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Effect of row spacing and nitrogen levels on growth and yield of wheat (*Triticum aestivum* L.)

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Abstract
A field experiment to investigate the effect of row spacing and nitrogen levels on growth and yield of wheat (*Triticum aestivum* L.) was conducted on sandy clay loam soil at Instructional Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (Chhattisgarh) during the *rabi* season of 2022-23. The investigation was carried out in a split-plot design with 12 treatment combinations comprising of three row spacings (15, 20 and 25 cm) in the main plot and four nitrogen levels (100, 120, 140 and 160 kg ha^{-1}) in the sub-plot, which were replicated three times. The wheat variety CG 1023 (Chhattisgarh Hansa Wheat) was used for the research. Results of field experiment revealed that growing of wheat at 15 cm row spacing recorded significantly higher growth attributes, which was statistically at par with 20 cm row spacing but significantly better than 25 cm row spacing at all growth stages under study. Row spacing 15 cm recorded significantly higher yield attributes and grain yield (45.54 q ha^{-1}) of wheat which was at par with 20 cm row spacing but significantly better than 25 cm row spacing. Among nitrogen levels, 160 kg N ha^{-1} recorded the highest values of growth attributes, which was statistically at par with 140 kg ha^{-1} but significantly better than its lower levels. Application of 160 kg N ha^{-1} recorded significantly higher yield attributes and grain yield (45.54 q ha^{-1}) but at par with 140 kg N ha^{-1}. The Harvest index was not significantly affected by row spacing and nitrogen levels. The highest benefit: cost ratio (1.53) was recorded in row spacing 15 cm which was followed by 20 cm row spacing (1.50). Among nitrogen levels the highest benefit: cost ratio (1.82) was recorded in 160 kg N ha^{-1} which was followed by 140 kg N ha^{-1} (1.80). The interaction effect of row spacing and nitrogen levels did not reach a level of significance.

Keywords: Wheat, row spacing, nitrogen levels, growth parameters, yield attributes, yield and economics

1. Introduction
Wheat (*Triticum aestivum* L.) is an important food grain, providing nourishment to almost 35 percent of the world's population (Akram *et al.*, 2022) [1]. It is primarily consumed as a staple food, since it contains more protein than any other cereal crops. It is widely grown throughout the temperate zone as well as in some higher elevation tropical and subtropical regions. Although, it may be grown on a range of soils from sandy to heavy clay. The best soil for higher production is fertile and well-drained loam to clay loam (Hossain *et al.*, 2006) [9]. Wheat has occupied an area of 220.75 m ha with a total production of 770.88 Mt and a productivity of 3.52 t ha^{-1} in the world (Anonymous, 2021) [4]. In India, wheat is grown in 31.13 m ha and produced 109.59 Mt with an average productivity of 3.52 t ha^{-1} during 2020-2021 (Anonymous, 2022 a.) [5]. India is the second-largest producer of wheat in the world, next only to China and the crop has helped Indian agriculture to grow at the fastest rate in the world (Akram *et al.*, 2022) [1]. In Chhattisgarh, wheat occupies an area of about 0.22 m ha with an average productivity of 1.6 t ha^{-1} during 2020-21 (Anonymous, 2022 b.) [6].

Wheat crops have a high potential yield and are responsive to many agro-management practices, including tillage, seed rate, crop geometry, sowing date and nutrient management (Sultana and Sheikh, 2022) [16]. Inter-row spacing is one of the most important agronomical factors and is crucial for the proper distribution of plants across the cultivated area and for the best use of the soil and natural resources (Mali and Choudhary, 2012) [10]. Researchers were compelled to optimize row spacing in order to achieve better production because plants don't use available resources efficiently, especially solar radiation under wider row spacing and plants in narrow rows compete highly with one another.

Nitrogen (N) plays an important role in increasing the yield of the crop. In order to produce a bumper yield of wheat, the right amount of nitrogen must be applied. Nitrogen is a constituent of many fundamental cell components such as amino acids, nucleic acids, photosynthetic pigments and enzymes as well as it comprises about 7 percent of total plant dry matter. Nitrogen deficiency results in drying and firing of leaves, poor growth, grain becomes poorly filled and yield is severely affected. High nutrient can, however, also be detrimental because they increase the possibility of lodging in wheat plants, harm the environment through leaching and nitrate volatilization and cause economic loss to farmers (Sultana and Sheikh, 2022) [16]. Therefore, in order to maximize yield, it is necessary to determine the optimum nitrogen dose.

2. Materials and Methods

An experiment was conducted at Instructional Farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (C.G.) during *rabi* season 2022-23. The investigation was carried out in a split plot design where there were twelve treatment combinations of row spacing and nitrogen levels with three replications. The treatment comprised of three row spacings *i.e.*, 15, 20 and 25 cm and four nitrogen levels *i.e.*, 100, 120, 140 and 160 kg ha^{-1}.

The soil of the experiment plot was sandy clay loam in texture, neutral in reaction (7.3), medium in organic carbon (0.49%), low in available nitrogen (212.68 kg ha^{-1}), medium in available phosphorus (10.26 kg ha^{-1}) and high in available potassium (327.28 kg ha^{-1}). The wheat variety CG 1023 (Chhattisgarh Hansa Wheat) was sown on 28th November 2022 and harvested on 20th March 2023. The weather condition during crop season was favourable for normal growth and development of wheat. Seed bed was prepared thoroughly and seeds of wheat were sown using a rate of 100 kg ha^{-1} in line manually as per the treatments on 15, 20 and 25 cm row spacings. As per the treatments nitrogen was applied in three splits *viz.* half as basal and the remaining half was top dressed equally after first and second irrigation. A uniform recommended dose of P_2O_5 (60 kg ha^{-1}) and K_2O (40 kg ha^{-1}) were applied as basal in all the plots through single superphosphate and muriate of potash, respectively.

3. Results and Discussion

3.1 Pre harvest observations

3.1.1 Plant height (cm)

Plant height of wheat was significantly affected due to various treatments (Table-1). At 30 DAS of crop, the maximum plant height (36.37 cm) was recorded in 15 cm row spacing which was statistically at par with row spacing of 20 cm (34.42 cm) but both were significantly better than 25 cm row spacing (31.14 cm). Similar trends were also observed at 60, 90 DAS and harvest of crop. This might be due to more uniform spatial distribution and less intra row plant to plant competition compared with the wider row spacing. This result was confirmative with Singh *et al.* (2017) [14]. Among nitrogen levels, application of 160 kg N ha^{-1} recorded the highest plant height of 38.46 cm which was statistically at par with 140 kg N ha^{-1} (37.03 cm) but significantly better than the other treatments at 30 DAS. Similar trends were also observed at 60, 90 DAS and harvest of crop. Application of 160 kg N ha^{-1} produce maximum plant height may be due to the fact that nitrogen plays an important role in cell division and cell elongation and thus growth in terms of plant height. These results were supported by findings of Ali *et al.* (2011) [2], Patra and Ray (2018) [11], Singh *et al.* (2019) [15] and Shende *et al.* (2020) [13] in wheat, who reported that increasing the level of nitrogen, increased the plant height.

Table 1: Effect of row spacing and nitrogen levels on plant height and number of total tillers at different growth stages of wheat

Treatment	Plant height (cm)				Number of total tillers (m^{-2})			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
(A) Row spacing								
S_1 – 15 cm	36.37	81.53	98.84	97.34	215.40	323.46	398.27	389.93
S_2 – 20 cm	34.42	79.02	97.63	96.04	210.95	319.59	390.28	382.36
S_3 – 25 cm	31.14	73.17	91.74	89.90	191.77	300.35	372.28	361.36
S.Em±	0.78	1.29	1.17	1.07	3.59	3.78	3.79	4.56
CD (0.05)	3.06	5.07	4.58	4.20	14.09	14.85	14.89	17.92
(B) Nitrogen levels								
N_1 – 100 kg ha^{-1}	28.12	72.07	88.35	86.46	186.73	290.87	363.26	354.71
N_2 – 120 kg ha^{-1}	32.30	75.81	93.00	92.67	201.77	311.27	383.76	376.09
N_3 – 140 kg ha^{-1}	37.03	80.81	100.01	97.90	216.07	324.62	397.12	389.46
N_4 – 160 kg ha^{-1}	38.46	82.95	102.89	100.67	219.11	331.11	403.61	391.28
S.Em±	0.93	1.34	1.40	1.39	3.29	3.91	3.89	4.02
CD (0.05)	2.76	3.97	4.17	4.14	9.76	11.61	11.55	11.95
Interaction (S×N)								
S.Em±	1.61	2.31	2.43	2.41	5.69	6.77	6.73	6.97
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

3.1.2 Number of total tillers (m^{-2})

Number of total tillers of wheat was significantly affected due to row spacing (Table-2). At 30 DAS of crop, the maximum number of total tillers (215.40) was recorded in 15 cm row spacing (S_1) which was statistically at par with row spacing 20 cm *i.e.*, S_2 (210.95) but both were significantly higher than S_3-25 cm row spacing (191.77). Similar results were also observed at 60, 90 and harvest. This result was confirmative with Ali *et al*. (2016) [3], Mali and Choudhary (2012) [10]. Among nitrogen levels, application of 160 kg N ha^{-1} recorded the highest number of total tillers of 219.11 which was statistically at par with 140 kg N ha^{-1} (216.07) but significantly better than its lower levels at 30 DAS. Similar trends were also observed at 60, 90 DAS and harvest of crop. This may be due to greater supply of nitrogen used for cell division and enlargement. These results were supported by findings of Ali *et al.* (2011) [2], Patra and Ray (2018) [11], Singh *et al.* (2019) [15] and Shende *et al.* (2020) [13] in wheat, who reported that increasing the level of nitrogen, increased the number of total tillers.

3.1.3 Dry matter accumulation (g plant^{-1})

As regard to dry matter accumulation, 15 cm row spacing (S_1) recorded highest dry matter which was statistically at par with row spacing of 20 cm (S_2) but both were significantly higher than 25 cm row spacing (S_3) at all growth stages (Table-2 and Fig.1), indicating better resource utilization in narrow rows than wider rows. This result was confirmative with Ali *et al.* (2016) [3]. Among nitrogen levels, application of 160 kg N ha^{-1} (N_4) recorded the highest dry matter accumulation of 0.70 g which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (0.67 g) but significantly better than the other treatments at all growth stages. These results were supported by findings of Patra and Ray (2018) [11], Singh *et al.* (2019) [15] and Ghanasai *et al.* (2020) [8] in wheat, who reported that increasing the level of nitrogen, increased the plant dry matter.

Table 2: Effect of row spacing and nitrogen levels on dry matter accumulation at different growth stages of wheat

Treatment	Dry matter accumulation (g plant^{-1})			
	30 DAS	60 DAS	90 DAS	At harvest
(A) **Row spacing**				
S_1 – 15 cm	0.68	8.66	21.26	28.01
S_2 – 20 cm	0.65	7.72	20.65	27.90
S_3 – 25 cm	0.58	6.67	17.99	25.24
S.Em±	0.01	0.24	0.51	0.45
CD (0.05)	0.05	0.95	2.02	1.76
(B) **Nitrogen levels**				
N_1 – 100 kg ha^{-1}	0.54	6.34	17.43	24.65
N_2 – 120 kg ha^{-1}	0.62	7.33	19.00	26.22
N_3 – 140 kg ha^{-1}	0.67	8.34	21.31	28.09
N_4 – 160 kg ha^{-1}	0.70	8.73	22.13	29.24
S.Em±	0.02	0.32	0.52	0.48
CD (0.05)	0.05	0.96	1.55	1.43
Interaction (S×N)				
S.Em±	0.03	0.56	0.90	0.48
CD (0.05)	NS	NS	NS	NS

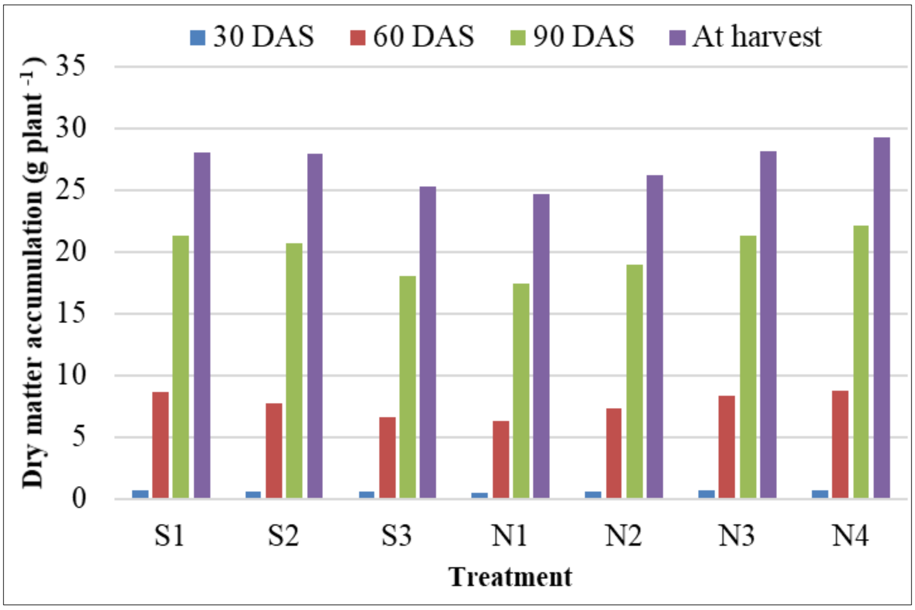

Fig 1: Effect of row spacing and nitrogen levels on dry matter accumulation (g plant^{-1}) at different growth stages of wheat

3.2 Post-harvest observations

3.2.1 Effective tillers (m^{-2}) at harvest

The maximum number of effective tillers (365.66) were recorded in 15 cm row spacing (S_1) which was statistically at par with row spacing 20 cm *i.e.*, S_2 (356.96) but both were significantly better than S_3-25 cm row spacing (340.60) as shown in Table-3. This result was confirmative with Singh *et al.* (2017) [14]. Among nitrogen levels, application of 160 kg N ha^{-1} (N_4) recorded the highest number of effective tillers (371.68) which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (367.86) but significantly better than its lower levels at harvest of crop. This result was confirmative with Patra and Ray (2018) [11], Shende *et al.* (2020) [13] and Sultana and Sheikh (2022) [16].

3.2.2 Ear length (cm)

The highest ear length (10.40 cm) was recorded in 15 cm row spacing (S_1) which was statistically at par with row spacing 20 cm *i.e.*, S_2 (10.22 cm) but both were significantly better than S_3-25 cm row spacing (8.75 cm). The application of 160 kg N ha^{-1} (N_4) recorded the highest ear length (10.87 cm) which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (10.30

cm) but significantly better than the other treatments at harvest of crop. This result was confirmative with Ali *et al.* (2011) [2], Patra and Ray (2018) [11] and Shende *et al.* (2020) [13].

3.2.3 Number of grains ear head^{-1}

Number of grains ear head^{-1} of wheat was significantly affected due to various treatments. The maximum number of grains ear head^{-1} (29.48) was recorded in 15 cm row spacing (S_1) which was statistically at par with row spacing 20 cm *i.e.*, S_2 (28.73) but both were significantly better than S_3-25 cm row spacing (25.95). The application of 160 kg ha^{-1} (N_4) recorded the maximum number of grains ear head^{-1} (30.91) which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (29.39) but significantly better than its lower levels at harvest of crop. This result was confirmative with Ali *et al.* (2011) [2], Patra and Ray (2018) [11], Shende *et al.* (2020) [13] and Sultana and Sheikh (2022) [16].

3.2.4 Test weight (g)

The highest test weight (43.34 g) was recorded in 15 cm row spacing (S_1) which was statistically at par with row spacing 20 cm *i.e.*, S_2 (42.55 g) but both were significantly better than S_3-25 cm row spacing (41.69 g). The application of 160 kg N ha^{-1} (N_4) recorded the maximum test weight (43.85 g) which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (43.52 g) but significantly better than its lower levels at harvest of crop. Nitrogen level, 120 kg ha^{-1} (N_2) also significantly better than 100 kg ha^{-1} (N_1). This result was confirmative with Warraich *et al.* (2002) [18], Ali *et al.* (2011) [2], Patra and Ray (2018) [11] and Sultana and Sheikh (2022) [16].

3.2.5 Grain yield (q ha^{-1})

Row spacing of 15 cm (S_1) recorded significantly highest grain yield of 46.27 q ha^{-1}. But it was at par with treatment S_2-20 cm row spacing (43.69 q ha^{-1}). Treatment S_3- 25 cm row spacing recorded significantly lowest yield (38.97 q ha^{-1}). This might be due to more uniform and accurate spatial distribution and less plant-to-plant competition, growth parameters and yield attributing characters increased resulted in increase of grain yield. This result was confirmative with Ali *et al.* (2016) [3], Chhokar *et al.* (2017) [7] and Singh *et al.* (2017) [14].

Nitrogen levels affect grain yield significantly under study. Treatment N_4-160 kg N ha^{-1} recorded significantly highest grain yield of 45.54 q ha^{-1} which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (44.94 q ha^{-1}) but significantly better than its lower levels. The increase in grain yield by increasing nitrogen level might be due to better plant growth and dry matter production due to higher photosynthetic area and increased all the yield attributing characters which ultimately increased the grain yield. This result was confirmative with Warraich *et al.* (2002) [18], Ali *et al.* (2011) [2], Patra and Ray (2018) [11], Satyanarayana *et al.* (2017) [12], Yadav and Dhanai (2017) [19], Singh *et al.* (2019) [15], Tyagi *et al.* (2020) [17] and Sultana and Sheikh (2022) [16].

3.2.6 Straw yield (q ha^{-1})

Row spacing of 15 cm (S_1) recorded significantly highest straw yield of 47.21 q ha^{-1}. But it was at par with treatment S_2-20 cm row spacing (44.69 q ha^{-1}). Treatment S_3-25 cm row spacing recorded significantly lowest straw yield (40.78 q ha^{-1}). This result was confirmative with Singh *et al.* (2017) [14].

Nitrogen levels affect straw yield significantly under study. Treatment N_4-160 kg N ha^{-1} recorded significantly highest straw yield of 46.44 q ha^{-1} which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (46.22 q ha^{-1}) but significantly better than its lower levels. This result was confirmative with Satyanarayana *et al.* (2017) [12], Singh *et al.* (2019) [15], Tyagi *et al.* (2020) [17] and Sultana and Sheikh (2022) [16].

3.2.7 Biological yield (q ha^{-1})

Row spacing of 15 cm (S_1) recorded significantly highest biological yield of 93.48 q ha^{-1}. But it was at par with treatment S_2-20 cm row spacing (88.38 q ha^{-1}). Treatment S_3-25 cm row spacing recorded significantly lowest biological yield (79.74 q ha^{-1}). Nitrogen level also affect biological yield significantly under study. Treatment N_4-160 kg N ha^{-1} recorded significantly highest biological yield of 91.98 q ha^{-1} which was statistically at par with 140 kg ha^{-1} *i.e.*, N_3 (91.16 q ha^{-1}) but significantly better than its lower levels. This result was confirmative with Shende *et al.* (2020) [13] and Tyagi *et al.* (2020) [17].

Table 3: Effect of row spacing and nitrogen levels on yield attributing characters, grain yield, straw yield, biological yield and harvest index of wheat

Treatment	Effective tillers (m^{-2}) at harvest	Ear length (cm)	No. of grains ear head^{-1}	Test weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
(A) Row spacing								
S_1 – 15 cm	365.66	10.40	29.48	43.34	46.27	47.21	93.48	49.52
S_2 – 20 cm	356.96	10.22	28.73	42.55	43.69	44.69	88.38	49.44
S_3 – 25 cm	340.60	8.75	25.94	41.69	38.97	40.78	79.74	48.87
S.Em±	3.77	0.26	0.57	0.22	0.80	0.99	1.59	0.17
CD (0.05)	14.78	1.03	2.24	0.86	3.14	3.87	6.25	NS
(B) Nitrogen levels								
N_1 – 100 kg ha^{-1}	326.33	8.54	24.85	40.28	39.20	40.70	79.90	49.06
N_2 – 120 kg ha^{-1}	351.76	9.43	27.07	42.45	42.23	43.53	85.76	49.24
N_3 – 140 kg ha^{-1}	367.86	10.30	29.39	43.52	44.94	46.22	91.16	49.30
N_4 – 160 kg ha^{-1}	371.68	10.87	30.91	43.85	45.54	46.44	91.98	49.51
S.Em±	3.90	0.28	0.73	0.22	0.88	1.09	1.78	0.19
CD (0.05)	11.59	0.82	2.16	0.65	2.62	2.67	5.28	NS
Interaction (S×N)								
S.Em±	6.76	0.48	1.26	0.38	1.53	1.56	3.08	0.33
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

3.2.8 Harvest index (%)
Row spacing and nitrogen levels did not show a significant effect on harvest index. This result was confirmative with Warraich *et al.* (2002) [18], who concluded that harvest index did not increase with increasing nitrogen levels.

3.3 Economics of the treatment
3.3.1 Cost of cultivation (₹ ha^{-1})
Among row spacing, the highest cost of cultivation (44,387 ₹ ha^{-1}) was recorded in treatment S_1 (15 cm) which was followed by S_2-20 cm row spacing (42,425 ₹ ha^{-1}). However, the lowest cost of cultivation of 41,117 ₹ ha^{-1} was recorded under treatment S_3-25 cm row spacing. Among nitrogen levels, the highest cost of cultivation (39,245 ₹ ha^{-1}) was recorded in treatment N_4 (160 kg N ha^{-1}) which was followed by N_3-140 kg ha^{-1} (38,989 ₹ ha^{-1}). However, the lowest cost of cultivation of 38,476 ₹ ha^{-1} was recorded under treatment 100 kg ha^{-1} (N_1).

Table 4: Effect of row spacing and nitrogen levels on economics of wheat

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	Benefit: Cost ratio
(A) **Row spacing**				
S_1 – 15 cm	44,387	1,12,487	68,100	1.53
S_2 – 20 cm	42,425	1,06,248	63,823	1.50
S_3 – 25 cm	41,117	95,045	53,928	1.31
(B) **Nitrogen levels**				
N_1 – 100 kg ha^{-1}	38,476	95,510	57,034	1.48
N_2 – 120 kg ha^{-1}	38,732	1,02,798	64,066	1.65
N_3 – 140 kg ha^{-1}	38,989	1,09,364	70,375	1.80
N_4 – 160 kg ha^{-1}	39,245	1,10,705	71,460	1.82

3.3.2 Gross return (₹ ha^{-1})
The highest gross return (1,12,487 ₹ ha^{-1}) was recorded in treatment S_1 (15 cm) which was followed by S_2-20 cm row spacing (1,06,248 ₹ ha^{-1}). However, the lowest gross return of 95,045 ₹ ha^{-1} was recorded under treatment S_3-25 cm row spacing. Among nitrogen levels, the highest gross return (1,10,705 ₹ ha^{-1}) was recorded in treatment N_4 (160 kg N ha^{-1}) which was followed by N_3-140 kg ha^{-1} (1,09,364 ₹ ha^{-1}). However, the lowest gross return of 95,510 ₹ ha^{-1} was recorded under treatment 100 kg ha^{-1} (N_1).

3.3.3 Net return (₹ ha^{-1})
The highest net return (68,100 ₹ ha^{-1}) was recorded in treatment S_1 (15 cm) which was followed by S_2-20 cm row spacing (63,823 ₹ ha^{-1}). However, the lowest net return of 53,928 ₹ ha^{-1} was recorded under treatment S_3-25 cm row spacing. Among nitrogen levels, the highest net return (71,460 ₹ ha^{-1}) was recorded in treatment N_4 (160 kg N ha^{-1}) which was followed by N_3-140 kg ha^{-1} (70,375 ₹ ha^{-1}). However, the lowest net return of 57,034 ₹ ha^{-1} was recorded under treatment 100 kg ha^{-1} (N_1).

3.3.4 Benefit: Cost ratio
The highest benefit: cost ratio (1.53) was recorded in treatment S_1 (15 cm) which was followed by S_2-20 cm row spacing (1.50). However, the lowest benefit: cost ratio of 1.31 was recorded under treatment S_3-25 cm row spacing. Among nitrogen levels, the highest benefit: cost ratio (1.82) was recorded in treatment N_4 (160 kg N ha^{-1}) which was followed by N_3-140 kg ha^{-1} (1.80). However, the lowest benefit: cost ratio of 1.48 was recorded under treatment 100 kg ha^{-1} (N_1).

4. Conclusion
On the basis of the present investigation, it can be concluded that 15 cm row spacing recorded higher grain yield (46.27 q ha^{-1}), net return (68,100 ₹ ha^{-1}) and B: C ratio (1.53), followed by 20 cm row spacing. Further nitrogen (160 kg N ha^{-1}) recorded the highest grain yield (45.54 q ha^{-1}), net return (71,460₹ ha^{-1}) and B: C ratio (1.82) than its lower levels.

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