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Effect of planting geometry and nutrient management on yield and it's attributing characters of coriander (*Coriandrum sativum* L.)

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Abstract
A field experiment was conducted at Krishi Vigyan Kendra, Pahanda-A, Durg (C.G.) during the *rabi* seasons of 2022-23 and 2023-24. The study evaluated the effects of three planting geometries (G_1-20 x 15 cm, G_2- 30 x 10 cm and G_3- 40 x 7.5 cm) and five nutrient management practices on coriander. The nutrient management practices included: N_1-100% RDN (80, 60, and 40 kg of N, P_2O5, and K_2O ha^{-1}), N_2-125% RDN, N_3-75% RDN + foliar spray of nano urea at 60 and 75 DAS, 100% RDN + foliar spray of nano urea at 60 and 75 DAS, N_4 -100% RDN + foliar spray of nano urea at 60 and 75 DAS, and 100% RDN + foliar spray of nano urea at 60 and 75 DAS, N_4- 100% RDN + foliar spray of nano urea at 60 and 75 DAS, N_5 -100% RDN + foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS. The experimental design was a split-plot with planting geometry as the main plot and nutrient management as the sub-plot. The results indicated that the 20 x 15 cm planting geometry achieved the highest yield attributes, including the number of umbels $plant^{-1}$, umbellates $umbel^{-1}$, seeds $umbellate^{-1}$, 1000-seed weight, seed yield, stover yield, and economic values (Gross and net returns, and benefit-cost ratio) of coriander. The lowest values were observed with the 40 x 7.5 cm planting geometry. Among nutrient management practices, 100% RDN + foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS recorded the maximum yield and its attributing characteristics of coriander. Conversely, the lowest values for these characteristics were recorded with 75% RDN + foliar spray of nano urea at 60 and 75 DAS.

Keywords: Coriander, seed yield, planting geometry and nutrient management

Introduction
India has long been recognized as the "home of spices." Among the various seed spices, coriander (*Coriandrum sativum* L.) stands out as a highly significant spice and medicinal crop, valued for its diverse applications. This annual herbaceous plant, which belongs to the Apiaceae (Umbelliferae) family, primarily reproduces through cross-pollination. Locally available coriander seeds contain 0.2-0.3% essential oil, with major components including d-linalool and linalyl acetate, alongside other important compounds such as thymol, geraniol, and pinene (Gupta *et al*., 1977) [5]. Coriander has been noted for its health benefits, including alleviating skin disorders and reducing symptoms of cough, high blood pressure, diarrhea, and elevated cholesterol levels. The seeds are composed of 16.1% fatty oil, 14.1% protein, 21.6% carbohydrate, 32.6% fiber, 11.2% moisture, and 4.4% minerals, while the leaves are rich in vitamins A and C (Singh *et al*., 2017) [11].

Spices are essential in the human diet due to their flavor and aroma. India is the leading global producer, consumer, and exporter of seed spices. Approximately 20 types of seed spices are cultivated in India, with cumin, coriander, fennel, fenugreek, and celery being the most prominent. These spices account for about 20% of the total spice exports from India. Coriander is grown on 629,000 hectares in India, producing 822, 000 metric tons with a productivity rate of 1200 kg ha^{-1} (Ministry of Agriculture & Farmers Welfare, Government of India, 2021). In Chhattisgarh, coriander is an important crop both as a leafy vegetable and as a spice, cultivated on 14,980 hectares with a production of 66,290 metric tons and a productivity rate of 442 kg ha^{-1} (Director, Horticulture and Farm Forestry, Chhattisgarh, 2021).

Coriander yields in India average 10.27 q ha^{-1}, significantly lower than the global average of

23.78 q ha^{-1}. This disparity highlights the potential for optimizing cultivation techniques to maximize coriander seed yield. In Chhattisgarh, farmers grow coriander during the *rabi* season for both leaf and seed purposes. Rising input costs, environmental and climate variations, and the prevalent monoculture system have driven farmers to explore crop diversification options. Essential agronomic practices, including planting geometry, nutrient management, and weed control, are critical for boosting coriander productivity.

Materials and Methods

Krishi Vigyan Kendra, Pahanda (A), Durg, located in central Chhattisgarh, is positioned at a latitude of 21°20' N and longitude of 81°53' E, with an elevation of 291.79 meters above mean sea level. A field experiment was carried out at this location during the *rabi* seasons of 2022-23 and 2023-24. The experimental soil was characterized as clay loam (*Vertisol*), known locally as "*Kanhar*." It was neutral in pH, with low organic carbon and available nitrogen, medium levels of phosphorus, and high levels of available potassium. The experiment investigated three planting geometries (G_1-20 x 15 cm, G_2- 30 x 10 cm and G_3- 40 x 7.5 cm) and five nutrient management practices on coriander. The nutrient management practices included: N_1-100% RDN (80, 60, and 40 kg of N, P_2O5, and K_2O ha^{-1}), N_2- 125% RDN, N_3-75% RDN + foliar spray of nano urea at 60 and 75 DAS, 100% RDN + foliar spray of nano urea at 60 and 75 DAS, N_4 -100% RDN + foliar spray of nano urea at 60 and 75 DAS, and 100% RDN + foliar spray of nano urea at 60 and 75 DAS, N_4- 100% RDN + foliar spray of nano urea at 60 and 75 DAS, N_5 -100% RDN + foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS. The experimental design was a split-plot, with planting geometry as the main plots and nutrient management practices as the sub-plots. Seeds of the coriander variety CG Shri Chandrahasini Dhania-2 were treated and sown at the specified planting geometries on November 22, 2022, and November 22, 2023. The crops were harvested manually on March 8, 2023, and March 9, 2024.

Results

The results of the first experiment revealed that the planting geometry of 20 x 15 cm produced the highest yield attributes, including the number of number of umbels $plant^{-1}$, umbellates $umbel^{-1}$, seeds $umbellate^{-1}$, 1000-seed weight. This geometry also resulted in the highest seed and stover yields, quality parameters (oil content and yield), nutrient uptake (N, P, and K) in seed and stover, and economic values (gross and net returns, and benefit-cost ratio) for coriander. Conversely, the lowest values for these parameters were recorded with the 40 x 7.5 cm planting geometry during both years and on a mean basis (Tables 1 and 2).

Effect on yield attributes

Umbels $plant^{-1}$ (No.)

The number of number of umbels $plant^{-1}$, was significantly affected by planting geometry during both years of the experiment. The data showed that increasing plant-to-plant spacing significantly increased the number of umbels $plant^{-1}$. The highest number of umbels $plant^{-1}$ (32.44) was recorded under the 20 cm x 15 cm planting geometry, which was statistically at par with the 30 cm x 10 cm geometry (31.06). The minimum number of umbels $plant^{-1}$ (28.69) was observed under the 40 cm x 7.5 cm planting geometry during both years, and the mean data also indicated the same trend. Among the nutrient management treatments, 100% RDN + foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS (N5) resulted in the maximum number of umbels per plant (33.72), followed by 125% RDN (N2) (31.94). The lowest number of umbels per plant (27.13) was recorded with 75% RDN + foliar spray of nano urea at 60 and 75 DAS (N3).

Umbellates $umbel^{-1}$ (No.)

The was also notably influenced by planting geometry during the experiment. With increased plant-to-plant spacing, the number of umbellates per umbel significantly increased. The 20 cm x 15 cm planting geometry achieved the highest number of umbellates per umbel (7.51), followed by the 30 cm x 10 cm geometry. The lowest number was recorded under the 40 cm x 7.5 cm geometry during both years, with the mean data supporting these findings. Regarding nutrient management, the treatment of 100% RDN + foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS (N5) showed the highest number of umbellates per umbel (7.62), closely followed by 125% RDN (N2) (7.55). The lowest number of umbellates per umbel (5.88) was found with 75% RDN + foliar spray of nano urea at 60 and 75 DAS (N3).

Seeds $umbellate^{-1}$ (No.)

The planting geometry of 20 cm x 15 cm resulted in the highest number of seeds per umbellate (7.60), followed by the 30 cm x 10 cm geometry (7.30), while the lowest number of seeds per umbellate (6.67) was observed under the 40 cm x 7.5 cm geometry during both years. The mean data also reflected this trend. Of the various nutrient management treatments tested, the use of 100% RDN with a foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS (N5) yielded the highest number of seeds per umbellate (7.82). This result was statistically comparable to the 125% RDN treatment (N2), which produced 7.55 seeds per umbellate. The lowest number of seeds per umbellate (6.39) was observed with the 75% RDN + foliar spray of nano urea at 60 and 75 DAS (N3).

1000 - seed weight (g)

The 1000- seed weight of coriander was significantly affected by the different planting geometries. The 20 cm x 15 cm spacing resulted in the highest test weight (14.26), which was statistically similar to the 30 cm x 10 cm spacing (13.81), while the lowest test weight (13.37) was observed with the 40 cm x 7.5 cm spacing, consistent across both years and in the mean analysis. Regarding nutrient management treatments, the combination of 100% RDN with a foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS (N5) produced the highest test weight (14.14). This was statistically similar to the 125% RDN treatment (N2) (13.94), while the lowest test weight (13.48) was recorded with 75% RDN plus a foliar spray of nano urea at 60 and 75 DAS (N3).

Effect on yield and economics

Seed yield (q ha^{-1})

The 20 cm × 15 cm spacing recorded the highest seed yield (15.73 q ha^{-1}) of coriander, which was statistically similar to

the 30 cm x 10 cm spacing (15.39 q ha^{-1}), while the lowest yield (14.04 q ha^{-1}) was observed with the 40 cm x 7.5 cm spacing in both years and the mean analysis. Among the nutrient management treatments, 100% RDN combined with foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS (N5) produced the highest seed yield (17.45 q ha^{-1}), statistically similar to the 125% RDN treatment (N2) (16.86 q ha^{-1}), while the lowest seed yield (11.62 q ha^{-1}) was recorded with 75% RDN plus a foliar spray of nano urea at 60 and 75 DAS (N_3).

Stover yield (q ha^{-1})

The 20 cm × 15 cm planting geometry resulted in the highest stover yield (31.74 q ha-1) for coriander, which was similar to the yield obtained with the 30 cm x 10 cm spacing (29.94 q ha^{-1}). In contrast, the 40 cm x 7.5 cm spacing produced the lowest stover yield (25.97 q ha^{-1}) in both years and the overall mean. Among the different nutrient management strategies, the combination of 100% RDN with a foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS (N5) achieved the highest stover yield (32.68 q ha^{-1}), comparable to the 125% RDN treatment (N2) which yielded 30.48 q ha^{-1}. The lowest stover yield (26.70 q ha^{-1}) was observed with 75% RDN plus a foliar spray of nano urea at 60 and 75 DAS (N3). The interaction between planting geometry and nutrient management treatments did not significantly affect the stover yield of coriander. However, the combination of the 20 cm x 15 cm planting geometry with 100% RDN and a foliar spray of water-soluble fertilizer (19: 19: 19) applied at 60 and 75 DAS (N5) resulted in the highest stover yield, reaching 35.94 q ha^{-1}.

Harvest index (%)

The 20 cm × 15 cm planting spacing achieved the highest harvest index (34.95%) for coriander, which was similar to the harvest index recorded with the 30 cm x 10 cm spacing (34.20%). Conversely, the lowest harvest index (33.05%) was observed with the 40 cm x 7.5 cm spacing in both years and the average analysis. Among the nutrient management strategies, the combination of 100% RDN with a foliar spray of water-soluble fertilizer (19: 19: 19) at 60 and 75 DAS (N5) resulted in the highest harvest index (36.94%). This was statistically similar to the 125% RDN treatment (N2), which had a harvest index of 36.24%. The lowest harvest index (30.05%) was recorded with 75% RDN plus a foliar spray of nano urea at 60 and 75 DAS (N3). The interaction between planting geometry and nutrient management did not significantly affect coriander's yield and its attributes.

Economics

The benefit-cost B: C ratio for coriander was significantly affected by different planting geometries. The 20 cm x 15 cm spacing achieved the highest B: C ratio (2.35), followed closely by the 30 cm x 10 cm spacing (2.29) across both study years. In contrast, the 40 cm x 7.5 cm spacing recorded the lowest B: C ratio (1.75). Among the various nutrient management treatments, the combination of 100% RDN with a foliar spray of water-soluble fertilizer (19:19:19) applied at 60 and 75 DAS (N5) resulted in the highest B: C ratio (2.56). This was followed by the 125% RDN treatment (N2) with B: C ratio of 2.51, while the lowest B: C ratio (1.75) was noted with 75% RDN plus a foliar spray of nano urea at 60 and 75 DAS (N3). The higher yield achieved with the 20 cm x 15 cm planting geometry translated into greater gross monetary returns, consistent with the findings of Diwan *et al*. (2018) [3] and Painkra *et al.* (2024) [9].

Discussion

The impact of planting geometry on coriander's growth characteristics revealed that the 20 cm x 15 cm spacing produced the most favorable growth parameters, such as the highest number of leaves and both primary and secondary branches. This spacing also promoted a greater number of umbels per plant and umbellets per umbel, which contributed to an increased seed yield. These findings are consistent with previous research by Diwan *et al*. (2018) [3]. The 30 cm × 10 cm planting geometry also resulted in a high seed yield, comparable to the 20 cm x 15 cm planting geometry, while the lowest yield was observed with the 30 cm x 5 cm spacing in both years and in the overall analysis. Although the 30 cm x 10 cm planting geometry led to overcrowding, which reduced growth and yield attributes compared to the 20 cm x 15 cm spacing, it still compensated to some extent due to a higher number of plants per unit area. This is in line with the findings of Meena *et al*. (2013) [7].

The influence of nutrient management practices on coriander yield attributes and overall yield was evident in the results. The application of a foliar spray with water-soluble fertilizer (WSF) containing all three major nutrients enhanced photosynthetic activity, which led to increased carbohydrate and auxin production. This, in turn, favored the retention of more flowers, resulting in a higher number of reproductive parts per plant. The improved yield attributes observed with higher concentrations of WSF can be attributed to increased chlorophyll levels, enhanced photosynthesis, and better nutrient uptake. These factors contributed to greater plant dry matter production, which positively impacted seed development and the number of seeds per umbel, ultimately boosting productivity. These findings align with the results of Jadav and Kumawat (2018) [6] on coriander. Additionally, Mishra *et al*. (2019) [8] reported that foliar application of nitrogen, phosphorus, and potash significantly increases coriander leaf yield. The data from this study showed an upward trend in per-plot yield and yield per hectare due to the use of 19:19:19 soluble fertilizers. In case of economics, the increased cost of fertilizers, which raised cultivation expenses, the higher seed and stover yields associated with this planting geometry resulted in improved gross and net returns, as well as a favorable B: C ratio. The treatment (T_5) emerged as the most effective for coriander farming, supporting the conclusions of Painkra *et al*. (2024) [9].

Table 1: Effect of planting geometry and nutrient management practices on yield attributes of *rabi* coriander

Treatments	No. of umbels plant^{-1}			No. of umbellates umbel^{-1}			No. of seeds umbellate^{-1}			1000- seed weight (g)		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
A. Planting geometry												
G1-20 x 15 cm	31.41	33.47	32.44	7.44	7.59	7.51	7.54	7.65	7.60	14.20	14.32	14.26
G2-30 x 10 cm	29.65	32.48	31.06	6.86	7.11	6.98	7.26	7.34	7.30	13.79	13.83	13.81
G3-40 x 7.5 cm	27.73	29.66	28.69	6.34	6.55	6.45	6.61	6.73	6.67	13.29	13.46	13.37

B. Different nutrient management practices												
N_1- 100% RDN	28.91	31.24	30.07	6.72	6.89	6.80	6.96	7.09	7.02	13.68	13.76	13.72
N_2- 125% RDN	30.25	33.63	31.94	7.25	7.55	7.40	7.31	7.57	7.44	13.84	14.04	13.94
N_3-75% RDN+ foliar spray of nano urea at 60 and 75 DAS	26.54	27.73	27.13	5.78	5.98	5.88	6.44	6.34	6.39	13.51	13.45	13.48
N_4-100% RDN+ foliar spray of nano urea at 60 and 75 DAS	29.62	31.98	30.80	7.10	7.29	7.20	7.19	7.34	7.27	13.73	13.87	13.80
N_5- 100% RDN + foliar spray of water soluble fertilizer (19:19:19) at 60 and 75 DAS	32.66	34.78	33.72	7.54	7.70	7.62	7.79	7.86	7.82	14.03	14.24	14.14

Table 2: Effect of planting geometry and nutrient management practices on seed yield, stover yield, harvest index and economics of *rabi* coriander

Treatment	Seed yield (q ha^{-1})			Stover yield (q ha^{-1})			Harvest index (%)			Benefit cost ratio		
	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean	2022-23	2023-24	Mean
A. Planting geometry												
G1-20 x 15 cm	15.59	15.88	15.73	31.25	32.22	31.74	34.84	35.11	34.95	2.33	2.36	2.35
G2-30 x 10 cm	15.17	15.60	15.39	28.91	29.94	29.42	34.20	34.21	34.20	2.27	2.31	2.29
G3-40 x 7.5 cm	13.80	14.07	14.04	25.72	26.23	25.97	32.97	33.16	33.05	2.10	2.09	2.09
B. Different nutrient management practices												
N_1- 100% RDN	13.49	14.38	13.95	27.37	28.33	27.85	32.57	33.01	32.80	2.07	2.17	2.12
N_2- 125% RDN	17.10	16.56	16.86	29.94	30.48	30.21	36.35	36.13	36.24	2.56	2.46	2.51
N_3- 75% RDN + foliar spray of nano urea at 60 and 75 DAS	11.42	11.83	11.62	25.23	26.70	25.96	29.88	30.14	30.05	1.73	1.77	1.75
N_4- 100% RDN + foliar spray of nano urea at 60 and 75 DAS	14.81	15.92	15.38	28.50	29.14	28.82	33.83	33.74	33.79	2.20	2.34	2.27
N_5- 100% RDN + foliar spray of water soluble fertilizer (19:19:19) at 60 and 75 DAS	17.46	17.24	17.45	32.10	32.68	32.39	36.78	36.88	36.94	2.60	2.52	2.56

Conclusion

The findings clearly visualized that 20 cm x 15 cm spacing produced the most favorable growth parameters and achieved the highest yield attributes, including the number of umbels plant^{-1}, umbellates umbel^{-1}, seeds umbellate^{-1}, 1000 - seed weight, seed yield, stover yield, and economic values (Gross and net returns, and benefit-cost ratio) of coriander. Among nutrient management practices, 100% RDN + foliar spray of water-soluble fertilizer (19:19:19) at 60 and 75 DAS recorded the maximum yield and its attributing characteristics of coriander.

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