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RESEARCH ARTICLE

Seed priming and foliar micronutrients application: Enhancing phenophasic development and quality of coriander (*Coriandrum sativum* L.)

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Abstract

The present study was carried out during the rabi season of 2020-21 at the Vegetable Research Centre, Maharajpur, under the Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The objective of the field study was to evaluate the influence of seed priming and foliar micronutrients on coriander phenology and quality traits. The experiment was laid out in a Factorial Randomized Block Design comprising 18 treatment combinations. Based on the findings, it was concluded that seed priming with Mn @ 450 ppm combined with foliar application of 0.1 % Mn at 45 days after sowing (DAS) significantly improved growth, physiological, yield and quality parameters. This treatment resulted in the highest plant height, maximum number of primary branches per plant, earliest flowering and superior values for Net Assimilation Rate (NAR) and Crop Growth Rate (CGR).

Keywords: copper; coriander; foliar application; manganese; micronutrients; seed priming

Introduction

Micronutrients play a vital role in crop nutrition, significantly influencing growth and yield. Coriander shows a positive response to both seed priming and foliar application of micronutrients (1). Nutri-priming with micronutrients, viz. helps reduce the time between sowing and seedling establishment. It is also beneficial in promoting faster and uniform germination, crop stands better growth, yield and quality by influencing morpho-physiological, biochemical and molecular aspects of the plants (2). However, the effectiveness of seed priming depends on several factors, including the plant species, duration and temperature of priming, type and concentration of the priming solution, as well as storage conditions after priming.

Foliar spray of micronutrients is one of the possibilities for increasing productivity and reducing environmental hazards. The foliar spray helps in efficient utilization of nutrients by to plant directly through leaves within a few days. Foliar application of micronutrients at active growth stages will improve plant growth and consequently yield and quality in coriander (3). The positive influence of foliar application of micronutrients on crop growth may be due to the improved ability of the crop to absorb nutrients, proper photosynthesis and better sink-source relationship, as these play a vital role in various biochemical processes (4).

Copper (Cu) and manganese (Mn) play an important role in the growth, quality and high yield of crops. However, their deficiencies are widespread and may cause a great disturbance in the physiological and metabolic processes in the plants (5, 6). Cu is an essential micronutrient for all living organisms, including plants, playing an irreplaceable role in many metalloenzymes, photosynthesis-related plastocyanin, membrane structure and vital to cell metabolism. Mn increased the vegetative growth characters and essential oil content of coriander (7). Mn plays a key role in photosynthesis, reactive oxygen species (ROS) detoxification, is involved in nitrogen (N) metabolism, synthesis of several compounds needed for plant metabolism act as cofactor for various enzymes like metalloenzyme cluster of oxygen-evolving complex (OEC) in photosystem II (8).

All these clearly indicate that seed priming enables enhancement in germination and seed vigor, while foliar application has a positive influence on increasing the production of the crop. Limited attempts have been made so far to observe the response of the crop when seed priming and foliar application of micronutrients are practiced together. Therefore, this investigation aimed to study the response of coriander to nutri-priming and time of foliar application of micronutrients on growth, yield and quality.

Materials and Methods

The study was conducted at VRC, Maharajpur, Department of Horticulture, JNKVV, Jabalpur, Madhya Pradesh, India, during rabi 2020-21 to evaluate the response of coriander to nutri-priming and foliar application of micronutrients. The experiment was laid under factorial randomized block design in 3 replicated trials, consisting of 18 treatments (details of treatments are presented in Table 1), 3

Table 1. Details of treatments

Treatment code	Priming agents	Concentration of seed priming	Foliar timing	Treatment description
T_1 (A_1B_1)	Copper	150 ppm	No spray	SP at150 ppm Cu+ No FS
T_2 (A_1B_2)	Copper	150 ppm	45 DAS	SP at 150 ppm Cu + FS at 0.1 % Cu at 45 DAS
T_3 (A_1B_3)	Copper	150 ppm	75 DAS	SP at 150 ppm Cu + FS at 0.1 % Cu at 75 DAS
T_4 (A_2B_1)	Copper	300 ppm	No spray	SP at 300 ppm Cu + No FS
T_5 (A_2B_2)	Copper	300 ppm	45 DAS	SP at 300 ppm Cu + FS at 0.1 % Cu at 45 DAS
T_6 (A_2B_3)	Copper	300 ppm	75 DAS	SP at 300 ppm Cu+ FS at 0.1 % Cu at 75 DAS
T_7 (A_3B_1)	Copper	450 ppm	No spray	SP at 450 ppm Cu + No FS
T_8 (A_3B_2)	Copper	450 ppm	45 DAS	SP at 450 ppm Cu+ FS at 0.1 % Cu at 45 DAS
T_9 (A_3B_3)	Copper	450 ppm	75 DAS	SP at 450 ppm Cu+ FS at 0.1 % Cu at 75 DAS
T_{10} (A_4B_1)	Manganese	150 ppm	No spray	SP at 150 ppm Mn + No FS
T_{11} (A_4B_2)	Manganese	150 ppm	45 DAS	SP at 150 ppm Mn+ FS at 0.1 % Mn at 45 DAS
T_{12} (A_4B_3)	Manganese	150 ppm	75 DAS	SP at 150 ppm Mn+ FS at 0.1 % Mn at 75 DAS
T_{13} (A_5B_1)	Manganese	300 ppm	No spray	SP at 300 ppm Mn + No FS
T_{14} (A_5B_2)	Manganese	300 ppm	45 DAS	SP at 300 ppm Mn+ FS at 0.1 % Mn at 45 DAS
T_{15} (A_5B_3)	Manganese	300 ppm	75 DAS	SP at 300 ppm Mn + FS at 0.1 % Mn at 75 DAS
T_{16} (A_6B_1)	Manganese	450 ppm	No spray	SP at 450 ppm Mn + No FS
T_{17} (A_6B_2)	Manganese	450 ppm	45 DAS	SP at 450 ppm Mn + FS at 0.1 % Mn at 45 DAS
T_{18} (A_6B_3)	Manganese	450 ppm	75 DAS	SP at 450 ppm Mn + FS at 0.1 % Mn at 75 DAS

Where, Cu- copper, Mn- manganese, DAS- days after sowing, SP- seed priming, FS- foliar spray.

concentrations of Cu (150, 300 and 450 ppm), 3 concentrations of Mn (150, 300 and 450 ppm). Seed priming was done by pre-soaking the split seeds for 16 hr and a 0.1 % foliar spray at 45 and 70 days after sowing (DAS). The seeds were sown in the plot of size 3 m × 2.4 m using the line sowing method. Land was prepared by ploughing followed by harrowing. Well-decomposed farmyard manure @ 15 t/ha was applied during final ploughing. The recommended dosages of N, P and K @ 60:40:20 kg/ha were applied in the form of urea, single super phosphate and muriate of potash respectively. Suitable plant protection interventions were adopted against insect pests and diseases, including Acetamiprid (60 DAS) and Propiconazole (65 DAS). Throughout the season, all the recommended cultural practices were implemented consistently to cultivate a standard coriander crop.

Five plants were randomly selected from each plot and tagged for recording observations on various growth, physiological, yield and quality parameters. Plant height and the number of primary branches per plant were counted at physiological maturity. The growth analysis parameters recorded are as follows:

Net assimilation rate (NAR): It was calculated for different plant growth stages (60, 90 DAS and at physiological maturity) using the following formula and expressed as g/g/day (9).

$$NAR = \frac{(\log_e L_2 - \log_e L_1)}{(L_2 - L_1)} \times \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

Where, t_1, t_2 = days of observations; L_1, L_2 = leaf dry weight at t_1 and t_2

W_2, W_1 = whole plant dry weight at t_2 and t_1.

Crop growth rate (CGR): It is expressed as g/m^2/day. Then, the CGR is calculated using the following formula

$$CGR = \frac{(W_2 - W_1)}{P\,(t_2 - t_1)}$$

Where, t_1, t_2 = days of observation

W_2, W_1 = whole plant dry weight at t_2 and t_1, P = Spacing in m^2

Chlorophyll content index (CCI): Chlorophyll content index was estimated in the 4th leaf from the top (fully expanded leaf) with the help of a non-destructive method that uses an optical instrument chlorophyll meter (Model: CCM 200, Made in USA). Chlorophyll content is expressed in terms of SPAD (Soil and Plant Analysis Development) units at 30, 60 and 90 DAS.

Leaf area index (LAI): The leaf area was recorded from leaves of 10 randomly selected plant using leaf area meter at 30 DAS and 60 DAS. LAI is calculated by the formula (10):

$$LAI = \frac{X}{Y}$$

Where, X = Leaf area, Y = Ground area

Number of umbels per plant, umbellets per umbel and number of seeds per umbel were counted from randomly selected 5 plants.

Estimation of essential oil: The essential oil was extracted using Soxhlet apparatus. Then, essential oil content was determined by using the following formula:

$$Fat\ \% = \frac{(W_2 - W_1)}{W} \times 100$$

Where, W_1 = weight of empty collection vessel, W_2 = final weight of collection vessel W = weight of sample taken

Statistical analysis

The experimental data were analysed statistically by the method of analysis of variance (ANOVA) (11).

Results and Discussion

Phenological and Growth parameters

As regards the interaction of seed priming and foliar application, significant results were obtained and the data are presented in Table 2 and illustrated in Fig. 1. Seed priming with Mn @ 450 ppm with foliar Mn at 45 DAS exhibited the maximum height, number of branches per plant and recorded early flowering, while Cu treatments were moderately effective. The results of the present study are consistent with those of previous studies in coriander, that the micronutrients have shown a significant increase in the growth and development of the crop (12-14).

Table 2. Effect of seed priming, foliar application of micronutrients and their interaction on the mean performance of phenological and growth parameters

Treatment code	Plant height (cm) at physiological maturity	Number of branches at physiological maturity	Number of days to flower initiation
T_1 (A_1B_1)	101.63	6.00	46.22
T_2 (A_1B_2)	105.91	6.13	44.44
T_3 (A_1B_3)	103.13	6.46	42.33
T_4 (A_2B_1)	107.06	6.53	47.33
T_5 (A_2B_2)	110.94	6.80	43.66
T_6 (A_2B_3)	105.96	6.06	43.00
T_7 (A_3B_1)	100.63	5.87	45.77
T_8 (A_3B_2)	100.30	6.27	44.66
T_9 (A_3B_3)	107.43	6.60	43.66
T_{10} (A_4B_1)	103.07	6.06	46.55
T_{11} (A_4B_2)	107.63	6.44	42.33
T_{12} (A_4B_3)	108.80	6.67	44.77
T_{13} (A_5B_1)	99.80	6.06	45.66
T_{14} (A_5B_2)	110.33	5.93	41.66
T_{15} (A_5B_3)	111.46	6.78	43.00
T_{16} (A_6B_1)	99.76	5.93	45.11
T_{17} (A_6B_2)	115.46	6.93	44.00
T_{18} (A_6B_3)	110.23	6.33	44.33
Mean	106.08	6.33	44.36
S.D.	4.66	0.34	1.57
S.E. ±	1.20	0.15	0.35
C.D. 5 % level	3.49	0.43	1.00

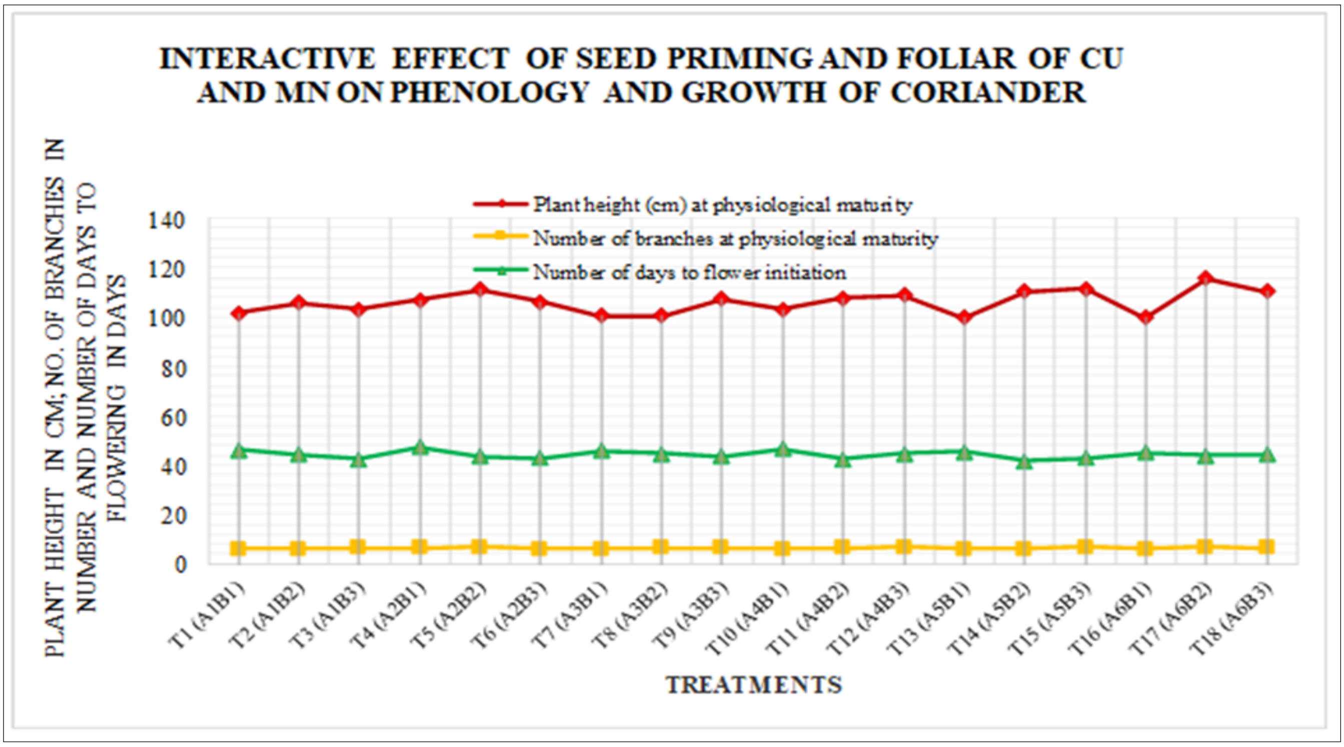

Fig. 1. Graphical representation of the effect of seed priming and foliar application of micronutrients on the mean performance of phenology and growth of coriander.

Physiological parameters

The data of physiological parameters are displayed in Table 3 and illustrated in Fig. 2a, 2b. In case of interaction, at 60-90 DAS and 90 DAS and physiological maturity, Cu priming @ 300 ppm and foliar spray of 0.1 % Cu at 45 DAS recorded significantly enhanced photosynthetic efficiency (net assimilation rate, crop growth rate) compared with the Mn treatment.

It was observed that the chlorophyll content index recorded at 30, 60 and 90 DAS was the maximum in treatment T_{17}, where seeds were primed with Mn 450 ppm and foliar spray was done at 45 DAS. The LAI was also maximum in T_{17}. The present studies show conformity with the previous findings (15-18).

Yield parameters

The data of yield and its associated parameters are displayed in Table 4 and illustrated in Fig. 3. The interaction showed a significant effect on yield contributing attributes. Treatment, T_{17} seed priming @ 450 ppm Mn + foliar spray @ 0.1 % Mn at 45 DAS consistently produced the best yield attributes, i.e. umbels/plant (48.26), number of umbellets/plant (388.93 umbellets/plant) and seed yield (12.11 q/ha) outperforming all other treatments. The results were in concurrence with the previous findings (4, 13, 19-22). They have highlighted that foliar application of micronutrients (Cu, Mn, Zn, Fe) increases the seed yield, which may be attributed to increased plant height, the maximum number of primary branches and secondary

Table 3. Effect of seed priming, foliar application of micronutrients and their interaction on the mean performance of physiological traits

Treatments	Net assimilation rate (g/g/day) At 60 and 90 DAS	Net assimilation rate (g/g/day) At 90 and physiological maturity	Crop growth rate (g/m²/day) At 60 and 90 DAS	Crop growth rate (g/m²/day) At 90 and physiological maturity	Chlorophyll content index 30 DAS	Chlorophyll content index 60 DAS	Chlorophyll content index 90 DAS	Leaf area index 30 DAS	Leaf area index 60 DAS
T_1 (A_1B_1)	3.45	2.86	5.48	3.21	19.72	5.86	1.30	0.07	1.28
T_2 (A_1B_2)	4.25	2.73	5.45	3.43	19.66	7.12	1.49	0.07	1.36
T_3 (A_1B_3)	4.28	2.84	6.84	3.83	19.99	7.28	1.51	0.08	1.39
T_4 (A_2B_1)	3.72	2.94	5.67	3.48	19.75	6.05	1.32	0.07	1.25
T_5 (A_2B_2)	4.51	3.72	7.06	4.63	19.96	6.33	1.33	0.08	1.42
T_6 (A_2B_3)	4.16	3.37	6.63	3.42	20.20	7.46	1.40	0.07	1.46
T_7 (A_3B_1)	3.31	2.71	5.81	3.41	19.07	6.30	1.37	0.06	1.26
T_8 (A_3B_2)	4.27	2.69	5.68	3.40	19.63	7.06	1.41	0.07	1.45
T_9 (A_3B_3)	3.83	3.00	5.76	3.48	20.03	7.01	1.39	0.07	1.40
T_{10} (A_4B_1)	3.64	2.93	6.82	3.66	19.26	6.68	1.30	0.08	1.29
T_{11} (A_4B_2)	4.23	3.53	6.64	4.31	19.91	7.40	1.51	0.08	1.47
T_{12} (A_4B_3)	4.19	2.93	7.02	4.41	19.43	7.19	1.42	0.08	1.42
T_{13} (A_5B_1)	4.13	2.24	5.85	3.52	19.51	6.91	1.29	0.06	1.24
T_{14} (A_5B_2)	4.04	3.14	7.01	4.36	20.01	6.90	1.41	0.07	1.44
T_{15} (A_5B_3)	4.14	2.52	6.99	3.64	18.90	7.24	1.43	0.07	1.39
T_{16} (A_6B_1)	3.44	2.57	5.46	3.28	19.16	6.53	1.31	0.07	1.27
T_{17} (A_6B_2)	4.30	3.62	7.03	4.52	21.90	8.02	1.53	0.09	1.48
T_{18} (A_6B_3)	4.27	2.74	6.93	4.37	20.07	6.83	1.46	0.07	1.45
Mean	4.01	2.95	6.34	3.80	19.79	6.90	1.40	0.07	1.37
S.D.	0.35	0.40	0.66	0.49	0.65	0.54	0.08	0.01	0.08
S.E. ±	0.05	0.05	0.16	0.07	0.16	0.11	0.01	-	0.01
C.D. 5 % level	0.16	0.15	0.46	0.21	0.48	0.33	0.04	NS	0.03

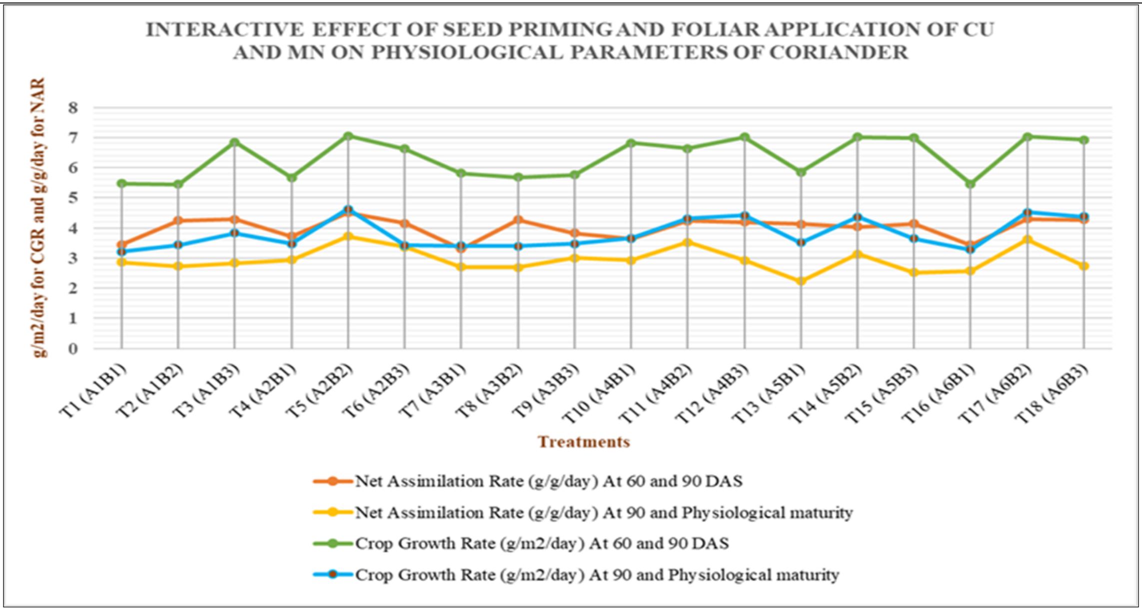

Fig. 2a. Graphical representation of the effect of seed priming and foliar application of micronutrients on the mean performance of physiological parameters of coriander.

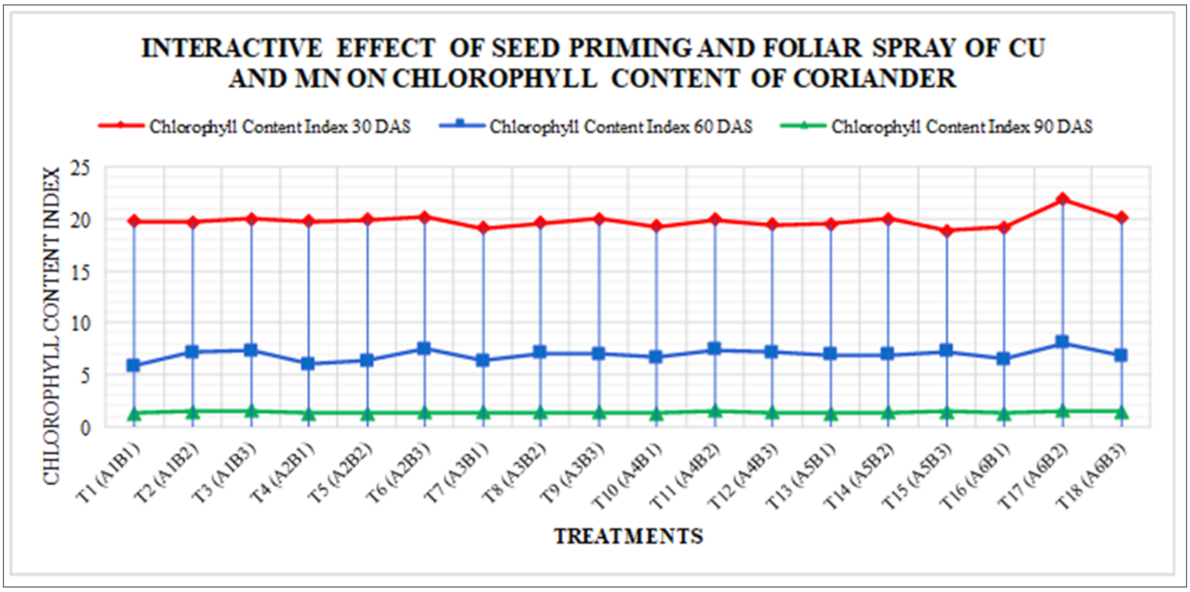

Fig. 2b. Graphical representation of the effect of seed priming, foliar application of micronutrients on the mean chlorophyll content of coriander.

Table 4. Effect of seed priming, foliar application of micronutrients and their interaction on mean performance of yield and its associated traits

Treatments	Number of umbels per plant	Number of umbellets per plant	Number of seeds per umbel	Test weight (g)	Seed yield (q/ha)
T_1 (A_1B_1)	31.20	211.46	46.07	11.75	7.71
T_2 (A_1B_2)	28.13	264.60	67.63	11.21	9.38
T_3 (A_1B_3)	43.36	303.53	42.70	11.81	9.88
T_4 (A_2B_1)	31.53	154.80	43.10	11.34	8.37
T_5 (A_2B_2)	46.33	330.93	64.72	12.29	11.10
T_6 (A_2B_3)	29.33	241.33	57.85	11.21	9.38
T_7 (A_3B_1)	33.06	180.66	52.66	11.88	8.09
T_8 (A_3B_2)	35.53	213.20	80.66	11.76	9.48
T_9 (A_3B_3)	32.33	236.00	44.23	11.05	9.36
T_{10} (A_4B_1)	37.21	208.33	52.77	10.65	8.59
T_{11} (A_4B_2)	36.60	325.46	54.03	12.11	11.09
T_{12} (A_4B_3)	40.86	298.73	54.00	11.31	10.01
T_{13} (A_5B_1)	30.66	238.00	63.93	11.91	9.85
T_{14} (A_5B_2)	25.80	194.80	86.77	12.13	8.89
T_{15} (A_5B_3)	42.66	226.26	47.44	11.29	9.44
T_{16} (A_6B_1)	40.00	199.06	74.55	11.79	8.53
T_{17} (A_6B_2)	48.26	388.93	85.14	11.93	12.11
T_{18} (A_6B_3)	37.60	272.13	70.91	11.54	9.41
Mean	36.14	249.35	60.51	11.61	9.48
S.D.	6.43	60.66	14.48	0.43	1.11
S.E. ±	2.38	12.77	2.29	-	0.37
C.D. 5 % level	6.88	36.71	6.60	NS	1.07

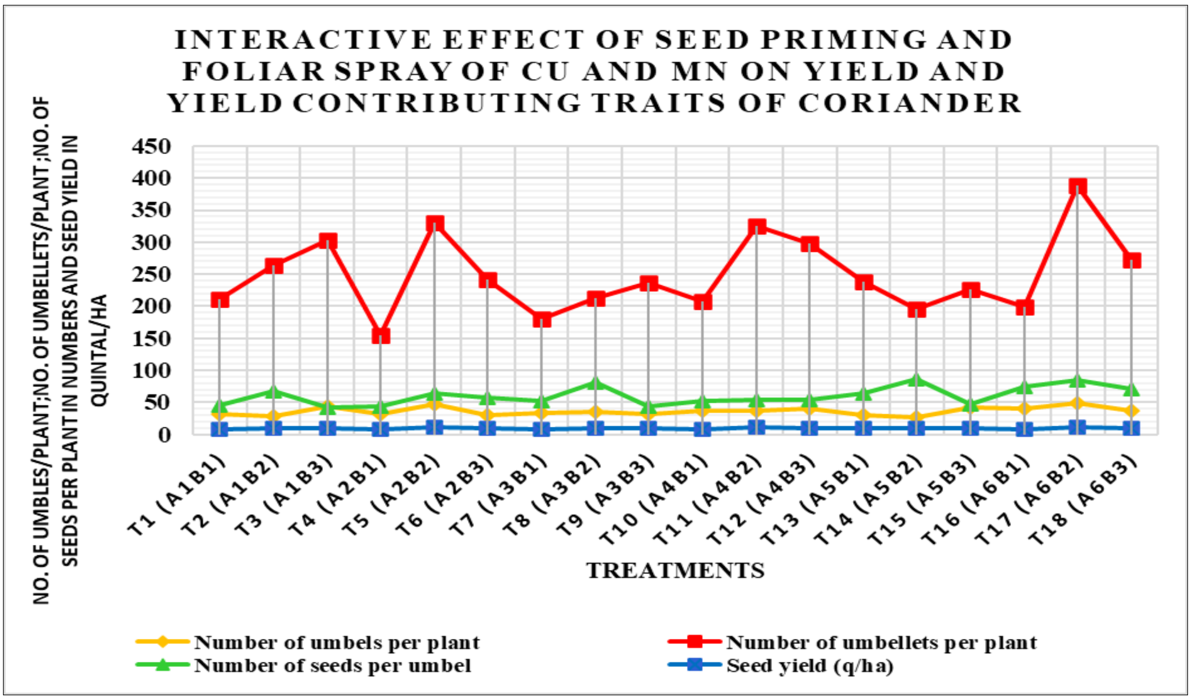

Fig. 3. Graphical representation of the effect of seed priming and foliar application of micronutrients on the mean performance of yield and its associated traits of coriander.

branches and the maximum number of umbels and umbellets and seeds per umbel. The observed improvement in growth and yield attributes may be attributed to more efficient nutrient uptake and utilization by the plants, leading to enhanced photosynthetic efficiency, accelerated metabolic processes and better translocation of assimilates towards seed development.

Quality parameters

The data of quality parameters are displayed in Table 5 and illustrated in Fig. 4. In the case of the interaction effect, it was noted that seed priming with Cu @ 450 ppm and foliar spray of 0.1 % Cu at 45 DAS resulted in the highest essential oil content (0.363 %), which was at par with A_6B_2, which corelates with the previous findings (7, 23, 24). Linalool, geranyl acetate, cis-dihydrocarvone, nerol and neral were the main components of essential oil during different stages of coriander (25). In coriander, Cu causes toxicity by their increased lipid peroxidation and electrolyte leakage (26).

Correlation between seed yield and physiological parameters

The correlation study presented in Table 6 and illustrated using a heat map (Fig. 5) indicated that there was a significant correlation exists between the seed yield and physiological parameters, viz. NAR, CGR and LAI. The results highlighted that all 3 physiological parameters have a significant positive correlation with the seed yield. CGR, NAR, LAI and chlorophyll content were positively associated with seed yield, which may be due to their interrelation with the photosynthesis activity of the plant, which is contributing more towards the growth, yield and its contributing characters. The results obtained in the present study conform with the earlier findings in chickpea (27). Net assimilation rate, crop growth rate and leaf area index are the important physiological parameters that directly or indirectly reflect the crop growth and thus influence the seed yield (9, 10).

Table 5. Effect of seed priming, foliar application of micronutrients and their interaction on essential oil (%)

Treatments	Essential oil content (%)
T_1 (A_1B_1)	0.313
T_2 (A_1B_2)	0.323
T_3 (A_1B_3)	0.350
T_4 (A_2B_1)	0.337
T_5 (A_2B_2)	0.353
T_6 (A_2B_3)	0.333
T_7 (A_3B_1)	0.337
T_8 (A_3B_2)	0.363
T_9 (A_3B_3)	0.327
T_{10} (A_4B_1)	0.337
T_{11} (A_4B_2)	0.347
T_{12} (A_4B_3)	0.350
T_{13} (A_5B_1)	0.327
T_{14} (A_5B_2)	0.340
T_{15} (A_5B_3)	0.353
T_{16} (A_6B_1)	0.347
T_{17} (A_6B_2)	0.360
T_{18} (A_6B_3)	0.353
Mean	0.34
S.D.	0.01
S.E. ±	0.008
C.D. 5 % level	0.024

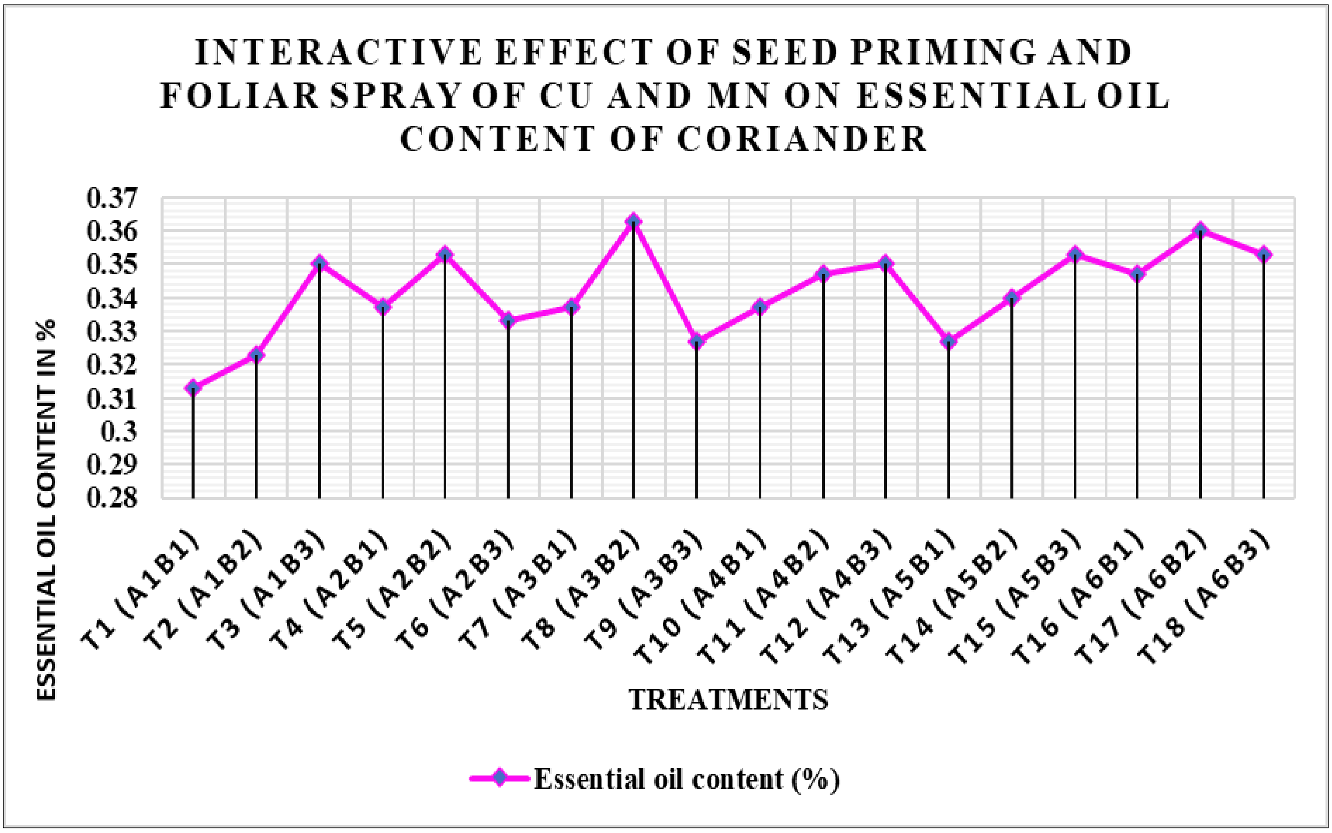

Fig. 4. Graphical representation of the effect of seed priming and foliar application of micronutrients on essential oil content of coriander.

Table 6. Correlation between seed yield and physiological parameters

	NAR (90 DAS & maturity)	CGR (60 & 90 DAS)	CGR (90 DAS & maturity)	LAI 60 DAS	Seed yield (q/ha)
NAR (60 & 90 DAS)	0.317	0.528*	0.618**	0.686**	0.864**
NAR (90 DAS & Maturity)		0.454	0.52*	0.62**	0.287
CGR (60 & 90 DAS)			0.893**	0.523*	0.645**
CGR (90 DAS & Maturity)				0.516*	0.705**
LAI 60 DAS					0.603**

** Correlation is significant at 0.01 level (two tailed)

* Correlation is significant at 0.05 level (two tailed)

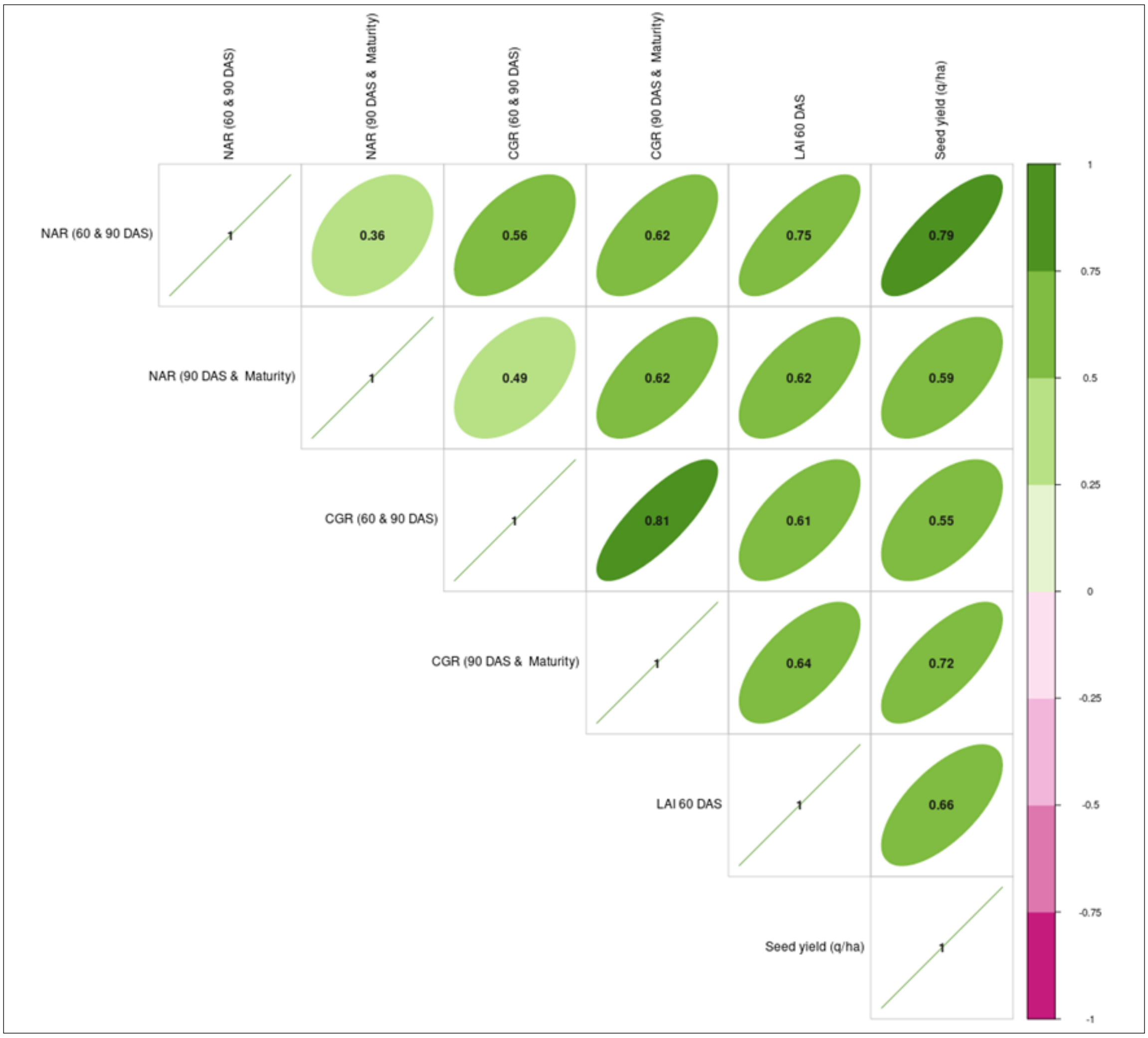

Fig. 5. Heatmap representing the correlation between seed yield and physiological parameters of coriander.

Conclusion

Low seed germinability and poor seed vigor are among the major limitations in coriander cultivation, which adversely impact the overall crop yield. Based on the findings of the present study, it can be concluded that seed priming with 450 ppm Mn, combined with foliar application of 0.1 % Mn at 45 DAS had significantly improved the growth, physiological, yield and quality attributes of coriander. Mn ultimately increased the productivity of coriander by influencing better germination, photosynthetic efficiency, metabolic processes, better nutrient absorption and assimilation. Thus, Mn seed priming and foliar application can be recommended to the farmers for increasing the productivity and profitability of coriander. Further research can also be conducted with other micronutrients, different concentrations and different techniques for seed priming and foliar application for improving the present agricultural practices.

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Authors' contributions

PM has carried out the whole research, recorded observations, compiled and analysed data and drafted the manuscript. RN as major advisor, who supervised the research and participated in the design of the study and also assisted with the statistical analysis. SSP assisted with the recording of data at field, drafting the manuscript and with statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The Authors do not have any conflicts of interest to declare.

Ethical issues: None

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