Original Research Article

Study the interactive effects of different nitrogen doses and spacingon quality characteristics ofcoriander (*Coriandrum sativum* L.)

Abstract

Coriander (*Coriandrum sativum* L.) is one of the most important spice crops worldwide, possessing varied medicinal impacts. It is majorly grown for its leaves; however, its seeds occupy a major place in various cuisinesaround the world.Several studies have reported the interactive effects of different nitrogen doses and spacing in coriander and provided valuable insights into the optimal conditions for its growth and development.In this sequence, the present studyexploresthe effect of various nitrogen doses and spacing on coriander under field conditions at Research Farm of Vegetable Science, Chaudhary Charan Singh Haryana Agricultural University, Hisar (India) during*Rabi*, 2019-20. Amongst all the treatments, treatment S_3N_3 (40×15; N@75 kg/ha) was found best for harvest index, Test weight, Standard Germination, Seedling Length, Seedling Dry weight, Vigour Indices I & II, and S_2N_1 (30×15; N@50 kg/ha) for minimum Electrical Conductivity. Based on this study, the following treatments can be exploited for sustainable coriander production.

*Keywords:*Nitrogen;*Rabi;* Spacing; Sustainable

Introduction

Coriander (*Coriandrum sativum* Linn.), a memberof*Apiaceae*family which is also known as *Dhania,* cilantro, and Chinese parsley; grown as an annual herb around the world.It is originated from the Mediterranean region, however, extensively cultivated inCentral Europe North Africa, and Asia as a medicinal as well as culinary herb (Seidemann, 2005). Its matured fruits and fresh leaves are used as spices and traditional medicine. The essential oil content in matured coriander fruits ranges from 0.03% to 2.7%. Linalool, the primary component of the oil, constitutes approximately two-thirds of its composition (Izgi, 2020). India is the largest producer of coriander in the world. Within Indian courtesy, it is mainly cultivated in Rajasthan, Madhya Pradesh, Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Haryana and Punjab, West Bengal, and Himachal Pradesh. The crop was grown over an area of 583 thousand hectares with the production of 784 thousand MT (NHB, 2018-19) and in Haryana, the crop occupied an area of 2.40 thousand hectares with the production of 4.4 thousand metric tonnes during 2018-19 (Anonymous, 2019).

In India, it is primarily grown in *Rabi* season specifically for its leaves and seeds (Gil *et al.*, 2002). Besides various culinary applications, itpossess a range of medicinal properties (Prachayasittikul*et al.*, 2018) owing to its broad phytochemical profile and a variety of chemical compounds present in every plant part (root, fruits, leaves, and seeds) (Mandal and Mandal, 2015). There are several documented health benefits of coriander in literature i.e., swellings, diarrhoea, mouth ulcers, anaemia, digestion, menstrual disorders, smallpox, eye care, conjunctivitis, skin disorders, blood sugar disorders, and protection and soothing liver,*etc*. (Diwan *et al.*, 2018; Wangensteen *et al.*, 2004; Maroufi *et a.,l* 2010).

The application of nitrogen fertilizer has been found to enhance plant growth, as well as increase the production of essential oil, fixed oil, total carbohydrates, and soluble sugars. Nitrogen plays a crucial role in key plant processes such as photosynthesis, respiration, and protein synthesis. It contributes to the development of dark green leaves, stimulates vigorous vegetative growth, improves the utilization of available resources, and ultimately results in higher productivity (Izgi, 2020). In the coriander cultivation system, nitrogen fertilization is considered a major production factor that imparts a direct effect on the quality, composition, andthe yield of volatile compounds. As per previous documentations, the application of nitrogen fertilizer has improved seed yield and biomass of coriander by 43-68% and 25-42% (Ali *et al.*, 2015).In contrast, a nitrogen deficiency in plants leads to the yellowing of lower leaves, stunted growth, and the premature shedding of both leaves and fruits, which directly impacts overall yield negatively. On the other hand, excessive nitrogen application results in excessive shoot growth, rendering plants more vulnerable to pest and disease attacks. It also hampers root development, leading to lodging, and causes a delay in crop maturity. Consequently, the excessive application of nitrogen diminishes crop yield and degrades the quality of the produce (Javiya et al., 2017).Therefore, the incorporation of essential plant nutrients in the right proportion and adequate quantity concerning soil and climatic conditions is very essential (Ali *et al.*, 2015). Besides, maintaining the optimum plant population is also a beneficial, non-monetary agronomical practice of crop production.Maintaining optimum density of plants results in reduced nutrient competition within the plant population.Various studies have reported that optimum plant density increased the growth and yield of coriander significantly (Katiyar *et al.*, 2014). However, Wider or too close spacing beyond the optimum can negatively affect the yield of a crop. (Kaium*et al.*, 2015). Therefore, the present investigation was undertaken to demonstrate the effect of various nitrogen and spacing effects on coriander under field conditions.

Materials and Methods

Experimental site

The field trial was conducted at Research Farm of Vegetable Science Chaudhary Charan Singh Haryana Agricultural University, Hisar (India) (29^0 10’ N, 75^0 46’ E, Elevation 215.2 m) in the *Rabi* season of 2019-20. The temperature varies from 40 °C to 48 °C during summer to as low as to freezing point accompanied with chilling frost in winters. The approximate average rainfall was 450 mm.

Properties of the soil before the experiment conducted

The soil of the experimental field was analyzed for mechanicaland chemical properties, and cropping history detailsare given below in table 1.

Table 1 Detailed description of Mechanical, and chemical analysis of soil and cropping history

Mechanical analysis of the soil			
Sr. No.	Soil parameters	Proportion %(%)	Methods and reference
1	Sand	56	International pipette method (Piper, 1950)
2	Silt	32	
3	Clay	12	
4	Soil texture	Sandy - loam	
Chemical analysis of the soil at the start of the experiment			
S. No.	Soil Parameters	Value	Methods and reference
1	pH (1:2 soil: water suspension)	8.1	Potentiometric method (Jackson, 1973)
2	EC (ds/m) at 25^0C (1:2 soil: water suspension)	0.36	Conductometric method (Jackson, 1973)
3	Organic Carbon (%)	0.35	Wet oxidation method (Walkley and Black, 1934)
4	Available nitrogen (kg/ha)	138	Kjeldhal- distillation method (Subbiah and Asija, 1956)

5	Available phosphorus (kg/ha)	22.5	$NaHCO_3$ extraction and colorimetry method (Olsen *et al.*, 1954)
6	Available potassium (kg/ha)	227	N NH_4OAC extraction and Flame photometry method, (Jackson 1973)

Cropping history of the experimental field

	Crop seasons	
Year	*Kharif*	*Rabi*
2017-18	*Okra*	*Potato*
2018-19	*Okra*	*Fennel*
2019-20	Bottle gourd	Coriander

Field preparation

Experimental details

The coriander variety DH 220, developed by department of vegetable science, was chosen for experiment. The seeds were sown in a plot size of3.0 m x 2.4 mwithRandomized Block Design(RBD)inthree replications.A total of twelve treatments (Table 2) were formulated and raised with the standard agronomic practices.In the study, half of the nitrogen was applied at the sowing time and the rest of the dose was applied after 6 weeks of the first dose. The five were selected randomly and tagged data collection

Table2 Detailed treatment dose of N with combinatorial application with various spacing

Treatment (number)	**A detailed description of treatments**
1	N_1: 0 kg/ha (control)+ S_1: 20x15 cm
2	N_1: 0 kg/ha (control)+ S_2: 30x15 cm
3	N_1: 0 kg/ha (control)+ S_3: 40x15 cm
4	N_2: 25 kg/ha+ S_1: 20x15 cm
5	N_2: 25 kg/ha+ S_2: 30x15 cm
6	N_2: 25 kg/ha+ S_3: 40x15 cm
7	N_3: 50 kg/ha+ S_1: 20x15 cm
8	N_3: 50 kg/ha+ S_2: 30x15 cm
9	N_3: 50 kg/ha+ S_3: 40x15 cm

10	N_4: 75 kg/ha+ S_1: 20x15 cm
11	N_4: 75 kg/ha+ S_2: 30x15 cm
12	N_4: 75 kg/ha+ S_3: 40x15 cm

Evaluation of physical parameters:

Harvest index

The calculation of the harvest index, expressed as a percentage, is determined by dividing the economic yield by the biological yield using the following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Test weight

The count and weight of one thousand seeds were measured in triplicate for each treatment, and the average seed weight for each treatment was calculated.

Standard germination

In each replication of the experiment, fifty seeds from each treatment were placed between germination papers and kept at a temperature of 20ºC with 90-95% relative humidity in a germinator. The first count of germinated seeds was recorded on the 7th day, and the final count was taken on the 21st day. The recorded observations for seed germination were then converted into a percentage to determine the percent seed germination.

Seedling length

At the end of the germination test, the root and shoot length of five randomly chosen seedlings from each treatment in each replication were measured in centimetres. These measurements were then averaged to determine the total root and shoot length.

Seedling dry weight

After the final count in the standard germination test (21 days), the dry weight of seedlings was evaluated. Five seedlings from each treatment, replicated three times, were selected for assessment. The seedlings were dried in a hot air oven for 48 hours at a temperature of 80±10 °C. Following the drying process, the seedlings from each replication were weighed, and the average seedling dry weight for each treatment was calculated.

Vigour indices

Seedling vigour indices were calculated according to the method suggested by Abdul-Baki and Anderson (1973):

I. Vigour index-I (on seedling length basis):

Vigour index–I = Standard germination (%) × Average seedling length (cm)

II. Vigour Index–II (on seedling dry weight basis):

Vigour index–II = Standard germination (%) × Average seedling dry weight (mg)

Electrical conductivity test

To assess the electrical conductivity, three replications of 50 intact and undamaged seeds were immersed in 75 ml of distilled water within 100 ml beakers. The seeds were fully submerged in the water, and the beakers were covered with foil. Subsequently, these samples were left at a temperature of 25°C for 24 hours. The electrical conductivity of the leachates from the seeds was measured using a direct reading conductivity meter, with the conductivity value expressed in micro Siemens per centimetre per gram (µS $cm^{-1}g^{-1}$).

Statistical Analysis

The data was statistically analyzed in Randomized Block Design using SPSS software (IBM, SPSS Inc., USA). The p-values were calculated and the results were expressed as CD at 5% level of significance. Data was subjected to two-way ANOVA (Gomez and Gomez 2010).

Results and Discussion

Harvest index

Harvest index was recorded maximum in spacing 40 x 15 cm (37.50)which was followed by 30 x 15 cm(37.12). In their study, Sharma et al. (2016) found that spacing played a significant role in promoting vigorous plant growth, as evidenced by abundant branching and increased biomass accumulation per plant. The extensive branching not only facilitated enhanced flower initiation but also ensured an optimal supply of metabolites. The higher biomass per plant likely contributed to better retention of flowers, resulting in greater seed formation and seed growth.

Harvest index was recorded maximum at nitrogen dose 75 kg ha^{-1} (39.22) which was followed by 50 kg ha^{-1} (38.67) Choudhary *et al.* (2014) and they stated that the enhancement in yield of coriander is directly associated with the parallel increase in growth and yield attributing characters. As nitrogen is a major nutrient of biological significance, it is mainly required in the synthesis of protein, chlorophyll, and other organic compounds. Therefore, with an increased availability of nitrogen in the soil medium and thereafter, effective absorption and translocation in various parts of plants impartsactive cell division and elongation which results in greater plant height.

Test Weight

The maximum test weight was observed in spacing 40 x 15 cm (9.05 g) which was followed by 30 x 15 cm (8.87 g), Katar and Katar (2016) and Diwan *et al.* (2018) they stated that it might be due to broader spacing as it provides adequate water, nutrients, air and light which endorses better growth of plants and help in generating the maximum weight of seeds. The test weight (g) was recorded maximum at nitrogen dose 75 kg ha^{-1} (9.58) which was followed by 50 kg ha^{-1} (9.06). According to Diwan et al. (2018), the impact of nitrogen on seed production occurs indirectly through an increase in the availability of nutrients to the floral components. This implies that maintaining a large and photo synthetically efficient leaf area during the flowering stage is crucial for maximizing seed weight.

Standard Germination

The maximum standard germination (%) was recorded at nitrogen dose 75 kg ha^{-1} (88.89) followed by 50 kg ha^{-1} (86.56) and maximum standard germination (%) was observedin spacing 40 x 15 cm (85.58) followed by 30 x 15 cm (84.00).

Amare et al. (2020) observed similar findings in onions, where the combined effect of narrower plant spacing and increased fertilization led to a higher proportion of seeds originating from primary umbels. This improvement in seed quality can be attributed to the larger size of embryos obtained from primary umbel seeds compared to those obtained from secondary and tertiary umbels. This is likely due to the active involvement of minerals in embryo development and the activation of hormones during seed germination.

Seedling Length

The maximum seedling length (cm) was obtained with nitrogen dose 75 kg ha^{-1} (15.4 cm) followed by 50 kg ha^{-1} (15.1 cm) and maximum seedling length (cm) was found with spacing 40 x 15 cm (14.5 cm) followed by 30 x 15 cm (14.3 cm).

Harshita et al. (2017) found similar outcomes in coriander, and Kumar et al. (2019) observed comparable results in fennel. In both studies, it was observed that an increased synthesis of photosynthates resulted in the formation of larger, bolder seeds. This can be attributed to a higher translocation of photosynthates into the seeds. Bolder seeds were found to contain more reserve food in their cotyledons, leading to greater seedling length in fennel plants.

Seedling dry weight

The maximum seedling dry weight (mg) was observed with nitrogen applied at 75 kg ha^{-1} (5.11 mg) followed by 50 kg ha^{-1} (4.83 mg) and maximum seedling dry weight (mg) was found with spacing 40 x 15 cm (4.58 mg) followed by 30 x 15 cm (4.45 mg). Similar results were observed by Harshita *et al.* (2017) in coriander and Kumar *et al.* (2019) in fennel that accumulation of more photosynthates which aided in formation of bolder seeds due to higher translocation of photosynthates in the seed. Bolder seeds have more reserve food present in the cotyledons, which resulted into higher seedling dry weight (mg) of the fennel plant.

Vigour indices

Maximum vigour index-I was recorded with nitrogen applied at 75 kg ha^{-1} (1348.03) followed by nitrogen supplied at 50 kg ha^{-1} (1302.98) and maximum vigour index-I was found with spacing 40 x 15 cm (1236.19) followed by 30 x 15 cm (1202.77). Similar results were observed by Harshita *et al.* (2017) in coriander and Amare *et al.* (2020) in fennel that in larger seed size there is more reserved food in the cotyledon of the seeds to sustain the seedlings growth and make seedlings to be vigorous than the smaller seed sizes whose reserved food could be exhausted very soon. These result into higher vigour index-I.

Maximum vigour index-II (449.62) was recorded with nitrogen applied at 75 kg ha^{-1} followed by nitrogen supplied at 50 kg ha^{-1} (410.84) and maximum index-II was found with spacing 40 x 15 cm (393.27) followed by 30 x 15 cm (375.27). Similar results were observed by Harshita *et al.* (2017) in coriander and Amare *et al.* (2020) in fennel stated that broader spacing with adequate application of fertilizer produced larger size seeds and gave high vigour index-II. These results showed the highest vigour index-II.

Electrical conductivity

Minimum electrical conductivity ($\mu S\ cm^{-1}g^{-1}$) (129 $\mu S\ cm^{-1}g^{-1}$) was recorded with nitrogen applied at 50 kg ha^{-1} followed by nitrogen supplied at 75 kg ha^{-1} (137 $\mu S\ cm^{-1}g^{-1}$) and minimum electrical conductivity ($\mu S\ cm^{-1}g^{-1}$) was found with spacing 30 x 15 cm (138 $\mu S\ cm^{-1}g^{-1}$) followed by 40 x 15 cm (140 $\mu S\ cm^{-1}g^{-1}$). In coriander, Harshita et al. (2017) and in fennel, Kumar et al. (2019) obtained similar findings regarding the increase in electrical conductivity of seeds. This increase was attributed to the leaching of electrolytes, nitrogen, and amino acids, which subsequently led to a loss of membrane integrity in aged seeds. Consequently, this reduction in membrane integrity resulted in decreased seed vigor and viability.

Conclusion:

The study on the interactive effects of different nitrogen doses and spacing in coriander has provided valuable insights into the optimal conditions for growing this important herb. The results of the study indicate that both nitrogen dose and spacing have a significant impact on the growth, yield, and quality of coriander. The findings can be useful for farmers and researchers in developing effective strategies for improving the production of coriander, which can have significant economic and nutritional benefits. Further research can be conducted to explore the long-term effects of different nitrogen doses and spacing on coriander and to identify additional factors that may impact its growth and development.

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Harvest index:

Table 3: Interaction effect of nitrogen levels under different spacing on harvest index on coriander (*Coriandrum sativum*L.)

Harvest Index (%)				
Treatments	**S_1 (20 × 15cm)**	**S_2 (30 × 15cm)**	**S_3 (40 × 15cm)**	**Mean N**
N_0= Control (0 kg/ha)	31.96	33.49	34.33	33.26
N_1= 25 kg/ha	34.81	35.67	35.67	35.38
N_2= 50 kg/ha	37.00	39.33	39.67	38.67
N_3= 75 kg/ha	37.33	40.00	40.33	39.22
Mean S	35.28	37.12	37.50	
CD (5%)	N= 0.75	S= 0.65	N × S= NS	

Test weight:

Table4 : Interaction effect of nitrogen levels under different spacing on test weight on coriander (*Coriandrum sativum* L.)

Test Weight (g)				
Treatments	**S_1 (20 × 15cm)**	**S_2 (30 × 15cm)**	**S_3 (40 × 15cm)**	**Mean N**
N_0= Control (0 kg/ha)	7.97	8.13	8.23	8.11
N_1= 25 kg/ha	8.33	8.33	8.40	8.36
N_2= 50 kg/ha	8.50	9.17	9.50	9.06
N_3= 75 kg/ha	8.83	9.83	10.07	9.58
Mean S	8.41	8.87	9.05	
CD (5%)	N= 0.49	S= 0.39	N × S= NS	

Standard Germination:

Table5 : Interaction effect of nitrogen levels under different spacing on Standard Germination on coriander (*Coriandrum sativum* L.)

	Standard Germination (%)			
Treatments	**S_1 (20 × 15cm)**	**S_2 (30 × 15cm)**	**S_3 (40 × 15cm)**	**Mean N**
N_0= Control (0 kg/ha)	78.00	78.33	79.67	78.67
N_1= 25 kg/ha	81.00	81.67	83.33	82.00
N_2= 50 kg/ha	85.00	86.67	88.00	86.56
N_3= 75 kg/ha	86.00	89.33	91.33	88.89
Mean S	82.50	84.00	85.58	
CD (5%)	N= 2.30	S= 1.99	N × S= NS	

Seedling Length:

Table6 : Interaction effect of nitrogen levels under different spacing on Seedling Length on coriander (*Coriandrum sativum* L.)

	Seedling Length (cm)			
Treatments	**S_1 (20 × 15cm)**	**S_2 (30 × 15cm)**	**S_3 (40 × 15cm)**	**Mean N**
N_0= Control (0 kg/ha)	12.4	13.0	13.3	12.9
N_1= 25 kg/ha	13.0	13.4	13.6	13.3
N_2= 50 kg/ha	14.4	15.3	15.4	15.1
N_3= 75 kg/ha	14.8	15.5	15.7	15.4
Mean S	13.6	14.3	14.5	
CD (5%)	N= 0.29	S= 0.25	N × S= NS	

Seedling Dry Weight:

Table7 : Interaction effect of nitrogen levels under different spacing on Seedling Dry Weight on coriander (*Coriandrum sativum* L.)

	Seedling Dry Weight (mg)			
Treatments	**S_1 (20 × 15cm)**	**S_2 (30 × 15cm)**	**S_3 (40 × 15cm)**	**Mean N**
N_0= Control (0 kg/ha)	3.23	3.63	3.73	3.53
N_1= 25 kg/ha	3.90	3.97	4.10	3.99
N_2= 50 kg/ha	4.47	4.93	5.10	4.83
N_3= 75 kg/ha	4.70	5.27	5.37	5.11
Mean S	4.08	4.45	4.58	
CD (5%)	N= 0.10	S= 0.09	N × S= 0.17	

Vigour Indices:

Table8 : Interaction effect of nitrogen levels under different spacing on Vigour Index - I on coriander (*Coriandrum sativum* L.)

	Vigour Index - I			
Treatments	**S_1 (20 × 15cm)**	**S_2 (30 × 15cm)**	**S_3 (40 × 15cm)**	**Mean N**
N_0= Control (0 kg/ha)	966.22	1016.43	1052.45	1011.70
N_1= 25 kg/ha	1059.14	1097.63	1131.05	1095.94
N_2= 50 kg/ha	1223.66	1327.18	1358.08	1302.98
N_3= 75 kg/ha	1271.10	1369.84	1403.15	1348.03
Mean S	1130.03	1202.77	1236.19	
CD (5%)	N= 46.44	S= 40.22	N × S= NS	

Vigour Indices:

Table9 : Interaction effect of nitrogen levels under different spacing on Vigour Index - II on coriander (*Coriandrum sativum* L.)

	Vigour Index - II			
Treatments	**S_1 (20 × 15cm^2)**	**S_2 (30 × 15cm^2)**	**S_3 (40 × 15cm^2)**	**Mean S**
N_0= Control (0 kg/ha)	252.92	292.17	304.47	283.19
N_1= 25 kg/ha	324.88	328.63	339.66	331.06
N_2= 50 kg/ha	377.89	410.02	444.60	410.84
N_3= 75 kg/ha	393.14	470.27	485.44	449.62
Mean N	337.21	375.27	393.54	
CD (5%)	N= 16.69	S= 14.45	N × S= 28.91	

Electrical Conductivity:

Table10 : Interaction effect of nitrogen levels under different spacing on Electrical Conductivityon coriander (*Coriandrum sativum* L.)

	Electrical Conductivity (µS cm^{-1}g^{-1})			
Treatments	**S_1 (20 × 15cm)**	**S_2 (30 × 15cm)**	**S_3 (40 × 15cm)**	**Mean N**
N_0= Control (0 kg/ha)	152	150	149	150
N_1= 25 kg/ha	146	142	144	144
N_2= 50 kg/ha	132	127	129	129
N_3= 75 kg/ha	141	132	138	137
Mean S	143	138	140	
CD (5%)	N= 3.66	S= 3.17	N × S= NS	