



RESEARCH ARTICLE

# Performance of direct seeded rice (DSR) in relation to planting patterns and weed control methods on weed dynamics and productivity

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## Abstract

Rice (*Oryza sativa* L.) is the major significant staple food of Indian population. Compared to puddled transplanting, direct seeded rice (DSR) is environmentally friendly but faces severe weed infestation and iron deficiency, resulting in low yields and poor farmer adoption. To examine these problems, a field study was conducted using a Split-Plot Design at Lovely Professional University, Punjab, India during 2022 and 2023. Different planting patterns were kept in main plots were flat sowing, two rows per bed, three rows per bed and two rows per bed and one in furrow and sub plots treatments were “pendimethalin fb. bispyribac, pendimethalin fb. metsulfuron, weed free up to harvest and unweeded (control)”. Among the planting patterns, three rows per bed produced significantly higher paddy yield than flat sowing. This treatment was followed by two rows on bed and one in furrow. Also weed density was lower in all bed planting treatments as compared to flat sowing technique due to deep burial of weed seeds. Among weed control treatments, unweeded (control) resulted in more than 95 % yield loss compared with herbicidal treated plots. Pre-emergence application of pendimethalin fb. post-emergence application of bispyribac showed better performance on typical non-paddy and paddy weeds i.e., grasses, sedges and broad leaved weeds in DSR and resulted in higher yields over other weed control treatments but weed free upto harvest treatment was found at par to this treatment during both years.

**Keywords:** bed planting; direct seeded rice (DSR); flat sowing; planting patterns; weed control

## Introduction

Global rice production in 2023-24 is projected to reach a record 520.5 million tons and its consumption is projected to reach 590 million tonnes by 2040. In India, rice accounts for 45 % of total food grain production (1). India has the largest area of rice, 47 million hectares and the second largest producer, with 134 million tonnes, second only to China. Uttar Pradesh and Telangana in 2023-24 rank first and second in area and production, respectively, with Punjab and West Bengal ranked seventh and third in production and area, respectively. The countries that are the biggest rice-exporters are India, Thailand and Vietnam. India alone exports the largest amount of rice around the globe with 16.5 million metric tons (including basmati) in 2023-24 (2).

In a bid to comprehend the importance of rice cultivation on the local scale, in Punjab, the area under rice plantation was 31.49 lakh hectares and the yield of paddy was 208.83 lakh tonnes in 2020-21. The paddy yield was average of 66.31 q/ha. The government’s support for rice production, a good monsoon season, an increase in rice processing companies and rice-related exports all help the Indian rice industry (3).

Irrespective of this advancements, the problem of weed infestation is a key obstacle in developing direct-seeded rice (DSR),

particularly in dry fields (4). Yield losses in DSR due to weeds are nearly 40-100 % (5). Weed growth reduced grain production in wet and dry rice by up to 53 % and 74 %, respectively (6). Herbicides have been used for weed management in croplands since the Green Revolution. Herbicide use has expanded drastically owing to its effectiveness in weed control and cheaper labor costs (7). A study was conducted on weed management in rice cultivation in Gambia and it was discovered that under direct cultivation, every day, a delay in weeding produces a 25 kg/ha drop in rice crop output (8). Some important weeds of DSR are “*Echinochloa colonum* (L.) Link, *E. crusgalli* (L.) Beav, *Oryza sativa* L. (volunteer/weedy rice), *Fimbristilis miliacea* (L.), *Ischaemum rugosum*, *Cyperus iria*, *Cyperus compressus*, *Digitaria sanguinalis*, *Eleusine aegyptiacum*, *Cyperus rotundus* (L.), *Cynodon dactylon* (L.), *Eleusine indica* (L.), *Leptochloa chinensis* and *Eragrostis* spp.) and a few broadleaves like *Ammania baccifera*, *Caesulia axillarism*, *Sphenoclea zeylanica*, *Eclipta alba* (L.), *Digitaria arvensis* and *Amaranthus viridis*”, etc (9).

To increase rice productivity, it is critical to use the optimal planting techniques. In order to achieve this, research and development take initiatives on innovative rice crop establishment methods such as raised bed planting, direct sowing and aerobic rice culture were launched in various areas of the world (10). These technologies will be used in nations such as Pakistan due to the

country's widespread water scarcity (11). DSR is often cultivated on flat beds, however raised beds may be used to save water and improve crop growth and development. Beds measuring 67.5 cm (37.5 cm bed top and 30 cm furrow) are made and two to three rows of rice can be seeded in either dry or wet environments.

In present, there is widespread water scarcity all over the world. Cultivation of transplanted rice not only require huge amount of water but also deteriorates soil texture due to repeated puddling which necessitated new techniques for rice cultivation i.e., DSR and this technique is not new as it was practiced in back 1950s. The percolation rate of water decreases with puddling which had a adverse effect on following wheat crop also. There is lot of water saving and physical conditions of soil are not deteriorated with cultivation of DSR as it is sown in unpuddled field. Some problems of DSR are that weeds are big problem as both rice and non rice weeds appears, crop stands may be poor due to lack of appropriate machinery, iron deficiency is more especially on light to medium soils. Moreover, laser land levelling is required for uniform crop stand and water saving.

DSR is an evolving agricultural technology in Asia due to certain advantages, i.e., there is labour saving, irrigation water saving, improved physical state of the soil for subsequent crops and reduced methane emissions, easy and faster planting, less labor, early crop maturity in 7-10 days, more tolerance for scarcity of water deficit, comparable yield and high benefit cost ratio (12). Various studies indicated that DSR provides saving of 12-60 % of irrigation water, 8-60 % in labour, reduction in global warming potential by 32-44 %, saving cost of cultivation by Rs. 6436-7950 ha<sup>-1</sup> and results in better wheat yield (8-10 %) than PTR (13). The saving of irrigation water in dry DSR is mainly achieved through omission of puddling (which requires 10-15 cm irrigation water) along with adoption of alternate wetting and drying conditions for regulating irrigation to the crop (14). The transplanted puddled rice also worsens soil physical characteristics by forming a hardpan at plough layer resulting significant reduction rates of water percolation and adversely influencing the next wheat crop, DSR will over come these problems.

DSR has become popular among farmers because it has reduced labor costs, better management of nutrients and the availability of chemical methods of weed control, it also give high total production and it is easy method for planting with minimum labor and hence most of farmers from the Philippines, Malaysia, Thailand and India adopt this technology. At present, about 23 % of total rice is under DSR world wide for DSR technology, short duration varieties are more suitable due to their quick initial growth as compared to long duration varieties. The cost of labor in rice cultivation is higher than that of most other crops; therefore, there is need to change from TPR to DSR immediately. Thus, the current research aims at identifying the best planting pattern and weed management strategy to achieve better productivity and sustainability of DSR.

## Materials and Methods

### Location, climate and crop variety

The field experiment was carried out in the kharif seasons of 2022 and 2023 in Agronomy Research Farm, Lovely Professional University (LPU), Phagwara, District Kapurthala, Punjab, India. It is located in the central plain agro-climatic zone at latitude 31°22' 31.81" N and longitude 75°23'03.02" E, with an altitude of 252 m above the mean sea level, approximately 360 km near Delhi. It is a subtropical area and the climatic conditions are such that there are hot and humid summers (up to 46 °C) and cold winters, with an average annual rainfall of 650 mm, mainly caused by the Southwest monsoon, which occurs in July to September. Rice cultivation thrives well in such climatic conditions because of its high humidity and constant water supply with 21-37 °C being its optimal growth temperature (accepting up to 40-42 °C).

PR 126, a short-duration, early-maturing rice type suggested by Punjab Agricultural University (2017), was used in the experiment. The average plant height of this variety is 102 cm, it reaches maturity in 93 days after transplanting (or 123 days in DSR), its grain is long and slender and translucent and resistant to seven major bacterial blight pathogens that are common in Punjab. It produces up to 75 quintals per hectare and transplantation of seedlings is recommended between 25 and 30 days. The treatment details are listed in Table 1.

### Agronomic practices

#### Crop establishment and management practices

The experimental area was also pre-soaked with irrigation (rauni) during the first week of May and it was plowed three times, the first ploughing was with disc harrow and then planked to assure enhancement of germination of the seed and levelling the field to enhance irrigation efficiency. PR 126 seeds were sown at a row spacing of 22.5 cm, seed rate of 60-80 kg/ha and a depth of 3-4 cm. A germination analysis carried out in the Agricultural Laboratory of Lovely Professional University indicated 80-85 % germination. In both years, sowing was done on 25th May and irrigation was done immediately. The phosphorus and potassium fertilizers were used as one broadcast dose applied at sowing and nitrogen fertilisers were used as three splits, at 20 days after sowing (DAS), tillering and prior to panicle initiation. Irrigation was provided on demand especially where the monsoon rains were inadequate.

**Table 1.** Treatment details

#### Main plots - Planting patterns

**M<sub>1</sub>** - Flat sowing

**M<sub>2</sub>** - Two rows/bed

**M<sub>3</sub>** - Three rows/bed

**M<sub>4</sub>** - Two rows/bed and one in furrow

#### Sub plots - Weed control methods

**T<sub>1</sub>** - Pendimethalin 30 EC 0.75 kg/ha, followed by bispyribac 10 SC 25 g/ha

**T<sub>2</sub>** - Pendimethalin 30 EC 0.75 kg/ha followed by metsulfuron 20 WG 15 g/ha

**T<sub>3</sub>** - Weed free

**T<sub>4</sub>** - Weedy check (control)

Pendimethalin was applied as pre-emergence. Bispyribac was applied 18 to 20 days after sowing.

Weed management was conducted in accordance with the subplot treatments: In weed free plot pre-emergence application of pendimethalin was done which was followed by post-emergence application of bispyribac. Hand pulling of left over weeds was done manually to kept the crop free from weeds. In the weedy check (control) plots, there were no weed control interventions undertaken and the weeds were allowed to grow along with the crop to harvest. A knapsack sprayer was used to apply herbicides with a pre-emergence treatment of 500 L/ha and a post-emergence treatment of 250 L/ha. During the growing period, PR 126 was not infested with pests and diseases. Harvesting was performed when plants had reached 100 % of grain maturity and a net plot area of 2 m<sup>2</sup> was harvested separately per each subplot. The harvested crop was dried in the sun and threshed by hitting the plants on hard surface.

### Weed dynamics and assessment

In the experimental field, the major weed flora of the two *Kharif* seasons of 2022 and 2023 of PR 126 production included “*Echinochloa crusgalli*, *Echinochloa colona*, *Elusine indica*, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Leptochloa chinensis*, *Caesulia axillaries*, *Commelina benghalensis*, *Physalis minima*, *Eclipta alba*, *Euphorbia hirta*, *Phyllanthus niruri*, *Ludwigia* spp., *Trianthema monogyna*, *Achyranthes aspera*, *Digiteria sanguinalis*, *Ammannia baccifera* and *Fimbristylis miliacea*”. Weed count (weeds/m<sup>2</sup>) was determined at day 30, day 60 and day 90 after sowing (DAS) and at harvest time, using a 30 cm × 30 cm quadrat randomly positioned on each plot and the values were expressed as weeds per square meter. Weed dry matter (q/ha) was measured by picking weeds at a 1 ft<sup>2</sup> quadrat in two random locations per plot at 30, 60 and 90 days and at harvest. The collected weeds were cut at the surface, sun-dried and subsequently oven-dried at a temperature of 55 ± 5 °C and then the dry weight of the weeds ground on an electronic weighing balance and dry weight accumulation was converted into q/ha.

### Yield and yield attributes

Measurement of yield and its components were taken at the time of crop maturity. A 30 cm × 30 cm quadrat was used in counting the number of panicles per m<sup>2</sup> and was transformed into the square meter. The grains per panicle were calculated as a mean of five representative panicles per tagged plants and have been expressed as grains per panicle. Panicle length (cm) was taken on five tagged panicles between node and apex. Test weight (g) was determined by weighing 1000 grains of each net plot by counting the grains with an automatic seed counter. Biological yield (q/ha) was obtained by dividing total weight of harvested plants of each net plot and straw yield was determined by subtracting the seed yield from the biological yield (total weight of rice plants - seed weight). Seed yield (q/ha) was calculated by threshing, cleaning, drying and weighing the yield of each harvested net plot. The formula used to calculate the harvest index (HI%):

$$\text{Harvest index (HI)} = \text{Seed yield} / \text{Biological yield} \times 100$$

The results obtained on all recorded data underwent two-way ANOVA analysis through OPSTAT software (CCS Haryana Agricultural University, Hisar) and statistical significance was measured at  $p=0.05$ .

## Results and Discussion

### Weed parameters

#### Total weed count

At harvest, the differences in the weed count due to planting patterns were observed as non-significant in both the years (Table 2). the unweeded control recorded a significantly higher weed count than the other treatments in both years of the study. The lowest weed count was observed in weed free up to harvest when compared to all other weed management treatments during both the years. Also weed count per square meter at harvest was significantly less in pendimethalin fb. bispyribac than pendimethalin fb. metsulfuron treatment during both years. Generally weed count per square meter was high in flat sowing method when recorded at all periodic intervals during both years than bed sowing methods as weed seeds were buried deep in bed planting treatments. Total number of weeds per square meter was significantly less in bispyribac treatment due to its broad spectrum weed control as compared to metsulfuron which controls sedges and broad leaf weeds in paddy and this holds good at all periodic intervals. Pendimethalin controlled all non-paddy weeds (Fig. 1) where as bispyribac controlled all paddy weeds (Fig. 2) due to its broad spectrum nature and metsulfuron provided control on broad leaf weeds and sedges growing in rice. The weed population in unweeded (control) was significantly higher due to availability of more space as initial growth of direct seeded rice is very slow and its mortality rate was also high (Fig. 3). Identical findings conforms to previous findings (15, 16).

**Table 2.** Effect of planting patterns and weed management treatments on weed count and weed dry matter accumulation at harvest during 2022 and 2023

	Weed count (sq/m)		Weed dry matter (q/ha)	
	2022	2023	2022	2023
<b>Main plots - Planting patterns</b>				
M <sub>1</sub> - Flat sowing	8.0(65)	9.2(85)	5.0(25)	5.4(29)
M <sub>2</sub> - Two rows/bed	7.9(63)	8.5(73)	4.9(24)	5.2(27)
M <sub>3</sub> - Three rows/bed	7.8(61)	8.7(77)	5.0(25)	5.3(28)
M <sub>4</sub> - Two rows/bed and one in furrow	8.1(67)	9.0(81)	4.9(25)	5.3(28)
SE(m)	0.18	0.22	0.27	0.48
CD at $P < 0.05$ %	NS	NS	NS	NS
<b>Sub plots - Weed control treatments</b>				
T <sub>1</sub> - Pendi. fb. bispyribac	6.4(42)	7.9(63)	2.6(7)	3.3(11)
T <sub>2</sub> - Pendi. fb. metsulfuron	7.2(53)	9.0(81)	3.0(9)	3.7(14)
T <sub>3</sub> - Weed free	1.0(0.0)	1.0(0.0)	1.0(0)	1.0(0)
T <sub>4</sub> - Unweeded (control)	12.6 (161)	13.1(172)	9.1(83)	9.3(87)
SE(m)	0.17	0.23	0.26	0.38
CD at $P < 0.05$ %	0.38	0.59	0.77	1.12
CD for interaction	NS	NS	NS	NS

Pendi.: Pendimethalin.

Figures without parenthesis are statistically analysed square root transformed values. Figures in parenthesis are original values.

Pendi. stands for pre-emergence application of stomp 30 EC (pendimethalin) at 0.75 kg/ha. Bispyribac was applied at 25 g/ha as post-emergence and metsulfuron was applied at 15 g/ha as post-emergence (30 DAS).

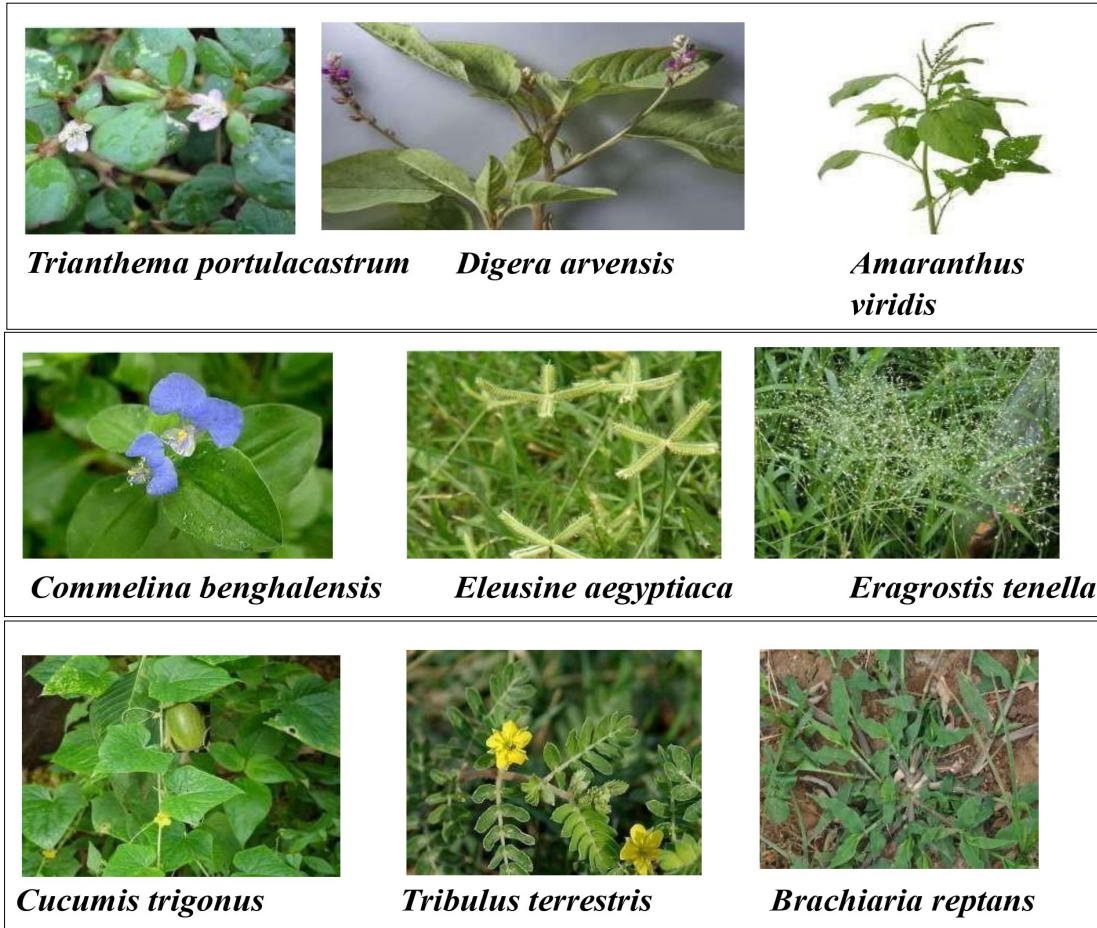


Fig. 1. Important weeds in DSR (non-paddy weeds).

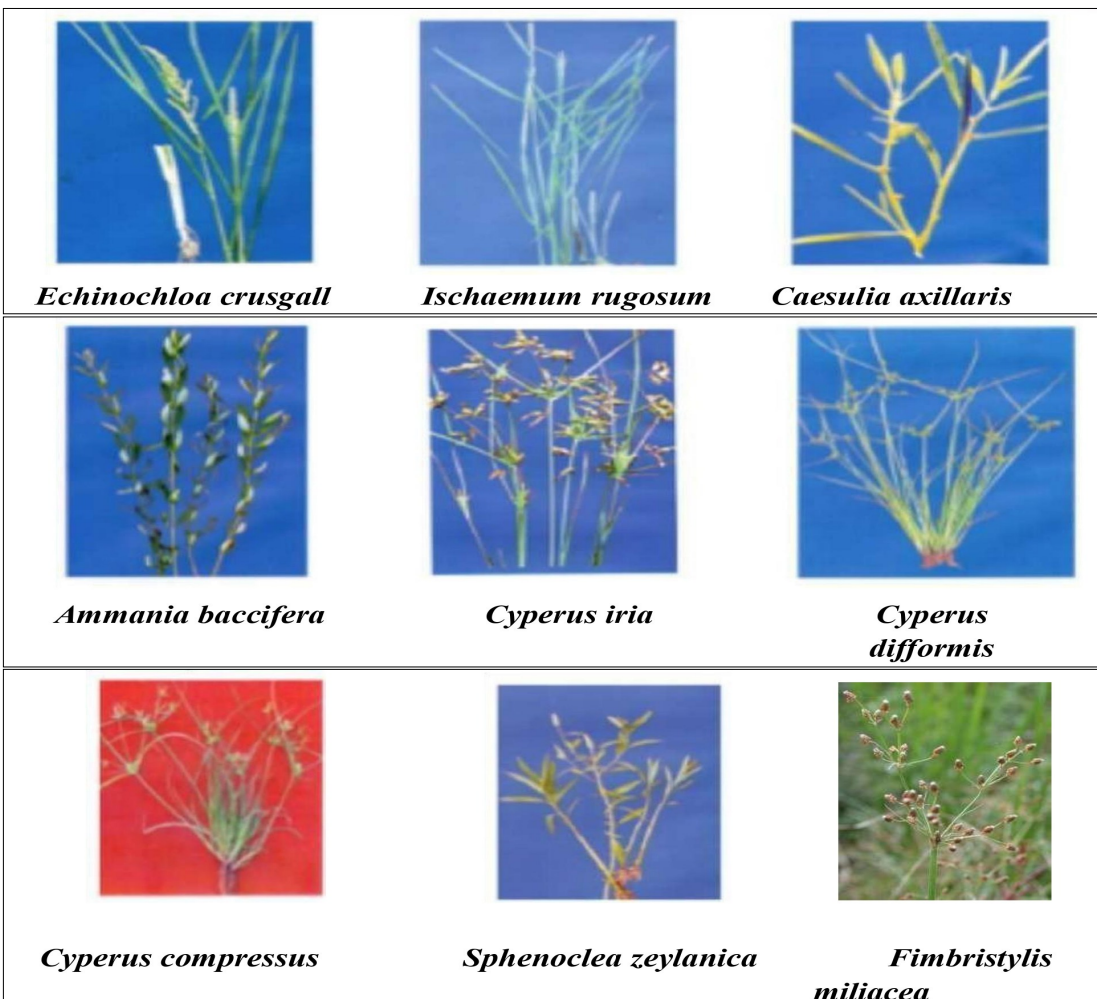


Fig. 2. Important weeds in DSR (paddy weeds).

### Dry matter of weeds

The accumulation of weed dry matter per (q/ha) was also recorded at harvest. At this stage, the dry matter accumulation by weeds was not influenced significantly by the different planting patterns for both years. Among the planting patterns, overall more dry matter was observed in flat sowing technique than bed sowing as weed growth was comparatively less in bed sowing technique, may be due to burial of some weed seeds deep in soil. Among the weed management treatments, the unweeded (control) treatment recorded significantly more dry matter than all weed management treatments for both years (Table 2). This indicates the effectiveness of weed control methods in reducing weed dry matter accumulation compared to unmanaged conditions. The significantly lowest weed dry matter accumulation was observed in weed free up to harvest as compared to all other weed control treatments. The dry matter accumulation by weeds in pendimethalin fb. bispyribac, pendimethalin fb. metsulfuron treatments was found at par with each other during both years. Effective control of weeds at all periodic intervals with bispyribac herbicide may be due to its broad weed control spectrum as compared to metsulfuron. The dry matter of weeds in unweeded (control) was exceptionally high due to low smothering effect of crop on weeds during initial stages (Fig. 3). Identical outcomes are also revealed by previous findings (15, 16).

### Yield and yield attributing characters

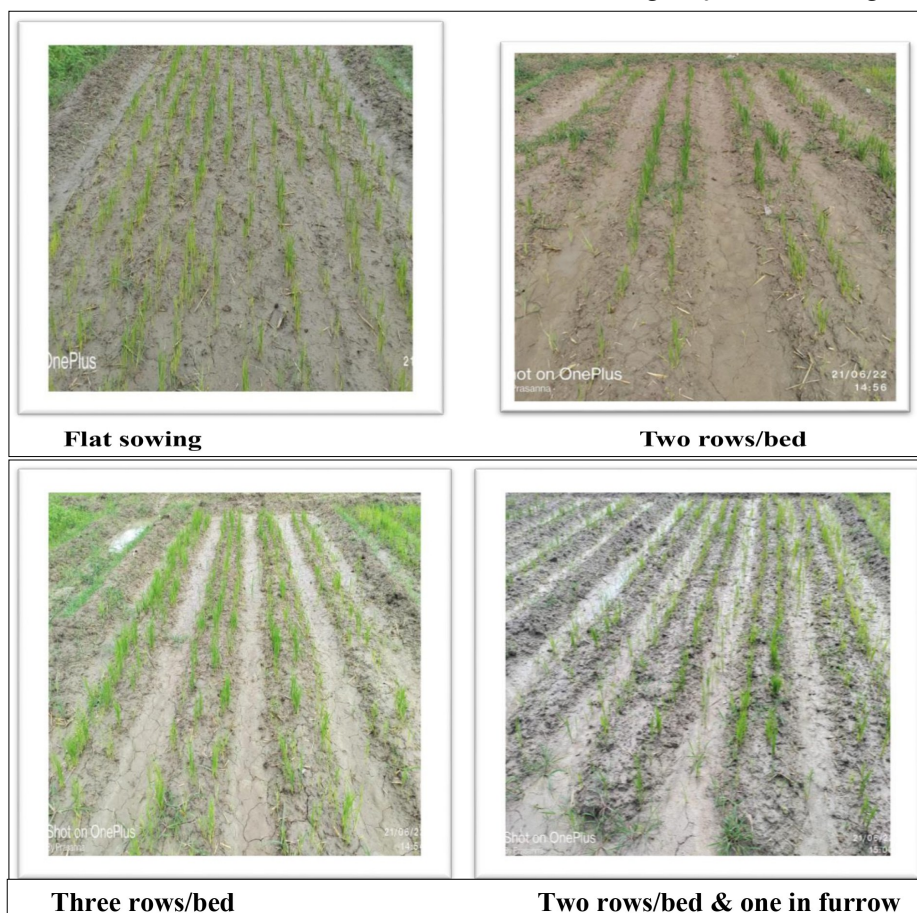
#### Effective tillers per meter row length

Effective tillers per square meter is the most important parameter as it is the yield determining factor for the cereal crops. Effective tillers per square meter were recorded at harvest for both the years (Table 3). The differences in the effective tillers were significantly influenced by both planting patterns and weed management treatments when

recorded for both the years. Among the planting patterns, the significantly higher count of effective tillers per square meter were observed by three rows per bed (M3) as compared to all other planting patterns during both years. Also the planting pattern of two rows per bed and one row in furrow (M4) recorded significantly more effective tillers than two rows per bed and flat sowing technique during both years. Also flat sowing recorded significantly more effective tillers than two rows per bed (Fig. 4) during 2022 but these differences during 2023 were non-significant. Out of all other weed management treatments, the greatest number of effective tillers were observed in pendimethalin fb. bispyribac which were observed as statistically similar to weed free treatment and these two treatments observed significantly higher effective tillers as compared to pendimethalin fb. metsulfuron during both years. The significantly less number of effective tillers were recorded in unweeded (control) than all other weed management treatments for both the years. The present data conform to previous findings (15, 16).

#### Number of grains per panicle

The differences in the total number of grains per panicle had been significantly affected by both planting patterns and weed management treatments in both the years of study (Table 3). Amongst planting patterns, the significantly higher count of grains per panicle had been observed by two rows per bed than all other planting patterns when recorded during 2022. Also during 2023, significantly less count of grains per panicle were observed in two rows per bed as compared to all other planting patterns which being at par among themselves. Out of all other weed management methods, the significantly higher count of grains per panicle had been observed in weed free up to harvest in comparison with other treatments during the year 2023. During 2022, the higher count of



**Fig. 3.** Planting patterns (15 DAS).

**Table 3.** Effect of planting patterns and weed control treatments on effective tillers/square meter, number of grains/panicle and panicle length (cm) during 2022 and 2023

	Effective tillers (sq m)		No of grains/panicle		Panicle length (cm)	
	2022	2023	2022	2023	2022	2023
<b>Main plots - Planting patterns</b>						
M <sub>1</sub> - Flat sowing	432.7	386.7	201.3	196.8	18.5	18.1
M <sub>2</sub> - Two rows/bed	408.7	378.2	216.5	206.8	22.1	20.9
M <sub>3</sub> - Three rows/bed	628.0	596.3	211.9	206.6	21.2	20.4
M <sub>4</sub> - Two rows/bed and 1 in furrow	540.7	501.3	207.8	207.5	19.6	21.5
SE(m)	5.91	6.01	0.82	0.46	0.24	0.27
CD at <i>P</i> < 0.05%	20.1	19.20	2.87	1.63	0.72	0.91
<b>Sub plots - Weed control treatments</b>						
T <sub>1</sub> - Pendi. fb. bispyribac	609.6	569.2	280.5	269.6	23.4	24.0
T <sub>2</sub> - Pendi. fb. metsulfuron	539.6	503.3	272.2	266.7	22.0	22.7
T <sub>3</sub> - Weed free	577.3	552.8	281.0	277.7	24.3	24.7
T <sub>4</sub> - Unweeded (control)	283.6	237.1	3.8	3.7	11.7	9.5
SE(m)	12.5	8.66	1.10	0.62	0.28	0.15
CD at <i>P</i> < 0.05 %	36.7	27.3	3.23	1.83	0.80	0.39
CD for interaction	NS	NS	NS	NS	1.57	0.88

Pendi.: Pendimethalin.

grains per panicle had been observed in weed free up to harvest which were found to be statistically at par with pendimethalin fb bispyribac treatment and both these treatments were significantly better than other weed management treatments. The significantly less number of grains per panicle were recorded in unweeded (control) in comparison with all other weed management methods in both the years of study. The present data conform to previous findings (15, 16).

#### Panicle length

Panicle length was recorded at the harvest stage in both the years of study. The variations in panicle length had been significantly influenced by both planting patterns and weed management treatments in both the years of study (Table 3). Amongst all planting patterns, the largest panicle length had been recorded by two rows per bed during the year 2022, which was significantly higher than all other planting patterns. but in the year 2023, the highest panicle length was observed in two rows per bed and one row in furrow which was statistically at par with two rows per bed but significantly more than three rows per bed and flat sowing. The significantly less panicle length was observed in flat sowing as compared to all other planting patterns in two years of study. Out of all the weed management treatments, the significantly higher panicle length was observed in weed free up to harvest which was statistically similar to pendimethalin fb. bispyribac treatment and these two treatments showed significantly greater panicle length than other weed management methods when recorded for both the years. The significantly less panicle length was recorded in unweeded (control) treatment in both the years of study in comparison with further weed management methods. Similar outcomes were reported in earlier studies (15, 16).

#### Panicle weight

Panicle weight was recorded at the harvest stage in both the years of study and data presented in Table 4. The differences in panicle weight due to planting patterns was found to be non-significant during 2022 but it was found to be significant for the year 2023. Among the planting patterns, the significantly higher panicle weight (g) was observed by two rows per bed as compared to three rows per bed and two rows per bed and one row in furrow and flat sowing method (Fig. 4). But the differences of panicle weight between three rows per bed and two rows per bed and one row in furrow were found to be statistically at par with each other. The significantly lower panicle weight was observed in flat sowing

as compared to all other planting patterns. The differences in the panicle weight was significantly influenced by weed management treatments. Among the weed management treatments, highest panicle weight was recorded in weed free up to harvest which was observed as similar with pendimethalin fb. bispyribac during both the years and both of these treatments were observed as significantly superior to other weed management treatments. The significantly less panicle weight was recorded in weedy check in both the years of study as compared to all other herbicidal treatments. Also pendimethalin fb. metsulfuron produced significantly less panicle weight than pendimethalin fb. bispyribac and weed free treatments. Similar results have been reported in earlier studies (15, 16).

#### Test weight

Test weight was recorded at the harvest stage in both the years of study. The differences in test weight because of planting patterns had been observed as non-significant in the year 2022 but it was found to be significant for the year 2023 (Table 4). Among the planting patterns, the significantly highest test weight during 2023 was observed in two rows per bed which was significantly superior to all other planting patterns. But three rows per bed recorded significantly less test weight than two rows per bed and one row in furrow and flat sowing methods (Fig. 4). The differences in the panicle weight had been significantly impacted by weed management methods. Out of all the weed management treatments, the significantly highest test weight had been recorded by weed free up to harvest which had recorded significantly more test weight than all other weed management methods during 2022, but during 2023, it was found at par with pendimethalin fb. bispyribac and both these treatments were found to be significantly better than other weed management treatments. Pendimethalin fb. metsulfuron recorded significantly less test weight (g) than weed free and pendimethalin fb. bispyribac treatment during both years. The significantly lowest test weight was recorded in weedy check in both the years of study, as compared to other treatments. Comparable results have been reported in previous studies (15, 16).

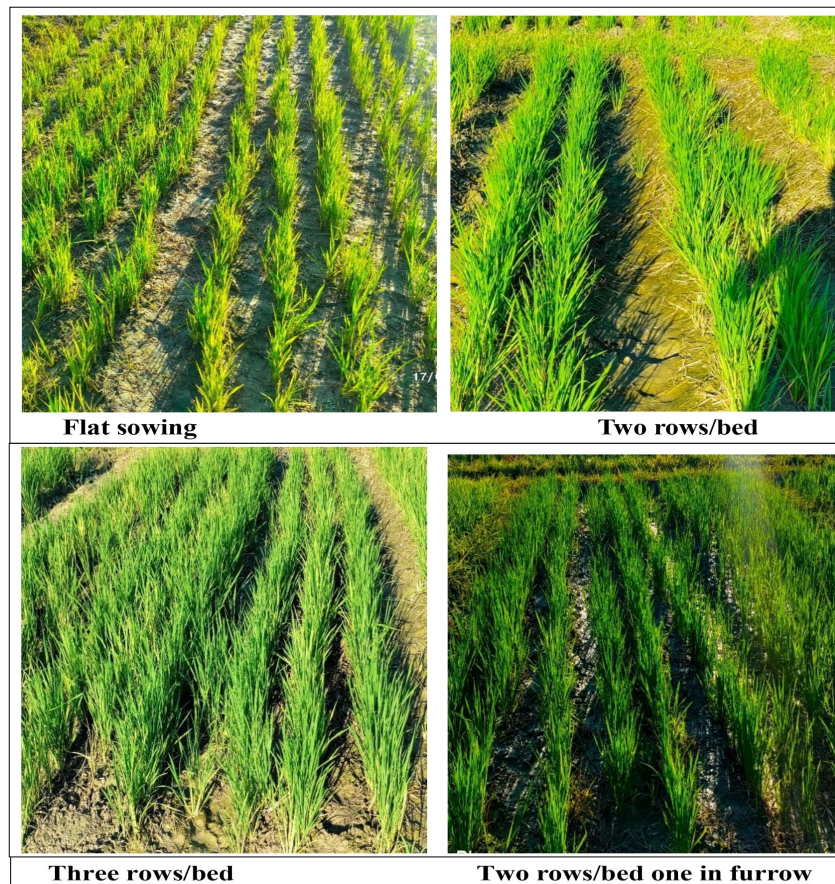
#### Paddy yield

Paddy yield was recorded at harvest for both the years and given in Table 5. The statistics data of paddy yield of rice revealed that various planting patterns and weed management treatments exhibited significant disparity in paddy yield when recorded in

**Table 4.** Effect of planting patterns and weed control treatments on panicle weight (g) and test weight (g) during 2022 and 2023

	Panicle weight (g)		Test weight (g)	
	2022	2023	2022	2023
<b>Main plots - Planting patterns</b>				
M <sub>1</sub> - Flat sowing	5.45	4.53	21.36	20.63
M <sub>2</sub> - Two rows/bed	5.70	5.11	21.50	21.30
M <sub>3</sub> - Three rows/bed	5.60	4.78	21.24	19.61
M <sub>4</sub> - Two rows/bed and one in furrow	5.63	4.78	21.30	20.39
SE(m)	0.06	0.06	0.12	0.14
CD at $P < 0.05\%$	NS	0.21	NS	0.48
<b>Sub plots - Weed control treatments</b>				
T <sub>1</sub> - Pendi. fb. bispyribac	5.96	5.20	22.80	21.69
T <sub>2</sub> - Pendi. fb. metsulfuron	5.71	4.79	20.50	19.84
T <sub>3</sub> - Weed free	6.2	5.31	23.35	22.15
T <sub>4</sub> - Unweeded (control)	4.38	3.90	18.75	18.25
SE(m)	0.04	0.06	0.13	0.20
CD at $P < 0.05\%$	0.12	0.18	0.38	0.58
CD for interaction	NS	NS	NS	NS

Pendi.: Pendimethalin.

**Fig. 4.** Planting patterns (50 DAS).**Table 5.** Effect of planting patterns and weed control treatments on paddy yield (q/ha) and straw yield of DSR (q/ha) during 2022 and 2023

	Paddy yield (q/ha)		Straw yield (q/ha)	
	2022	2023	2022	2023
<b>Main plots - Planting patterns</b>				
M <sub>1</sub> - Flat sowing	48.5	49.2	62.7	61.6
M <sub>2</sub> - Two rows/bed	46.8	45.1	62.3	62.3
M <sub>3</sub> - Three rows/bed	57.5	56.1	71.5	66.7
M <sub>4</sub> - Two rows/bed and one in furrow	53.6	50.0	65.1	60.6
SE(m)	0.57	0.57	0.97	1.02
CD at $P < 0.05\%$	1.84	1.87	3.43	3.59
<b>Sub plots - Weed control treatments</b>				
T <sub>1</sub> - Pendi. fb. bispyribac	64.5	59.1	85.6	69.1
T <sub>2</sub> - Pendi. fb. metsulfuron	58.8	53.7	80.8	65.7
T <sub>3</sub> - Weed free	42.7	37.3	81.0	66.6
T <sub>4</sub> - Unweeded (control)	3.01	2.25	3.46	2.50
SE(m)	1.21	1.57	1.81	1.24
CD at $P < 0.05\%$	4.20	4.86	5.48	3.75
CD for interaction	NS	NS	NS	NS

Pendi.: Pendimethalin.

both the years of study. Among, planting patterns significantly higher yield was observed in three rows per bed than all other planting patterns when recorded for both the years. The significantly less yield was observed in two rows per bed than other planting patterns for both the years. Also planting pattern of two rows per bed and one in furrow (M4) recorded significantly more paddy yield than two rows per bed and flat sowing methods during both the years of investigations. More yield in three rows per bed might be because of less weed density (Table 2). Planting three rows per bed, two rows per bed and one in furrow and flat sowing (Fig. 4) increased paddy yield by 18.6 %, 12.6 % and 3.5 % during 2022 and by 19.6 %, 9.8 % and 8.3 % during 2023 than two rows per bed, respectively. Among the weed management treatments, significantly higher seed yield was observed in weed free up to harvest treatment than another weed management methods in two consecutive years of study. The significantly low seed yield had been observed by unweeded (control) in both the years. Pre-emergence application of pendimethalin fb. bispyribac recorded significantly higher yield than pendimethalin fb. metsulfuron during both years which was because of good management of weeds in the former treatment. The yield of weedy check had significantly lower among all weed management methods, which was very less due to more intensity of weeds during both years. The seed yield in all weed management treatments was significantly more than control during both years which was because of greater management of weeds (Table 2), improved attributes of growth and better yield attributes. The unweeded (control), due to high weed intensity resulted in severe reduction in paddy yield to the tune of 96.9 %, 96.8 % and 96.5 %, during 2022 and 96.1 %, 95.8 % and 95.6 %, during 2023 as compared to weed free, pendimethalin fb. bispyribac and pendimethalin fb. Metsulfuron, respectively. Such drastic reduction in yield was because of greater infestation of weeds which smothered the crop very effectively and resulted in more than 96 % loss in yield, if weeds are not controlled in directly sown rice severe weed problem in directly sown rice is hindering the popularity of this technology among farmers. Similar results were reported in earlier research (15).

The interactive influence on paddy yield in between planting patterns and weed management treatments had been observed as significant in both the years of study (Table 6). During 2022, the yield of rice crop in three rows per bed planting pattern treated with pendimethalin fb. bispyribac was found at par with the weed free crop raised with two rows per bed and one in furrow planting pattern. The seed yield of weed free flat sown crop was significantly less than three rows per bed and two rows per bed and one in furrow

(M3 & M4) crop treated with pendimethalin fb. bispyribac. During 2023, three rows/bed crop treated with pendimethalin fb. bispyribac produced at par seed yield than flat sown crop but kept weed free up to harvest. Also three rows per bed planting pattern treated with pendimethalin fb. metsulfuron produced. Similar (at par) paddy yield than two rows per bed and one in furrow treated with pendimethalin fb. bispyribac.

#### Straw yield

The statistical data of straw yield revealed that various planting patterns and weed management treatments exhibited significant differences in straw yield of rice in both the years of study (Table 5). Among the planting patterns, significantly more straw yield was recorded in three rows per bed than all other planting patterns for both years. The straw yield in flat sowing, two rows per bed and one row in furrow and two rows per bed were found to be at par among themselves in both the years. Out of all other weed management methods, significantly more yield of straw had been obtained in weed free upto harvest than all other herbicidal treatments except pendimethalin fb. Bispyribac during 2023. However, the lowest straw yield of paddy crop was obtained under unweeded (control) which had been significantly least when compared to other weed management methods in both the years. Straw yield in pendimethalin fb. metsulfuron was significantly less than pendimethalin fb. bispyribac treatment during both years. The present data are consistent with previous findings (15, 16).

#### Biological yield

The statistical data on biological yield revealed that different planting patterns exhibited significant variation in biological yield of rice when recorded for both the years (Table 7). Among the different planting patterns, significantly more biological yield was recorded by three rows per bed planting pattern as compared to all other planting patterns during both years. The differences in biological yield among flat sowing, two rows per bed and three rows per bed (Fig. 5) were found to be non-significant in both the years of study. Out of all weed management methods maximum biological yield had been observed in treatment with weed free, also it was succeeded by pendimethalin fb. bispyribac and these two treatments yielded significantly greater biological yield compared to pendimethalin fb. metsulfuron and (unweeded) control treatment during 2023. During 2022, biological yield had been significantly higher in weed free when compared to other weed management methods. Significantly less biological yield had been recorded in the (control) in comparison with other weed management methods in two consecutive years of research.

**Table 6.** Interaction among planting patterns and weed control treatments on paddy yield of direct seeded rice during 2022 and 2023

Treatments	Pendi fb. bispyribac	Pendi fb. metsulfuron	Weed free	Unweeded (control)	Mean
<b>Paddy yield (q/ha) (2022)</b>					
Flat sowing	63.7	60.0	68.4	1.8	48.5
Two rows/bed	62.5	59.0	63.6	2.3	46.8
Three rows/bed	77.0	71.4	79.5	2.3	57.5
Two rows/bed and one in furrow	72.8	62.7	76.7	2.5	53.6
Mean	69.0	63.2	72.0	2.2	
CD at 5 %				2.42	
<b>Paddy yield (q/ha) (2023)</b>					
Flat sowing	63.2	59.9	71.4	2.4	49.2
Two rows/bed	57.6	56.1	64.1	2.8	45.1
Three rows/bed	73.6	71.9	76.4	2.8	56.1
Two rows/bed and one in furrow	68.3	61.4	67.5	3.0	50.0
Mean	65.6	62.3	69.8	2.75	
CD at 5 %				3.57	

### Harvest index

The statistical data on the harvest index was given in Table 7. The data showed that differences in harvest index under different planting patterns were found in the range from 42.7 to 45.2 for the year 2022 and from 41.7 to 44.2 for the year 2023. Out of all the weed management methods, the values of harvest index had found to vary from 43.1 % to 44.5 % for the year 2022 and 43.1 % to

45.5 % for the year 2023. The highest value of harvest index had been recorded by weed free up to harvest succeeded by pendimethalin fb. bispyribac and pendimethalin fb. metsulfuron treatments. The least harvest index had been observed by control in comparison with other weed management treatments in both the years of study.

**Table 7.** Effect of planting patterns and weed control treatments on biological yield (q/ha) and harvest index (%) of DSR (q/ha) during 2022 and 2023

	Biological yield (q/ha)		Harvest index (%)	
	2022	2023	2022	2023
<b>Main plots - Planting patterns</b>				
M <sub>1</sub> - Flat sowing	111.2	110.9	43.5	44.1
M <sub>2</sub> - Two rows/bed	109.2	107.5	42.7	41.8
M <sub>3</sub> - Three rows/bed	129.0	122.9	45.3	44.0
M <sub>4</sub> - Two rows/bed and 1 in furrow	118.8	110.6	44.8	44.3
SE(m)	2.65	2.10	NA	NA
CD at <i>P</i> < 0.05 %	8.44	7.58	NA	NA
<b>Sub plots - Weed control methods</b>				
T <sub>1</sub> - Pendi fb. bispyribac	155.2	150.8	44.4	43.5
T <sub>2</sub> - Pendi fb. metsulfuron	146.6	140.9	43.2	44.1
T <sub>3</sub> - Weed free	161.5	153.5	44.6	45.5
T <sub>4</sub> - Unweeded (control)	5.0	6.8	44.1	41.0
SE(m)	1.91	1.75	NA	NA
CD at <i>P</i> < 0.05 %	6.02	5.83	NA	NA
CD for interaction	NS	NS	NA	NA

Pendi.: Pendimethalin. NA: Not analyzed.



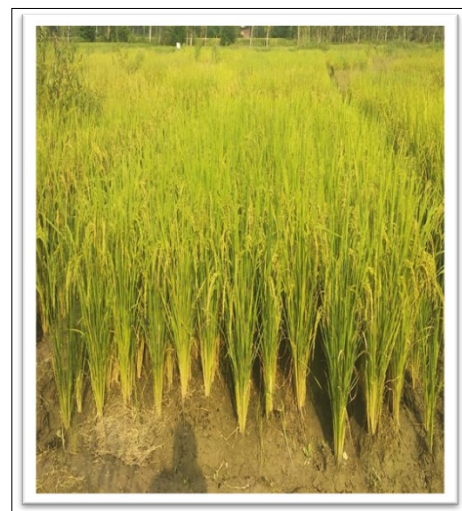
**Flat sowing**



**Two rows/bed**



**Three rows/bed**



**Two rows/bed and one in furrow**

**Fig. 5.** Planting patterns (85 DAS).

## Conclusion

More weed count (weeds/m<sup>2</sup>) and higher weed biomass (q/ha) were observed in the flat sowing technique than in bed sowing, as weed growth was comparatively less in the bed sowing technique. The planting pattern of three rows per bed was found significantly better than other planting patterns (Fig. 5) with respect to paddy yield. Pre-emergence application of pendimethalin (stomp) followed by bispyribac sodium (Nominee Gold) recorded significantly higher paddy yield than pendimethalin followed by metsulfuron during both years, possibly because of better control of all weeds of DSR in the former treatment. The yield of the unweeded control treatment was significantly less than all weed management treatments, resulting in more than 95 % yield loss compared to herbicide-treated plots due to heavy weed infestation during both years. Herbicide application of pendimethalin 0.75 kg/ha followed by bispyribac 25 g/ha was found to be a better weed control option than other treatments. Therefore, the planting pattern of three rows per bed along with the application of pendimethalin 0.75 kg/ha followed by bispyribac 25 g/ha, is beneficial to farmers in direct seeded rice.

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## Authors' contributions

BS, TP and USW conducted the field experiment, collected the data and wrote the manuscript. BS, TP and USW conceptualized the research and designed the experiment. GSKR drafted the manuscript. BSS, TP and USW performed the statistical analysis. BSS and TP revised the manuscript. All authors read and approved the final manuscript.

## Compliance with ethical standards

**Conflict of interest:** Authors do not have any conflict of interest to declare.

**Ethical issues:** None

## References

- Hashim M, Singh VK, Singh KK, Dhar S, Pandey UC. Weed management strategies in direct seeded rice: A review. *Agric Rev.* 2024;45(2):258-65. <https://doi.org/10.18805/ag.R-2245>
- Center for Agriculture and Rural Development Policy Research (CARP). ANGRAU paddy outlook report 2023-24. [https://angrau.ac.in/downloads/AMIC/OutlookReports/2023\\_24/paddy%20outlook-June-july-2023-24.pdf](https://angrau.ac.in/downloads/AMIC/OutlookReports/2023_24/paddy%20outlook-June-july-2023-24.pdf)
- Food and Agriculture Organization of the United Nations. FAOSTAT. Rome: FAO; 2020 [cited 2024 Sept 18]. <https://www.fao.org/faostat/en/#data/QC/visualize>
- Rao AN, Johnson DE, Sivaprasad B, Ladha JK, Mortimer AM. Weed management in direct-seeded rice. *Adv Agron.* 2007;93:153-255. [https://doi.org/10.1016/S0065-2113\(06\)93004-1](https://doi.org/10.1016/S0065-2113(06)93004-1)
- Choubey NK, Kobe SS, Tripathi RS. Relative performance of cyhalofop butyl for weed control in direct seeded rice. *Indian J Weed Sci.* 2001;33:132-5.
- Shyamsunder B, Walia US, Prasanna T, Menon S, Nawabpet P, Raju GSK, et al. Phytotoxicity of pendimethalin on the emergence of seedlings and microbial count in direct-seeded rice across different concentrations. *J Pure Appl Microbiol.* 2024;18(2):1121-5. <https://doi.org/10.22207/JPAM.18.2.31>
- Ramzan M. Evaluation of various planting methods in rice-wheat cropping system, Punjab, Pakistan. *Rice Crop Rep.* 2003;4-5.
- Remington TRJ, Posner L. On-farm evaluation of weed control technologies in direct-seeded rice in the Gambia. In: Starkey P, Simalenga T, editors. *Animal power for weed control.* Wageningen: Technical Centre for Agricultural and Rural Cooperation; 2000.
- Chauhan BS, Mahajan G, Sardana V, Timsina J, Jat ML. Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: Problems, opportunities and strategies. *Adv Agron.* 2012;117:315-69. <https://doi.org/10.1016/B978-0-12-394278-4.00006-4>
- Reddy BS, Reddy SR. Soil, water and weed management for lowland rice (*Oryza sativa*). *Indian J Agron.* 2000;45(2):327-33.
- Baloch MS, Awan IU, Hassan G, Zubair M. Studies on plant population and stand establishment techniques for higher productivity of rice in Dera Ismail Khan. *Rice Sci.* 2007;14(2):118-24. [https://doi.org/10.1016/S1672-6308\(07\)60017-1](https://doi.org/10.1016/S1672-6308(07)60017-1)
- Dhillon BS, Mangat GS. Direct seeded rice in Punjab: opportunities and challenges. In: *Proceedings of national seminar on Sustainable Rice Production Technology for Increasing the Farmers' Income.* Raipur, Chhatisgarh: Indra Gandhi Krishi Vishav Vidyalaya; 2018. p. 20-21.
- Basavalingaiah K, Ramesha YM, Paramesh V, Rajanna GA, Jat SL, Dhar Misra S, et al. Energy budgeting, data envelopment analysis and greenhouse gas emission from rice production system: A case study from puddled transplanted rice and direct-seeded rice system of Karnataka, India. *Sustainability.* 2020;12(16):6439. <https://doi.org/10.3390/su12166439>
- Yadav S, Gill G, Humphreys E, Kukal S. Effect of water management on dry seeded and puddled transplanted rice. Part 1: Crop performance. *Field Crops Res.* 2011;120:112-22. <https://doi.org/10.1016/j.fcr.2010.09.002>
- Pooja K, Saravanane P. Performance of rice cultivars with weed management practices in dry direct-seeded rice. *Ind J Weed Sci.* 2021;53(1):92-4. <https://doi.org/10.5958/0974-8164.2021.00015.0>
- Singh V, Jat ML, Ganie ZA, Chauhan BS, Gupta RK. Herbicide options for effective weed management in dry direct-seeded rice under scented rice-wheat rotation of western Indo-Gangetic Plains. *Crop Protect.* 2016;81:168-76. <https://doi.org/10.1016/j.cropro.2015.12.021>

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