Indian Journal of Weed Science **52**(3): 222–226, 2020

Print ISSN 0253-8040 Online ISSN 0974-8164

Efficacy of herbicides in managing weeds in direct-seeded rice

R.K. Satyaraj Guru*, Sanjay K. Dwivedi, S.N. Khajanji and S.K. Jha

Department of Agronomy, Indira Gandhi Krishi Vishwavidyalaya, Raipur Chhattisgarh 492 012, India

**Email: rksatyaraj34@gmail.com*

Article information

DOI: 10.5958/0974-8164.2020.00042.8

Type of article: Research article

Received : 8 June 2020
Revised : 1 September 2020
Accepted : 4 September 2020

Key words

Direct-seeded rice

Post–emergence herbicide

Weed control efficiency

ABSTRACT

A field experiment was conducted during *Kharif* 2017 and 2018 at I.G.K.V, Raipur, Chhattisgarh to study the effect of existing herbicides in managing weeds in direct-seeded rice (*Oryza sativa* L.) and to assess their residual effect on succeeding crops. Application of bispyribac-sodium 2% (BS) + 2,4-D sodium salt 54.3% SP (DSS) with adjuvant (WA) (30.0 + 814.5 g/ha), BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha), BS+ 2,4-DSS (30.0 + 814.5 g/ha) and BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha) was at par to weed free in terms of grain yield. BS + 2,4- DSS (WA) (30.0 + 814.5 g/ha) controlled the weeds more effectively throughout the crop growth period and recorded higher weed control efficiency (97.5% at 30 DAS and 92.4% at 60 DAS), herbicide efficiency index (47.1 and 13.2), reduction of weed density (88.1 and 80.6%) and weed biomass (97.5 and 92.4%) and lower weed persistence index (0.2 and 0.4) during both the years. The phytotoxicity effect was observed with higher doses of BS + 2,4-DSS, alone and with adjuvant at 25.0 + 678.8 g/ha and 30.0 + 814.5 g/ha, however it was recovered quickly. There was no phytotoxicity and carryover effect of these herbicides tested on chickpea + linseed intercrop, grown as succeeding crop. Application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) recorded highest net returns (₹ 65444 and 76762/ha) and B:C ratio (2.2 and 2.6) during 2017 and 2018, respectively.

INTRODUCTION

Rice is the source for 35-80% of total calorie intake of Asian population (Rahman and Masood 2012). Puddling and transplanting operations in conventional rice production system consume a significant quantity of water, creates a hard pan below the plough layer, reduces soil permeability, and deteriorates soil quality for the subsequent upland crops (Hossain *et al.* 2016). However direct-seeded rice (DSR) requires 35-57% less water and 67% less labour over transplanting rice (Chauhan 2012). Nevertheless, weeds are a major biological constraint in DSR, mainly due to the absence of impounding of water at crop emergence, hence weed management are crucial for increasing the productivity of DSR (Rao *et al.* 2007, Chauhan *et al.* 2012).

The extent of yield reduction of rice due to weeds has been estimated up to 95% in India (Pathak *et al.* 2011). The chemical method of weed control is becoming more popular and is the best alternative to hand weeding as hand weeding needs high labour involvement (190 man-days/ha), is tedious, time-consuming and impractical under adverse weather conditions (Rao *et al.* 2017). Use of herbicide mixtures would be more acceptable option as the operation would be completed in a single application and would save time (Menon 2019, Yadav *et al.* 2018) as well as it overcome the problem of herbicide resistance and the shift in weed flora (Damalas *et al.* 2005). It also reduces the usage rate, herbicide injury to crops and broadens the spectrum of weed control in a single application and reduces the cost of application (Afrin *et al.* 2015).

MATERIALS AND METHODS

The field experiment was conducted during *Kharif* 2017 and 2018 at the I.G.K.V, Raipur (21^{0}23’ N, 81^{0}71’ E and 290 m above mean sea level), Chhattisgarh to study the effect of herbicides in managing weeds in direct-seeded rice and to assess their residual effect on succeeding chickpea + linseed crops. The soil was neutral in reaction (pH 6.5), low in available nitrogen, medium in phosphorus and high in potassium.

Eleven treatments *viz.* bispyribac-sodium 2% (BS) + 2,4-D-sodium salt 54.3% SP (DSS) (20.0 + 543.0 g/ha), BS+ 2,4-DSS (25.0 + 678.75 g/ha), BS + 2,4- DSS (30.0 + 814.5 g/ha), BS+ 2,4-DSS with adjuvant (WA) (20.0 + 543.0 g/ha), BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha), BS + 2,4-DSS (WA) (30.0

+ 814.5 g/ha), bispyribac-sodium 10% SC 20 g/ha, 2,4-D ethyl ester 38% EC (34% W/W) (EE) (850 g/ha), penoxsulam 21.7% SC (22.5 g/ha), weed free (20 and 40 DAS) and weedy check were laid out in a randomized block design with three replications. Pre-germinated seeds of medium duration rice variety '*Indira Rajeshwari (IGKV R 1)*' were line sown on non-puddled levelled field on 20th and 30th June of 2017 and 2018, respectively with a seed rate of 80 kg/ha.

The crop was fertilized with 100:60:40 N:P:K kg/ha during both the years, and 50% nitrogen, entire dose of phosphorous and potassium were applied as basal. The remaining 50% of the nitrogen was top dressed at two equal splits at tillering and panicle initiation stages. The study area receives rainfall of 716.0 mm in 2017 and 973.6 mm in 2018 during rice season, with a temperature variation of 24.9 to 32.2°C in 2017 and 24.3 to 31.3°C in 2018. The herbicides were sprayed at 2-3 leaf stage of weeds by knapsack sprayer with spray volume of 500 L/ha. All herbicide treatments were applied at 18 days after seeding (DAS). The data on weed density and weed biomass (at 30 and 60 DAS) were recorded with the help of quadrat (0.5 x 0.5 m). Phytotoxic effect of herbicides on rice was evaluated by observing for chlorosis, vein clearing, necrosis, wilting, scorching, epinasty and hyponasty of leaf at 1, 3, 5, 7 and 10 days after application (DAA) of herbicides. The observation on the level of phytotoxicity through visual assessment of crop response was rated in the scale of 1-10. Data on yield attributes like number of effective tillers, number of grains per panicle, test weight and grain yield were recorded. The weed control efficiency (at 30 and 60 DAS) was worked out on the basis of weed biomass. The herbicide efficiency index (HEI) was calculated as suggested by Krishnamurthy *et al.* (1975).

$$HEI = \frac{\frac{(Yt-Yc)}{Yt}}{\frac{WDMt}{WDMc}}$$

Where, Yt = Crop yield from the treated plot

Yc = Crop yield from the weedy check

WDMt = Weed dry weight in the treated plot

WDMc = Weed dry weight in the weedy check

The weed persistence index (WPI) was calculated by the given formula as suggested by Sarma (2016)

$$WPI = \frac{W_T}{W_C} \times \frac{WD_C}{WD_T}$$

Where, W_T and W_C = Weed biomass in treated and weedy check plot, respectively

WD_T and WD_C = Weed density in treated and weedy check plot, respectively

The per cent reduction of weed density (%RWD) and reduction of weed biomass (%RWB) were calculated as per the given formula as suggested by Islam *et al.* (2018)

$$\%\ RWD = \left(1 - \frac{\text{Number of weeds per m}^2 \text{ in treated plot}}{\text{Number of weeds per m}^2 \text{ in weedy plot}}\right) \times 100$$

$$\%\ RWB = \left(1 - \frac{\text{Weed biomass per m}^2 \text{ in treated plot}}{\text{Weed biomass per m}^2 \text{ in weedy plot}}\right) \times 100$$

In the succeeding intercropping system, chickpea was considered as the main crop and linseed as an intercrop component. Then the grain yield of linseed from each plot was converted to chickpea equivalent yield of intercropping system as suggested by Agegnehu *et al.* (2006)

$$EY_L = Y_L \times \frac{P_1}{P_2}$$

$$EY_i = Y_c + EY_L$$

Where, EY_L= Chickpea equivalent yield of linseed (t/ha)

EY_i= Chickpea equivalent yield of intercropping system (t/ha)

Y_C and Y_L= Yield (q/ha) of chickpea and linseed respectively

P_1 and P_2= Price of linseed and chickpea respectively

RESULTS AND DISCUSSION

Weed density, weed biomass and weed control efficiency

The major weed flora with their relative composition observed in experimental field included *Echinochloa colona* (39.3 and 55.3%), *Ischaemum rugosum* (2.0 and 5.1%), *Dactyloctenium aegyptium* (2.2 and 2.9%), *Cynodon dactylon* (10.1 and 4.6%) among grasses; *Cyperus iria* (3.3 and 2.5%) among sedges, whereas among broad-leaf weeds, *Alternanthera sessilis* (15.2 and 6.7%), *Physalis minima* (1.9 and 2.8%), *Phyllanthus niruri* (2.6 and 4.4%), *Cyanotis axillaris* (3.2 and 2.6%) , *Eclipta alba* (9.6 and 4.9%) and *Cassia tora* (7.5 and 5.0%) during 2017 and 2018, respectively.

Significant variation in per cent reduction of weed density and biomass over control was observed among weed management practices at 30 and 60 DAS during both the years (**Table 2**). Among the herbicide treatments, the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) gave higher per cent reduction of weed density and biomass followed by BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha), BS + 2,4-DSS (30.0 + 814.5 g/ha) and BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha) (**Table 1**). Application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) recorded the highest weed control efficiency followed by BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha) during both the years at 30 DAS and 60 DAS (**Table 1**). The lowest weed control efficiency was found with the application of 2, 4- D EE (850 g/ha) at 30 and 60 DAS during both the years due to the poor control of grassy weeds by 2,4-D. The higher weed control efficiency recorded in *Kharif* 2017, may be attributed to the lower infestation of weeds as compared to *Kharif* 2018. The low infestation of weeds in *Kharif* 2017 was due to lower rainfall (398.40 mm) received during early growth period of crop up to 60 DAS when compared to the *Kharif* 2018 (587.60 mm).

Herbicide efficiency index and weed persistence index

Amongst herbicide, the maximum herbicide efficiency index (HEI) and minimum weed persistence index (WPI) were witnessed under the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) followed by BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha) at 30 and 60 DAS, during both the years (**Table 2**). The application of 2,4-D EE recorded the minimum HEI and maximum WPI. Thus, there was an inverse relationship between HEI and WPI. Similar findings were also reported by Singh *et al.* (2017). As compared to 2018, in 2017, greater HEI was recorded at 30 DAS and 60 DAS, where as vice versa in case of WPI.

Yield and yield attributes

Among the herbicide treatments, the highest number of effective tillers/m^2, number of grains/panicle, grain yield and the lowest sterility percentage was recorded under the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) (**Table 3**). The lowest grain yield was in weedy check treatment, with a reduction in grain yield of 51.0% in 2017 and 50.6% in 2018 as compare to weed free treatment. The lowest grain yield in weedy check might be due to season-long weed competition exerted by the weeds at the critical stages of crop growth. The weed free treatment recorded significantly higher grain yield (5.92 t/ha in 2017 and 5.75 t/ha in 2018) and was found at par with the application of BS+ 2, 4- DSS (WA) (30.0 + 814.5 g/ha), BS + 2, 4- DSS (WA) (25.0 + 678.75

Table 1. Effect of herbicides treatments on weed control efficiency (WCE), per cent reduction in weed density and biomass

Treatment	WCE (%)				Reduction in weed density (%)				Reduction in weed biomass (%)			
	30 DAS		60 DAS		30 DAS		60 DAS		30 DAS		60 DAS	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
BS + 2,4-DSS (20.0 + 543.0 g/ha)	79.2	77.0	79.0	75.9	60.9	62.5	53.4	50.5	79.2	77.0	79.0	75.9
BS + 2,4-DSS (25.0 + 678.75 g/ha)	84.3	80.5	79.6	77.8	66.9	67.6	59.4	55.9	84.3	80.5	79.6	77.8
BS + 2,4-DSS (30.0 + 814.5 g/ha)	88.6	87.7	85.4	84.4	80.0	81.2	70.9	67.4	88.6	87.7	85.4	84.4
BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha)	87.7	86.4	84.6	82.7	77.4	79.7	67.7	63.6	87.7	86.4	84.6	82.7
BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha)	96.8	94.2	90.6	90.2	85.4	84.8	76.4	75.2	96.8	94.2	90.6	90.2
BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha)	98.5	96.5	92.5	92.4	88.9	87.3	82.6	78.6	98.5	96.5	92.5	92.4
Bispyribac-sodium 10% SC (20 g/ha)	76.2	74.5	76.7	73.2	57.1	57.6	47.4	45.9	76.2	74.5	76.7	73.2
2,4-D-ethyl ester 38% EC (34% W/W) (850 g/ha)	62.2	58.7	66.5	61.2	44.6	44.8	23.0	35.3	62.2	58.7	66.5	61.2
Penoxsulam 21.7% SC (22.5 g/ha)	73.6	71.6	75.0	70.9	53.2	54.6	39.6	43.5	73.6	71.6	75.0	70.9
Weed free (20 and 40 DAS)	100.0	100.0	99.6	98.3	100.0	100.0	94.7	91.7	100.0	100.0	99.6	98.3
Weedy check	-	-	-	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAS: Days after sowing; BS - Bispyribac-sodium; DSS - 2,4-D-sodium salt; WA - With adjuvant

Table 2. Effect of herbicides treatments on Herbicide efficiency index (HEI) and Weed persistence index (WPI)

Treatment	HEI				WPI			
	30 DAS		60 DAS		30 DAS		60 DAS	
	2017	2018	2017	2018	2017	2018	2017	2018
BS + 2,4-DSS (20.0 + 543.0 g/ha)	2.47	2.22	2.45	2.12	0.53	0.61	0.45	0.49
BS + 2,4-DSS (25.0 + 678.75 g/ha)	4.14	3.23	3.19	2.84	0.47	0.60	0.50	0.50
BS + 2,4-DSS (30.0 + 814.5 g/ha)	6.99	6.48	5.45	5.13	0.57	0.66	0.50	0.48
BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha)	6.30	5.52	5.00	4.35	0.54	0.67	0.48	0.48
BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha)	26.86	14.93	9.28	8.78	0.22	0.38	0.40	0.40
BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha)	65.59	28.59	13.30	13.05	0.14	0.27	0.43	0.36
Bispyribac-sodium 10% SC (20 g/ha)	1.61	1.33	1.65	1.26	0.56	0.60	0.44	0.50
2,4-D ethyl ester 38% EC (34% W/W) (850 g/ha)	0.62	0.59	0.69	0.63	0.68	0.75	0.43	0.60
Penoxsulam 21.7% SC (22.5 g/ha)	0.95	0.95	1.01	0.93	0.56	0.63	0.41	0.51

DAS: Days after sowing; BS - Bispyribac-sodium; DSS - 2,4-D-sodium salt; WA - With adjuvant

Table 3. Effect of herbicide treatments on rice yield attributes and yield of DSR and their residual effect on chickpea equivalent yield as succeeding crop

Treatment	No. of effective tillers/m²		No. of grains/ panicle		Sterility percentage		Test weight (g)		Rice grain yield (t/ha)		Chickpea equivalent yield as succeeding crop (t/ha)		Net returns (×10³ ₹/ha)		B:C ratio	
	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018	2017	2018
BS + 2,4-DSS (20.0 + 543.0 g/ha)	381.7	371.3	124.5	121.0	12.4	12.8	24.3	24.2	4.39	4.29	2.31	2.16	44.0	52.5	1.6	1.9
BS + 2,4-DSS (25.0 + 678.75 g/ha)	382.3	375.3	127.2	123.3	11.4	11.9	24.4	24.4	4.79	4.63	2.31	2.25	49.3	58.5	1.7	2.1
BS + 2,4-DSS (30.0 + 814.5 g/ha)	412.7	407.3	138.7	135.5	8.7	9.4	24.7	24.7	5.20	5.11	2.36	2.28	56.9	67.1	2.0	2.3
BS + 2,4-DSS (WA) (20.0 + 543.0 g/ha)	412.0	406.8	137.7	134.7	9.1	9.5	24.4	24.4	5.14	4.97	2.33	2.27	54.7	64.7	1.9	2.3
BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha)	415.0	407.5	140.7	136.7	8.3	9.0	24.7	24.7	5.43	5.28	2.38	2.29	59.5	70.0	2.1	2.4
BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha)	416.5	408.0	141.3	137.3	7.1	8.4	24.8	24.8	5.80	5.66	2.37	2.33	65.4	76.8	2.2	2.6
Bispyribac-sodium 10% SC (20 g/ha)	380.0	367.3	123.3	120.7	13.8	13.0	24.2	24.2	4.01	3.80	2.27	2.12	36.4	44.0	1.3	1.6
2,4-D-ethyl ester 38% EC (34% W/W) (850 g/ha)	326.2	320.8	110.3	108.7	17.8	18.4	24.1	24.0	3.57	3.53	2.23	2.00	32.3	39.4	1.2	1.5
Penoxsulam 21.7% SC (22.5 g/ha)	332.0	325.5	112.2	109.5	17.1	18.1	24.1	24.1	3.63	3.61	2.26	2.14	31.9	39.1	1.1	1.4
Weed free (20 and 40 DAS)	418.5	410.3	142.3	137.7	6.7	8.0	24.9	24.8	5.92	5.75	2.40	2.32	59.2	70.6	1.6	1.9
Weedy check	242.2	237.2	102.2	100.0	22.3	27.0	24.0	23.9	2.90	2.84	2.21	2.10	21.6	27.3	0.8	1.0
LSD (p=0.05)	7.6	5.7	6.6	3.8	3.3	1.5	NS	NS	0.84	0.86	NS	NS	-	-	-	-

DAS: Days after sowing; BS - Bispyribac-sodium; DSS - 2,4-D-sodium salt; WA - With adjuvant

g/ha), BS + 2, 4- DSS (30.0 + 814.5 g/ha) and BS + 2,4- DSS (WA) (20.0 + 543.0 g/ha) during both the years (**Table 3**). The highest grain yield was attributed to the higher reduction of weed density and biomass during both years. The bispyribac sodium inhibits the acetohydroxy acid synthase (ALS) to achieve a broad-spectrum control of weeds. Rao and Nagamani (2007) also reported that post-emergence application of bispyribac-sodium at 30 g/ha applied at 15 DAS was found to be the most effective due to its broad-spectrum control of weeds in rice, without any phytotoxic effect. On the other hand, 2,4-D EE controls broad-leaved weeds by inhibiting cell division (Das 2016). So the combination of both chemical stands more effective than their sole application against weed flora and fetched higher yield. No significant difference was observed in chickpea equivalent yield in chickpea + linseed intercrop, as succeeding crop

Phytotoxicity

The herbicide phytotoxicity effect was observed on rice during both the years but the crop recovered quickly. The application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha), BS + 2,4- DSS (WA) (25.0 + 678.75 g/ha), BS+ 2,4-DSS (30.0 + 814.5 g/ha) and BS + 2, 4-DSS (25.0 + 678.75 g/ha) reported phytotoxicity in terms of chlorosis in rice crop at 3, 5 and 7 DAA with scale of 0 to 3 during both the years . Very low scale of 0 to 1 phytotoxicity was observed for necrosis and scorching with the application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha), BS + 2,4-DSS (WA) (25.0 + 678.75 g/ha) and BS + 2,4-DSS (30.0 + 814.5 g/ha) treatments.

Economics

Among different weed management practice, the highest net returns (₹ 65444 and 76762/ha) and B:C ratio (2.2 and 2.6) were recorded with application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) during 2017 and 2018, respectively (**Table 3**). While, the lowest net returns (₹ 21620 and 27295/ha) and B:C ratio (0.8 and 1.0) were observed in weedy check. The weedy check treatment recorded 67 and 64 per cent loss in net returns during 2017 and 2018, respectively as compare to the application of BS+ 2,4-DSS (WA) (30.0 + 814.5 g/ha).

Thus it may be concluded that application of BS + 2,4-DSS (WA) (30.0 + 814.5 g/ha) may be suggested for managing weeds in DSR as it controlled the weeds more effectively throughout the crop growth period and recorded higher gain yield, net returns and B:C ratio.

REFERENCES

Afrin N, Bhuiya M, Uddin MR, Bir H, Shahidul Mand Park KW. 2015. Combined effect of herbicides on the weed management of rice. *Research on Crops* **16** (3): 28–29.

Agegnehu G, Ghizaw A and Sinebo W. 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. *European Journal of Agronomy* **25**(3): 202–207.

Chauhan BS. 2012. *Weed Management in Direct-Seeded Rice Systems*. International Rice Research Institute, Los Baños, 2p.

Chauhan BS, Mahajan G, Sardana V, Timsina J and Jat ML. 2012. Productivity and sustainability of the rice–wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. *Advances in Agronomy* **117**(2): 315–369.

Damalas CA, Dhima KV and Eleftherohorinos IG. 2005. Control of early watergrass (*Echinochloa oryzoides*) and late watergrass (*Echinochloa phyllopogon*) with cyhalofop, clefoxydim, and penoxsulam applied alone and in mixture with broad-leaf herbicides. *Weed technology* **20**(4): 992–998.

Das TK. 2016. *Weed Science Basics and Application*. Jain Brothers, New Delhi, 901p.

Hossain MM, Begum M, Rahman MM and Akanda MM. 2016. Weed management on direct-seeded rice system-a review. *Progressive Agriculture* **27** (1): 1–8.

Islam AM, Hia MAUH, Sarkar SK and Anwar MP. 2018. Herbicide based weed management in aromatic rice of Bangladesh. *Journal of the Bangladesh Agricultural University* **16** (1): 31–40.

Krishnamurty K, Rajashekara BG and Raghunatha G. 1975. Herbicidal efficiency index in sorghum. *Indian Journal of Weed Science* **7**(2): 75–79.

Menon MV, 2019. Herbicide mixtures for weed management in wet-seeded rice. *Indian Journal of Weed Science* **51**(3): 295–297.

Pathak H, Tewari AN, Sankhyan S, Dubey DS, Mina U, Singh VK and Jain N. 2011. Direct-seeded rice: potential, performance and problems-A review. *Current Advances in Agricultural Sciences* **3**(2): 77–88.

Rahman MM and Masood MM. 2012. Aerobic System: A potential water saving Boro rice production technology, pp 1-2. In: *National Conference* on *Adaptation of aerobic system for boro rice cultivation in farmer's field for saving irrigation water and attaining food security-Project*, Manilla, Philippines. International Rice Research Institute, Manilla.

Rao AN and Nagamani A. 2007. Available technologies and future research challenges for managing weeds in dry-seeded rice in India, pp 391–401. In: *Proceeding 21st Asian Pacific Weed Science Society* Conference, 2-6 October 2007, Colombo, Sri Lanka Asian Pacific Weed Science Society, Colombo.

Rao AN, Jhonson DE, Sivaprasad B, Ladha JK and Mortimer AM. 2007. Weed management in direct-seeded rice. *Advances in Agronomy* **93**: 153–255.

Rao AN, Wani SP, Ahmed S, Ali HH and Marambe B. 2017. An Overview of Weeds and Weed Management in Rice of South Asia. pp. 247 to 281. In: *Weed Management in Rice in the Asian-Pacific Region.* Asian-Pacific Weed Science Society (APWSS), (Eds. Rao AN and Matsumoto H), The Weed Science Society of Japan, Japan and Indian Society of Weed Science, India

Sarma A. 2016. *Numerical Agronomy*. Kalyani Publishers, Noida, 63p.

Singh VP, Singh SP, Bisht N, Kumar A, Satyawali K and Paliwal A. 2017. Assessment of post-emergence weed management in direct-seeded rice. *Indian Journal of Weed Science* **49** (3): 211–215.

Yadav RI, Singh MK, Singh RK and Nagargade M. 2018. Planting methods and weed management to improve yield in dry-seeded rice. *Indian Journal of Weed Science* **50**(1): 22–26.