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Study on the effect of integrated nitrogen management on morphological characters of coriander (*Coriandrum sativum* L.)

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Abstract
The experiment was carried out in Coriander (*Coriandrum sativum* L.)with the following treatments: T_1=15 t ha^{-1} FYM (Control), T_2: N (100% Inorganic) PK, T_3: N (75% Inorganic + 25% FYM) PK, T_4: N (75% Inorganic + 25% VC) PK, T_5: N (75% Inorganic + 25% PM) PK, T_6: N (50% Inorganic + 50% FYM) PK, T_7: N (50% Inorganic + 50%VC) PK, T_8: N (50% Inorganic + 50% PM) PK. Growth parameters like plant height (cm), girth of stem (cm), primary branch $plant^{-1}$, secondary branch $plant^{-1}$ recorded highest mostly at T_6, whereas it was also showed maximum in umbels $plant^{-1}$ (22.20), umbellets $umbel^{-1}$ (7.20), seeds umbellate $^{-1}$ (39.07), seed yield (14.28 q ha-1), biological yield (30 q ha^{-1}), Stover yield (15.72 q ha^{-1} and Benefit: Cost ratio (2.15). Therefore, from economic point of view, T_6 (N (50% Inorganic + 50% FYM) PK) may be recommended for coriander under *Terai* zone of West Bengal.

Keywords: FYM, coriander, nitrogen, vermicompost

Introduction
Coriander (*Coriandrum sativum* L.) commonly known as Dhania in India, is one of the major seed spices and annual herb, grown for both green leaves and dried seeds. It belongs to the family Apiaceae (Umbelliferae) and originated in Mediterranean region. Coriander (2n=22) is widely used as culinary spice and food flavoring agent. The presence of essential oil in coriander seeds is responsible for its mild aromatic fragrance and taste. Coriander is one of the major seed spices cultivated across the country and considered as an important value-added export produce in the global spice market. India is the largest producer of coriander in the world with a production of 8,88,760 tons over an area of 6,56,075 hectare in the fiscal year 2020-21, which include a share of 70% of the total world output (Estimated by Spice Board). Other major producing countries are Iran, Morocco, Russia, Canada, Australia, Bulgaria. It is also one of the most important seed spices with respect to export and foreign exchange earnings in India. The major producing states in the country are Madhya Pradesh, Rajasthan, Gujarat, Assam, Uttar Pradesh, Andhra Pradesh, West Bengal. Madhya Pradesh produced the largest volume of coriander seeds i.e., 4,01, 340 tons over an area of 2,9,895 hectare in fiscal year 2020-21, which accounts for 56.33% share of total production in the country (Estimated by Spice Board). India is also the largest exporter of coriander (57,350 MT) and mainly exported in the form of dried whole seeds and powder form. In case of dried coriander seeds Malaysia is the largest export destination with 51.1% share while in case of coriander powder South Africa is the largest export destination with 20.4% share (Estimated by Spice Board). Various fertilizers have to be applied in an integrated manner in a fertilizer schedule of a crop as sole application of a fertilizer doesn't fulfil its nutritional requirements, as stated by Mahajan and Gupta (2009) [7]. Application of chemical fertilizers in an intensive way in agriculture causes many health hazards and environmental pollution. Due to many ill effects of inorganic fertilizers on soil health like accumulation of salt, they are to be applied in a judicious manner as to not degrade the soil health. The high concentration of salt in soil ultimately causes plants to wilt. The leaching of inorganic fertilizers from the root zone of soil is also a serious problem in agriculture. Moreover, they also possess a threat to human health by entering into the ecological food chain through plant system. On the other hand, organic fertilizers being bulky in nature and takes longer time to decompose and release nutrient in the soil. So, organic manures slowly and gradually release soil nutrients throughout the growth period (Sharma and Chetani, 2017) [11].

Mahajan and Gupta, (2009) [7] stated that the integrated application of both organic and inorganic fertilizers makes a way for ecologically sound, economical, and sustainable agriculture system that is safe for humankind. To maintain the soil fertility and plant nutrient supply at an optimum level for sustaining the desired productivity by utilizing the beneficial effects from application of all possible sources of organic, inorganic and biological components in a combined manner is referred to as Integrated Nutrient Management (INM). The application of integrated sources of nutrients regulates the nutrient mobility within the rhizosphere has also been stated by Srivastava and Ngullie (2009) [16]. Therefore, to get consistently higher yield and quality produce of coriander, choice of appropriate source of nitrogen is very essential. Considering the previously mentioned realities, the current experiment was carried out to observe the effect of integrated sources of nitrogen on yield and quality of coriander crop under *Terai* zone of West Bengal.

Materials and Methods

The experiment was carried out during 2020-21 under the experimental site of Department of Plantation Crops and Processing, Faculty of Horticulture, Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar, West Bengal. The experimental plot was situated at latitude of 26^0 22`N and longitude of $89^0$ 29`E with an altitude of about 48 m above mean sea level. The field experiment was conducted in the experiment station having acidic soil and sandy loam to clay loam in texture. The soil pH ranged from 5.97 to 6.50 while the organic carbon varied from 1.51 to 2.29% (Sarkar *et al.* 2017) [10]. Well decomposed FYM @ 15 tonnes ha^{-1} was incorporated into the field before last harrowing & mixed thoroughly in the soil, after which the field was levelled.

Seeds of the variety 'Rajendra Coriander-1' were used as planting material @ 10-12 kg ha^{-1}. Before sowing, seeds were soaked in water overnight. Before sowing, the seeds were treated with Bavistin powder @ 2 g Kg^{-1} of seeds to check any fungal diseases. The seeds were line sown at a spacing of 20 cm row to row and 10 cm between plant to plant so that each plot comprises of 80 plants. After sowing at a depth of 2-2.5 cm seeds were covered with soil lightly. The size of the experimental plot was adopted as 2m x 1m with irrigation channels 50 cm between the plots. The recommended dose of Nitrogen (N), Phosphorous (P) and Potash (K) fertilizers is 60:30:20 (N:P:K) kg ha^{-1} in the form of Urea, Single Super Phosphate (SSP) and Muriate of potash (MOP. In different treatment the nitrogen was partially or fully substituted by organic manures like vermicompost (VC), Farm yard manure (FYM) or Poultry manure (PM).

The treatment combinations were: T_1: 15ton ha^{-1} FYM (Control), T_2: N (100% Inorganic) PK, T_3: N (75% Inorganic + 25% FYM) PK, T_4: N (75% Inorganic + 25% VC) PK, T_5: N (75% Inorganic + 25% PM) PK, T6: N (50% Inorganic + 50% FYM) PK, T_7: N (50% Inorganic + 50%VC) PK, T_8= N (50% Inorganic + 50% PM) PK.

Full dose of organic sources of nitrogen (FYM, vermicompost, poultry manure) was applied as basal at the time of land preparation along with first split of inorganic nitrogen fertilizer i.e., Urea (46% N) and full dose of potassium and phosphorus as basal. The remaining half of urea was applied in two splits at 30 DAS and 45 DAS.

During the experimental period, growth parameters like plant height (cm), no. of primary branches $plant^{-1}$, no. of secondary branches $plant^{-1}$, girth of stem $plant^{-1}$ (cm), length of internodes $plant^{-1}$ (cm) and yield parameters like umbels $plant^{-1}$, umbellets $umbel^{-1}$, seeds $umbellet^{-1}$, test weight of seeds (g), seed yield (q ha^{-1}), Stover or straw yield (q ha^{-1}), biological Yield (q ha^{-1}), green leaf yield (q ha^{-1}) was taken. Parameters was also recorded on number of days 100% flowering and seed maturity etc. The experiment was carried out from during November, 2020-March, 2021. First morphological observations were taken at 30 days after sowing of coriander seeds and then at monthly interval i.e., 60 DAS & 90 DAS until harvest. The data was taken from randomly selected 5 plants per plot from each treatment after they were labelled.

After sun-drying, biological weight of bundles was recorded and then threshing was done by beating the plants with wooden sticks. Manual winnowing was performed thereafter to separate the seeds and Stover and their yield was recorded. Tagged plants from each plot was harvested and uprooted entirely from the soil to determine the total dry matter content and then dried in hot air oven at 50 °C until they attained a constant weight.

Results and Discussion

Effect on morphological observations on growth parameters

Average monthly increment of plant height (cm): It was observed that there was statistically superior increase in monthly increment of plant height of coriander plants at 90 DAS (81.94 cm), 60 DAS (71.18 cm) and 30 DAS (22.09 cm) by the plants under the treatment with N (50% Inorganic + 50% FYM) PK). On the other hand, the lowest result was recorded from control i.e., FYM @ 15 t ha^{-1} at 90 DAS (68.32 cm), 60 DAS (57.79 cm) and 30 DAS (12.07 cm).

Number of primary branches $plant^{-1}$: Number of primary branches $plant^{-1}$ at 30 DAS was obtained highest (5.55) by the plants treated with treatment T_6 (N (50% Inorganic + 50% FYM) PK). While at 60 DAS, the treatment T_6 (7.46) recorded highest value which was at par with T_2 (6.39). There was less significant difference observed amongst all the treatments regarding the number of primary branches $plant^{-1}$ at 90 DAS.

Number of secondary branches $plant^{-1}$: Average monthly production of number of secondary branches $plant^{-1}$ resulted in statistically superior value at 90 DAS (30.53) by the plants treated under treatment T_6 (N (50% Inorganic + 50% FYM) PK). While at 60 DAS, highest value was observed under the treatment T_6 [N (50% Inorganic + 50% FYM) PK] (15.42) which was at par with treatments T_2 (13.87) and T_3 (13.99). On the other hand, the lowest number of secondary branches was recorded from T_1 (control i.e., FYM @ 15 t ha^{-1}) at 60 DAS (10.13). While at 90 DAS, lowest value was recorded from T_1 (18.88) and T_5 (19.70). It was to be noted that there was no emergence of secondary branch in plants at 30 DAS.

Girth of stem $plant^{-1}$ (cm): Maximum girth of stem $plant^{-1}$ was recorded at 90 DAS (2.67 cm) by the plants treated under treatment T_6 (N (50% Inorganic + 50% FYM) PK) which was also at par with treatment T_7 (2.27 cm). While at 60 DAS, highest value was recorded by T_6 (2.26 cm) which was at par with T_8 (1.42 cm), T7 (1.46 cm), T_5 (1.62 cm), T_4 (1.47 cm), T_3 (1.58 cm), T_2 (1.40 cm). At 30 DAS, highest value of girth of stem $plant^{-1}$ was recorded under treatment T_6 (1.54 cm) which was at par with T_8 (1.12 cm), T_7 (1.27 cm) and T_5 (1.02 cm).

The results were similar with Kanwer *et al.* (2014) [5] who achieved superior growth parameter like girth of stem plant^{-1} under the application of nitrogen @ (FYM 50% + inorganic source 50%) in tomato (*Lycopersicon esculentum* Mill). Malghani *et al.* (2014) [8] also received maximum stem girth in maize (*Zea mays* L.) under the treatment combination of nitrogen as (Urea + FYM).

Internodal length plant^{-1} (cm): Highest internodal length plant^{-1} was obtained under treatment T_6 (N (50% Inorganic + 50% FYM) PK) (8.37 cm) which was at par with treatments like T_3 (7.34 cm), T_4 (7.86 cm), T_8 (7.46 cm) at 60 DAS. While at 90 DAS, the highest value was observed under T_6 [N (50% Inorganic + 50% FYM) PK] (9.38 cm) which was also at par with T_3 (9.12 cm), T_4 (8.57 cm), T_7 (8.67 cm), T_8 (8.49 cm). It was to be noted that there was no emergence of internodes on main stem of plants at 30 DAS and the growth was comparatively low.

Observations on yield and yield attributing parameters

Umbel's plant^{-1}: Statistically superior umbels plant^{-1} (22.20) at harvest was recorded from the plants treated with treatment T_6 (N (50% Inorganic + 50% FYM) PK) at harvest which was followed by treatment T_7 (N (50% Inorganic + 50% VC) PK) and T_8 (N (50% Inorganic + 50% PM) PK) with 18.53 and 17.20 umbels plant^{-1} respectively. The lowest value of umbels plant^{-1} (10.00) was obtained under T_1 (control i.e., FYM @ 15 t ha^{-1}).

Umbellets umbel^{-1}: Umbellets umbel^{-1} (7.20) at harvest was realized from the plants treated with treatment T_6 (N (50% Inorganic + 50% FYM) PK. The lowest value of umbellets umbel^{-1} (3.23) was obtained under T_1 (control i.e., FYM @ 15 t ha^{-1}).

Seeds umbellet^{-1}: The treatment T_6 (N (50% Inorganic + 50% FYM) PK) revealed maximum (39.07) seeds umbellet^{-1} at harvest which was followed by T_7 (N (50% Inorganic + 50% VC) PK) with 35.82 seeds umbellet^{-1}. The lowest value of seeds umbellet^{-1} (24.97) was obtained under T_1 (control i.e., FYM @ 15 t ha^{-1}).

Patil *et al* (2004) [9] based on their experiment results, found superior increase in yield attributing character of cumin (*Cuminum cyminum*) like umbels plant^{-1} and umbellets umbel^{-1} and seeds umbellet^{-1} under the treatment combination of nitrogen @ (50% inorganic fertilizer +50% FYM) over sole application of FYM and inorganic fertilizer which also justifies our experiment.

Test weight of seeds (g)

Highest test weight of seeds (12.33 g) at harvest was recorded from the plants treated with treatment T_6 (N (50% Inorganic + 50% FYM) PK) which was at par with T_7 (N (50% Inorganic + 50% VC) PK) with 11.37 g weight of seeds. On the other hand, the lowest test weight of seeds (7.63 g) was observed under T_1 (control i.e., FYM @ 15 t ha^{-1}). While the other treatments were at par with each other.

Gaur (1998) [4] recorded highest value in yield attributing parameters like no. of grains ear^{-1} and test weight of grains (g) in barley (*Hordeum vulgare*) with the application of 75% of nitrogen as fertilizer + 25% of nitrogen as FYM over control and other treatment combinations.

See yield (q ha^{-1}): Seed yield (14.28 q ha^{-1}) at harvest was found statistically superior in treatment T_6 (N (50% Inorganic + 50% FYM) PK) over other treatments. T_6 was followed by T_7 (N (50% Inorganic + 50% VC) PK) and T_8 (N (50% Inorganic + 50% PM) PK) with 10.17 q ha^{-1} and 9.22 q ha^{-1} seed yield respectively. The lowest seed yield (3.96 q ha^{-1}) was recorded under T_1 (control i.e., FYM @ 15 t ha^{-1}). Similar result was obtained in case of Stover or straw yield (q ha^{-1}) and biological yield (q ha^{-1}). Highest Stover or straw yield (15.72 q ha^{-1}) and biological yield (30.00 q ha^{-1}) was recorded in the treatment T_6 (N (50% Inorganic + 50% FYM) PK).

Green leaf yield (q ha^{-1}): Less difference was observed between the treatments regarding green leaf yield taken at 30 DAS and 45 DAS and all the treatments were at par with each other. The slightly higher leaf yield in coriander at 45 DAS compared to 30 DAS might be due to gradual and increased availability of both inorganic and organic nutrients which led to higher vegetative growth. Our results were in accord with Datta *et al* (2008) [3] who found that one leaf cutting at 30 DAS did not affect the later vegetative and reproductive growth of coriander crop under *Terai* zone of West Bengal.

Number of days to 100% flowering

It had been showed that the number of days taken to 100% flowering in coriander crop, did not show much significant difference between the treatments. However, treatments like T_5 (63.67 days), T_6 (63.33 days) and T_8 (63.04 days) took the least number of days to 100% flowering. While the maximum days to 100% flowering was observed under T_1 (control i.e. FYM @ 15 t ha^{-1}) (67.04 days), T_2 (66.33 days), T_4 (66.33 days) and T_7 (66.33 days) which were at par with each other.

Number of days to 100% seed maturity: The data showed that the least number of days taken to 100% seed maturity (110.85 days) was recorded under treatment T_6 (N (50% Inorganic + 50% FYM) P). While the maximum number of days was recorded under T_1 (control i.e., FYM @ 15 t ha^{-1}) (118.02 days) and T_2 (117.07 days) which were at par with each other.

Yadav *et al.* (2004) [17] who concluded that maximum value in yield parameter like grain yield in isabgol was achieved under the treatment applying nitrogen @ (FYM 75% + Urea 25%) over other treatments and sole application of FYM or urea. Khoja (2004) [6] also reported that higher seed yield of coriander might be due to aggregate impact of better return of yield attributing parameters such as umbels plant^{-1}, umbellets umbel^{-1} and seeds umbellate^{-1} with the application of (N @ 30kg ha^{-1}) as FYM + (N @ 30 kg ha^{-1}) as Urea + *Azotobacter*. These findings are similar with the results obtained by Singh *et al* (2005) [12] and Chand *et al* (2007) [2]. Bhat *et al.* (2007) [1] and Singh *et al* (2010) [13] who received similar results that application of organic manures results in better root growth which leads to availability of several macro and micro-nutrients in soil which led to higher yield.

Economics and Benefit: cost ratio: By calculating the B:C ratio of the experiment T_6 (N (50% Inorganic + 50% FYM) PK) showed most profitable (2.15) and least (0.28) was shown by T_1 (control i.e., FYM @ 15 t ha^{-1}). Thus, it can be concluded that, from economic point of view T_6 (N (50% Inorganic + 50% FYM) PK) was recorded as most benefitted treatment over other treatments and can be recommended for cultivation of

coriander crop under *Terai* zone of West Bengal. The cost of cultivation has been reduced in integrated nutrient management as inputs which are incorporated in fertilizer schedule are a combination of organic manures like FYM, VC, PM along with Urea, SSP, MOP. The combine application of FYM and urea resulted in higher nutrient uptake and better yield which in turn led to increase in net returns and B:C ratio of the crop. The high seed and leaf yield of the coriander crop may be attributed to the continuous and adequate supply of nutrients throughout the crop growth period with the help of INM approach. Datta *et al* (2008) [3] also reported similar outcome with highest net return and B:C ratio obtained with application of N @ 60 kg ha^{-1} and one leaf cutting at 30 DAS of coriander crop under *Terai* zone of West Bengal. The application of (N @ 30 kg ha^{-1}) as FYM + (N @ 30 kg ha^{-1}) as Urea + *Azotobacter* which resulted in high net returns and B:C ratio of coriander cultivation has been reported by Khoja (2004) [6] which justifies results of the present experiment.

Table 1: Effect of integrated nitrogen management on vegetative growth of coriander.

Treatment	Plant height (cm)			Primary branches plant^{-1}			Secondary branches plant^{-1}		Internodal length plant^{-1} (cm)	
	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	60 DAS	90 DAS	60 DAS	90 DAS
T_1 :15 t ha^{-1} FYM (Control)	12.07^{f}	57.79^{h}	68.32^{g}	0.52^{c}	4.49^{d}	6.45^{c}	0.78^{b}	1.11^{c}	4.49^{d}	6.45^{c}
T_2: N (100% Inorganic) PK	14.54^{e}	59.32^{g}	69.98^{f}	0.61^{c}	5.47^{cd}	7.12^{bc}	1.40^{ab}	1.54^{bc}	5.47^{cd}	7.12^{bc}
T_3: N (75% Inorganic + 25% FYM) PK	15.59^{d}	61.64^{f}	72.51^{e}	0.74^{bc}	7.34^{ab}	9.12^{a}	1.58^{ab}	1.71^{bc}	7.34^{ab}	9.12^{a}
T_4: N (75% Inorganic + 25% VC) PK	17.95^{c}	63.40^{e}	74.58^{d}	0.86^{bc}	7.86^{ab}	8.57^{ab}	1.47^{ab}	1.71^{bc}	7.86^{ab}	8.57^{ab}
T_5: N (75% Inorganic + 25% PM) PK	18.96^{b}	65.54^{d}	76.29^{c}	1.02^{abc}	5.36^{cd}	7.00^{c}	1.62^{ab}	1.70^{bc}	5.36^{cd}	7.00^{c}
T_6: N (50% Inorganic + 50% FYM) PK	22.09^{a}	71.18^{a}	81.94^{a}	1.54^{a}	8.37^{a}	9.38^{a}	2.26^{a}	2.67^{a}	8.37^{a}	9.38^{a}
T_7: N (50% Inorganic + 50%VC) PK	17.47^{c}	68.43^{b}	78.12^{b}	1.27^{ab}	6.43^{bc}	8.67^{a}	1.46^{ab}	2.27^{ab}	6.43^{bc}	8.67^{a}
T_8= N (50% Inorganic + 50% PM) PK	16.31^{d}	66.65^{c}	75.83^{c}	1.12^{abc}	7.46^{ab}	8.49^{ab}	1.42^{ab}	1.67^{bc}	7.46^{ab}	8.49^{ab}
C.D. (P=0.05)	0.77	0.64	0.46	0.42	2.05	1.92	0.75	0.77	2.05	1.92
S.Em. (±)	0.25	0.21	0.15	0.21	0.67	0.63	0.24	0.25	0.67	0.63

Conclusion

From this experiment, it can be concluded that, from economic point of view, T_6 (N (50% Inorganic + 50% FYM) was recorded most benefitted treatment over the other treatments and maybe recommended for coriander under *Terai* zone of West Bengal.

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