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Influence of spacing and nitrogen levels on quality parameters and nutrient dynamics in mustard (*Brassica juncea* L.) in the north part of Gujarat

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Abstract

To reduce intraspecific competition for essential resources, including sunlight, water and nutrients, mustard (*Brassica juncea* L.) agriculture must optimise plant spacing and nitrogen levels. Additionally, increasing crop output and boosting soil nutrient usage efficiency depend on figuring out the right amount of nitrogen fertiliser (urea). Both oil yield and the uptake of nutrients by mustard seed and straw are strongly influenced by plant geometry and nitrogen application rates. Additionally, increasing crop output and boosting soil nutrient usage efficiency depend on figuring out the right amount of nitrogen fertiliser (urea). Both oil yield and the uptake of nitrogen by mustard seed and straw are strongly influenced by plant geometry and nitrogen application rates. Consequently, adopting the optimum spacing and nitrogen dosage can substantially improve nutrient uptake, oil yield and overall crop performance. Thus, in *rabi* 2024–2025, a field experiment was carried out on loamy sand soil at the Agronomy Instructional Farm, C.P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. Three spacing levels (S₁: 30 cm × 15 cm, S₂: 30 cm × 30 cm, and S₃: 45 cm × 15 cm) and four nitrogen levels (N₁: 37.5 kg N/ha, N₂: 50 kg N/ha, N₃: 75 kg N/ha, and N₄: 100 kg N/ha) comprised the twelve treatment combinations used in the Split Plot Design experiment. The findings showed that the oil output (829.1 kg/ha) and nitrogen uptake by seed (52.82 kg/ha) of mustard grown at 45 cm × 15 cm spacing were significantly greater. Straw absorbed the most nitrogen in a spacing of 30 cm × 15 cm (27.51 kg/ha). However, spacing and nitrogen levels revealed that the nitrogen content of seed and straw, as well as the available soil N, P₂O₅, and K₂O after harvest, were not significant.

Keywords: Nutrient uptake, nitrogen, oil content, oil yield, spacing

1. Introduction

Second only to groundnuts, mustard (*Brassica juncea* L.) is an essential oilseed crop in India that accounts for about 28% of global production. Cultivated primarily during the *rabi* season, mustard thrives in cool, moist conditions and is well-suited to diverse agro-climatic regions due to its resilience and low input requirements. India's mustard cultivation spans 6.3 million hectares, yielding 8-9 million tonnes annually, with Rajasthan leading production, followed by Haryana, Uttar Pradesh, and Gujarat. Mustard is valued for its high oil content (30-40%) and versatile uses, including cooking, industrial applications and medicinal purposes. Gujarat, a significant producer, contributes 10-12% of India's mustard output, though its productivity remains below the national average due to climatic and soil variability. Plant spacing is one of the major agronomic parameters that affects mustard (*Brassica juncea*) yield. The proper spacing of mustard plants ensures optimal growth by balancing the availability of sunlight, nutrients, water and air circulation. Spacing is essential, since it directly impacts plant development, resource use, oil yield and nutrient uptake. Spacing is one of the most effective agronomic factors for determining the yield, which is individually affected by cultivar and climatic conditions as well as production system (Zandi *et al.*, 2011)^[21]. Plant spacing is crucial for increasing agricultural productivity because it influences how incoming solar radiation is intercepted, absorbed, penetrated and used. The variety, growth habit and agroclimatic

conditions all affect the ideal plant density with the right planting density. Higher plant populations and closer plant spacing increase competition for moisture and nutrients. Whereas too much wider spacing might not have taken full advantage of the nutrients and allow weeds to grow, leading to poor yield (Dewangan *et al.*, 2012) ^[7]. Spacing is a non-monetary input that can be altered to get a good yield (Lakra *et al.*, 2018) ^[14]. Wider plant spacing results in a low population, which fails to compensate for the yield obtained in an optimal plant stand, whereas narrower row and plant spacing increase inter and intra plant competition, resulting in poor growth and development, dry matter accumulation and yield (Sonani *et al.*, 2002) ^[18]. As an oilseed crop, mustard benefits greatly from improved synthesis of proteins and oil in its seeds. Excess nitrogen can reduce oil content while increasing protein levels in seeds, which may affect the quality of mustard oil, reducing its commercial value. Mustard seeds' fatty acid composition and oil content are influenced by nitrogen. The quality of the oil improves with sufficient nitrogen levels, particularly in terms of the concentration of oleic and linoleic acid, which are crucial for nutritional value. A lack of nitrogen has a detrimental effect on overall output because it causes poor seed filling, smaller seeds and lower oil content. It is a major nutrient element that provides lush green colour in crops (due to an increase in chlorophyll) and its deficiency in arid and semiarid regions is more common because the amount of organic matter, which are the main nitrogen reserves, is very low in these regions and even if they were found, they would be quickly decomposed (Bandi-Saeedi, 2001). It is a crucial component of enzymes and chlorophyll, both of which are necessary for plant growth processes. Because it is a necessary component of many various kinds of metabolically active substances, such as proteins and amino acids, it has a significant impact on plant metabolism. While nitrogen promotes vegetative development, photosynthesis, and seed production, proper spacing maximises the use of available resources. However, excessive nitrogen can reduce oil content and increase lodging. In order to improve production methods in sandy loam soil, this study intends to assess the effects of spacing and nitrogen levels on oil content, oil output, nutrient content and uptake by mustard seed and straw.

2. Materials and Methods

Location and soil of the experimental field plot

During the 2024–2025 *rabi* season, a field experiment was carried out in Sardarkrushinagar, Gujarat. Geographically, Sardarkrushinagar is located in the North Gujarat Agro-climatic Zone at a latitude of 24°-19' N and longitude 72°-19' E. It is 154.52 meters above mean sea level, with mean minimum temperatures ranging from 6.3 °C to 22.9 °C and maximum temperatures ranging from 24.6 °C to 37.2 °C. Prior to the experiment, composite soil samples were taken from the experimental site at a depth of 0 to 15 cm. These samples were prepared and analysed for physical and chemical characteristics, and the initial nutrient status in the soil was determined using standard procedures. The mean relative humidity recorded in the morning and evening ranged between 65.0 and 87.0 per cent and 13.0 to 46.0 per cent, respectively. Bright sunshine hours and evaporation ranged between 3.8 and 10.1 hours per day and 3.3 and 6.7 mm per day. The soil's EC (0.13 dS/m) was normal, its organic carbon (0.27%) and available nitrogen (159.85 kg/ha) were low, its available phosphorus (36.85 kg/ha) and potash (244.2 kg/ha) were medium and its pH (7.30) was neutral.

Experimental procedure and statistical analysis

A split-plot design with three spacings and four nitrogen levels was used to set up the experiment. (S₁: 30 cm × 15 cm, S₂: 30 cm × 30 cm and S₃: 45 cm × 15 cm) in main plots: (N₁: 37.5, N₂: 50, N₃: 75 and N₄: 100 kg N/ha) in sub-plots. The experiment consists of 12 treatment combinations. Mustard variety GDM-4 was sown with 3 levels of spacing with seed rates of S₁: 3.69 kg/ha, S₂: 1.85 kg/ha, and S₃: 2.46 kg/ha. The furrows were opened manually in each plot at 30 and 45 cm intervals as per treatments. All of the plots received a half-dose of nitrogen as a basal in already opened furrows in the form of neem-coated urea in accordance with treatments. As top dressing in the form of urea coincided with irrigation according to treatments, the remaining half dose of nitrogen was applied in two equal splits at 30 and 45 DAS.

Phosphorus @ 50 kg/ha and sulphur @ 40 kg/ha were applied as a common dose in all the treatments through SSP and elemental sulphur, respectively, at the time of sowing in furrows. Sulphur added through SSP fertilizer was subtracted from 40 kg S and the remaining quantity of S was applied through elemental sulphur. In order to achieve equal plant stands and satisfactory seed germination, the initial irrigation was applied right away after seeding. The next five irrigations were given based on the needs of the crops. One interculturing by bullock-drawn hoe at 30 DAS, followed by two hand weeding operations at 20 DAS and 40 DAS, was carried out to keep all the plots free from weeds to minimise the crop weed competition during the crop season, as well as for better soil aeration. Observations on quality parameters, nitrogen content and uptake by seed and straw of mustard, as well as soil nutrient analysis after harvest and the economy of mustard for treatment combinations were recorded and analysed. Data were analysed and the standard error of mean SE(m) and critical difference at 5% possibility level (P = 0.05) were calculated as per the formulae (Gomez and Gomez, 1984) ^[8] to interpret the results.

3. Results and Discussion

3.1. Quality parameters

3.1.1. Oil content (%)

Effect of spacing

The data on oil content presented in Table 1 showed that oil content (%) was not significantly influenced by different treatments of spacing. However, a marginal increase in oil content 36.26% was recorded under 30 cm × 30 cm (S₂) spacing. Similarly, Kumar *et al.* (2018) ^[12] also reported a non-significant effect of plant geometry on oil content (%) among various spacing in mustard seed.

Effect of nitrogen levels

Although the impact of varying nitrogen levels on mustard oil content (%) was not determined to be significant, there was a numerical modest rise in oil content (36.34%) under 100 kg N/ha (N₄) and a decrease in oil content (35.79%) under 37.5 kg N/ha (N₁). Aminpanah (2013) ^[1] noted that there was no variation in the oil content of mustard due to varying levels of nitrogen application (0, 50, 100, 150 and 200 kg/ha). Contrast results were reported by Cheema *et al.* (2001) ^[4], oil content in canola reduced significantly as the N application rate increased. Additionally, unfertilised winter oilseed rape had the maximum oil content, whereas high N supply had the lowest.

3.1.2. Oil yield (kg/ha)

Effect of spacing

The information presented in Table 1 made it abundantly evident

that different plant spacing had a substantial impact on mustard oil yield. Sowing the crop at 45 cm × 15 cm spacing resulted in a much greater oil yield (829.1 kg/ha) that was comparable to treatment S₂ (30 cm × 30 cm). However, at a spacing of 30 cm by 15 cm, the lowest oil output (687.9 kg/ha) was recorded (S₁). The oil content and seed yield determine the oil yield. The oil yield was significantly boosted by the larger seed yield (Table 1) in 45 cm × 15 cm (S₃) spacing. An increase in oil yield at narrow row spacings was attributed to more seed yield than the wider row spacings. It might be due to the ability of the plant to utilise the resources efficiently when it was sown under 45 cm × 15 cm spacing and it has comparatively lesser competition due to minimal plant population per unit area than 30 cm × 15 cm spacing. On the contrary, Cheema *et al.* (2001) [4] observed that the significantly highest oil yield was obtained under closer (30 cm) row spacing as compared to 45 and 60 cm row spacing.

Effect of nitrogen levels

Mustard oil output was significantly impacted by the effects of varying nitrogen dosages. Over the remaining N levels, treatment N₄ (100 kg N/ha) produced the highest oil production of 898.7 kg/ha; nevertheless, this yield did not differ substantially from treatment N₃ (75 kg N/ha). However, treatment N₁ (37.5 kg N/ha) had the lowest oil yield (558.9 kg/ha). A small increase in oil content and a large rise in seed production could be the reasons for the increase in oil yield after N application. Sharma *et al.* (2020) [17], Bankoti *et al.* (2021), and Singh *et al.* (2022) [19] have reported similar findings. They came to the conclusion that applying 100 and 120 kg N/ha greatly increased mustard oil yield.

Interaction effect

With the exception of treatment combination S₃N₃ (45 cm × 15 cm spacing with 75 kg N/ha), the results displayed in Table 2 showed that sowing mustard at 45 cm × 15 cm spacing together with 100 kg N/ha (S₃N₄) produced a much greater oil yield (1003.1 kg/ha). Treatment combinations S₁N₁ (30 cm × 15 cm spacing with 37.5 kilogram N/ha) and S₃N₁ (45 cm × 15 cm spacing with 37.5 kg N/ha) were found to be statistically comparable to treatment combination S₂N₂ (30 cm × 30 cm spacing with 50 kg N/ha), which produced a much lower oil production (532.3 kg/ha). In the current investigation, treatment combinations S₃N₄ and S₃N₃ produced oil yields that were 18.84 and 18.26 percent greater, respectively, than treatment combination S₂N₁. More seed production in this treatment was the primary cause of the increase in oil yield in the S₃N₄ combination. Keivanrad and Zandi (2013) [10] reported opposite findings. They found that a considerably higher oil yield (912.5 kg/ha) was produced at a lower plant density (80 plants/m²).

3.2. Effect on N content in seed and straw (%)

Effect of spacing

Various spacing treatments failed to vary greatly in terms of the amount of nitrogen in the seed and straw of mustard (Table 1).

Effect of nitrogen levels

The nitrogen content of mustard straw and seed was significantly impacted by varying N levels. The application of 100 kg N/ha (N₄) was shown to be statistically equivalent to treatment N₃ (75 kg N/ha) in terms of the maximum nitrogen content in seed (2.46%) and straw (0.56%). Moreover, significantly lower nitrogen content in seed (2.20%) and straw (0.50%) was recorded with treatment N₁ (37.5 kg N/ha). However, it remained statistically at par with treatment N₂

(2.26%) and N₃ (2.38%) in the case of seed and treatment N₂ (0.54%) in the case of straw. With each subsequent rise in nitrogen levels, the amount of nitrogen in seed and straw rose, maybe as a result of increased soil N application. Kumar and Janeja (2021) [13] revealed that the highest N content in the seed and straw of mustard was observed by application of 150 kg N/ha.

3.3. Effect on N uptake by seed and straw (kg/ha)

Effect of spacing

The information presented in Table 1 made it abundantly evident that different spacing greatly affected the amount of nitrogen absorbed by mustard straw and seed. The results showed that, in terms of N uptake by straw (27.51 kg/ha), the highest N uptake by seed (52.82 kg/ha) was obtained when the crop was sown at 45 cm × 15 cm (S₃) spacing and treatment S₁ (30 cm × 15 cm). While significantly lower N uptake by seed and straw (46.76 and 24.73 kg/ha, respectively) was registered with 30 cm × 30 cm spacing (S₂) and remained statistically at par with treatment S₁ (30 cm × 15 cm) in case of N uptake by seed and treatment S₃ in case of N uptake by straw. When the crop was sown under closer spacing of S₁ (30 cm × 15 cm), the plants were closer together and they started to grow taller as well as produce more leaves and stems to compete for sunlight. So, they spend most of the absorbed nitrogen on vegetative growth and production of plant biomass (straw). On the other hand, straw and seed have the lowest N uptake at the widest spacing S₂ (30 cm × 30 cm), showing sub-optimal plant density, leading to less efficient nutrient capture and nitrogen uptake by seed and straw was not compensated by the rest of the spacing treatments. Further, higher nitrogen uptake by seed and straw might be due to higher nitrogen content and yield of seed and straw obtained in this treatment. Kumari *et al.* (2012) [11] reported that significantly higher nitrogen uptake by mustard was sown at 30 cm × 10 cm spacing.

Effect of nitrogen levels

Due to different nitrogen levels, the data on mustard seed and straw nitrogen uptake varied considerably. Significantly, the highest N uptake by seed and straw (60.38 and 31.25 kg/ha, respectively) was obtained with application of 100 kg N/ha (N₄). Conversely, the application of 37.5 kg N/ha resulted in the significantly lowest N uptake by seed and straw (34.37 and 18.97 kg/ha, respectively). Higher soil availability of these nutrients (Table 1) and higher mustard seed and straw yield (Table 3) may be the cause of the increased nitrogen uptake under higher N doses. As nitrogen levels rise, seed and straw seem to absorb more nitrogen overall. Bali *et al.* (2000) [2] reported a significant increase in nitrogen and phosphorus uptake by seed and straw of brown sarson up to 60 kg N/ha. Rana and Rana (2003) [15] and Kumar *et al.* (2009) [9] stated that higher total nitrogen uptake with 80 kg N/ha and Reager *et al.* (2006) [16] observed significantly higher total uptake of nitrogen, phosphorus and potash with 100 kg N/ha.

3.4. Effect on available N, P₂O₅ and K₂O status in soil after harvest of crop

Effect of spacing: No significant variation was observed on available N, P₂O₅ and K₂O in soil due to various spacing treatments after harvest of mustard.

Effect of nitrogen levels

Nitrogen levels had no discernible impact on the amount of N, P₂O₅ and K₂O in the soil following crop harvest.

3.5. Effect of spacing and nitrogen levels on the economics of mustard

Effect of spacing

The data (Table 3) clearly shows that mustard was sown at 45 cm × 15 cm (S₃) spacing secured maximum gross realization of ₹1,31,645/ha, net realization of ₹83,760/ha as well as BCR of 2.74 followed by 30 cm × 15 cm (S₁) spacing which earned gross realization of ₹1,22,449/ha and net realization of ₹73,614/ha. Whereas, the minimum gross realisation of ₹1,09,475/ha, net realisation ₹62,476/ha and BCR of 2.32 was obtained under plant spacing of 30 cm × 30 cm (S₂). Higher seed yields (Table 3) in these treatments were the primary cause of the rise in net returns. Maximum gross and net realisation was obtained from 45 cm × 15 cm (Chaniyara *et al.*, 2002)^[5], 40 cm row spacing (Pyare *et al.*, 2008) and 45 cm × 10 cm spacing

(Kumari and Singh, 2012)^[11].

Effect of nitrogen levels

The data (Table 3) suggests that applying 100 kg N/ha (N₄) secured maximum gross realization of ₹1,41,944/ha, net realization of ₹96,653/ha as well as BCR of 3.13 followed by 75 kg N/ha (N₃), which earned gross realization of ₹1,36,233/ha, net realization of ₹91,282/ha as well as BCR of 3.01. In contrast, the application of 37.5 kg N/ha (N₁) resulted in the lowest gross realisation of ₹89,719/ha, net realisation of ₹45,483/ha, and BCR of 2.02. The increased seed yield in these treatments was the primary cause of the profitability rise. Similar results were reported by Chaurasiya *et al.* (2019)^[6], Sharma *et al.* (2020)^[17] and Tyagi *et al.* (2022)^[20]; they reported that the application of 100 to 120 kg N/ha gave higher net returns and B.C ratio.

Table 1: Effect of spacing and nitrogen levels on quality parameters, N content and uptake by seed and straw as well as available nutrients in soil after harvest of mustard

Treatments	Oil content (%)	Oil yield (kg/ha)	N content (%)		N uptake (kg/ha)		Available nutrients (kg/ha) in soil		
			Seed	Straw	Seed	Straw	N	P ₂ O ₅	K ₂ O
S ₁ : 30 cm × 15 cm	35.98	687.9	2.25	0.54	48.26	27.51	155.85	34.83	244.01
S ₂ : 30 cm × 30 cm	36.26	773.9	2.43	0.56	46.76	24.73	157.48	35.83	243.85
S ₃ : 45 cm × 15 cm	36.04	829.1	2.29	0.52	52.82	25.23	153.09	34.37	240.40
S.E.m. ±	1.02	19.54	0.06	0.01	1.18	0.58	3.94	1.13	4.87
C.D. at 5%	NS	67.60	NS	NS	4.08	2.02	NS	NS	NS
N ₁ : 37.5 kg/ha	35.79	558.9	2.20	0.50	34.37	18.97	151.15	34.21	238.41
N ₂ : 50 kg/ha	36.08	734.5	2.26	0.54	46.10	24.74	154.29	34.85	241.95
N ₃ : 75 kg/ha	36.17	862.4	2.38	0.55	56.26	28.33	157.37	35.38	243.21
N ₄ : 100 kg/ha	36.34	898.7	2.46	0.56	60.38	31.25	162.07	35.59	244.43
S.E.m. ±	0.73	16.10	0.07	0.01	0.98	0.61	4.14	1.07	4.84
C.D. at 5%	NS	46.72	0.19	0.04	2.86	1.78	NS	NS	NS
Interaction (S × N)									
S.E.m. ±	1.26	27.89	0.11	0.02	1.71	1.06	7.18	1.85	8.39
C.D. at 5%	NS	80.92	NS	NS	NS	NS	NS	NS	NS

Table 2: Interaction effect of spacing and nitrogen levels on oil yield of mustard

Spacing (S)	Oil yield (kg/ha)			
	Nitrogen levels (N)			
	N ₁	N ₂	N ₃	N ₄
S ₁	538.0	672.0	762.5	779.0
S ₂	532.3	797.3	852.3	913.9
S ₃	606.5	734.3	972.4	1003.1
S.E.m. ±	27.89			
C.D. at 5%	80.92			

Table 3: Effect of spacing and nitrogen levels on economics of mustard

Treatments	Yield (kg/ha)		Gross return (₹/ha)	Total cost of cultivation (₹/ha)	Net realization (₹/ha)	BCR
	Seed	Straw				
S ₁ : 30 cm × 15 cm	2134.6	5045.8	122449	48835	73614	2.50
S ₂ : 30 cm × 30 cm	1909.9	4430.4	109475	46999	62476	2.32
S ₃ : 45 cm × 15 cm	2305.4	4847.6	131645	47885	83760	2.74
N ₁ : 37.5 kg/ha	1561.9	3814.9	89719	44236	45483	2.02
N ₂ : 50 kg/ha	2040.8	4615.3	116859	44406	72453	2.63
N ₃ : 75 kg/ha	2383.9	5118.9	136233	44951	91282	3.01
N ₄ : 100 kg/ha	2479.9	5549.2	141944	45291	96653	3.13

4. Conclusion

A field experiment was undertaken on the mustard variety (GDM-4) on the loamy sand soils of the North Gujarat Agro-climatic Zone. It is concluded that optimising plant geometry and nitrogen fertilisation is crucial for maximising crop performance and profitability. While plant spacing and nitrogen levels did not significantly alter the oil content or the post-harvest available soil nutrient status (N, P₂O₅, K₂O), they profoundly impacted oil yield, nutrient uptake and economic

returns.

Optimal Spacing

The highest oil yield (829.1 kg/ha) and maximum nitrogen uptake by the seeds (52.82 kg/ha) resulted from a wider spacing of 45 cm × 15 cm, which greatly reduced intra-plant competition. In contrast, closer spacing (30 cm × 15 cm) primarily favoured vegetative growth, resulting in the highest nitrogen uptake by the straw.

Optimal Nitrogen Level

The crop's nutritional dynamics were gradually enhanced by increasing the nitrogen dose to 100 kg N/ha, which resulted in the highest overall nitrogen uptake, the maximum oil yield (898.7 kg/ha) and the maximum nitrogen content in both seed and straw.

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