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Research Paper

Optimization of seeding rates and nitrogen scheduling in direct-seeded rice (*Oryza sativa*) under drought-prone environment in middle Indo-Gangetic plains

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2014 and 2015 at Patna, Bihar to optimise the seeding rates and nitrogen scheduling for direct-seeded rice (*Oryza sativa* L.) under the rainfed drought-prone environment. The soil of the experimental plot was loamy, low in organic carbon (0.42) and available N (149.6 kg/ha), high in available phosphorus (25.8 kg/ha), medium in available potash content (183.6 kg/ha) and slightly alkaline (*p*H 7.7). The treatments consisted of 3 seeding rates (S_1: 20 kg/ha; S_2: 30 kg/ha; and S_3: 40 kg/ha) in main-plot and four nitrogen schedules (N_1, 1/3 N as basal and 2/3 N at maximum tillering; N_2, 1/3 N as basal and 1/3 N at maximum tillering and 1/3 N at panicle initiation; N_3, 1/2 N at first shower/enough moisture availability preferably after first weeding and 1/2 N at maximum tillering; and N_4, 1/3 N at first shower/enough moisture availability preferably after first weeding, 1/3 N at maximum tillering and 1/3 N at panicle initiation stage) in sub-plot and replicated thrice in split-plot design. The results revealed that the grain yield was significantly higher with S_3 (3.2 t/ha) than that to S_1 (2.4 t/ha), but statistically at par with that obtained with S_2 (3.1 t/ha). Varying nitrogen schedules did not affect the grain yield markedly. Comparatively higher grain yield was recorded with N_4 (3.0 t/ha) followed by N_3 (2.94 t/ha) and N_1 (2.87 t/ha). The gross returns (32.1 ×10^3₹/ha), net returns (15.9 × 10^3₹/ha) and benefit: cost ratio (1.64) were significantly higher with 40 kg/ha seed rate compared to 20 kg/ha (₹22.4 ×10^3/ha, ₹6.2 ×10^3/ha and 1.26 but statistically similar to 30 kg/ha (₹28.9 ×10^3/ha, ₹13.4 ×10^3/ha and 1.55. The net returns were significantly higher with N_4 closely followed by N_3. Hence, growing of direct-seeded rice using 40 kg/ha seed rate along with split application of 1/3rd N at first shower/enough moisture availability preferably after first weeding, 1/3rd N at maximum tillering and 1/3rd N at panicle initiation stage is an ideal and sustainable approach in terms of productivity and profitability under rainfed drought-prone environment of Eastern India.

Key words : Carbon output, Direct-seeded rice, Drought prone, Indo-Gangetic plains, Nitrogen scheduling, Seeding rate

Direct seeding of rice (DSR) is an emerging and attractive alternative approach to traditional puddled transplanted rice (PTR) production system, as it enables better use of early rains, needs less labour, and allows early establishment, thus reducing drought risk (Kumar *et al.*, 2017). Promotion of DSR as a technology to successfully establish rice has shown very promising results in wide range of experiments and large-scale demonstration trials in drought-prone rainfed ecosystem. Reduced seed germination and restricted early-seedling growth associated with urea-induced soil ammonia volatilization are the major constraints in adoption of dry DSR (Xiaoli *et al.*, 2011). Limited studies have been conducted on optimizing the seeding rate and scheduling of nitrogen application for improving nitrogen-use efficiency. Seed rate and nitrogen scheduling these are two important researchable issues in DSR for new drought-tolerant varieties, as these vary as per the severity of stress and tolerance-limit of genotypes. It is suggested that increasing seeding rates in DSR can suppress weed growth and reduce grain yield losses from weed competition; however, 40 kg seed/ha was sufficient for optimum yield in weed-free conditions (Ahmed *et al.,* 2014). Higher plant density (50 kg/ha) provided good smothering potential on weeds but maximum grain yield was recorded with planting density of 30 kg/ha (Walia *et*

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al., 2011). Positive response to nitrogen application in rice has been reported but its time of application contributes significantly towards nitrogen-use efficiency and rice productivity. Application of adequate quantity of nitrogen at right crop stage synchronizing well with most efficient utilization is an important factor that influence the yield of rice. Nitrogen moves very rapidly in the soil and is subjected to the various losses mainly due to leaching, denitrfication, volatilization and surface runoff resulting into reduced nitrogen-use efficiency. To overcome this problem, split application of nitrogen is recommended and response per unit of nitrogen in rice was more when applied in split doses (Singh *et al.,* 2017). Keeping the above points in view, the present investigation was undertaken to optimise seed rate and nitrogen scheduling for direct-seeded rice under the rainfed drought-prone environment.

MATERIALS AND METHODS

The experiment was conducted during rainy (*kharif*) seasons of 2014 and 2015 at ICAR Research Complex for Eastern Region, Patna (25°30'N, 85°15'E, 52 m above mean-sea level), Bihar. Soil was loamy, low in organic carbon (0.42) and available N (149.6 kg/ha), high in available phosphorus (25.8 kg/ha) and medium in available potash (183.6 kg/ha) with slightly alkaline reaction (*p*H 7.7). The experiment was laid out in split-plot design with 3 replications. Treatments consisted of 3 seed rates (S_1, 20 kg/ha; S_2, 30 kg/ha and S_3, 40 kg/ha) in the main-plot and the recommended dose of N (80 kg/ha) with 4 different schedules, viz. N_1, one-third N as basal and two-third N at maximum tillering; N_2, one-third N as basal, one-third N at maximum tillering and one-third N at panicle initiation (PI); N_3, half N after first weeding and half N at maximum tillering; and N_4, one-third N at first shower/enough moisture availability preferably after first weeding, one-third N at maximum tillering and one-third N at PI in the sub-plot. Besides nitrogen schedules as per treatment, uniformly full doses of P (40 kg/ha), K (20 kg/ha) and $ZnSO_4$ (25 kg/ha) were applied as basal. Field was prepared by dry shallow ploughing (1 harrowing + 2 cultivator + levelling). Rice variety 'Shahbhagi Dhan' was sown in rows at a spacing of 20 cm. Weeds were initially managed through integrated use of pre-emergence application of pendimethalin @ 1.0 kg/ha followed by bispyribac-sodium at 30 g/ha at 20 days after sowing (DAS) and one manual-weeding at 30 DAS. Total rainfall received during the two consecutive cropping seasons was 914 and 657 mm respectively. Mean maximum temperature was relatively higher during flowering and grain filling stage in 2015 compared to previous year (Fig. 1). The amount of rainfall received during 2015 was less (41% of normal), thus two additional life-saving irrigations (6.0 cm) were applied in August and September as per crop need. For recording the biometric observations like dry-matter production, plants at maturity were cut close to the ground in 0.5 m transects at 5 random places within each plot. Samples were first dried in sun and then oven-dried at 65°C until constant weight was achieved and expressed in g/m^2. Yield attributes, viz. number of panicles, grains/panicle, filled grains and unfilled grains were counted from 10 randomly selected plants from each plot and averaged. 1,000-grains from each plot were counted and their weight was recorded based on the moisture content values of 14%. Grain and straw yields were taken from an area of 4 m × 3 m in the centre of each plot and finally expressed in t/ha. Production efficiency and economic efficiency were computed as suggested by Kumawat *et al*. (2012). Economic yield of rice was converted into equivalent value of carbohydrate (t/ha) as suggested by Gopalan *et al*. (2004). Carbon output was calculated based on plant biomass as suggested by Singh and

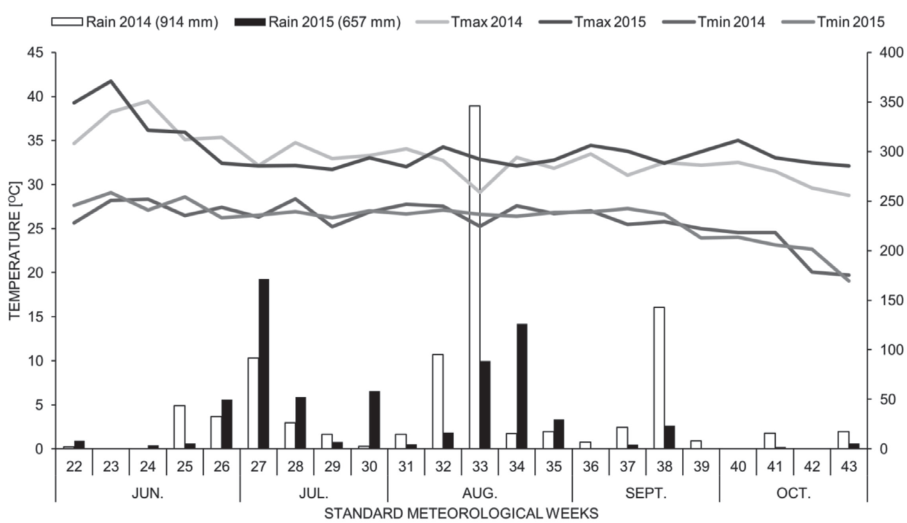

Fig. 1. Meterological data of the experimental site

Ahlawat (2015). Cost of cultivation under different treatments was estimated on the basis of approved market rates for inputs as fixed by institute by taking into account costs of seed, fertilizer, chemicals, and hiring charges of human labour. Gross returns were calculated on the basis of minimum support price offered by Commission for Agricultural Costs and Prices, Government of India for rice in 2014 and 2015 respectively. Net returns were calculated as difference between gross returns and total cost of cultivation. Data were statistically analyzed by using standard statistical procedures according to Gomez and Gomez (1984). All the variables were subjected to analysis of variance (ANOVA) to examine the treatment effect in field experiment. The data of growth, yield attributes, gross and net returns, carbon output were statistically pooled analyzed. Fisher's least significant difference (LSD) was used to test for significance of differences between various means at $P < 0.05$. The significance of differences among means was compared, when F-values were significant.

RESULTS AND DISCUSSION

Effect of weather

Meteorological data depicted in Fig.1 showed that marked variation in the weather conditions in 2014 and 2015. During 2014, amount of precipitation was more and equally distributed across the vegetative and flowering stages. Severe moisture stress was faced by crop during 2015, as ~46% less rainfall was received as compared to 2014. Moreover, fluctuation of rains during cropping period, both in terms of quantum and interval was higher in 2015 compared to 2014. Therefore, plants absorbed more nutrients and produced higher yields during 2014, owing to adequate availability of moisture as compared to 2015. Temperatures regimes, particularly at reproductive phases of crop during 2014, were more conducive as compared to 2015. This resulted in better performance of crop in terms of higher yield during 2014 as compared to 2015. Similar findings were reported by Kumar *et al*. (2015).

Growth attributes

Plant height at maturity did not differ significantly due to varying seeding rates (Table 1). It was interesting to note that increasing the seeding rate correspondingly shortened the plants. The dry-matter production was significantly higher with S_3 (40 kg seed/ha) than S_1 (20 kg seed/ha), but statistically at par with that obtained with S_2 (30 kg seed/ha). The higher seeding rate of 30 and 40 kg/ha produced 6.4 and 8.9% higher dry-matter than that at 20 kg seed/ha. This can be attributed to the fact that optimum plant population is based on plant ideotypes and management practices. Therefore, optimum level of plant density is very essential for harnessing the maximum returns from a given set of environment and any deviation from it is compensated only up to a limit, and there is drastic yield reduction beyond that limit (Kumar *et al.,* 2009). This phenomenon may be explained on the basis that growth attributes are recorded on individual plant basis. Performance of a plant on individual basis is better than its performance under the group or community. Kumar and Kumawat (2014) also recorded maximum dry-matter production at higher seeding rate (30 and 35 kg/ha). However, reverse trends was observed in case of root length, where significantly higher root length was associated with lower seeding rate (20 kg seed/ha) (15.3 cm) as opposed to

Table 1. Effect of seeding rates and nitrogen scheduling on growth attributes and crop ontogeny of direct-seeded rice (pooled data of 2 years)

Treatment	Plant height at maturity (cm)	Dry-matter production (g/m^2)	Root length (cm)	Days to 50% flowering	Days to maturity
Seeding rate (kg/ha)					
20	112.5	1062	15.3	84	110
30	112.7	1131	13.5	84	110
40	112.5	1156	12.5	85	111
SEm±	1.2	13	1.2	1.0	1.0
CD (P=0.05)	NS	39	2.1	NS	110
Nitrogen Scheduling					
N_1	113.0	1076	14.1	84	111
N_2	112.6	1110	14.1	84	111
N_3	112.7	1126	13.3	84	111
N_4	111.9	1128	15.7	84	110
SEm±	0.9	10	1.1	0.9	0.37
CD (P=0.05)	2.6	30	2.0	NS	NS

N_1, one-third N as basal and two-third N at maximum tillering (MT); N_2, one-third N as basal and one-third N MT and one-third N at at panicle initiation PI; N_3, half N after first weeding and half N at MT; and N_4, one-third N after first weeding, one-third N at MT and one-third N at PI higher seeding rates (Table 1), which might be due to the fact that root attributes are positively influenced by lower plant density (Kumar *et al.,* 2015). This clearly indicated an increase in internal competition for growth and development among themselves at higher seeding rates. Lower plant density received better growth environment of space and air. Days taken to 50% flowering and maturity did not vary significantly due to different seeding rate during the study.

Varying nitrogen scheduling did not cause significant effect on plant height at maturity (Table 1). Varying nitrogen scheduling had marked influenced on dry-matter production. Significantly higher dry-matter was recorded (1,128 g/m^2) being at par with N_3 (1,126 g/m^2) and N_2 (1110 g/m^2) and superior to N_1 (1,076 g/m^2). This phenomenon may be ascribed to the positive effect of split scheduling of nitrogen for higher uptake of nutrition through better established root resulting into better growth and dry-matter production (Singh *et al.*, 2017). Root length was influenced markedly by varying nitrogen scheduling. Significantly higher root length was noted with N_4 (15.7 cm) compared to rest of the treatments. Days to 50% flowering and maturity did not differ significantly due to varying levels of nitrogen schedules.

Yield attributes

Yield attributes of direct-seeded rice, viz. number of panicles/m^2, grains/panicle and filled grains/panicle were influenced markedly by varying seeding rates (Table 2) and yield attributes increased with an increase in seeding rate. Higher seeding rate, viz. S_3 (40 kg/ha) had significantly higher values of yield attributes being at par with S_2 (30 kg seed/ha) and superior to S_1 (20 kg/ha). However, reverse trend was observed in case of 1,000-grain weight; where lower seeding rate (S_1, 20 kg seed/ha) positively influenced this attribute and significantly higher 1,000-grain weight was recorded with 20 kg seed/ha (S_1) over rest of the treatments. This might be due to intra-competition occurring amongst plants ideotypes at higher seeding rate, which resulted into decline in yield attributes. The present findings are in close conformity with those of Kumar and Kumawat (2014). Similarly, yield attributes of direct-seeded rice, viz. panicles/m^2, grains/panicle and filled grains/panicle were significantly higher with N_4 but at par with those obtained with N_3. Treatment N_2 had significantly higher 1,000-grain weight being at par with N_1.

Yield

Grain yield varied markedly with varying seeding rates (Table 2). Grain yield was significantly higher at S_3 (3.2 t/ha) than S_2 (2.4 t/ha) but being statistically at par with that obtained with S_2 (3.1 t/ha). Higher seeding rates (30 and 40 kg/ha) produced 29 and 33% higher grain yield than S_1 (20 kg seed/ha). This might be due to the fact that optimum plant density is very essential for harnessing maximum returns from a given set of environment and any deviation from normal yield it is compensated only up to a limit, and there is drastic yield reduction beyond that limit (Kumar *et al.,* 2009). This phenomenon may be explained on the basis that growth characters are recorded on individual plant basis. Performance of a plant on individual basis is better than its performance under group or community (Kumar *et al*., 2015). Nwokwu *et al*. (2015) also reported better performance of rice at higher seeding rate

Table 2. Effect of seeding rates and nitrogen scheduling on yield attributes and yields of direct seeded rice (pooled data of 2 years)

Treatment	Panicles/m^2 (no.)	Grains/ panicle (no.)	Filled grains/ panicle (no.)	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)
Seed rate (kg/ha)						
20	185.0	162.5	147.5	21.3	2.40	5.21
30	191.5	183.5	154.5	20.5	3.09	6.25
40	195.0	188.0	162.5	20.6	3.25	6.59
SEm±	1.4	3.7	6.8	0.0	0.12	0.60
CD (P=0.05)	4.0	11.0	21.5	0.2	0.34	NS
Nitrogen scheduling						
N_1	187.5	175.0	149.5	20.8	2.85	6.14
N_2	190.0	175.5	150.0	20.9	2.87	5.82
N_3	190.0	180.5	159.5	20.6	2.94	6.47
N_4	193.5	181.0	161.5	20.7	3.00	6.82
SEm±	1.0	3.0	5.1	0.0	0.05	0.35
CD (P=0.05)	2.9	8.8	15.7	0.1	0.20	0.98

N_1, one-third N as basal and two-third N at maximum tillering (MT); N_2, one-third N as basal and one-third N MT and one-third N at at panicle initiation PI; N_3, half N after first weeding and half N at MT; and N_4, one-third N after first weeding, one-third N at MT and one-third N at PI

(40 kg seed/ha). Straw yield did not vary significantly due to varying seeding rates. It was interesting to note that increased seeding rate correspondingly increases the straw yields but it did not reach the levels of significance. Trend of straw yield varied in the order; $S_3>S_2>S_1$. Similarly, higher seeding rate S_3 (40 kg/ha) had significantly higher crop productivity (28.5 kg/ha/day) being at par with S_2 (27.5 kg/ha/day). This might be due higher yields at higher seeding rates (Kumar *et al.* 2015).

Grain yield was not influenced markedly by varying schedules of nitrogen (Table 2). Comparatively higher grain yield was recorded with N_4 (3.0 t/ha) followed by N_3 (2.94 t/ha) and N_1 (2.87 t/ha). But reverse trend was observed in case of straw yield. Significantly higher straw yield was recorded with N_4 (6.82 t/ha)-N_2 (5.82 t/ha) being statistically similar to that recorded with N_1 (6.14 t/ha) and N_3 (6.47 t/ha). This phenomenon may be attributed to the positive effect of split application of nitrogen for higher uptake of nutrition through better crop establishment resulting into better growth attributes which ultimately led to production (Singh *et al.*, 2017).

Interaction

Varying seeding rates and different nitrogen scheduling had marked influence on grain yield (Table 3). Treatment combination S_3 (40 kg/ha) seed and N_4 had significantly higher grain yield than rest of the combinations. Singh *et al.* (2017) reported that highest rice yield was achieved when one-third N was at planting and two-thirds at tillering stage.

Carbohydrate equivalent and carbon output

Carbohydrate equivalent and carbon output were not influenced by varying seeding rate and nitrogen scheduling (Fig. 2). These attributes increased with each successive increase in seeding rates from 20 to 40 kg/ha. Higher values of carbohydrate equivalent (2.54 t/ha) and carbon output (4.33 t/ha) were recorded with 40 kg seed/ha compared to to 20 kg seed/ha. This might be ascribed to successive increase in grain yield and total biomass (Kumar *et al.,* 2018). Higher carbohydrate equivalent (2.37 t/ha) and carbon output (4.32 t CE/ha) were recorded with N_4. The trend of these attributes varied in order of $N_4>N_2>N_3>N_1$. This might be due to higher yield and biomass production (Singh *et al.*, 2017).

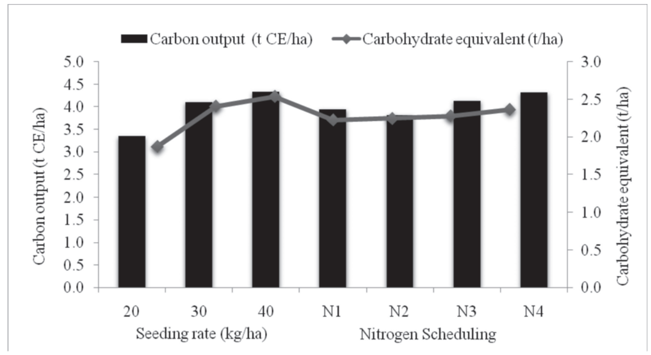

Fig. 2. Effect of seeding rates and nitrogen scheduling on carbohydrate equivalent and carbon output of direct-seeded rice (pooled data of 2 years)

Economics

Economic attributes, viz. gross returns, net returns and benefit: cost ratio of direct-seeded rice were markedly influenced by varying seeding rates (Table 4). These attributes were significantly higher with S_3 (40 kg seed/ha) than that to S_1 (20 kg seed/ha) but statistically similar to those obtained with S_2 (30 kg seed/ha). This might be due to higher yields associated with the respective treatments (Kumar *et al*., 2015). Higher seeding rate (40 kg/ha) had significantly higher economic efficiency (₹141/ha/day) than 20 kg seed/ha (₹119/ha/day) being at par with 30 kg/ha (₹119/ha/day).Varying N scheduling did not significantly influence gross returns, net returns, benefit: cost ratio and economic efficiency except net returns (Table 4). However, net returns were significantly higher with N_4 closely followed by N_3. This might be due to higher yields and associated monetary returns (Kumar *et al*., 2017).

Based on these results, it can be concluded that grow-

Table 3. Interaction effect of seeding rates and nitrogen scheduling on grain yield of direct-seeded rice (pooled data of 2 years)

Nitrogen scheduling	Seeding rate (kg/ha)			Mean
	20	30	40	
N_1	2.27	3.02	3.22	2.85
N_2	2.30	3.00	3.31	2.87
N_3	2.48	3.13	3.19	2.94
N_4	2.55	3.22	3.27	3.00
Mean	2.40	3.09	3.25	
CD (P=0.05)	Seeding rate (S) × Nitrogen scheduling (N) = 0.33			

N_1, one-third N as basal and two-third N at maximum tillering (MT); N_2, one-third N as basal and one-third N at panicle initiation MT and one-third N at PI; N_3, half N after first weeding and half N at MT; and N_4, one-third N after first weeding, one-third N at MT and one-third N at PI

Table 4. Effect of seeding rates and nitrogen scheduling on economics of direct-seeded rice (pooled data of 2 years)

Treatment	Gross returns (×10³ ₹/ha)	Net returns (×10³ ₹/ha)	Benefit : cost ratio	Crop productivity (kg/ha/day)	Economic efficiency (₹/ha/day)
Seed rate (kg/ha)					
20	22.4	6.2	1.26	21.0	54
30	28.9	13.4	1.55	27.5	119
40	32.1	15.9	1.64	28.5	141
SEm±	1.5	1.2	0.09	0.7	11
CD (P=0.05)	4.3	3.6	0.25	2.2	36
Nitrogen scheduling					
N_1	27.5	11.6	1.48	25.0	102
N_2	27.4	10.8	1.44	25.0	95
N_3	28.3	12.4	1.51	26.0	109
N_4	28.0	12.5	1.51	26.0	111
SEm±	1.3	0.9	0.06	0.3	9
CD (P=0.05)	NS	NS	NS	1.0	28

N_1, one-third N as basal and two-third N at maximum tillering (MT); N_2, one-third N as basal and one-third N MT and one-third N at at panicle initiation PI; N_3, half N after first weeding and half N at MT; and N_4, one-third N after first weeding, one-third N at MT and one-third N at PI

ing of direct-seeded rice using 40 kg seed/ha along with split application of one-third N at first shower/enough moisture availability preferably after first weeding, one-third N at maximum tillering and one-third N at panicle initiation stage is an ideal and sustainable approach to achieve the optimum productivity and monetary returns under rainfed drought-prone ecology of middle Indo-Gangetic plains of Eastern India.

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