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Growth, yield and economics of coriander (*Coriandrum sativum* L.) influenced by integrated nutrient management in semi-arid regions of India

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Integrated nutrient management (INM) includes wide range of applications for improving plant productivity and resource optimisation whilst still facilitating for environmental and resource protection. The effects of integration of nutrient sources on coriander growth, yield, and economics were investigated during two consecutive *rabi* seasons (2016-2017 and 2017-18) at the vegetable research farm, CCS Haryana Agricultural University, Hisar, Haryana. The experiment used an eighteen treatment combination of organic manures (Farm yard manure and vermicompost), bio-fertilizers (Azotobacter and Phosphate solubilising bacteria), and inorganic fertilisers in a randomised block design that was duplicated three times. Experimental results showed that the application of 100% recommended dose of nitrogen (RDN- 60 kg/ha) through inorganic sources along with biofertilizers (*Azotobacter* and Phosphate solubilising bacteria) showed better performance over other treatment combinations, recorded significantly higher values for all the growth and yield traits *viz.* Height of plant, number of primary and secondary branches per plant, number of umbelets per umbel, number of seeds per umbel, seeds per umbelet, seed yield per plant (g), seed yield (q/ha), biological yield (q/ha) and harvest index (%). Also, the net returns (Rs. 76895 and 76232) and benefit cost ratio (2.08 and 2.06) were found highest in the same treatment during both the years of experimentation *i.e.,* 2016-17 and 2017-18, respectively.

Keywords: Biofertilizers, Chemical fertilizers, Net returns, Plant nutrition, RDN

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The green revolution has provided a path to food self-sufficiency in underdeveloped nations, but for sustainable agricultural output against a limited natural resource base, demands must be adjusted from a resource-degrading chemical strategy to a resource-protecting organic one (biological/ecological)[1]. India has made a huge breakthrough in production and utilization of fertilizers during the last four decades. But consumption of non-renewable form of nutrient sources *i.e.,* chemical fertilizers will be quite a restrictive factor of agricultural production in near future[2]. Because of increasing energy cost, chemical fertilizers are not available at reasonable price to the farmers. Moreover, the imbalance and constant use of chemical fertilizers has disastrous effect on soil chemical, physical and biological properties thereby affecting the sustainability of agricultural production, besides causing environmental pollution[3]. However, the soil incorporation of organic manures helps in improving soil physical, chemical, and biological properties[4], and enhances nutrient accumulation by plants and crop productivity[5].

The majority of the populace is unaware that organic fertilizers have been around for quite long time, and not just in the last decade. The origins of organic fertilizers can be traced back to several millennia[6]. The application of fertilisers for the soil is mentioned in ancient literature from India, Korea, Japan, and China dating back many centuries BC; at the time, they were livestock, bird, and other animal droppings. Organic manures and biofertilizers including Farm Yard Manure (FYM), goat manure, vermicompost, and nitrogen-fixing bacteria have reduced the use of chemical fertilisers while providing higher quality products free of hazardous agrochemicals for human safety. Application of organic inputs can have a huge additive impact to improve the efficiency of fertilizer use by increasing the microbial activity of soil[4,7]. Seed inoculation with PSB and Azospirillum cultures can supply nitrogen

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and phosphorus comparable to a 30 kg nutrient treatment per hectare[8]. Therefore, it might be synthesized that many sources are available that can provide essential nutrients to the plants but each of them has its own advantages and disadvantages. The INM, therefore, could be a sound strategy to enhance output and income of farmers from any crop. In the light of foregoing, the present study was conducted under semi-arid regions of Haryana to investigate the effect of integrated nutrient management on growth, yield and economics of coriander seed crop.

Methodology

Experimental site

The research experiment took place in CCS Haryana Agricultural University's experimental field in Hisar, Haryana, during the *rabi* season (November-April) of 2016-2017 and 2017-2018. The research region was located at 29°10' North latitude and 75°46' East longitude, with an elevation of 215.2 m above mean sea level. A semi-arid climate characterises this region. The soil texture in the experimental field was sandy loam, with a pH of 8.13 and an EC of 0.39 dS/m. The soil, on the other hand, had low organic carbon (0.38%), available nitrogen (140 kg/ha), available phosphorus (21 kg/ha) and available potassium (220 kg/ha).

Experimental design and field management

With three replications of eighteen treatments, the trial was done in Randomized Block Design (RBD) (Table 1). During both seasons, seeds of the coriander cultivar "Hisar Bhoomit" were sown in a net plot of 4.0 m × 2.4 m in the second week of November. As a biofertilizer sticker, a 10% gur (jaggery) solution was utilized. The solution was first spread over the seeds and stirred to form a thin, uniform covering. After determining the required slurry coating over the seeds, the inoculants (10 mL/kg seed) were spread over the seeds and the content was thoroughly mixed again and dried in shade for two hours before sowing. Well decomposed farm yard manure having nitrogen content (0.50% N and 0.48% N) and vermicompost (1.0% N and 1.03% N) during 2016-17 and 2017-18, respectively were incorporated into the soil before sowing to fulfil the recommended nitrogen dose (60 kg per ha). The chemical properties of organic manures are presented in Table 2.

Data Collection

Data on growth and yield parameters *viz.,* plant height at harvesting (cm), primary branches/plant (Nos.), secondary branches/plant (Nos.), days to 50 per cent flowering, days taken to maturity, umbels per plant at harvesting stage (Nos.), umbelets per umbel (Nos.), seeds/umbel (Nos.), and seeds perumbelet

Table 1 — Treatment details

T_1	100% RDN (Inorganic) + *Azotobacter* + Phosphate Solubilising Bacteria (PSB)
T_2	75% RDN (Inorganic) + *Azotobacter* + PSB
T_3	100% RDN through Farm Yard Manure(FYM) + *Azotobacter* + PSB
T_4	75% RDN through Farm Yard Manure(FYM) + *Azotobacter* + PSB
T_5	100% RDN through Vermicompost + *Azotobacter* + PSB
T_6	75% RDN through Vermicompost + *Azotobacter* + PSB
T_7	75% RDN (Inorganic) + 25 % RDN through FYM + *Azotobacter* + PSB
T_8	50% RDN (Inorganic) + 50 % RDN through FYM + *Azotobacter* + PSB
T_9	75% RDN (Inorganic) + 25 % RDN through Vermicompost + *Azotobacter* + PSB
T_{10}	50% RDN (Inorganic) + 50 % RDN through Vermicompost + *Azotobacter* + PSB
T_{11}	75% RDN through FYM + 25 % RDN through Vermicompost + *Azotobacter* + PSB
T_{12}	50% RDN through FYM + 50 % RDN through Vermicompost + *Azotobacter* + PSB
T_{13}	25% RDN through FYM + 75 % RDN through Vermicompost + *Azotobacter* + PSB
T_{14}	100% RDN (Inorganic)
T_{15}	100% RDN through FYM
T_{16}	100% RDN through Vermicompost
T_{17}	*Azotobacter* + PSB
T_{18}	Control (Without Nitrogen and biofertilizer)

RDN- Recommended Dose of Nitrogen, FYM- Farm Yard Manure

Table 2 — The chemical composition of organic manures

Organic sources	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
FYM	0.50	0.475	0.36	0.30	0.30	0.28
Vermicompost	1.00	1.035	0.70	0.78	0.70	0.80

(Nos.) were taken from ten tagged plants. Economic and biological yield were taken from each plot and converted into yield per hectare (q) and harvest index was calculated. The economics of all eighteen treatments were calculated based on current market pricing of inputs and outputs and stated in terms of net returns per hectare to determine their economic feasibility.

Analysis

Initial soil samples were collected randomly from several field locations in a *zig-zag* pattern at 0-15 cm of soil depth before crop sowing with a hand auger. A combined sample was ground and passed through a 2 mm sieve and thereafter put away in the polythene pack for further analysis. The chemical analysis of soil samples for texture, pH, EC, available N, P, K and organic carbon, was done by standard methods as outlined by Antil[7]. However, organic manures (FYM and VC) were collected from the HAU farm, Hisar, and incorporated into the field before sowing of crop. Before analysis, the manure's samples were air-dried, ground and passed through a 2 mm sieve. Digestion (with the di-acid mixture) is the main step followed, thereafter; standard methods were adopted for analysis purpose[9].

Statistical analysis

The mean values of the parameters and LSD were calculated using one factor analysis in OPSTAT software developed by CCS HAU, Hisar[10].

Results and Discussion

The results revealed that the effect of different nutrient sources combination significantly affected the growth as well as yield parameters (Table 3). The maximum plant height (135.70 cm), number of primary branches/plant at harvest (11.25), and number of secondary branches per plant (31.83) at maturity were obtained with the treatment where 100% RDN was given through inorganic sources in conjoint application with biofertilizers, which was at par with the treatment *i.e.*, T_9 and T_7. The inferior yields attributes were found under control where no fertilizer was applied. The response of treatment combinations on these growth attributes may be due to increased nutrient availability through inorganic fertilizers and increased nitrogen fixation by *Azotobacter* bacteria and availability of phosphorous due to phosphorous solubilising bacteria (PSB) which helped in better nutrient absorption and proper utilization in plant growth which enhanced plant height of coriander[11,12].

Integrated nutrient management also significantly influenced the days to 50% flowering and days taken to maturity, which increased with the increase in nutrient availability (Table 3). The maximum number of days it took to reach 50% flowering and maturity was recorded in the treatment T_1 which was at par with the treatments T_7, T_9, T_{10}, T_{10} and T_{13}, while the minimum days taken to 50% flowering and maturity was recorded in T_{18}. An application of the recommended dose of nitrogen through chemical fertilizer might have

Table 3 — Effect of integrated nutrient.management on growth attributes of coriander (Pooled mean data of two years)

Treatments	Plant height	No of primary branches	Secondary branches	Days to 50% flowering	Days taken to maturity
T_1	135.70	11.25	31.83	122.88	158.67
T_2	120.34	10.38	28.57	113.50	154.00
T_3	118.77	10.53	29.11	114.64	156.83
T_4	115.28	9.77	27.05	111.20	151.17
T_5	125.37	10.77	30.32	116.90	156.83
T_6	118.83	10.32	26.97	112.82	152.00
T_7	130.88	10.71	30.32	121.07	158.17
T_8	122.98	10.53	29.43	117.27	156.50
T_9	132.95	11.27	30.47	122.35	159.50
T_{10}	127.82	11.18	30.58	119.85	156.33
T_{11}	126.52	10.65	28.78	117.05	156.00
T_{12}	127.07	10.55	28.97	117.50	154.67
T_{13}	127.47	10.63	29.02	120.22	155.83
T_{14}	124.02	10.39	30.01	120.50	152.33
T_{15}	117.52	9.82	27.85	115.60	149.00
T_{16}	121.18	9.67	29.02	116.97	151.33
T_{17}	112.08	9.20	26.20	112.92	146.83
T_{18}	110.43	8.73	24.40	109.10	145.00
LSD (p=0.05)	9.52	0.62	2.02	5.33	6.93
SEM	3.30	0.22	0.70	1.85	2.40

Table 4 — Effect of integrated nutrient management on yield attributing characters of coriander (Pooled mean data of two years)

Treatments	Number of umbels per plant	Number of umbelets per umbel	Number of seeds per umbelet	Number of seeds per umbel
$T_{1.}$	67.73	7.43	8.93	55.48
T_2	52.92	6.20	7.00	41.55
T_3	55.20	6.00	7.47	42.92
T_4	49.15	5.90	6.30	40.17
T_5	62.23	6.63	8.43	45.67
T_6	49.92	5.97	6.50	41.52
$T_{7.}$	63.37	7.03	8.77	52.70
T_8	58.60	6.67	8.50	46.53
T_9	66.58	7.27	8.83	54.30
T_{10}	62.73	6.83	8.70	48.93
T_{11}	58.47	6.57	7.70	42.65
T_{12}	56.98	6.57	7.97	44.25
T_{13}	54.28	6.47	8.27	45.45
T_{14}	61.43	7.03	8.63	51.37
T_{15}	53.17	6.00	6.80	41.37
T_{16}	56.03	6.63	7.27	42.03
T_{17}	47.83	5.47	6.17	39.60
T_{18}	44.57	5.30	5.97	36.55
LSD(p=0.05)	4.52	0.46	0.55	2.36
SEM	1.57	0.16	0.19	0.82

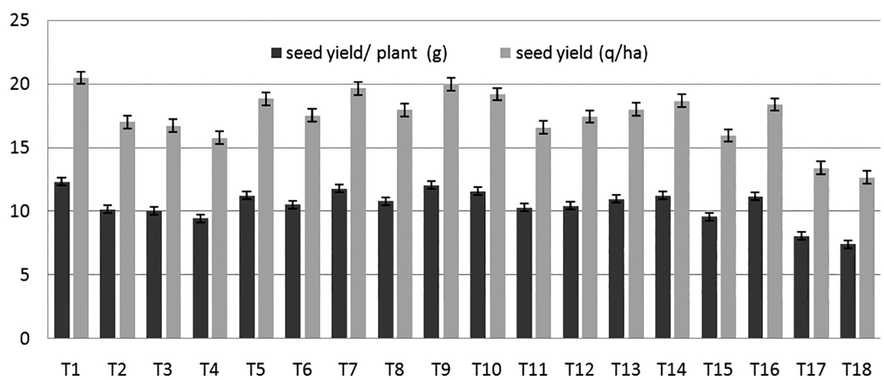

Fig. 1 — Influence of integrated nutrient management on seed yield/plant (g) and seed yield (q/ha) of coriander (Pooled)

boosted nutrients availability, which resulted in enhanced photosynthetic activities and photosynthates transfer from source to sink and this could be a cause of faster vegetative growth leading to more days to maturity for a crop. The outcomes of the present finding are in accordance with the observations of several studies on coriander[13-15] but contradict the findings from studies on fenugreek[16].

Yield attributes are one of the most important factors for evaluating productivity under field conditions and are presented in Table 4. The highest number of umbels per plant (67.73), umbelets per umbel (7.43), seeds per umbelet (8.93) and seeds per umbel (55.48) was reported with the treatment in which 100 % recommended dose of nitrogen was given through inorganic sources along with biofertilizers (*Azotobacter* and PSB) whereas lowest yield component was reported in control. It is also clear from the analysis of data that a lower number of yield components was recorded during the second season of experiment compared to first year of experimentation due to the late onset of rainfall. The positive effect on yield attributing parameters could possibly be linked to enhanced supply of required nutrients which could have resulted in increased food synthesis and its consequent partitioning to sink[17-20]. Furthermore, addition of biofertilizers reported higher seed yield components, which could be due to the increased activity of beneficial micro-organisms *i.e.,* PSB and *Azotobacter*, which facilitated biological processes like phosphorus solubilisation and nitrogen fixation, respectively.

Results related to seed yield per plant (g) and seed yield per hectare (q) revealed significant variation among the different combinations of nutrient doses in the integrated nutrient management (Fig. 1). Highest

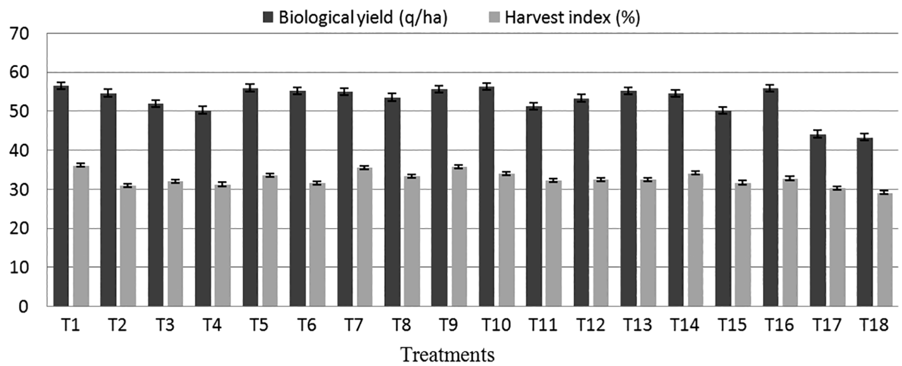

Fig. 2 — Influence of integrated nutrient management on Biological yield (quintal/ha) and Harvest index (%) of coriander (Pooled)

Table 5 — Economics of different treatment combinations as influenced by integrated nutrient management in coriander

Treatments	Total cost (Rs/ha)		Gross returns (Rs/ha)		Net returns (Rs/ha)		B-C ratio	
	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18	2016-17	2017-18
T_1	71517	72063	148295	148412	76895	76232	2.08	2.06
T_2	71322	71868	123368	122798	51476	51500	1.72	1.72
T_3	76737	77666	122542	119716	42979	44876	1.56	1.58
T_4	75237	76070	113550	114822	39585	37480	1.53	1.49
T_5	94737	94359	138014	134775	40038	43655	1.42	1.46
T_6	88737	88590	128279	125665	36928	39689	1.42	1.45
T_7	72822	73463	141382	143107	70285	67919	1.97	1.92
T_8	74127	74864	132067	128052	53925	57203	1.73	1.76
T_9	77322	77637	143095	146175	68853	65458	1.89	1.84
T_{10}	83127	83211	139393	138398	55271	56182	1.66	1.68
T_{11}	81237	81839	121420	118735	37498	39581	1.46	1.48
T_{12}	85737	86012	125579	126858	41121	39567	1.48	1.46
T_{13}	90237	90185	129399	131207	40970	39214	1.45	1.43
T_{14}	71477	72023	135580	134955	63478	63557	1.89	1.88
T_{15}	76697	77626	118460	112730	36033	40834	1.47	1.53
T_{16}	94697	94319	134127	132315	37618	39808	1.40	1.42
T_{17}	70737	71283	97594	96618	25881	26311	1.37	1.37
T_{18}	70697	71243	90769	92417	21720	19526	1.31	1.27

Rs- Rupees

seed yield per plant (12.32 g) and seed yield/hectare (20.49 q) of coriander was reported with the application of 100 % recommended dose of nitrogen was given through inorganic sources along with biofertilizers (*Azotobacter* and PSB). The treatment T_1 increased the seed yield per plant and per hectare by 66.30% and 61.95% over control, respectively. The quick and continuous availability of the appreciable amount of essential plant nutrients from inorganic source, fixation of nitrogen by *Azotobacter*, balanced carbon-nitrogen ratio, auxin synthesis, enhanced growth substances, and conversion of insoluble form of phosphate to a readily soluble form by Phosphorous Solubilising Bacteria (PSB) perhaps increased the seed yield of coriander in T_1[16]. The lowest seed yield (q/ha) was recorded in control which may be because of the low availability of essential nutrients to plants which is required to complete their various reproductive stages. The outcome of these parameters is in close conformity with the previous findings in coriander[21,22]. The application of nutrients as combination of organic and inorganic sources significantly improved the growth-related parameters *viz*., plant height (cm), no. of branches per plant, dry matter, yield attributing characters namely umbels per plant, number of umbelets per umbel and no. of seeds per umbelet. The consequential result of these characters might have resulted in higher biological yield (q/ha) and harvest index (Fig. 2) under this treatment *i.e.,* T_1 which was a recipient of 100% RDN (Inorganic) along with biofertilizers. Similar results were also reported due to the combination of organic manures and chemical sources of nitrogen in coriander[9], cumin[23] and fennel[24].

Highest net returns (Rs. 76895 and Rs. 76232) and benefit cost ratio (2.08 and 2.06) was found under treatment receiving 100% RDN through inorganic sources along with biofertilizers (*Azotobacter* and PSB) during both the years of experimentation *i.e.,* 2016-17 and 2017-18, respectively (Table 5). This was due to higher yield by using ecofreindly traditional agricultural inputs like vermicompost and biofertilizers which ultimately reflected into higher net returns and benefit: cost ratio[15,25].

Conclusion

Based on the experimental results it can be concluded that the application of 100% RDN through inorganic sources along with biofertilizers (*Azotobacter* and PSB) showed superior performance over other treatments which was at par with the treatments in which 25% recommended dose of nitrogen was provided through organic manures and 75% with inorganic sources along with biofertilizers. In addition to enhancing soil health the application of organic based fertilizers in an integrated manner with chemical fertilizers can substitute the fertilizer which will directly benefit to the farmers by reducing the cost of cultivation.

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Conflicts of Interest

Authors have cleared that there is no conflict of interest.

Authors' Contributions

All the authors worked together to complete this manuscript. Authors VK, SKT, and SK did the statistical analysis, collected field data, and authored the initial draught of the manuscript. The study analyses were overseen by author Ankush. The literature searches were managed by authors VSH and VS. The final manuscript was read and approved by all authors.

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