PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.6966

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RESEARCH ARTICLE

Influence of nitrogen levels and weed management treatments on weed growth and yield of direct seeded rice (DSR) in the central plains of Punjab

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OPEN ACCESS

ARTICLE HISTORY
Received: 29 December 2024
Accepted: 09 February 2025
Available online
Version 1.0 : 31 March 2025

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE
Burra S, Thulisekari P, Ujagar SW, Guntimadugu SKR. Influence of nitrogen levels and weed management treatments on weed growth and yield of direct seeded rice (DSR) in the central plains of Punjab. Plant Science Today (Early Access). https://doi.org/10.14719/pst.6966

Abstract

Rice (*Oryza sativa* L.) is the most important staple food of the Indian population. The huge infestation of both paddy and non-paddy weeds in direct-seeded rice and poor knowledge of weed management results in low yields in DSR. This was the major drawback resulting in farmers' poor adoption of this technology, as uncontrolled weeds lead to more than 95 % crop yield losses. Considering the facts as mentioned above, The present study was conducted at Lovely Professional University, Phagwara, Punjab (India). The field trials were designed in the Split Plot Design during 2022 and 2023. Different nitrogen levels viz., 0 kg/ ha, 120 kg/ha, 150 kg/ha and 175 kg/ha were included in the main plots and four weed management treatments in the subplots viz., pendimethalin followed by bispyribac, brown manuring with pre-emergence. The experiment included the application of pendimethalin followed by bispyribac, brown manuring followed by bispyribac and unweeded (control)". Among the nitrogen levels, maximum paddy yield was observed at 175 kg N/ha, which was found to be at par with 150 kg N/ha. Both these treatments were superior to 125 kg N/ha and 0 kg N/ha. Among weed management treatments, pre-emergence application of pendimethalin followed by post-em. bispyribac recorded significantly higher yield than all other weed management treatments. The higher yield in pre-emergence pendimethalin followed by post-emergence bispyribac treatment may be due to better control of paddy and non-paddy weeds. Also, application of pre-emergence pendimethalin followed by bispyribac in the brown manuring treatment significantly increased paddy yield compared to its no application of pendimethalin.

Keywords

brown manuring; Direct Seeded Rice (DSR); nitrogen levels; weed control

Introduction

During 2021, global paddy rice output was 787.7 mMT, with China and India accounting for 51 % of the total. Other notable manufacturers included Bangladesh, Indonesia and Vietnam. In 2021, the five major producers contributed about 72 % of overall output, whereas the le Developing countries contribute approximately 95 % of overall output (1). India ranked second in rice production globally with total production of over 178.31 million metric tons of paddy an The highest production of rice globally was in China, i.e. 213.61 mMT. In Punjab, the rice crop comprised of 31.49 lakh hectares, with a total paddy yield of 208.83 lakh tons in 2020-21. Paddy yields were 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 (2).

Direct-seed rice (DSR) is an evolving agricultural technology in Asia due to certain advantages, i.e., labour saving, irrigation water saving, improved physical state of the soil for subsequent crops and reduced methane emissions. Additionally (DSR) also offers easy and faster planting, less labour, early crop maturity in 7-10 days, more tolerance for the scarcity of water deficit, comparable yield and a high benefit-cost ratio (3).

Various studies indicated that DSR provides savings of 12-60 % in irrigation water, 8-60 % in labour, reduction in global warming potential by 32-44 %, saving the cost of cultivation by Rs. 6436-7950 ha-1 and results in better wheat yield (8-10 %) than PTR (4). The saving of irrigation water in dry DSR is mainly achieved through the omission of puddling (which requires 10-15 cm irrigation water) along with adopting alternate wetting and drying conditions for regulating irrigation to the crop (5). Transplanted puddled rice crop deteriorates soil physical properties due to the creation of a hard pan at the plough layer, resulting in a drastic reduction in water percolation rates. It also adversely affects the following wheat crop. This problem can be omitted by cultivating (DSR).

Weed infestation is a key obstacle in developing direct -seeded rice (DSR), particularly in dry fields (6). Yield losses in DSR due to weeds are nearly 40 to 100 % (7). Weed growth reduced grain production in wet and dry rice by up to 53 % and 74 %, respectively (8). 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 (9). Some important weeds of DSR are *Echinochloa colonum* (L.) Link, *E. crusgalli* (L.) Beav, *Oryza sativa* L. (volunteer/weedy rice), *Fimbristlis miliacea* (L.), *Ischaemum rugosum*, *Cyperus iria*, *Cyperus compressus*, *Digitaria sanguinalis*, *Eleusine aegyptiacum*, *Cyperus rotundus* (L.), *Cynodon dactylon* (L.), *Eleusine indica* (L.), *Leptochloa chinesis* and *Eragrostis* spp) and a few broadleafs like *Ammania baccifera* and *Caesulia axillarism*, *Sphenoclea zeylanica, Eclipta alba* (L.), *Digiteria arvensis* and *Amaranthus viridis* etc.

Nitrogen plays a key role in plant metabolism and is essential for various metabolic pathways (10). Nitrogen is a vital macronutrient for plant activity and a fundamental component of amino acids, which serve as the building blocks for plant proteins and enzymes. Proteins are the structural ingredients of all living things and enzymes help to improve a plant's biochemical processes widely. Nitrogen is also an element of the chlorophyll molecule, which permits the plant to absorb solar energy via photosynthesis, increasing plant growth and crop production. Nitrogen is essential in the plant because it ensures energy availability when and where it is required to increase production. These essential nitrogen macronutrients can also be present in the roots as enzymes and proteins that regulate water and nutrient uptake. Due to its reduced labour costs, enhanced nutrient management strategies and accessibility to chemical weed control technologies, DSR has attracted many farmers. It also results in higher total production and is an easy planting method that requires minimal labour. As a result, many farmers from the Philippines, Malaysia, Thailand and India have adopted this technology. About 23 % of the world's total rice is cultivated using DSR. Short-duration varieties are more suitable for DSR due to their quick initial growth than long-duration varieties. Since labour costs in rice cultivation are higher than in other crops, especially in transplanted rice. Therefore, there is an urgent need to transition to (DSR). The present investigation aims to determine the appropriate nitrogen dosage and the best weed control option for DSR.

Materials and Methods

During the kharif season of 2022 and 2023, the experiment was carried out at the Lovely Professional University's Agronomy Research Farm in Phagwara, District Kapurthala. The farm is at latitude 31°22'31.81'' N and longitude 75°23'03.02" E, with an average altitude of 252 m above mean sea level. It is situated in central Punjab and 360 km from Delhi. It is in the agroclimatic zone's central plain zone, a subtropical region.

Weather and climate conditions

This experimental site, located in a subtropical climate, has cold winters and hot summers, with most of its rainfall falling in July, August and September due to the Southwest monsoon. The highest temperature recorded in May and June throughout the summer was close to 46 °C. If the Southwest monsoon is not delayed, monsoon rains will begin in the second fortnight of July and extend until the end of September. Both the months of July and August get a lot of rain. The region receives approximately 650 mm of rain annually, with most rains falling in July, August and September. The majority of the year, the weather is hot and humid. The cultivation of paddy requires a hot and humid environment. It performs best in regions with high humidity, constant sunlight and an ongoing water supply. Crops need an average temperature range of 21-37 °C throughout their life cycle. The crop can tolerate temperatures up to 40 to 42 °C

Details of variety

PR 126, a short-duration rice cultivar, was sown in both experiments. It's an early maturing rice variety. It has an average plant height of 102 cm and matures approximately 93 days after transplantation. PR 126 matures in 123 days if grown using the DSR method. It has long, slender, transparent, translucent grains. It resists seven of Punjab State's 10 most common bacterial blight pathogens. The average paddy production is 75.0 quintals per hectare. Transplantation is recommended using a 25-30 day-old nursery. The Punjab Agricultural University (PAU) recommends cultivating PR 126 in 2017.

Agronomic practices

Preparation of field : Pre-sowing irrigation (rauni) was applied in the first week of May. The field was ploughed three times: once with a disc harrow and twice with a cultivator, followed by planking to ensure proper germination. The field was levelled correctly to improve irrigation efficiency.

Treatment details
Main plots Nitrogen levels
N_1- 0 kg N/ha
N_2- 125 kg N/ha
N_3- 150 kg N/ha
N_4- 175 kg N/ha
Sub plots Weed control methods
T_1- Pendimethalin 30 EC 0.75 kg/ha, followed by bispyribac 10 SC 25 g/ha
T_2- Brown manuring (sesbania), pendimethalin 30 EC 0.75 kg/ha followed by bispyribac 10 SC 25 g/ha
T_3- Brown manuring (sesbania) followed by bispyribac 10 SC 25 g/ha
T_4- Weedy check (control)
Note -Pendimethalin was applied as pre-emergence - Bispyribac was applied 30 to 35 days after sowing. -Sesbania was killed with the spray of 2,4-D when it was 25 years old. *BM- indicates Brown manuring Sesbania *Pendi- indicates pendimethalin.

Seed rate and spacing : The seeds were sown, maintaining row to row distance of 22.5 cm. The seed rate was 20 kg/ha. The sowing depth was 3-4 cm.

Sowing time : A seed germination test was performed in the Agricultural Laboratory of Lovely Professional University. The germination ranged from 80-85 %. Usually, the recommended direct seeded rice sowing time is 25th May to 20th June for this variety. For both experiments, sowing was done on the 25th of May during both years in the dry field, followed by irrigation immediately.

Fertilizer application : During the sowing period, potassium and phosphorus were applied in a single split by broadcast method. Nitrogen was applied in three split doses: 20 DAS, tillering and before panicle initiation. Nitrogen was used as per treatment.

Irrigation : Irrigation was supplied as necessary by the crop, i.e., irrigation was applied when a lack of moisture was observed in soil due to a break in monsoon rains.

Weed management : Weed management practices were done as per treatments given in subplots.

Brown manuring (sesbania) : Sesbania was sown in lines between the inter-row spaces along with rice to smother the weeds and the Sesbania was killed by spraying 2-4 D sodium salt at 0.80 kg a.i/ha, as a post-emergence, i.e. between 25 to 30 DAS, when it started smothering the rice plants.

Weedy check : No efforts were made to control the weeds of weedy check (control) treatment and weeds were allowed to grow along with the crop up to harvest.

Herbicide application : The herbicides were calculated as per treatment and a knapsack sprayer was sprayed in the required plot per the treatment, using 500 L/ha for pre-emergence herbicides and 250 L/ha for post-emergence herbicides.

Insect management : During the entire growing season, the paddy variety PR 126 was not infested by any disease or pest during both years.

Harvesting : The crop was harvested when the plants began to dry and reached 100 % of the grain maturity in the panicles. A net plot area of 2 square metres from each subplot was harvested separately. Then, after the proper sun drying, threshing was done by beating the plants on a hard surface.

Brown manuring along with paddy

Appearing plants after 10 days

Fig. 1. Stages of sesbenia for brown manuring.

Weed studies : Major weed flora of the experimental trail was observed during both years 2022 & 2023 of the growing season of PR 126 paddy on the experimental field. The infesting weeds were *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*, *Ammania baccifera* and *Fimbristylis miliacea.*

Weed count (weeds/m²) :Weed count was recorded at 30, 60 and 90 DAS and harvested using a 30 cm^2 quadrant. The quadrant was thrown randomly twice per plot and the number of weed plants in the quadrant was counted and converted on a square meter basis.

Dry matter of weed (q/ha) : Weed plants were collected from one square foot quadrat and thrown randomly at two spots/plots across all experimental treatments cut from the soil surface at 30, 60 and 90 DAS and harvest. Sun drying of plants was done and dry weight of weeds was recorded after drying in the oven at 55 ± 5°C on an electronic weighing machine and dry weight accumulation was converted into q/ha.

Yield and yield attributes

***Number of panicles per m²* :** The number of panicles was counted at maturity with the help of a quadrate of 30 cm × 30 cm and converted to a sq.m basis for both experiments.

***Number of grains per panicle* ":** The number of grains per panicle in five representative panicles and their average number of grains were expressed as grains/panicle-1

***Panicle length (cm)* ":** Five panicles from the tagged plants were taken individually and their length in centimetres was measured from the node to the apex.

***Test weight (gm)* ":** 1000 grains were collected from each net plot and were counted at random with the help of an automatic seed counter. The counted seeds were weighed and subsequently recorded in grams.

Biological yield (q/ha) : The weight was recorded after harvesting the representative net area. This was reported as biological yield (q/ha).

Straw yield (q/ha) : The average straw yield was determined by subtracting the seed yield from the biological yield (total weight of rice plants - seed weight). Seed yield in q/ha was calculated.

Seed yield (q/ha) : Crop harvested from a representative net plot was threshed by beating on a hard surface, cleaned carefully and weighed on the electronic balance after drying. Then, the seed yield in q/ha was worked out.

Harvest index (H.I.) : The harvest index (%) was done with the help of using the Equation 1 formula

Harvest Index (H.I.) = Seed yield/biological yield × 100

(Eqn. 1)

Statistical analysis

The data recorded on various characters of the experimental crop were analyzed using a two-way ANOVA through OPSTAT software (CCS Haryana Agricultural University, Hisar). All analysis work was done on a computer at CD (0.05).

Results and Discussion

Weed parameters

***Total weed count* :** A significantly higher weed count was observed in unweeded (control) compared to all other weed management treatments (Table 1). Among different herbicidal treatments, the lowest weed count was observed in the pendimethalin followed by bispyribac application, which was statistically similar to the brown manuring method with pre-emergence of pendimethalin followed by bispyribac and these two methods had observed significantly lowest weed count compared to brown manured crop treated with alone bispyribac (T_3) during both years.

Weed count was not significantly affected by nitrogen levels at all periodic intervals in two consecutive years of research except 60 DAS during 2023, only indicating that nitrogen application did not influence weed emergence. Significantly less weed count in pre-emergence pendimethalin followed by bispyribac treatments because of the management of non-paddy weeds using pendimethalin and paddy weeds with bispyribac herbicide. The data conforms to previous findings (11-14).

Dry matter of weeds : Higher dry matter accumulation by weeds (Table 1) in higher doses of nitrogen 150 kg of nitrogen per hectare and 175 kg of nitrogen per hectare was because the reason as direct seeded rice crop had slow growth habits during initial stages, which failed to smooth weed plants and hence weed plants enjoyed available resources including nitrogen and irrigation water for growth. Weed dry matter accumulation in 0 kg of N/ha and 125 kg of N/ha was less because of no/less nitrogen availability for weed growth. Similar data confirms previous findings(15,16).

Amongst all the weed management methods, the pre-emergence application of pendimethalin controlled annual grassy and broadleaf non-paddy weeds. Post em. bispyribac's application regulated all the kinds of typical paddy weeds. The outcomes conform to the findings (11, 12). The smothering effect of brown manuring crops (Sesbania) on weeds was less when observed in every stage of crop growth. The dry matter accumulation by weeds in unweeded (control) treatment was exceptionally high (unlike other field crops).

Table 1. Effect of nitrogen levels 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
Main plots - Nitrogen levels				
N_1 – 0 kg N /ha	9.2(85)	11.7(139)	4.2(18)	4.7(22)
N_2 – 125 kg N /ha	9.3(88)	12.1(147)	4.5(20)	4.9(24)
N_3 – 150 kg N /ha	9.4(89)	11.1(125)	4.7(23)	5.5(30)
N_4 – 175 kg N /ha	9.1(84)	11.3(128)	5.0(25)	6.1(37)
SE(m)	0.13	0.38	0.27	0.30
CD at P < 0.05%	NS	NS	0.60	0.55
Sub plots - Weed control treatments				
T_1 - Pendi fb. Bispyribac	6.5(43)	7.0(50)	2.2(5)	2.9(9)
T_2 -BM,pendi fb. Bispyribac	7.0(50)	7.2(53)	2.5(7)	3.3(11)
T_3 – BM,Bispyribac	9.0(81)	11.1(125)	2.9(9)	3.5(12)
T_4 -Unweeded (control)	13.0(171)	17.4(305)	8.2(67)	9.9(97)
SE(m)	0.23	0.57	0.18	0.48
CD at P < 0.05%	0.64	1.68	0.57	1.65
CD for interaction	NS	NS	NS	NS

Note: BM- Brown manuring and Pendi- Pendimethalin

Figures without paranthesis are square root transformed values after adding one to original value. Figures without parenthesis are original values without statistical analysis.

This may be due to crops' very poor smothering effect on weeds owing to very slow initial crop growth.

Yield and yield attributing characters

Effective tillers per meter row length : Effective tillers per meter row length are the most important parameters as they determine the yield of cereal crops. Effective tillers per meter row length were recorded at the harvest stage in two consecutive years of research (Table 2). When recorded in two successive years, the variations in the count of effective tillers recorded per meter row length have been significantly affected by both nitrogen levels and weed management methods. Among the nitrogen levels, a substantially greater number of effective tillers recorded per meter row length by 175 kg of N/ha over 150 kg of N/ha during 2022, but in the year 2023, the differences were non-significant among these nitrogen levels, i.e. 150 and 175 kg N/ha. The significantly least number of effective tillers was recorded at 0 kg of N/ha, which was statistically similar to 125 kg of N/ha in both years. The number of effective tillers per meter row length was significantly more in 150 kg of N/ha compared to 125 kg of N/ha during both years of experimentation. More effective tillers in 175 and 150 kg of N/ha, possibly because of crop growth compared to other nitrogen levels. Out of all weed management methods, the significantly more effective tillers count has been observed in pendimethalin, followed by bispyribac, compared to other weed management treatments. These results were also concluded by (16, 18, 19). The significantly least effective tillers have been observed in the weedy check (control) compared to all other treatments for both years. Among brown manuring treatments, the application of pendimethalin (T_2) recorded significantly more effective tillers than without pendimethalin treatment (T_3). These results agree with the finding (15). Significantly higher effective tillers without brown manuring treatment (T_1) may be due to no initial smoothering of rice crops compared to brown manuring treatments (T_2 &T_3).

Number of grains per panicle : The number of grains per panicle was recorded at harvest for both years (Table 2). Among the nitrogen levels, a significantly higher number of grains per panicle was observed in 175 kg N/ha compared to all other nitrogen levels when recorded in two consecutive years. In two consecutive years of experimentation, the number of grains/panicle was significantly greater in 150 kg of N/ha over 125 kg of N/ha. The significantly lowest number of grains per panicle was observed in 0 kg of N/ha compared to other nitrogen levels in two consecutive years. Out of all weed management methods, a significantly more number of grains per panicle were observed in pendimethalin followed by bispyribac treatment compared to other weed management treatments. Among the brown manuring treated plots, applying pendimethalin (T_2) significantly increased the number of grains/panicle than applying bispyribac (T_3) treatment alone. A considerably less number of grains per panicle was recorded in unweeded (control) treatment compared to all other weed management treatments in two consecutive years of experimentation.

Panicle length : Panicle length was recorded at the harvest stage in two consecutive years of experimentation (Table 2). As influenced by nitrogen levels, the highest panicle length was observed at 175 kg N/ha. It was statistically similar to 150 kg N/ha but significantly higher than 125 kg N/ha when recorded for both years. The significantly lowest panicle length was observed by 0 kg of N/ha compared to other nitrogen levels in two consecutive years of experimentation. Amongst weed management methods, the substantially greater panicle length has been recorded in pendimethalin (stomp) followed by bispyribac treatment (T_1) which was found to be statistically at par with brown manuring treatment applied with pendimethalin followed by bispyribac (T_2) and these two treatments produced significantly greater panicle length over brown manuring applied with bispyribac treatment only i.e. without pre-emergence application of pendimethalin (T_3) for both the years. A significantly less panicle length was recorded in unweeded (control) treatment for both years than all other weed management treatments.

Panicle weight : Panicle weight was recorded at the harvest stage in two consecutive years of experimentation (Table 3). Panicle weight was recorded in grams at harvest. The differences in panicle weight have been significantly affected by various nitrogen levels along with weed management treatments when recorded for both years. Amongst various nitrogen levels, the greatest panicle weight was found to be 175 kg of N/ha and it was statistically

Table 2. Effect of nitrogen levels and weed control treatments on effective tillers /m row length number of grains/panicle and panicle length (cm) during 2022 and 2023

	Effective tillers /m row		No of grains/panicle		Panicle length(cm)	
Main plots - Nitrogen levels						
	2022	2023	2022	2023	2022	2023
N_1 – 0 kg N /ha	72.4	71.1	134.1	132.7	17.6	16.2
N_2 – 125 kg N /ha	76.6	71.8	150.7	149.8	19.0	17.3
N_3 – 150 kg N /ha	87.4	80.8	175.5	176.0	20.6	20.8
N_4 – 175 kg N /ha	96.8	88.1	193.3	194.5	21.1	21.1
SE(m)	1.42	2.15	0.66	0.96	0.19	0.15
CD at P < 0.05%	4.98	7.58	2.32	3.37	0.67	0.53
Sub plots - Weed control treatments						
T_1 - Pendi fb. bispyribac	106.3	99.3	229.1	225.1	23.4	22.8
T_2 - BM,Pendi fb.bispyribac	95.4	92.5	215.5	218.8	22.6	22.5
T_3 –BM,bispyribac	84.3	78.8	205.4	205.9	21.6	21.9
T_4 -Unweeded (control)	47.3	41.1	3.58	3.25	10.6	8.1
SE(m)	1.26	1.92	1.16	0.84	0.31	0.15
CD at P < 0.05%	3.72	5.64	3.39	2.46	0.89	0.44
CD for interaction	NS	NS	NS	NS	NS	NS

Note: BM- Brown manuring and Pendi- Pendimethalin

Table 3. Effect of nitrogen levels and weed control treatments on panicle weight (g) and test weight (g) during 2022 and 2023

	Panicle weight (g)		Test weight (g)	
Main plots - Nitrogen levels				
	2022	2023	2022	2023
N_1 – 0 kg N /ha	4.09	4.01	20.03	19.54
N_2 – 125 kg N /ha	4.39	4.35	20.29	19.96
N_3 – 150 kg N /ha	5.10	5.17	21.13	21.04
N_4 – 175 kg N /ha	5.36	5.20	21.29	21.53
SE(m)	0.06	0.06	0.18	0.19
CD at P < 0.05%	0.21	0.21	0.63	0.67
Sub plots - Weed control treatments				
T_1 - Pendi fb. bispyribac	5.36	5.31	22.09	22.31
T_2 - BM,Pendi fb.bispyribac	5.16	5.13	21.82	22.03
T_3 – BM,bispyribac	4.658	4.56	20.23	20.23
T_4 -Unweeded (control)	3.77	3.73	18.60	17.47
SE(m)	0.04	0.04	0.11	0.18
CD at P < 0.05%	0.14	0.13	0.34	0.53
CD for interaction	NS	NS	NS	NS

Note: BM- Brown manuring and Pendi- Pendimethalin

similar to 150 kg of N/ha during 2023, but it differed significantly during 2022. In two consecutive years, a substantially lower panicle weight was observed at 0 kg of N/ha. The application of 125 kg of N/ha recorded significantly less panicle weight than 150 and 175 kg of N/ha in two consecutive years of experimentation. Amongst all the weed management methods, the substantially greater weight of panicles has been observed by pendimethalin followed by bispyribac compared to other weed management methods. The significantly least panicle weight was recorded in unweeded (control) treatment in two consecutive years over other herbicide-applied treatments. Among the brown manuring treatments, applying pendimethalin (T_2) produced significantly more panicle weight than without application (T_3).

Test weight :Test weight was recorded at harvest for both years. Test weight was recorded in grams at harvest (Table 3). Among the nitrogen levels, the highest test weight was observed with the application of 175 kg N/ha, which was statistically at par with 150 kg N/ha when recorded for both years. Both treatments gave significantly more test weight than 125 kg N/ha. The significantly lowest test weight was observed by 0 kg N/ha, which was statistically at par with 125 kg N/ha for both years. Among the weed management treatments, the significantly highest test weight was observed in pendimethalin followed by bispyribac treatment (T_1), which was found to be statistically at par with brown manuring with sesbania applied with pendimethalin followed by bispyribac treatment (T_2) during 2023 and the first year these differences were found to be significant. Among brown manuring treatments, the pre-emergence application of pendimethalin (T_2) significantly increased the test weight of rice as compared to the treatment where pendimethalin was not applied. The significantly lowest test weight was recorded in unweeded (control) treatment for both s as c

All yield attributing parameters viz. effective tillers/m row length, number of panciles/m row length, number of grains/panicle, panicle length (cm), panicle weight (g) and test weight (g), were higher in 175 and 150 kg N/ha due to good vegetative and hence reproductive growth of rice crop under these treatments as compared to 0 kg N/ha and 125 kg N/ha due to poor crop growth under these treatments. Similar findings were reported (17, 18, 19). Among subplot treatments, all these yield attributes were higher in pre-emergence pendimethalin followed by bispyribac treatment (T_1) due to good vegetative and reproductive growth than all other weed management treatments. On the other hand, these yield parameters were less in brown manuring treatments, which may be due to the smoothering effect of sesbania on rice crop seedlings during initial growth stages, resulting in poor growth and development of crops under these treatments. Similar findings were reported (20,21).

Paddy yield : Grain yield is the most critical parameter governing the farmer's net profit, recorded at harvest for both years. The data on rice paddy yield revealed that different nitrogen levels and weed management treatments exhibited significant variation in paddy yield when recorded for both years (Table 4). Among the nitrogen levels, the maximum paddy yield was 175 kg N/ha, which was at par with 150 kg N/ha when recorded for both years. Both these nitrogen levels produced significantly higher paddy yield than 0 kg and 125 kg N/ha. Application of 125 kg N/ha during both years recorded significantly less paddy yield than 150 kg N/ha. The nitrogen level of 0 kg N/ha recorded significantly less yield than other nitrogen levels during both years. The significantly higher yield of 175 kg N/ ha and 150 kg N/ha than 125 kg N/ha during both years may be due to better crop growth parameters and yield attributes. It was also observed that application of 175 kg N/ ha, 150 kg N/ha and 125 kg N/ha increased paddy yield by 53.1 %, 48.5 % and 38.2 % during 2022 and 56.7 %,51.3 % and 40.9 % during 2023, respectively.

Among weed management treatments, the pre-emergence application of pendimethalin, followed by bispyribac, recorded a significantly higher yield than all other weed management treatments. However, the application of pendimethalin to brown manuring treatment (T_2) recorded a significantly higher yield than that of the non-pendimethalin application treatment (T_3) during both years. Significantly lower yield was observed in unweeded (control) as compared to all other weed management treatments during both years. Higher yield in pre-emergence application of pendimethalin followed by post-emergence. bispyribac treatment (T1) may be due to better control of paddy and non-paddy weeds (Table 1) and

Table 4. Effect of nitrogen levels and weed control treatments on paddy yield (q/ha) and straw yield of DSR (q/ha) during 2022 and 2023

Paddy Yield (q/ha)				
Main plots - Nitrogen levels				
	Paddy yield (q/ha)		**Straw yield (q/ha)**	
	2022	2023	2022	2023
N_1 – 0 kg N /ha	25.2	21.6	38.5	43.3
N_2 – 125 kg N /ha	40.8	36.6	45.4	54.0
N_3 – 150 kg N /ha	49.0	44.4	60	69.2
N_4 – 175 kg N /ha	54.0	49.9	62.4	73.2
SE(m)	1.71	1.84	1.92	1.68
CD at P < 0.05%	5.26	5.91	8.14	5.06
Sub plots - Weed control treatments				
T_1 - Pendi fb.bispyribac	64.5	59.1	85.6	69.1
T_2 -BM,pendi fb.bispyribac	58.8	53.7	80.8	65.7
T_3 – BM,bispyribac	42.7	37.3	81.0	66.6
T_4 -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

Note: BM- Brown manuring and Pendi- Pendimethalin

improved yield and yield attributes (Table 2-4). Also, pre-emergence pendimethalin in brown manuring treatment (T_2) significantly increased paddy yield compared to the non -pendimethalin application (T_3), which may be due to better control of weeds and crop growth and yield attributes. The negligible (very low) yield in unweeded control may be due to the abundance of paddy and non-paddy weeds smothered rice plants, resulting in their mortality as these (crop) plants were covered entirely by weed plants. Application of pendimethalin followed by bispyribac, brown manuring treatment sprayed with pre-emergence pendimethalin followed by bispyribac and brown manuring with post-em, application of bispyribac only increased paddy yield by 95.3 %, 94.8 % and 92.9 % during 2022 and 96.1 %, 94.6 % and 94.1 % during 2023 over unweeded (control) treatment, respectively, indicating thereby that failure of direct seeding technology is mainly due to uncontrolled weed problem in this crop.

Straw yield : The data on straw yield revealed that different nitrogen levels and weed management treatments exhibited significant variation in the straw yield of rice for both years (Table 4). Among the nitrogen levels, the maximum straw yield was recorded with the application of 175 kg N/ha, producing 62.4 kg/ha and 73.2 kg/ha, which was found to be statistically at par with 150 kg N/ha, which produced 60 kg/ha and 69.2 kg/ha during 2022 and 2023 respectively. These nitrogen levels were significantly superior to 125 kg N/ha concerning straw yield. It can be concluded that each increment in a dose of nitrogen from 0 to 175 kg/ha resulted in a significant increase in straw yield for both years. However, all the nitrogen levels significantly increased straw yield to 0 kg N/ ha during both years. Higher paddy straw yield in 175 and 150 kg N /ha may be due to good vegetative growth, i.e. plant height, no-tillers and crop dry matter accumulation of rice, compared to 125 and 0 kg N/ha.Among the weed management treatments, more straw yield was obtained in pendimethalin followed by bispyribac treatment and it was statistically at par with brown manuring with sesbania followed by bispyribac as well as brown manuring rice crop with pre-emergence pendimethalin followed by bispyribac treatments(T_2 & T_3) for both the years. However, the lowest straw yield of paddy was obtained under weedy check (control), which was significantly less than all other weed management treatments for both years. More straw yield in the herbicidal treatments may be due to better crop growth and the excellent control of weeds in these treatments. The unweeded (control) crop failed to grow due to the abundance of weeds in direct-seeded rice.

Biological yield : Among the nitrogen levels, the maximum biological yield was recorded with the application of 175 kg N/ha, followed by 150 kg N/ha and 125 kg N/ha, significantly higher than 0 kg N/ha for both years (Table 5). However, all the nitrogen level treatments significantly increased biological yield by over 0 kg N/ha for both years. The biological yield increased significantly with each increment of nitrogen dose i.e. 0 kg, 125 kg, 150 kg and 175 kg/ha. Among the weed control treatments, more biological yield was obtained in pendimethalin, followed by bispyribac which was significantly superior to the rest of the treatments when recorded for both the years. The biological yield in brown manuring crops applied with pre-emergence pendimethalin, followed by bispyribac (T2) was significantly higher than that of brown manuring crops, followed by bispyribac (T_3). However, the lowest biological yield was obtained under weedy check (control), significantly less than all weed management treatments for both years. The interactive effect of nitrogen levels and weed management treatments for biological yield were non-significant during both years.

Harvest index : The data revealed that differences in harvest index under different nitrogen levels varied from 43.2 to 49.4 for 2022 and 41.1 to 46.8 for 2023 (Table 5). Among the different weed management treatments, the harvest index values were found to vary from 38.8 % to 56.3 % for 2022 and 34.7 to 53.4 % for 2023. The highest value of harvest index was observed in unweeded (control) treatment due to significantly less biological and more grain yield. The lowest harvest index was recorded in the brown manuring, followed by bispyribac (T_3) compared to all other weed management treatments.

Table 5. Effect of nitrogen levels 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(%)	
Main plots - Nitrogen levels				
	2022	2023	2022	2023
N_1 – 0 kg N /ha	63.7	64.7	39.5	33.3
N_2 – 125 kg N /ha	86.2	90.6	47.3	40.3
N_3 – 150 kg N /ha	109	113.6	44.9	39.0
N_4 – 175 kg N /ha	116.4	123.1	46.3	40.5
SE(m)	1.86	0.55	0.48	0.96
CD at P < 0.05%	6.56	1.93	1.70	3.39
Sub plots - Weed control methods				
T_1 - Pendi fb. bispyribac	150.1	128.2	42.9	46.0
T_2 - BM, pendi fb. bispyribac	139.6	119.4	42.1	44.9
T_3 – BM,Bispyribac	123.7	103.9	34.5	35.8
T_4 -Unweeded (control)	6.47	4.75	46.5	47.3
SE(m)	1.42	1.04	1.03	0.92
CD at P < 0.05%	4.17	2.79	3.01	2.68
CD for interaction	NS	NS	NS	NS

Note: BM- Brown manuring and Pendi- Pendimethalin

Conclusion

Nitrogen levels of 175 kg N/ha and 150 kg N/ha were significantly superior over 125 kg N/ha and 0-kg N/ha for yield and yield attributes. The herbicide pendimethalin 0.75 kg/ha followed by bispyribac 25 g/ha was a better weed control option than other treatments. Brown manuring with sesbania and applying pendimethalin (0.75 kg/ha) followed by bispyribac (25 g/ha) was a better option for weed control due to more effective weed management. However, brown manuring with sesbania alone, without the pre-emergence application of pendimethalin, was ineffective in smothering weeds. Additionally, soil texture has deteriorated with continuous puddling. Compared to traditional puddled transplanting techniques, the new method of direct seeded rice, which is sown without puddling, is not environmentally friendly. Still, it is highly susceptible to weed pressure and iron deficiency. The yield reduction due to uncontrolled weeds in DSR exceeds 96 %, indicating complete crop failure without proper weed control.

Acknowledgements

The present study has been carried out at the Research Farm, Phagwara Punjab, School of Agriculture, Department of Agronomy, Lovely Professional University. We thank the institution for providing the required resources and continuous support during the research period.

Authors' contributions

BSS, TP and USW conducted field experiment, collected data and wrote the manuscript. BSS, TP and USW frame out the research work and designed the experiment. GSKR drafted the manuscript. BSS, TP and USW did the statistical analysis. BSS and TP did the revision of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors declare that they don't have any conflict of interest

Ethical issues: None

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