Indian Journal of Agronomy **67** (3): 233–239 (September 2022)

Research Paper

Influence of crop-establishment methods and weed-management practices on weeding efficiency and productivity of basmati rice (*Oryza sativa*)

ANURADHA SAHA[1] AND VIJAY BHARTI[2]

Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha, Jammu, Jammu and Kashmir, Union Territory 180 009

Received: June 2021; Revised accepted: August 2022

ABSTRACT

A field experiment was conducted on sandy clay loam soil at the research farm of Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu, Chatha, Jammu and Kashmir during the rainy (*kharif*) season of 2016 and 2017, to study the response of different establishment methods and weed management practices on basmati rice (*Oryza sativa* L.). The experiment comprising 3 establishment methods and 5 weed-management practices with 3 replications was laid in split-plot design. Among establishment methods, system of rice intensification (SRI) though at par with conventional transplanted rice (CTR) showed significant reduction in weed population, weed dry weight and nutrient uptake by weeds at 40 and 60 days after transplanting (DAT) over direct seeded rice (DSR). Likewise, for weed-management practices, application of pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) followed by (*fb*) bispyribac sodium at 25 g a.i./ha at 25 DAS/DAT recorded significantly lower weed density (no./m^2), weed biomass (g/m^2) at 40 and 60 DAS/DAT and weed nutrient uptake at 60 DAS/DAT. However, this treatment was at par with pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT. The same treatment recorded the highest weed-control efficiency (75.28%). Plant height and number of tillers at 60 DAS/DAT and at harvesting effective tillers/m^2, filled grains/panicle, 1,000ˆgrain weight (g) as well as grain and straw yields were significantly higher in SRI over DSR, but at par with CTR. Pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT recorded significantly higher values over other treatments but at par with pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* bispyribac sodium at 25 g a.i./ha at 25 DAS/DAT for plant height at 60 DAS/DAT, and at harvesting for effective tillers/m^2, filled grains/panicle, 1,000-grain weight (g) as well as grain and straw yields. The SRI resulted in the highest net returns (₹74,810/ha) and benefit: cost (B:C) ratio (1.63) among the establishment methods, whereas pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT among the weed-management methods fetched the highest net returns (₹60,639/ha) and B : C ratio (1.36).

Key words: Conventional transplanted rice, Direct-seeded rice, System of rice intensification, Weed-man agement

In sub-tropical Jammu plains, basmati rice (*Oryza sativa* L.) is grown over an area of about 0.06 million ha, with the production and productivity of 0.13 million tonnes (MT) and 20.96 q/ha, respectively. Being an important export item, basmati rice enjoys a premium place in Jammu economy. In most Asian countries, rice is grown by manual transplanting in puddled soil with continuous flooding. Puddling benefits rice by reducing percolation losses, controlling weeds and facilitating easy seedling establishment, but continuous flooding causes the deterioration of soil health and decreases soil microbial biodiversity. Repeated puddling adversely affects soil physical properties, and requires a large amount of water and labour and promotes formation of hard pan (Gathala *et al.,* 2011; Kumar and Ladha, 2011). Looming water crisis, water-intensive nature of rice cultivation, escalating labour costs and timely availability of farm labour drive the search for alternative management methods for rice cultivation. (Farooq *et al.,* 2011).

[1]**Corresponding author's Email:** anuradha_agron@yahoo.co.in
[1]Chief Scientist, All India Co-Ordinated Research Project on Rice, Division of Plant Breeding and Genetics, Sher-e-Kashmir University of Agricultural Sciences and Technology–Jammu, Chatha, Jammu and Kashmir, Union Territory; [2]Chief Scientist, (Water Management Research Centre), Sher-e-Kashmir University of Agricultural Sciences and Technology–Jammu, Chatha, Jammu and Kashmir, Union Territory

Direct seeding rice could be an alternative with less water, labour and capital input and can eliminate the adverse effects of puddling on soil health and productivity of the succeeding crop (Ladha *et al.,* 2009; Kumar and Ladha, 2011). Direct seeding rice (DSR) could also result in early crop maturity by 7–12 days (Gill, 2008) and comparatively similar productivity as of conventional transplanting method (Gangwar *et al.,* 2008). Despite multiple benefits of DSR, weeds are a serious problem because dry tillage and aerobic soil conditions are conducive to the many weeds, which can cause grain yield losses from 50 to 90% (Chauhan and Opena 2012; Chauhan and Abugho, 2012). The system of rice intensification (SRI) is an alternative practice which can increase rice yield with the consequent sustainable increase in the productivity of land, labour, water and capital (Uphoff, 2002). Unlike, direct seeded rice, weed can be controlled in SRI through cono-weeding which also improves the soil health, increases microbial population by incorporation of weeds in the soil. Weeds in different crop-establishment methods, can be controlled by several methods, like manual, mechanical and chemical weeding but it is a difficult proposition due to scarcity of labour, time consuming and cost involvement, whereas chemical weed management using herbicides alone or in combination may result in effective and economic control of weeds. Effective weed-management strategy can keep weed population under threshold levels which need to be evolved combining all the options like mechanical, cultural and chemical methods. Therefore, there is a need to identify suitable crop-establishment methods of rice along with appropriate combination of wide-spectrum weed control ability for efficient and economical weed management which is crucial for improving the potential of rice cultivation. Keeping these points in view, the present experiment was conducted to study the different crop-establishment methods and effective weed-management practices on weed growth, crop-growth parameters, viz. yield of rice and profitability of rice.

MATERIALS AND METHODS

A field experiment was conducted during the rainy (*kharif*) seasons of 2016 and 2017 at Research Farm of Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu, Main Campus, Chatha, Jammu, Jammu and Kashmir, (32°40′ N, 74°58′ E, 332 meters above mean sea-level) in the Shiwalik foothills of North-Western Himalayas. Soils were sandy clay loam in texture, medium in organic carbon (0.57%), available N (245.15 kg/ha), available P (14.35 kg/ha) and available K (146.31 kg/ha). The *p*H and electrical conductivity of the soil was 8.03 and 0.21 dS/m, respectively. The climate of the experimental site was mainly sub-tropical, endowed with hot and dry early summers followed by hot and humid monsoon and cold winter. The mean annual rainfall varies from 1,050 to 1,115 mm, of which about 75% is received from July to September. However, the total rainfall and its distribution are subject to large variations.

During the crop-growth period from 15 June to 30 November during, 2016 and 2017, maximum and minimum temperature varied from 28.6 to 38.5°C and 28.8 to 39.1°C, and 12.6 to 28.1°C, and 12.7 to 28.4°C respectively. Both maximum and minimum temperature showed a fluctuation throughout the crop-growth period. In general, the maximum temperature was recorded in the last week of June and thereafter decreasing trend was observed up to the harvesting of the crop in both the years. The mean relative humidity varied from 61 to 87% and 63 to 88% (maximum) and 42 to 77% and 41 to 78% (minimum) during the study periods. The total rainfall received during the crop season was 904.2 and 910.0 mm during both the years.

The experiment was laid in a split-plot design with 3 replications, comprising 3 crop-establishment methods, viz. direct seeded rice; system of rice intensification and conventional transplanted rice in main plots, and 5 weed-management practices, viz. pre–emergence herbicide application followed by post-emergence herbicide application [pendimethalin 1 kg a.i./ha as pre–emergence (for DSR) at 0 days after sowing (DAS) or butachlor 1.5 kg/ha as pre-emergence (for CTR) at 0 days after transplanting (DAT) *fb* bispyribac 25 g a.i./ha at 25 DAS/DAT]; Pre-emergence herbicide application [pendimethalin 1 kg a.i./ha as pre–emergence (for DSR) at 0 DAS or butachlor 1.5 kg/ha as pre-emergence (for CTR) at 0 DAT *fb* 2 mechanical weedings at 20 and 40 DAS/DAT]; 2 mechanical weedings at 20 and 40 DAS/DAT; weed–free and weedy check in subplots. With the seed rate at 25 kg/ha of 'Basmati 370' rice cultivar was sown at 20 cm in line to line for direct-seeded rice method during both the years of study. On the same day, nursery was sown for different methods with seed rate for SRI @ 8 kg/ha and for CTR @ 30 kg/ha as per the standard practice. Thirteen days old single seedling was transplanted for SRI in well puddled, levelled and moist plots at 25 cm × 25 cm hill spacing with single seedlings and 25 days old seedlings were transplanted at 20 cm × 10 cm hill spacing in well-puddled plots with 2 or 3 seedlings for CTR method. Recommended dose of fertilizer for 'Basmati 370' rice as per package of practices in Jammu conditions, i.e. 30 : 20 : 10 kg/ha of N, P_2O_5 and K_2O, was applied through urea, di-ammonium phosphate and muriate of potash, respectively. Nitrogen was applied in 3 splits-at basal, tillering and panicle-initiation stages. Urea was applied on the soil when there was no standing water. Immediately after broadcasting of urea, irrigation was applied in both the years. The herbicides were applied with a knapsack sprayer, having a delivery of about 320 L/ha of spray solution through a flat-fan nozzle and the granular herbicides were mixed with sand and applied uniformly across the plot. Irrigation was given to the plots as per the recommended practice for DSR, SRI and CTR and was withheld 15 days before harvesting in all establishment methods of rice. Initial composite soil samples from experimental field were collected by screw auger from 0–15 cm and were air-dried in shade on polythene sheets. After drying, samples were crushed on hard wooden slabs with the help of a wooden roller, passed through a 2-mm sieve and stored for further chemical analysis. At 60 DAS/DAT, weeds and after harvesting plant samples from each plot were collected, dried under shade and then oven dried at 65 $\pm$ 1°C for 48 h and grinded for chemical analysis. The data recorded for various parameters were statistically analysed using Analysis of Variance Test and the comparison of treatment means was made by least significant difference (LSD) at P=0.05. Observations on weed density (number/m^2) and weed biomass (g/m^2) were taken by sampling randomly at 3 places with the help of 0.25 m^2 quadrates at 40 and 60 DAS/DAT. Weeds were uprooted manually and were identified, counted into 3 groups (grasses, sedges and broad leaf). The samples collected for the weed density was then sun–dried first and then dried in an oven to determine the weed biomass. The weeds data were subjected to square–root transformation [$\sqrt{(X + 0.5)}$] before statistical analysis. Weed control efficiency (WCE) (%) was calculated.

RESULTS AND DISCUSSION

Weeds

The prominent weed flora observed in the experimental field comprised *Echinochloa* spp., Egyption crowfoot grass [*Dactyloctenium aegyptium* (L.) Willd.] and Bermuda grass [*Cyanodon dactylon* (L.) Pers.] among grassy weeds; *Cyperus* spp., among sedges; and stone breaker (*Phyllanthus niruri* L.), native gooseberry (*Physalis minima* L.), horse weed (*Erigeron canadensis* L.) and black night shade (*Solanum nigrum* L.) in broad-leaf weeds. In both the years, density of sedges outnumbered the grassy and broad-leaf weeds. Rice–establishment methods, viz. SRI and CTR recorded significant reduction in weed density and weed biomass as compared to DSR at 40 and 60 DAS/DAT. It may due to conoweeding, the profuse tillering in the crop and water management as per the principles of SRI which suppressed the weeds. Application of pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre–emergence (for CTR) followed by bispyribac sodium 25 g a.i./ha at 25 DAS/DAT recorded

Table 1. Effect of crop-establishment methods and weed-management practices on weed density in rice during rainy season of 2016 and 2017 (mean values)

Treatment	Weed density (No./m^2)							
	40 DAS/DAT				60 DAS/DAT			
	Grasses	Sedges	Broad leaf	Total	Grasses	Sedges	Broad leaf	Total
Crop-establishment methods								
DSR	3.38	3.85	2.29	6.06	3.58	4.37	2.80	6.71
	(13.47)	(17.87)	(5.73)	(37.07)	(15.28)	(23.67)	(7.73)	(46.41)
SRI	2.64	2.78	1.20	4.26	3.07	3.73	1.28	5.60
	(8.16)	(8.72)	(1.20)	(18.08)	(9.91)	(15.87)	(1.27)	(27.25)
CTR	2.98	2.95	1.35	4.55	3.24	4.28	1.68	5.72
	(10.19)	(9.97)	(1.60)	(21.76)	(11.52)	(18.53)	(2.80)	(32.85)
CD (P=0.05)	0.36	0.35	0.27	0.42	0.18	0.43	0.29	0.59
Weed-management practices								
PPE or B *fb* Bi	2.91	2.63	1.36	4.53	2.71	2.12	1.59	3.84
	(8.21)	(8.78)	(1.67)	(18.66)	(7.08)	(5.22)	(2.33)	(14.63)
PPE or B *fb* MW	3.07	3.32	1.53	4.87	3.76	4.80	2.12	6.03
	(9.22)	(10.83)	(2.11)	(22.16)	(12.32)	(19.89)	(4.67)	(36.88)
MW at 20 and	3.28	3.59	1.92	5.19	3.88	4.98	2.21	6.57
40 DAS/DAT	(10.49)	(12.76)	(3.56)	(26.81)	(13.01)	(21.89)	(5.44)	(40.34)
Weed-free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Weedy-check	5.03	5.31	2.55	7.71	5.58	7.15	2.74	9.23
	(25.11)	(28.56)	(6.89)	(60.56)	(28.78)	(49.78)	(7.22)	(85.78)
CD (P=0.05)	0.37	0.18	0.26	0.32	0.29	0.20	0.45	0.24

DSR, Direct-seeded rice; SRI, system of rice intensification; CTR-conventional transplanting rice, PPE or B *fb* Bi, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* bispyribac sodium 25 g a.i./ha at 25 to 30 DAS/DAT; PPE or B *fb* MW, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT; MW, 2 mechanical weedings at 20 and 40 DAS/DAT; figures in parentheses indicate transformed values significantly lower weed population and weed dry weight at 40 and 60 DAS/DAT compared to the weedy check plot. Pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) followed by bispyribac 25 g a.i./ha at 25 DAS/DAT recorded significantly lower weed density at 60 DAS/DAT than 40 DAS/DAT which may be due to the effect of bispyribac sodium application. Only 2 mechanical weeding at 20 and 40 DAS/DAT could not reduce the density and biomass of weeds effectively during both the years (Tables 1, 2). Chemical control with pre-emergence and post-emergence herbicides along with application of herbicide like bispyribac at later stages (25 days) were found effective in controlling *Echinochloa* spp. Mandal *et al.,* (2013) reported the efficacy of weed management that uses combination of different approaches. Verma *et al*., (2015) reported that the combined use of weedicides performed comparatively better to control the maximum diversity of weed flora.

SRI and CTR methods of rice controlled the weeds effectively both at 40 and 60 DAS/DAT. Lesser number of weeds due to standing water and reduced seed bank in the upper layer due to puddling decreased the weed density in SRI and CTR as compared to DSR. Aijaz *et al.* (2020) reported that, continuous submergence of the transplanted crop effectively suppressed the weed population and weed seed germination.

Highest weed-control efficiency was recorded in pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* bispyribac 25 g a.i./ha at 25 DAS/DAT, at 40 and 60 DAS/DAT (Table 3). This could be attributed to the suppression of all categories of weeds, viz. grasses, sedges and broad-leaf weeds, with the application of these herbicides which reduced the weed biomass than the other treatments during both the crop seasons.

The trend of nutrient uptake, viz. N, P and K, by weeds in 3 different crop-establishment methods followed the pattern of SRI < CTR < DSR. The DSR recorded significantly higher uptake of these nutrients due to presence of high weed infestations (Table 3). Herbicidal application resulted in significant reduction in nutrient uptake by the weeds at 60 DAS/DAT. Weedy check due to highest dry weight of weeds removed significant amount of N, P and K at 60 DAS/DAT than other treatments in both the years.

Rice

SRI and CTR crop-establishment methods recorded statistically at par plant height at 60 DAS/DAT but both showed significantly superior values to DSR but non-

Table 2. Effect of crop-establishment methods and weed-management practices on weed biomass in rice during rainy season of 2016 and 2017 (mean values)

Treatment	Weed biomass (g/m^2)							
	40 DAS/DAT				60 DAS/DAT			
	Grasses	Sedges	Broad leaved	Total	Grasses	Sedges	Broad leaved	Total
Crop-establishment methods								
DSR	2.24	2.72	2.27	4.56	3.26	5.57	3.121	7.08
	(5.77)	(8.46)	(5.05)	(19.28)	(11.52)	(27.13)	(11.46)	(49.91)
SRI	1.83	1.78	1.11	2.60	2.56	4.13	1.62	5.75
	(3.69)	(4.02)	(0.92)	(8.64)	(7.55)	(17.74)	(2.39)	(29.28)
CTR	1.99	2.09	1.05	3.14	2.64	4.65	2.13	5.82
	(4.30)	(4.53)	(1.29)	(10.12)	(7.85)	(20.75)	(4.77)	(34.30)
CD (P=0.05)	0.23	0.27	0.27	0.31	0.21	0.43	0.27	0.52
Weed-management practices								
PPE or B *fb* Bi	1.79	2.11	1.27	2.76	2.43	2.62	2.05	3.97
	(2.76)	(4.02)	(1.37)	(8.15)	(5.21)	(6.44)	(4.33)	(15.97)
PPE or B *fb* MW	1.47	2.33	1.39	3.16	3.01	4.86	2.53	6.16
	(3.14)	(5.09)	(1.72)	(9.95)	(9.02)	(22.83)	(6.56)	(38.41)
MW at 20 and	1.89	2.48	1.86	3.87	3.18	4.98	2.77	6.85
40 DAS/DAT	(3.52)	(5.84)	(2.97)	(12.33)	(9.68)	(24.66)	(7.88)	(42.22)
Weed-free	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
Weedy-check	3.72	3.67	2.40	5.69	4.60	7.45	3.29	9.56
	(13.52)	(13.40)	(6.06)	(32.97)	(20.97)	(55.44)	(12.26)	(88.67)
CD (P=0.05)	0.24	0.14	0.25	0.26	0.27	0.20	0.47	0.20

DSR, Direct-seeded rice; SRI, system of rice intensification; CTR, conventional transplanting rice, PPE or B *fb* Bi, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* bispyribac sodium 25 g a.i./ha at 25 to 30 DAS/DAT; PPE or B *fb* MW, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT; MW, 2 mechanical weedings at 20 and 40 DAS/DAT; figures in parentheses indicate transformed values

Table 3. Effect of crop-establishment methods and weed-management practices on weed control efficiency and weed nutrient uptake in rice during the rainy season of 2016 and 2017 (mean values)

Treatment	Weed-control efficiency (%)		Weed nutrient uptake at 60 DAS/DAT		
	40 DAS/DAT	60 DAS/DAT	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Crop-establishment methods					
DSR	–	–	10.69	2.66	9.25
SRI	–	–	5.61	1.34	4.47
CTR	–	–	6.70	1.64	5.36
CD (P=0.05)			1.25	0.34	0.99
Weed-management practices					
PPE or B *fb* Bi	75.28	81.98	3.08	0.73	2.25
PPE or B *fb* MW	69.98	56.68	7.48	1.82	6.12
MW at 20 and 40 DAS/DAT	62.60	52.38	8.58	2.06	6.90
Weed-free	100.00	100.00	0.00	0.00	0.00
Weedy-check	0.00	0.00	19.19	4.78	16.52
CD (P=0.05)			0.67	0.15	0.47

DSR, Direct-seeded rice; SRI, system of rice intensification; CTR, conventional transplanting rice, PPE or B *fb* Bi, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* bispyribac sodium 25 g a.i./ha at 25 to 30 DAS/DAT; PPE or B *fb* MW, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT; MW, 2 mechanical weedings at 20 and 40 DAS/DAT; figures in parentheses indicate transformed values

significant effect on number of tillers at 60 DAS/DAT during both the years. Leaving aside weed-free plots and pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* 2 mechanical weeding at 20 and 40 DAS/DAT produced at par with pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* bispyribac 25 g a.i./ha at 25 DAS/DAT and significantly taller plants and higher number of tillers than rest of the weed-management practices during both the years (Table 4). The pre-emergence weedicides along with 2 mechanical weeding creates more aeration at root zone which may be the cause of the better result for plant height and number of tillers.

The yield attributes, viz. effective tillers/m^2, panicle length, grains/panicle and 1,000-grain weight were significantly affected by crop-establishment methods and weed-management approaches (Table 4). Significantly more panicle length (24.40), filled grains/panicle (55.46) and 1,000-grain weight (21.55 g) were recorded in SRI than DSR and CTR methods. The highest yield-contributing characters were found in pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT. The lowest values were recorded in weedy plots. Proper weeding reduced inter-species competition between crop and weeds and increase aeration at crop root zone which might have facilitated efficient utilization of resources, viz. sunlight, nutrient and moisture, to produce higher values thus producing better yield-attributing characters.

Establishment methods and weed-management approaches had also significant effect on grain and straw yields of rice. Among the establishment methods, the higher grain and straw yields were recorded with SRI (3,092 and 6,295 kg/ha) as compared to CTR and DSR methods. The increase of 11.58 and 21.44% in grain yield with SRI method over CTR and DSR was probably owing to profuse tillering in SRI method; otherwise shy tillering habit of 'Basmati 370' showed low yield in CTR and DSR (Table 4). The application of SRI principles like wider spacing and controlled irrigation along with more humus through FYM provided better environment to plant rhizosphere. Singh *et al*., (2021) reported that the number of tillers in SRI and conventional transplanting method observed significantly high at harvesting stage which was better than other methods of planting.

Among the weed-management treatments, the highest grain and straw yields of basmati rice were recorded in the weed-free plots, whereas the lowest in weedy check plots (Table 4). The herbicidal application of pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT recorded statistically at par grain and straw yields with pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence (for CTR) *fb* bispyribac sodium 25 g a.i./ha at 25 DAS/DAT but significantly higher than mechanical weeding at 20 and 40 DAS /DAT.

The higher net returns (₹74,810/ha) and benefit : cost

Table 4. Effect of crop-establishment methods and weed-management practices on growth, yield attributes, yield and economics in rice during the rainy season of 2016 and 2017 (mean values)

Treatment	Plant height (60 DAS/ DAT)	Number of tillers (60 DAS/ DAT)	Effective tillers/m^2 at harvesting	Length of panicle (cm)	Filled grains/ panicle	1,000-grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	Benefit: cost ratio
Crop-establishment methods											
DSR	78.40	235.33	219.53	19.24	42.93	20.20	2,429	4,848	39,500	55,211	1.40
SRI	86.60	238.20	232.07	24.40	55.46	21.55	3,092	6,295	46,000	74,810	1.63
CTR	84.27	230.07	229.47	20.05	48.26	20.49	2,734	5,725	44,905	62,235	1.38
CD (P=0.05)	2.78	NS	5.91	3.67	3.13	0.30	216	444			
Weed-management practices											
PPE or B *fb* Bi	87.33	245.78	235.22	22.49	50.33	20.88	2,518	5,244	41,800	56,818	1.35
PPE or B *fb* MW	89.00	248.22	241.89	23.77	54.00	21.18	2,679	5,687	44,500	60,639	1.36
MW at 20 and 40 DAS/DAT	85.89	239.33	233.56	21.49	48.88	20.57	2,442	4,890	42,550	52,700	1.24
Weed-free	91.89	261.22	253.78	25.76	58.11	21.57	2,850	5,429	50,750	59,858	1.18
Weedy-check	63.00	182.78	175.67	12.66	33.11	19.53	1,482	3,126	29,489	28,633	0.97
CD (P=0.05)	2.28	4.72	5.90	1.43	3.84	0.22	159	423			

DSR, Direct-seeded rice; SRI, system of rice intensification; CTR, conventional transplanting rice, PPE or B *fb* Bi, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* bispyribac sodium 25 g a.i./ha at 25 to 30 DAS/DAT; PPE or B *fb* MW, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 ka/ha as pre-emergence (for CTR) *fb* 2 mechanical weedings at 20 and 40 DAS/DAT; MW, 2 mechanical weedings at 20 and 40 DAS/DAT; figures in parentheses indicate transformed values

Rate of basmati paddy ₹35/kg and straw ₹2/kg

(B : C) ratio (1.63) were realized in SRI method than DSR and CTR. The CTR and DSR registered ₹62,235 and ₹55,211 lesser gross returns than SRI. However, DSR proved to be more economically viable option with higher B : C ratio (1.40) than CTR (1.38) method (Table 4). This was owing to reduction in cost of cultivation owing to absence of expenses on puddling and manual transplanting of rice seedlings. Among the weed-management methods, the herbicidal treatment, i.e. pendimethalin 1 kg a.i./ ha as pre-emergence (for DSR) or butachlor 1.5 kg/ ha as pre–emergence (for CTR) *fb* 2 mechanical weeding at 20 and 40 DAS/DAT provided the highest net returns (₹60,639/ha) which was followed by weed-free plots (₹59,858/- net returns). Also, this treatment recorded highest B : C ratio of 1.36. This happened owing to reduction of ₹6,250/- in cost of cultivation as result of herbicidal application as compared to complete dependence on manual/mechanical weeding operations in weed-free treatment plots. Weeds can be economically and effectively controlled by combined application of herbicides and mechanical weeding (Reddy *et al.,* 2013).

On the basis of 2 years study it can be concluded that, among the establishment methods, system of rice intensification (SRI) provided higher values of grain yield, more net returns and highest benefit : cost ratio (1.63) while among the weed-management methods, pendimethalin 1 kg a.i./ha as pre-emergence (for DSR) or butachlor 1.5 kg/ha as pre-emergence *fb* 2 mechanical weedings at 20 and 40 DAS/ DAT recorded higher grain yield and fetched better economic returns and benefit : cost ratio (1.36).

REFERENCES

Chauhan, B.S. and Abugho, S.B. 2012. Effect of crop stages on the efficacy of post emergence herbicides on four weed species of direct seeded rice. *Scientific World Journal doi* 10.1100/2012/123071, 7 p.

Chauhan, B.S. and Opena, J. 2012. Effects of tillage systems and herbicides on weed emergences weed growth and grain yield in dry seeded rice systems. *Field Crop Research* **137**: 56–69.

Farooq, M., Kadambot H.M., Siddique, H., Rehman, T.A. and DongJinLee, A.W. 2011. Rice direct seeding: Experiences, challenges and opportunities–A review. *Soil and Tillage Research* **111**: 87–98.

Gangwar, K.S., Tomar O.K. and Pandey D.K. 2008. Productivity and economics of transplanted and direct–seeded rice (*Oryza sativa*)-based cropping systems in Indo–Gangetic plains. *Indian Journal of Agricultural Sciences* **78**: 655–658.

Gathala, M.K., Ladha, J.K., Sharawat, V.Y.S., Kumar, V., Sharma, P.K., Sharma, S. and Pathak, H. 2011. Tillage and crop establishment effects sustainability of

South Asian Rice–Wheat system. *Agronomy Journal* **103**(4): 961–971.

Gill, M.S. 2008. Productivity of direct-seeded rice (*Oryza sativa*) under varying seed rates, weed control and irrigation levels. *Indian Journal of Agricultural Sciences* **78**: 766–770.

Kumar, V. and Ladha, J.K. 2011. Direct seeding of Rice: Recent developments and future research needs. *Advances in Agronomy.* **111**: 299–413.

Ladha, J.K., Kumar, V., Alam, M.M., Sharma, S., Gathala, M., Chandna, P., Sharawat, Y.S. and Balasubramanian, V. 2009. Integrating crop and resource management technologies for enhanced productivity, profitability and sustainability of the rice–wheat system in South Asia. (In): Ladha, J.K., Singh, Y., Erenstein, O., Hardy, B. (Eds). Integrated Crop and Resource Management in Rice–Wheat System of South Asia. *International Rice Research Institute, Los Banos, Philippines*. 69–108.

Mandal, M.K., Duary B. and De G.C. 2013. Effect of crop establishment and weed management practices on weed growth and productivity of basmati rice. *Indian Journal of Weed Science* **45**(3): 160–170.

Nazir, A., Anwar, B.M., Tauseef, Rashid, Z., Mohi-ud-din, Rehana, Fayaz, Suhail and Wani, S.A. 2020. Crop establishment and weed management effect on weed parameters and rice yield under temperate zone of Kashmir. *Indian Journal of Weed Science* **52**(3): 217–221.

Reddy, G.S., Giri, U. and Bandyopadhyay P. 2013. Bioefficacy and phytotoxicity of imazethapyr on the predominant weeds in soybean, [*Glysine max* (L.) Merill]. *Journal of Crop and Weed* **9**(2): 203–206.

Singh, A.K., Yadav, R.S., Kumar, D., Kumar, G. and Kumar, S. 2021. Impact of planting methods and weed-control practices on growth, yield and quality of paddy. *The Pharma Innovation Journal* **10**(6): 1,130–1,134.

Verma, S.K., Singh, S.B., Meena, R.N., Prasad, S.K., Meena and Gaurav, R.S. 2015. A review of weed-management in India: The need of new directions for sustainable agriculture. *The Ecoscan* **10**(1): 253–263.

Uphoff, N. 2002. System of Rice Intensification (SRI) for enhancing the productivity of land, labour and water. *Journal of Agricultural Research Management* **1**: 43–49.