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INTERACTION EFFECT OF SPACING AND NITROGEN LEVELS ON GROWTH PARAMETERS AND YIELD ATTRIBUTES OF INDIAN MUSTARD (*BRASSICA JUNCEA* L. CZERN AND COSS)

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ABSTRACT

In order to assess the impact of spacing and nitrogen levels on the growth and yield of the Indian mustard variety (Gujarat Dantiwada Mustard 4) "GDM 4," a field experiment was carried out in Sardarkrushinagar, Gujarat, during the rabi season of 2024-2025. The experiment was conducted using a split-plot design with four nitrogen levels (N_1: 37.5 kg N/ha, N_2: 50 kg N/ha, N_3: 75 kg N/ha, and N_4: 100 kg N/ha) in sub-plots and three spacings (S_1: 30 cm × 15 cm, S_2: 30 cm × 30 cm, and S_3: 45 cm × 15 cm in the main plots. Wider spacing of 30 cm x 30 cm was found to have significantly more branches (4.22 and 11.19) and siliquae per plant (293.68). However, because of an ideal plant population, the spacing of 45 cm × 15 cm recorded the maximum seed output (2,305 kg/ha), net returns (Rs. 83,760/ha), and BC ratio (2.54). In terms of nitrogen levels, applying 100 kg N/ha greatly enhanced production qualities, resulting in the highest seed yield (2480 kg/ha), net returns (Rs. 96,653/ha), and BC ratio (3.13). Key words: Economics, Mustard, GDM 4, Nitrogen, Spacing, and Yield.

***Keywords*:** Indian Mustard (*Brassica juncea* L. Czern and Coss), Spacing and Nitrogen, Growth Parameters Levels, Yield Attributes

Introduction

In India, mustard, or *Brassica juncea* (L.) Czern and Coss, is the second most important oilseed crop after groundnuts. Often referred to as Rai or Laha, it is a member of the family Cruciferae (Brassicaceae), genus Brassica, and tribe Brassiceae. About 28% of the world's mustard is produced in India, making it one of the biggest producers (FAO, 2022). The consumption of edible oil in India has shown an increasing trend over the last three decades, driven by a rising population and increased purchasing power associated with economic growth. Consequently, India's self-sufficiency in edible oil is highly dependent on the successful cultivation of mustard, given its relatively high oil content (30–40%) (Singh *et al.*, 2021). Gujarat produces 0.50 million tonnes of rapeseed-mustard year on 0.25 million hectares of land (Anon., 2023). However, productivity in the state remains variable due to fluctuating climatic conditions, water availability, and soil quality. Among the agronomic factors determining yield, spacing is one of the most effective manipulable tools (Zandi *et al*., 2011).While it affects how incoming solar radiation is intercepted, absorbed, penetrated, and used, plant geometry is crucial for increasing total crop output. Each area, cultivar, and production system has a different ideal spacing. Maintaining ideal row spacing is essential for canopy closure and resource utilisation, even though the usual advice for mustard spacing in India is 30 cm × 10 cm for types and 45 cm × 10 cm for hybrids (Bhanu *et al*., 2019). Growth, yield, and yield-contributing traits are strongly influenced by population density resulting from planting geometry (Johnson *et al*., 2003).

Nitrogen is an essential ingredient that directly affects mustard growth, development, production and quality in addition to plant geometry. All living plant tissues depend on nitrogen, which makes up 1-4% of dry weight. Since most agricultural soils are generally lacking in nitrogen, successful agriculture can be achieved without the application of nitrogenous fertilisers. By optimising crop output and yield qualities, nitrogen fertilisation seeks to maximum economic rewards. Two important agronomic methods that affect plant competition, seed and straw yields, canopy structure, and overall resource efficiency are spacing and nitrogen levels. Therefore, achieving the maximum production potential of Indian mustard required optimising these parameters through field experimentation.

Materials and Methods

The field study was carried out at the Agronomy Instructional Farm, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat, during the rabi season of 2024–2025. The experimental site is situated 154.52 meters above mean sea level at latitude $24^{o}19'$ N and longitude $72^{o}19'$ E in the North Gujarat Agro-climatic Zone (AES-IV). The climate is characterised by a semi-arid condition with fairly cold winters and dry, hot summers. With mean maximum temperatures between 24.6°C and 37.2°C and mean minimum temperatures between 6.3°C and 22.9°C, the weather was generally cool and dry during the crop season (October to February), which was ideal for mustard development. The experimental field's soil had a loamy sand texture, a pH of 7.30, and an electrical conductivity of 0.13 dS/m. The soil had medium levels of accessible phosphorus (36.85 kg P_2O_5/ha) and potassium (244.20 kg K_2O/ha), but low levels of organic carbon (0.27%) and available nitrogen (159.85 kg/ha).

At 25 days after sowing (DAS) and right before harvest, plant populations per net plot were measured. Five randomly tagged plants per plot were used to assess growth attributes. Primary and secondary branches were only counted during harvest and plant height (measured from base to main shoot tip) was recorded at 60 DAS. Using a leaf area meter, the leaf area (cm²) of five destructively collected plants was measured at 60 DAS. Additionally, a handheld SPAD meter was used to measure the relative leaf chlorophyll content (SPAD index) at 65 DAS. At harvest, the number of siliquae from five tagged plants was counted from each net plot, and mean values for siliquae per plant for each treatment were calculated. The number of siliquae per plant was calculated by averaging five plants and reported as such. From each of the five tagged plants, five siliquae were randomly selected, measured using a linear scale, and recorded individually for each treatment. For every treatment, the average siliqua length (in centimetres) was determined and noted. The number of seeds per siliqua for each treatment was counted using the five siliquae that were used to measure the length of the siliqua.With the assistance of labourers, the harvested plants from each net plot area were thoroughly sun-dried and threshed individually for each treatment. After being sun-dried to a consistent weight, the seeds were cleaned and weighed to determine the seed yield in kilograms per net plot. The corresponding net plot seed production was additionally increased by the seed yield of five tagged plants that were utilised to document various findings from each treatment. The same was expressed as kg/ha after being converted to a hectare basis. Prior to threshing, the weight of each net plot's fully sun-dried plants was measured. Following threshing, the amount of seed generated from each net plot was subtracted from the plant's overall weight and recorded as straw yield, which was then translated to hectares. The ratio of economic yield (kg/ha) to biological yield (kg/ha) is known as the harvest index. The formula provided by Donald and Hamblin (1976) was used to calculate it.

Experimental design and treatments

A split-plot design with four replications was used to set up the experiment. The treatments included four nitrogen levels in subplots (N_1: 37.5 kg N/ha, N_2: 50 kg N/ha, N_3: 75 kg N/ha, and N_4: 100 kg N/ha) and three spacing levels in main plots (S_1: 30 cm × 15 cm, S_2: 30 cm × 30 cm, and S_3: 45 cm × 15 cm). Using a computer system at the Computer Center, C.P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar, the statistical analysis of the data generated for various parameters during the investigation was conducted using the split plot design procedure outlined by Gomez and Gomez (1984). When the "F test" was deemed significant, the important differences for comparing treatment means were calculated at the five percent significance level. Indian mustard variety 'GDM 4' (Gujarat Dantiwada Mustard 4) was sown on October 17, 2024, at a depth of 2–3 cm. The spacing treatments affected the seed rate, which was 3.69 kg/ha for S_1, 1.85 kg/ha for S_2, and 2.46 kg/ha for S_3. Single Super Phosphate (SSP) and elemental sulphur were used to apply a basal dose of 50 kg P_2O_5/ha and 40 kilogram S/ha, respectively. Neem-coated urea was used to apply nitrogen in accordance with treatments; 50% of the nitrogen dose was applied as basal, and the remaining 50% was top-dressed in two equal splits at 30 and 45 days after sowing (DAS). Throughout the growing season, the crop was irrigated six times. To maintain the necessary intra-row spacing, thinning was done at 15 DAS. The plots were kept weed-free by hand weeding and interculturing. On February 21, 2025, the crop reached physiological maturity and was harvested.

Results and Discussion

Growth parameters

Effect of spacing

The data presented in Table 1 reveal that crop spacing significantly influenced the plant stand per net plot at both 20 DAS and at harvest. The highest initial and final plant populations (188.1 and 184.4 per net plot, respectively) were recorded with the 30 cm × 15 cm spacing (S_1). However, at 20 DAS and harvest, the lowest mustard plant population (94.0 and 93.4/net plot) was seen at 30 cm x 30 cm (S_2) spacing. At both the starting and harvest stages, an increase in inter- and intra-row spacing resulted in a considerable drop in the number of plants per net plot.

The plant population per net plot decreased significantly with an increase in inter and intra row spacing at both stages, *i.e.* initial and at harvest. These results are closely linked to the findings of Cheema *et al*. (2001), who reported that the effect of variable spacing was non-significant with respect to plant height at 60 DAS and at harvest, and SPAD value at 65 DAS. The adopted plant geometry directly affects the number of plants per unit area. Wider spacing appeared to reduce competition, possibly leading to slightly shorter but sturdier plants. Lalruatfeli *et al.* (2021). Under spacing (30 cm x 30 cm), there may be more primary and secondary branches per plant since there is less intra-specific competition, giving each plant more sunlight and nutrients. On the other hand, resource availability restricts branch creation, thus closer spacing probably inhibited lateral expansion. The greatest leaf area per plant was 580.00 cm^2 when mustard was sown at 30 cm × 30 cm (S_2) spacing. On the other hand, under 30 cm × 15 cm (S_1) spacing, a much smaller leaf area per plant (509.83 cm^2) was recorded; this was comparable to 45 cm × 15 cm spacing, which had a leaf area per plant of 530.63 cm^2. Because there is less competition for nutrients, water and sunlight, wider plant spacing promotes healthy growth and development. The greatest leaf area per plant was 580.00 cm^2 when mustard was sown at 30 cm × 30 cm (S_2) spacing. On the other hand, under 30 cm × 15 cm (S_1) spacing, a much smaller leaf area per plant (509.83 cm^2) was recorded; this was comparable to 45 cm × 15 cm spacing, which had a leaf area per plant of 530.63 cm_2. Because there is less competition for nutrients, water, and sunlight, wider plant spacing promotes healthy growth and development and increases leaf area. These results are consistent with those of Yadav *et al*. (2018).

Effect of nitrogen levels

In terms of plant population per net plot at 20 DAS and harvest, plant height at 60 DAS and harvest and SPAD value at 65 DAS, Table 1 showed that the impacts of various nitrogen levels were determined to be non-significant. In comparison to the other N levels, the plot receiving 100 kg N/ha (N_4) developed the most primary and secondary branches (4.48 and 12.00) and leaf area per plant (606.17 cm^2). Although there was a noticeably less leaf area per plant (501.11 cm^2), 37.5 kg N/ha. Nonetheless, it was discovered to be statistically equivalent to treatment N_2 (50 kg N/ha). Mustard's leaf area rose dramatically when a larger dose of nitrogen was applied; this could be because of increased cellular growth and photosynthetic efficiency. The plant's supply of carbohydrates may have grown as a result of the increased nitrogen supply expanding the leaf area and maybe speeding up photosynthetic activity. The amount of leaf area per plant was thereby enhanced by nitrogen fertilisation. According to Reager et al. (2014), applying increasing amounts of nitrogen from 40 to 100 kg/ha, Raguvanshi *et al.* (2018) from 0 to 160 kg/ha, and Singh *et al.* (2022) from 0 to 150 kg/ha greatly increased the amount of leaf area per Indian mustard plant. Although variations between the treatments might not always be statistically significant, wider spacing promotes improved light penetration and canopy development, which may increase chlorophyll content. These results are consistent with those of Patel and Jat (2021).

Interaction effect

As shown in Table 3, the interaction between spacing and nitrogen doses was significantly influenced number of secondary branches per plant. The results showed that sowing mustard at 30 cm × 30 cm spacing with 100 kg N/ha (S_2N_4) produced a much higher number of secondary branches, which were statistically comparable to treatment combination S_3N_4 (sowing mustard at 45 cm × 15 cm with 100 kg N/ha). Wider plant spacing (30 cm × 30 cm) increases sunshine, soil moisture, and nutrients, which boosts photosynthesis, metabolic activity, and general growth and development, resulting in more branches. (Dekhane *et al*. 2024) reported similar findings. They observed that plants with 45 cm × 10 cm spacing and 90 kg N/ha application had the greatest number of branches per plant.

Yield attributes and yield

Effect of spacing

A review of the data presented in Table 2 revealed that, compared to the other spacings, the significantly highest number of siliquae per plant (293.68) was recorded under 30 cm × 30 cm (S_2) spacing. Conversely, sowing at 30 cm x 15 cm (S_1) resulted in a much lower number of siliquae per plant (220.30). The number of siliquae per plant increased in the current study as plant spacing increased. This could be because the wider spacing, or 30 cm × 30 cm planting pattern, increases the availability of nutrients and moisture as well as photosynthetic and stomatal activities, which improve reproductive organs, or yield attributes. In contrast, there was higher competition for natural resources under plant geometry of 30 cm × 15 cm and 45 cm × 15 cm because of the closer spacing between two rows and two plants, which had a negative impact on the crop's growth and yield characteristics.

In the present study, as plant spacing grew, along with the quantity of siliquae per plant. This may be due to the increased availability of nutrients and moisture, as well as photosynthetic and stomatal activities, which enhance reproductive organs or yield qualities, resulting from the wider spacing, or 30 cm x 30 cm planting pattern. The crop's growth and yield characteristics were negatively impacted by increased competition for natural resources under plant geometry of 30 cm × 15 cm and 45 cm × 15 cm due to the closer spacing between two rows and two plants.

Effect of nitrogen levels

The application of 100 kg N/ha (N_4) produced the considerably greatest number of siliquae per plant (318.50) compared to the other N levels, according to data on the number of siliquae per plant (Table 2). Applying 37.5 kg/ha (N_1) resulted in a significantly lower number of siliquae per plant (189.03), which is significantly different from the next higher N level (50 kg N/ha). Protoplasm is produced in greater quantities when the nitrogen supply is increased. Increased cell size, increased cell division and elongations, increased leaf area, and ultimately increased photosynthetic activity are the outcomes of this increase. In the end, it generates more dry matter and branches per plant, which finally results in more flowers.

In the end, it generates more dry matter and branches per plant, which results in more flowers and subsequently more siliquae per mustard plant. Reager *et al*. (2006) support these conclusions. They came to the conclusion that under 100 kg N/ha, more siliquae were formed. Siliqua length, seeds per siliqua, 1000-seed weight, and harvest index were not significantly impacted by nitrogen application levels. The results of Cheema *et al*. (2001) are consistent with this lack of importance in seeds per siliqua. Additionally, according to Kumar *et al*. (1996) and Bankoti *et al*. (2021), the greatest weight was numerically recorded at 100 kg N/ha, but the 1000-seed weight was statistically non-significant across treatments.

Interaction effect

The number of siliquae per plant was shown to be significantly impacted by the relationship between spacing and nitrogen levels (Table 4). The results demonstrated that, in comparison to the other treatment combinations, treatment combination S_2N_4 (30 cm x 30 cm spacing with application of 100 kg N/ha) recorded considerably more siliquae per plant (378.50). However, the number of siliquae per plant (184.50) was significantly reduced in treatment combination S_1N_1 (30 cm × 15 cm spacing with application of 37.5 kg N/ha), which was statistically comparable to treatment combinations S_2N_1, S_3N_1, S_1N_2, and S_3N_2. It could be explained by a decrease in plant competition for nutrients, light, moisture, and space. This played a major part in controlling photosynthesis, boosting metabolic processes that supported the production of chlorophyll and photosynthesis on the one hand, and root growth and faster nutrient absorption on the other. Additionally, greater spacing preserved a better balance between translocation and photosynthesis, which eventually led to improved mustard yield-attributing factors. Sai *et al*. (2022) found that applying 80 kg N/ha with a wider spacing of 50 cm × 15 cm resulted in a much higher number of siliquae per plant.

Seed yield

Effect of spacing

A thorough analysis of the data presented in Table 2 revealed that mustard sown at 45 cm × 15 cm (S3) spacing yielded a significantly higher seed yield of 2305.4 kg/ha than the other treatments, but did not significantly differ from 30 cm × 15 cm (S_1) spacing, which produced a seed yield of 2134.6 kg/ha. Notably, under 30 cm x 30 cm (S_2) spacing, the lowest seed production (1909.9 kg/ha) was found. Compared to treatment S_2 (30 cm × 30 cm), the seed yield increased by 20.71 percent under 45 cm × 15 cm (S_3) and 11.77 percent under 30 cm × 15 cm (S_1). The interaction between plant density and resource availability is responsible for the observed variation in seed output. Greater access to space, sunlight, and nutrients was made possible by wider spacing, which decreased competitive stress and improved growth and yield characteristics per plant (Tables 1 and 2). However, the yield gap brought on by low population density could not be closed by the individual plants' flexibility. Therefore, the main factor influencing the overall seed output was the greater plant population per unit area with closer spacings. There may be more siliquae per unit area with closer spacing (45 cm × 15 cm and 30 cm × 15 cm) than at broader spacing, which could explain the higher seed output. Higher seed yields were linked to higher plant density, which is in line with findings by Cheema *et al*. (2001), Chaniyara *et al*. (2002) and Ozer (2003). The yield advantage under the 45 cm × 15 cm spacing suggests that individual plant performance found in broader spacings is less important in determining yield than the total plant population per hectare. The crop's light extinction coefficient was probably enhanced by the optimised geometry, which raised photosynthetic rates. Additionally, the thick canopy successfully inhibited the growth of weeds, directing resources away from weed biomass and toward crop yield.

Effect of nitrogen levels

It was discovered that mustard seed output was significantly impacted by varying nitrogen levels. The findings showed that applying a greater dose of nitrogen, 100 kg N/ha (N_4), resulted in a significantly higher mustard seed yield (2479.9), which was statistically comparable to applying 75 kg N/ha (N_3). Conversely, a lower N dose of 37.5 kg N/ha (N_1) produced the lowest seed production of 1561.9 kg/ha. When 50, 75, and 100 kilogram N/ha were applied, the percentage increase in seed yield above 37.5 kg N/ha was 30.66, 52.63, and 58.77%, respectively.

The most vital nutrient, nitrogen (N), is a component of chlorophyll, cellulose, protoplasm, and protein. It is involved in a number of metabolic processes, including the production of more leaf area per plant (Table 1), which increased the rate of photosynthetic activity, and the effective partitioning of photosynthate from source to sink, which increased the production of dry matter, which significantly enhanced crop growth and productivity. Higher nitrogen administration led to increased meristematic activity, floral primordia development and tissue differentiation (from somatic to reproductive), all of which may have improved mustard growth. The beneficial effects of nitrogen application may be attributed to this nutrition, which promotes cell division, elongation, and expansion and gives leaves a deep green hue due to improved chlorophyll synthesis. This increases the effective area for photosynthesis, which leads to a comparatively higher amount of photosynthates accumulation in plants and their translocation, which manifests as increased crop growth.

The positive impact of a greater nitrogen dose on sink components may be explained by the plants' improved growth in terms of height and dry biomass output, which increases bearing capacity because of the higher nitrogen dose's optimal quality. Keerthi *et al*. (2017) and Bankoti *et al*. (2021) reported similar results. They came to the conclusion that while applying 100 kg N/ha resulted in a noticeably increased seed yield, it was still comparable to applying 60 and 120 kg N/ha.

Interaction effect

Seed yield was significantly impacted by the interplay between nitrogen levels and spacing. The mustard seed production was greatly impacted by the interaction between row spacing and nitrogen application (Table 5). The seed yield (2828.1 kg/ha) of treatment combination S_3N_4 (sowing at 45 cm × 15 cm spacing with application of 100 kg N/ha) was significantly higher than that of treatment combination S_3N_3 (sowing at 45 cm × 15 cm spacing with application of 75 kg N/ha), according to the results. In contrast, seeding mustard at a distance of 30 cm by 15 cm and applying 37.5 kg N/ha (S_1N_1) resulted in a much lower seed yield of 1470.0 kg/ha compared to the other treatment combinations.

However, it continued to be statistically comparable to treatment combinations S_2N_1 (30 cm × 30 cm spacing with 37.5 kilogram N/ha) and S_3N_1 (45 cm × 15 cm spacing with 37.5 kg N/ha). Treatment combinations S_3N_4 and S_3N_3 had higher seed yields than treatment combination S_1N_1 by 19.24 and 18.23 percent, respectively. The much larger leaf area per plant (Table 1) may be the result of improved photosynthetic activities brought on by adequate light interception and a balanced supply of nutrients throughout the growth phases. Light penetration, nutritional availability, and overall plant development are all impacted by spacing. The aforementioned findings demonstrated that mustard development and production are significantly influenced by the choice of suitable spacing with elevated nitrogen levels.

The seed production received under closer plant spacings with more plants per unit area could not be offset by wider plant spacings with fewer plants per unit area. In addition to increasing photosynthate production, which increases translocation to reproductive organs, nitrogen also affected seed yield through a source-sink relationship. The results of Dekhane *et al*. (2024) were validated by the current studies. They came to the conclusion that a 90 kg N/ha application combined with a 45 cm x 10 cm spacing resulted in a noticeably better mustard seed output.

Straw yield

Effect of spacing

An analysis of Table 2's data reveals that spacing had a major impact on straw yield. The maximum straw yield, 5045.7 kg/ha, was reported by the crop sowed at 30 cm × 15 cm (S_1), which was statistically comparable to the 45 cm × 15 cm spacing (S_3, 4847.6 kg/ha). The wider spacing of 30 cm x 30 cm produced the noticeably lowest straw yield (4430.4 kg/ha) (S_2). Treatments S_1 and S_3 outperformed the S_2 by 11.38% and 10.94%, respectively, in terms of relative performance. The greater plant population per unit area, which significantly contributed to the accumulation of total biomass, is the main cause of the improved straw production with the tighter spacing (S_1). Although there was less competition for light, moisture and nutrients among individual plants under wider spacing (S_2), this led to better individual plant growth rather than growth per unit area. The yield loss resulting from the reduced plant stand per hectare could not be offset by this individual benefit. These results corroborate the findings of Sondhiya *et al.* (2019), who also concluded that higher plant density (30 cm × 15 cm) maximises straw yield in mustard.

Effect of nitrogen levels

It was discovered that the straw yield of mustard was significantly impacted by varying nitrogen levels. A quick look at the data Table (2) revealed that treatment N_4: 100 kg N/ha produced a much greater straw yield of 5549.2 kg/ha than the other treatments, with the exception of N_3: 75 kg N/ha (5118.9 kg/ha). Treatment N_1 (37.5 kg N/ha) had the lowest seed yield (3814.9 kg/ha). A higher N dose of 100 kg N/ha produced the maximum straw yield, which was 14.54, 12.02 and 10.8% higher than treatments N_1, N_2, and N_3, respectively.

Additionally, the plot that received 100 kg N/ha showed a notable improvement in growth parameters such as plant height, number of primary and secondary branches per plant and leaf area per plant (Table 1), which led to the overall increase in mustard straw yield. The findings are consistent with those published by Bankoti *et al*. (2021) and Keerthi *et al*. (2017). They came to the conclusion that applying 100 kg N/ha produced noticeably more straw. A quick look at the data in Table 2 showed that variations in the harvest index caused by different plant spacing and nitrogen levels were not significant. Adhikari *et al*. (2021) and Bankoti *et al*. (2021) corroborate these findings.

Conclusion

Effect of spacing: The moderate spacing of 45 cm × 15 cm (S_3) offered the best balance between plant population and per-plant productivity, resulting in the highest seed yield and economic profitability. The wider spacing of 30 cm × 30 cm optimised individual plant architecture and yield attributes (branching and siliquae per plant).

Effect of nitrogen levels: In conclusion, the application of 100 kg N/ha (N_4) maximised vegetative architecture (branching and leaf area), siliquae production and overall economic returns while baseline metrics like plant population and height remained unaffected by nitrogen variance. However, since the seed and straw yields attained at 75 kg N/ha (N_3) were statistically comparable to the 100 kg N/ha rate, N_3 offers a highly effective alternative for optimising productivity while possibly lowering fertiliser inputs. According to the experiment's findings, in order to secure a higher yield and net return in loamy sandy soil, the mustard crop should be sown at 45 cm × 15 cm spacing and fertilised with 100 kg N/ha (50% as basal and the remaining 50% applied in two equal splits at 30 and 45 DAS).

Interaction effect: The experiment's findings lead to the conclusion that, in order to get a greater yield in loamy sand, mustard crops should be sown at 45 cm × 15 cm spacing and 75 kg N/ha (50% as basal and the remaining 50% applied in two equal splits at 30 and 45 DAS).

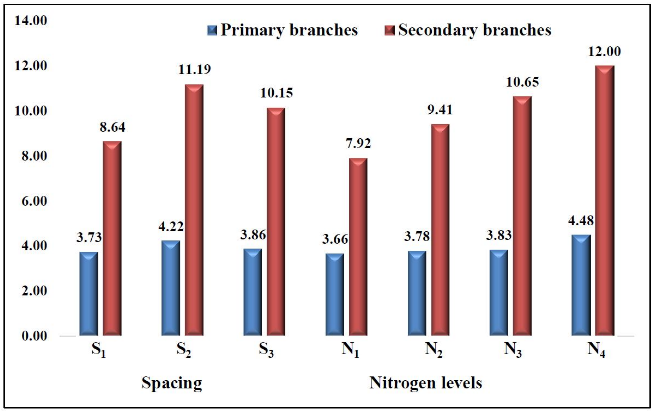

Fig. 1: Number of primary and secondary branches per plant

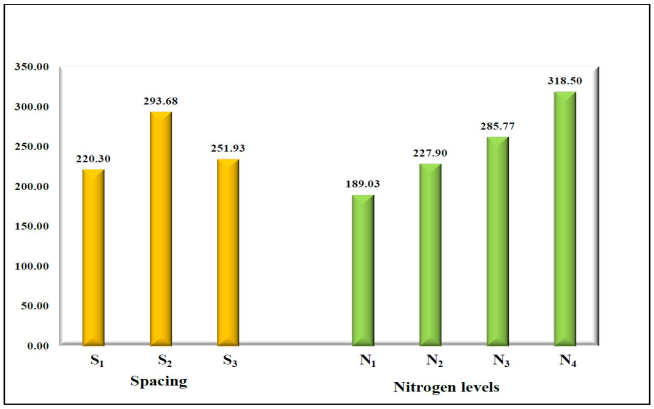

Fig. 3: Number of siliquae per plant of mustard

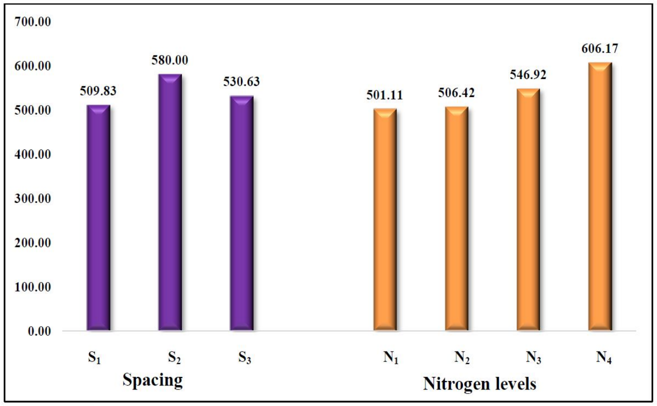

Fig. 2: Leaf area per plant at 65 DAS (cm^2)

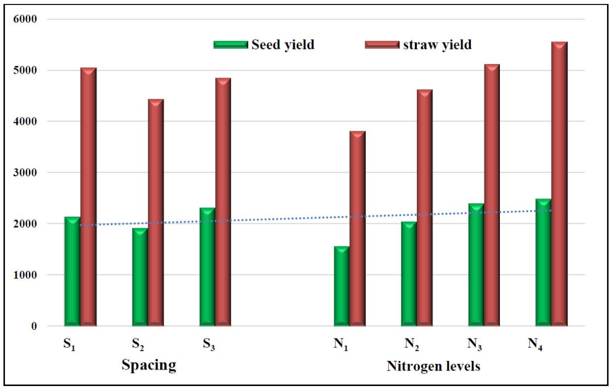

Fig. 4: Seed and straw yield of mustard

Table 1: Effect of spacing and nitrogen levels on growth parameters of mustard

Treatment	Plant population per net plot		Plant height (cm)		Number of branches		Leaf area per plant at 60 DAS (cm^2)	SPAD value at 65 DAS
	At 20 DAS	At harvest	60 DAS	At harvest	Primary	Secondary		
Spacing (S)								
S_1: 30 cm × 15 cm	188.1	184.4	146.0	193.3	3.73	8.64	509.83	25.75
S_2: 30 cm × 30 cm	94.0	93.4	137.7	182.9	4.22	11.19	580.00	26.45
S_3: 45 cm × 15 cm	142.4	140.8	138.7	189.4	3.86	10.15	530.63	25.79
S.Em±	3.88	3.22	3.73	6.10	0.09	0.29	10.90	0.90
CD at 5%	13.42	11.15	NS	NS	0.30**	0.99**	37.73**	NS
Nitrogen levels (N)								
N_1: 37.5 kg/ha	142.7	140.3	136.4	180.9	3.66	7.92	501.11	25.07
N_2: 50 kg/ha	141.1	138.6	140.8	187.1	3.78	9.41	506.42	25.68
N_3: 75 kg/ha	139.9	137.8	141.6	190.1	3.83	10.65	546.92	25.96
N_4: 100 kg/ha	142.3	141.3	144.5	195.9	4.48	12.00	606.17	27.29
S.Em±	2.87	2.46	3.56	4.37	0.09	0.29	11.03	0.71
CD at 5%	NS	NS	NS	NS	0.260**	0.83**	32.01**	NS

Interaction (S × N)								
S.Em. ±	4.96	4.26	6.17	7.58	0.16	0.50	19.11	1.23
C.D. at 5%	NS	NS	NS	NS	NS	1.44*	NS	NS

* Significant at 5 per cent level of significance, ** Significant at more than 5 per cent level of significance, NS- Non-Significant

Table 2: Effect of spacing and nitrogen levels on yield attributes of mustard

Treatment	**Number of siliquae per plant**	**Length of siliqua (cm)**	**No. of seeds per siliqua**	**1000 seed weight (g)**	**Seed yield (kg/ha)**	**Straw yield (kg/ha)**	**HI (%)**
Spacing (S)							
S$_1$: 30 cm × 15 cm	220.30	4.88	13.17	4.97	2134.6	5045.7	29.61
S$_2$: 30 cm × 30 cm	293.68	5.00	13.60	5.12	1909.9	4430.4	30.15
S$_3$: 45 cm × 15 cm	251.93	4.89	13.27	5.08	2305.4	4847.6	32.00
S.Em$\underline{+}$	4.69	0.15	0.33	0.13	55.41	129.12	0.73
CD at 5%	16.25	NS	NS	NS	191.75**	446.82*	NS
Nitrogen levels (N)							
N$_1$: 37.5 kg/ha	189.03	4.84	12.68	4.88	1561.9	3814.9	29.15
N$_2$: 50 kg/ha	227.90	4.93	13.25	5.05	2040.8	4615.3	30.63
N$_3$: 75 kg/ha	285.77	4.91	13.45	5.10	2383.9	5118.9	31.70
N$_4$: 100 kg/ha	318.50	5.01	14.01	5.20	2479.9	5549.2	30.87
S.Em$\underline{+}$	4.76	0.12	0.33	0.13	57.85	117.08	0.71
CD at 5%	13.83	NS	NS	NS	167.85**	339.74**	NS
Interaction (S × N)							
S.Em. ±	8.25	0.21	0.58	0.22	100.19	202.79	1.23
C.D. at 5%	23.95	NS	NS	NS	290.73*	NS	NS

* Significant at 5 per cent level of significance, ** Significant at more than 5 per cent level of significance, NS- Non-Significant

Table 3: Interaction effect of spacing and nitrogen levels on number of secondary branches per plant of mustard

Spacing (S)	**Secondary branches per plant**			
	Nitrogen Levels (N)			
	N$_1$	**N$_2$**	**N$_3$**	**N$_4$**
S$_1$	7.00	8.88	9.45	9.25
S$_2$	9.25	10.25	11.75	13.50
S$_3$	7.50	9.10	10.75	13.25
	S.Em. ±	0.50		
	C.D. at 5%	1.44		

Table 4: Interaction effect of spacing and nitrogen levels on number of siliquae per plant of mustard

Spacing (S)	**Number of siliquae per plant**			
	Nitrogen Levels (N)			
	N$_1$	**N$_2$**	**N$_3$**	**N$_4$**
S$_1$	184.50	200.41	242.05	254.25
S$_2$	186.15	280.05	330.00	378.50
S$_3$	196.45	203.25	285.25	322.75
	S.Em. ±	8.25		
	C.D. at 5%	23.95		

Table 5 : Interaction effect of spacing and nitrogen levels on seed yield of mustard

Spacing (S)	**Seed yield (kg/ha)**			
	Nitrogen Levels (N)			
	N$_1$	**N$_2$**	**N$_3$**	**N$_4$**
S$_1$	1470.0	2204.4	2331.7	2532.2
S$_2$	1520.0	1884.3	2156.0	2079.3
S$_3$	1695.5	2033.8	2664.1	2828.1
	S.Em. ±	100.19		
	C.D. at 5%	290.73		

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