogen was applied at 30 days after sowing of crop. The uniform representative samples of crop as well as weeds were randomly collected from each plot. Data were analyzed (pooled analysis) statistically by using standard methods of Panse and Sukhatme (1984).

RESULTS AND DISCUSSION

Effect on weed growth

Various weed control measures significantly influenced growth of monocots during all the years of experimentation and in pooled results (Table 1 and 2). 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, 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 (BLWS) during individual years as well as in pooled results at 60 DAS. Walia *et al.* (2012) also reported similar results in drilled rice.

Application of pendimethalin *fb* bispyribac–Na *fb* manual weeding, pendimethalin *fb* manual weeding and weed free check remained at par with each other and reduced significantly the weed growth of monocots during 1st, 3rd and 4th years as well as in pooled results at 90 DAS. However, weed free check (3 HW) reduced the weed growth of monocots significantly during 2013 over all other weed control measures tried except use of pendimethalin *fb* manual weeding.

Weed growth of BLWS was reduced significantly due to various weed control measures tried over weedy check and remained at par with each other during the year 2012, 2013, 2015 and in pooled results. However, weed free check (3 HW) reduced significantly the growth of BLWS during the year 2014 over all other treatments except the use of pendimethalin *fb* bispyribac-Na *fb* manual weeding and pyrazosulfuron *fb* bispyribac-Na.

The pooled data indicated that, the highest weed control index was recorded under weed free check (84.76 and 95.00 at 60 and 90 DAS) 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 attributes and yield

Different weed control treatments significantly influenced the yield attributes, *viz*. plant height, number of tillers and weight of filled grains per panicle over weedy check (Table 1). Weed free check (three hand weeding) recorded significantly higher plant height over all other treatments followed by pendimethalin 1000 g/ha at 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 1000 g/ha at 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 at 20 DAS, oxadiargyl at 100 g/ha 0 to 2 DAS *fb* bispyribac-Na at 25 g/ha 25 DAS, pendimethalin at 1000 g/ha 0 to 3 DAS *fb* bispyribac-Na at 25 g/ha at 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

Table 1. Effects of herbicide combinations on weed growth at 60 DAS (no. 0.25 m^2) (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 (4.74)	3.84 (1.97)	14.67 (3.88)	6.31 (2.58)	12.37 (3.55)	00.00 (0.71)	00.00 (0.71)	12.50 (3.59)	0.25 (0.85)	3.19 (1.91)	30.2	65.7	12.8	59.2	33.7
Pendimethalin (PE) 1000 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS	19.67 (4.34)	2.75 (1.79)	12.33 (3.56)	6.67 (2.67)	10.35 (3.28)	0.33 (0.88)	0.27 (0.87)	6.33 (2.61)	1.51 (1.41)	2.11 (1.61)	43.4	73.0	40.1	49.2	46.9
Oxadiargyl (PE) 100 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS	15.00 (3.40)	3.53 (2.00)	14.00 (3.80)	8.45 (2.99)	10.25 (3.24)	0.33 (0.88)	0.00 (0.71)	5.17 (2.37)	0.98 (1.16)	1.62 (1.45)	56.6	68.5	38.5	41.4	49.4
Pyrazosulfuron (PE) 20 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS	27.33 (4.83)	4.09 (2.13)	10.00 (3.30)	8.61 (2.98)	14.51 (3.83)	0.00 (0.71)	0.00 (0.71)	3.23 (1.92)	2.37 (1.69)	1.40 (1.38)	22.7	63.5	57.6	29.9	32.2
Pendimethalin (PE) 1000 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS *fb* manual weeding at 45 DAS	10.67 (2.79)	0.44 (0.96)	5.00 (2.34)	3.39 (1.96)	4.87 (2.24)	0.33 (0.88)	0.09 (0.77)	2.33 (1.66)	0.95 (1.15)	0.93 (1.19)	68.9	95.3	76.5	73.0	75.3
Pendimethalin (PE) 1000 g/ha *fb* manual weeding 25-30 DAS	1.00 (1.22)	0.12 (0.78)	6.50 (2.64)	1.60 (1.42)	2.31 (1.67)	0.33 (0.88)	0.36 (0.91)	4.17 (2.14)	0.00 (0.71)	1.22 (1.30)	96.2	95.7	65.8	90.1	83.9
Bispyribac-Na 20 g/ha + Almix 4 g/ha at 20 DAS (chlorimuron + metsulfuron)	10.33 (3.18)	2.42 (1.57)	13.83 (3.78)	6.23 (2.55)	8.20 (2.94)	3.33 (1.53)	0.00 (0.71)	7.00 (2.73)	1.31 (1.31)	2.91 (1.83)	61.3	78.4	33.2	53.2	52.6
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	4.33 (2.09)	4.37 (2.00)	12.67 (3.61)	4.13 (2.14)	6.38 (2.59)	1.33 (1.34)	0.44 (0.96)	4.17 (2.13)	0.87 (1.17)	1.70 (1.48)	84.0	57.0	46.0	68.9	65.6
Weed free check (HW at 20,40, and 60 DAS)	2.00 (1.52)	0.42 (1.03)	6.83 (2.70)	3.30 (1.94)	3.14 (1.91)	0.33 (0.88)	0.00 (0.71)	2.12 (2.26)	0.23 (0.83)	0.67 (1.08)	93.4	96.2	71.3	78.1	84.8
Weedy check	32.67 (5.70)	10.80 (3.25)	17.50 (4.22)	12.69 (3.63)	18.42 (4.34)	2.67 (1.45)	0.40 (0.98)	13.67 (6.87)	3.41 (1.92)	5.04 (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 indicate square root transformations $\sqrt{x+0.5}$; PE= Pre-emergence

Table 2. Effects of herbicide combinations on weed growth at 90 DAS (no. 0.25/m^2) (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	24.3	56.8	32.1
Pendimethalin (PE) 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 (PE) 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 (PE) 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 (PE) 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 (PE) 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=0.5)	- (1.61.)	- (1.52)	- (0.45)	- (0.42)	- (1.31)	- (3.42)	- (1.19)	- 0.70)	- (0.52)	- (1.25)					

Figures in parentheses indicate square root transformations $\sqrt{x+0.5}$; PE= Pre-emergence

(2013) and Chauhan *et al*. (2013). Consequently, weed free check (Table 4) (HW at 20, 40, and 60 DAS) produced significantly higher grain and straw yield (3.88 and 4.68 t/ha), respectively over rest of the treatments except pendimethalin 1000 g/ha 0 to 2 DAS *fb* manual weeding at 25 to 30 DAS (3.68 and 4.38 t/ha) and pendimethalin 1000 g/ha at 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 2). 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 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), weed index (WI) which indicate the increase in grain yield was maximum under pendimethalin 1000 g/ha 0 to 2 DAS *fb* manual

Table 3. 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	52.4	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 (PE) 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 (PE) 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 (PE) 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 (PE) 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 (PE) 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	2.04	2.23	1.88	1.86	1.86
LSD (P=0.05)	N.S.	N.S	1.0	1.7	0.8	N.S.	N.S	0.8	0.6	2.6	N.S.	N.S	0.3	N.S.	N.S.	N.S.	0.88	0.45	0.08	0.08

Table 4. Effects of herbicide combinations on yield and yield attributes of rice (four year pooled mean)

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	33.64	56.06	27.72	17.09	42.59
Pendimethalin (PE) 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	38.95	4.18	11.23	16.94	21.77
Oxadiargyl (PE) 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	38.91	22.95	7.27	13.72	19.99
Pyrazosulfuron (PE) 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	44.15	37.65	26.24	23.05	32.83
Pendimethalin (PE) 1000 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS *fb* manual weeding at 45 DAS	2.57	4.67	3.92	3.20	3.58	2.89	5.01	5.82	3.86	4.40	12.55	11.89	1.14	4.41	7.70
Pendimethalin (PE) 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	21.02	0.59	0.48	4.29	5.26
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	61.53	27.22	30.05	18.49	32.57
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	39.15	28.74	10.24	25.23	25.25
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	2.00	2.49	1.48	0.38	1.18	3.43	2.92	1.98	88.67	79.31	49.65	25.77	61.94
LSD (P=0.05)	0.16	0.21	0.07	0.16	0.08	0.11	0.12	0.15	0.17	0.10	-	-	-	-	-

Table 5. Pooled yield and economics for weed control measures applied in rice

Treatment	Pooled yield (2012 to 2015)		Economics			
	Grain yield (t/ha)	Straw yield (t/ha)	Gross Expenditure (x10^3 `/ha)	Gross returns (x10^3 `/ha)	Net returns (x10^3 `/ha)	B-C ratio
Bispyribac-Na 25 g/ha at 20 DAS	2.23	2.93	43.41	39.29	-4.12	0.91
Pendimethalin (PE) 1000 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS	3.04	3.79	52.55	53.12	0.57	1.01
Oxadiargyl (PE) 100 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS	3.10	3.76	52.74	54.09	1.35	1.03
Pyrazosulfuron (PE) 20 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS	2.61	3.21	44.69	45.52	0.83	1.02
Pendimethalin (PE) 1000 g/ha *fb* bispyribac-Na 25 g/ha at 25 DAS *fb* manual weeding at 45 DAS	3.58	4.40	52.50	62.52	10.02	1.19
Pendimethalin (PE) 1000 g/ha *fb* manual weeding 25-30 DAS	3.68	4.38	50.03	63.92	13.89	1.28
Bispyribac-Na 20 g/ha + Almix 4 g/ha at 20 DAS (chlorimuron + metsulfuron)	2.62	3.34	44.33	45.93	1.60	1.04
Three mechanical weeding 20, 40 and 60 DAS (cono / rotary weeder)	2.90	3.59	55.22	50.70	-4.52	0.92
Weed free check (HW at 20,40 and 60 DAS)	3.88	4.68	56.87	67.57	10.70	1.19
Weedy check	1.48	1.98	35.93	26.11	-9.82	0.73

* selling rate 1) Rice – 1500/- per Quintal (q) 2) Straw – 200/- per q., * Herbicide rate: 1) Bispyribac-Na – 7950/liter, 2) Pendimethalin – 500/liter, 3) Oxadiargyl – 6772/kg, 4) Pyrazosulfuron – 4000/kg, 5) chlorimuron + metsulfuron – 21750/kg; PE= Pre-emergence

weeding at 25 to 30 DAS (5.26%) closely followed by pendimethalin at 1000 g/ha 0 to 3 DAS *fb* bispyribac-Na 25 g/ha at 25 DAS *fb* manual weeding at 45 DAS (7.70%). Similar results of higher yield attributes of direct-seeded rice were reported by Veeraputhiran and Balasubramanian (2013) and Naseeruddin and Subramanyam (2013).

Economics

The highest net returns of ` 13,887/ ha was obtained with the application of pendimethalin 1000 g/ha at 0 to 2 DAS *fb* manual weeding at 25 to 30 DAS followed by weed free check (HW at 20, 40 and 60 DAS) (` 10,698/ ha) with B-C ratio of 1.28 and 1.19, respectively (Table 5).

On the basis of four years pooled data, it was concluded that application of pendimethalin 1000 g/ ha at 0 to 2 DAS *fb* manual weeding at 25 to 30 DAS was most effective and economical treatment (BC ratio 1.28) followed by weed free check (HW at 20, 40, and 60 DAS) (BC ratio 1.19) to control weeds effectively in direct-seeded drilled rice during *Kharif* season.

REFERENCES

Chauhan B and Yadav A. 2013. Weed management approaches for dry-seeded rice in India: a review. *Indian Journal of Weed Science* **45**(1): 1-6.

Ganie Z A, Singh Samar and Singh S. 2013. Effect of seed rate and weed control methods on yield of direct-seeded rice. *Indian Journal of Agronomy* **58**(1): 125-126.

Naseeruddin R and Subramanyam D. 2013. Performance of low dose high efficacy herbicides in drum seeded rice. *Indian Journal of Weed Science* **45**(4): 285-288.

Panse VG and Sukhatme PV. 1984. *Statistical Methods for Agricultural Research Workers.* ICAR, New Delhi.

Pillai GK and Rao MV. 1974. Integrated weed management in rice. *Indian Farming* **26**(12): 17-23.

Ravichandran VK. 1991. Integrated management is necessary to check the weeds in direct sown rice. *Indian Farming* 41(5): 5-6.

Veeraputhiran R and Balasubramanian R. 2013. Evaluation of bispyribac-sodium in transplanted rice. *Indian Journal of Weed Science* **45**(1): 12-15.

Walia US, Walia SS, Singh, A, Sidhu V and Nayyar S. 2012. Bioefficacy of pre and post-emergence herbicides in direct-seeded rice in Central Punjab. *Indian Journal of Weed Science* **44**(1): 30-33.