Seed Res. 48(2): 105-114, December, 2020

Effect of Micronutrient Application on Seed Yield and Quality of Coriander

CA BABARIYA, JB PATEL*, JYOTI SONDARVA AND DV SAVALIYA

Department of Seed Science and Technology, College of Agriculture,
Junagadh Agricultural University, Junagadh
*megaseed@jau.in

(Received: August 2020, Revised: October 2020, Accepted: December 2020)

ABSTRACT: Pure seeds of coriander cv. Gujarat Coriander-2 which formed the base material for the study were obtained from Department of Seed Science and Technology, College of Agriculture, JAU, Junagadh. The field experiment comprising 17 treatmentswas conducted at the Sagdividi farm, DSST, JAU, Junagadh for three seasons (Rabi 2016-17, 2017-18 and 2018-19) using Randomized Block Design (Factorial) with two factors, factor one was soil application and factor second was foliar application and one absolute control. The results revealed that on pooled basis, among the soil application treatments of micronutrients, significantly the higher seed yield (2099.75 kg/ha) was recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over $CuSO_4$ @ 25 kg/ha + RDF (1895.58 kg/ha), $MnSo_4$ @ 25 kg/ha + RDF (1888.32 kg/ha) and control (1592.96 kg/ha), and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher seed yield (2143.29 kg/ha) over $CuSO_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF (1863.68 kg/ha), $MnSo_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF) (1813.77 kg/ha) and control (1592.96 kg/ha). On mean basis, the treatment combination of soil application of $FeSO_4$ @ 25 kg/ha + RDF and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded the high means for seed yield, yield attributes and quality parameters. The highest gross return (280853 ₹/ha), net return (221849/ha) as well as benefit cost ratio (BCR) (3.76) was obtained from the seed harvested from treatment combination of soil application of $FeSO_4$ @ 25 kg/ha + RDF and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF.

Keywords: Coriander, Economics, Micronutrient, Seed Yield, Quality

The seed spices constitute an important group of commodities. Among the seed spices, coriander (*Coriandrum sativum* L.) is the most important spice crop with multipurpose utility. It is an annual herb of *Apiaceae* family. For adequate plant growth and seed production, micronutrients are needed in small quantities; however, deficiencies cause great disturbances in physiological and metabolic processes in the plant. Beneficial effect of foliar application of micronutrients on coriander may be due to the improved ability of the crop to absorb nutrients, photosynthesis and better sink source relationship as these play vital role in various biochemical processes [1]. The role of micronutrients in photosynthesis, N-fixation, respiration and other metabolic processes of the plant is well documented [2]. The effects of micronutrient on the promotion, growth and production of some medicinal and aromatic plants were observed by several researchers [3-5]. Application of micronutrients significantly influenced the number of branches, umbels per plant, seeds per umbel and seed yield of coriander [6]. Foliar application of iron and zinc exhibited significant effect on resultant seed yield parameters [7]. Considering these reviews, the experiment was planned to study the effect of micronutrient application on seed yieldand quality of coriander

MATERIALS AND METHODS

The field experiment using pure seeds of coriander cv. Gujarat Coriander-2 comprising 17 treatments was conducted at the Sagdividi farm, DSST, JAU, Junagadh for three seasons (Rabi 2016-17, 2017-18 and 2018-19) using Randomized Block Design (Factorial) with two factors, factor one was soil application (four doses, A_1=$ZnSo_4$ @ 25 kg/ha + RDF, A_2=$FeSO_4$ @ 25 kg/ha + RDF, A_3=$CuSO_4$ @ 25 kg/ha + RDF and A_4=$MnSo_4$ @ 25 kg/ha + RDF) and factor second was foliar application (four doses, B_1= $ZnSo_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF, B_2= $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF, B_3= $CuSO_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF and B_4 = $MnSo_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF) along with and one

absolute control. The main reason behind using of citric acid instead of calcium carbonate is that citric acid stabilizes $FeSO_4$ against oxidation to more toxic Fe^{3+} form, which is not useful in foliage application and had adverse effect on plant foliage leading toxicity and scorching. Before sowing, physical and chemical properties of the soil of the experimental site were determined as per Jackson, 1973 [8]. Seeds were sown in plot size of 5 x 3 m (gross plot size) and 4 x 1.8 m (net plot size) with a spacing of 15 x 10 cm. Soil application of micronutrients given as a basal dose at time of sowing.All other cultural practices were followed according to standard recommendations for the locality. Observations *viz*., numbers of branches per plant, numbers of umbels per plant, numbers of seeds per umbel, 100 seed weight and seed yield per plantwere taken on five randomly selected plants, while seed quality parameters *viz.,* germination percentage, root length, shoot length and seed vigour index I (length) were recorded in the laboratory from the produce of seed as per each treatment combinations from field experiment [9, 10]

RESULTS AND DISCUSSIONS

Micronutrients played a vital role in the growth and development of coriander cv. GC-2. Among the two methods (soil application and foliar spray) of application of micronutrients, foliar spray was more effective. The positive influence of foliar spray application of micronutrients on crop growth may be due to the improved ability of the crop to absorb nutrients, photosynthesis and better sink source relationship as these plays a vital role in various biochemical processes. These finding were inconformity with the studies of [3, 7].

The results presented in Table 1 revealed that soil application of micronutrient exhibited non-significant differences for number of branches per plant in individual years, but the results were significant on pooled basis, while foliar application of micronutrient registered significant effect for number of branches per plant in 2017-18, 2018-19 and on pooled basis. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher number of branches per plant (6.88) were recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over control and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher number of branches per plant (6.97) over control. The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait. These findings were supported by the finding of [5, 1].

The results revealed that soil application micronutrient exhibited significant differences for number of umbels per plant in 2018-19 and on pooled basis, while foliar application of micronutrient registered significant effect for number of umbels per plant in individual years as well as on pooled basis. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher number of umbels per plant (17.91) were recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over $CuSO_4$ @ 25 kg/ha + RDF (15.88), $MnSo_4$ @ 25 kg/ha + RDF (15.60) and control (11.97), and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher number of umbels per plant (18.77) over $CuSO_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF (15.21), $MnSo_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF) (14.38) and control (11.97). The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait (Table 1). Similarly, with respect to number of seed per umbel, soil application micronutrient exhibited non-significant differences for number of seed per umbel in individual years, but the results were significant on pooled basis, while foliar application of micronutrient registered significant effect for number of seed per umbel in individual years as well as on pooled basis. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher number of seed per umbel (30.55) were recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over control and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher number of seed per umbel (31.13) over control. The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait (Table 2).The results presented in Table 2 also revealed that soil application micronutrient exhibited non-significant differences for 100 seed weight in individual years as well as on pooled basis, while foliar application of micronutrient registered significant effect for 100 seed weight in 2017-18 only. The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait. These findings were supported by the finding of [5, 1].

Table 1. Effect of micronutrient application on number of branches per plant and number of umbels per planting coriander

Treatments	Number of branches per plant				Number of umbels per plant			
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
A_1	5.67	6.56	7.40	6.54	14.82	16.12	20.05	17.00
A_2	5.94	6.85	7.85	6.88	15.80	17.08	20.84	17.91
A_3	5.53	6.32	7.13	6.33	14.08	15.23	18.33	15.88
A_4	5.48	6.37	7.03	6.29	13.79	15.08	17.93	15.60
S. Em.+	0.19	0.21	0.29	0.14	0.57	0.68	0.40	0.32
C.D. at 5%	NS	NS	NS	0.38	NS	NS	1.16	0.91
B_1	5.80	6.80	7.73	6.78	15.79	16.92	21.42	18.04
B_2	5.94	6.87	8.10	6.97	16.35	17.58	22.37	18.77
B_3	5.49	6.29	6.88	6.22	13.53	14.88	17.21	15.21
B_4	5.37	6.13	6.70	6.07	12.83	14.13	16.17	14.38
S. Em.+	0.19	0.21	0.29	0.14	0.57	0.68	0.40	0.32
C.D. at 5%	NS	0.60	0.84	0.38	1.63	1.97	1.16	0.91
Y_1				5.65	-	-	-	14.62
Y_2				6.52	-	-	-	15.88
Y_3				7.35	-	-	-	19.29
S. Em.+				0.11	-	-	-	0.27
C.D. at 5%				0.32	-	-	-	0.77
A x B Interaction								
A_1B_1	5.84	6.73	7.93	6.83	15.94	17.13	22.53	18.53
A_1B_2	5.84	6.80	8.00	6.88	16.33	18.13	23.07	19.18
A_1B_3	5.52	6.37	6.93	6.27	13.74	15.00	17.80	15.51
A_1B_4	5.46	6.33	6.73	6.18	13.28	14.20	16.80	14.76
A_2B_1	6.12	7.13	8.27	7.17	16.96	18.53	23.13	19.54
A_2B_2	6.47	7.33	8.93	7.58	17.97	18.93	24.33	20.41
A_2B_3	5.59	6.53	7.13	6.42	14.35	15.67	17.97	15.99
A_2B_4	5.56	6.40	7.07	6.34	13.94	15.20	17.93	15.69
A_3B_1	5.63	6.67	7.40	6.57	15.34	16.00	20.00	17.11
A_3B_2	5.81	6.67	7.87	6.78	15.67	17.07	21.80	18.18
A_3B_3	5.41	6.00	6.67	6.02	12.68	14.13	16.00	14.27
A_3B_4	5.26	5.93	6.60	5.93	12.63	13.73	15.53	13.97
A_4B_1	5.63	6.67	7.33	6.54	14.90	16.00	20.00	16.97
A_4B_2	5.66	6.67	7.60	6.64	15.43	16.20	20.27	17.30
A_4B_3	5.46	6.27	6.80	6.18	13.34	14.73	17.07	15.05
A_4B_4	5.19	5.87	6.40	5.82	11.48	13.40	14.40	13.09
S. Em.+	0.39	0.41	0.59	0.27	1.13	1.36	0.80	0.65
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Control	5.07	5.80	6.07	5.64	11.05	12.27	12.60	11.97
C.V. %	12.00	11.04	13.92	12.62	13.63	15.08	7.38	11.93
	S. Em.+	C.D. at 5%			S. Em.+	C.D. at 5%		
Treatment	0.27	0.76			0.65	1.82		
Y × T	0.47	NS			1.12	NS		
Y × A	0.24	NS			0.56	NS		
Y × B	0.24	NS			0.56	NS		
Y × A × B	0.47	NS			1.12	NS		
Cont vs. rest	0.20	0.56			0.47	1.33		
Y × Cont vs. rest	0.47	NS			1.12	NS		

Table 2. Effect of micronutrient application on number of seeds per umbel and 100 seed weight (g) in coriander

Treatments	Number of seeds per umbel				100 seed weight (g)			
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
A_1	26.28	27.25	34.73	29.42	1.39	1.55	1.62	1.52
A_2	27.37	28.08	36.20	30.55	1.38	1.63	1.65	1.55
A_3	25.48	26.23	33.57	28.43	1.36	1.52	1.58	1.49
A_4	25.35	25.95	33.30	28.20	1.38	1.52	1.58	1.49
S. Em.+	0.74	0.78	1.37	0.58	0.03	0.03	0.04	0.02
C.D. at 5%	NS	NS	NS	1.63	NS	NS	NS	NS
B_1	27.20	27.92	35.88	30.33	1.38	1.59	1.64	1.53
B_2	27.48	28.58	37.33	31.13	1.33	1.63	1.67	1.54
B_3	25.30	25.75	32.62	27.89	1.42	1.51	1.58	1.50
B_4	24.50	25.27	31.97	27.24	1.38	1.49	1.55	1.47
S. Em.+	0.74	0.78	1.37	0.58	0.03	0.03	0.04	0.02
C.D. at 5%	2.13	2.24	3.95	1.63	NS	0.01	NS	NS
Y_1	-	-	-	26.12	-	-	-	1.38
Y_2	-	-	-	26.88	-	-	-	1.55
Y_3	-	-	-	34.45	-	-	-	1.61
S. Em.+	-	-	-	0.49	-	-	-	0.02
C.D. at 5%	-	-	-	1.37	-	-	-	0.05
A x B Interaction								
A_1B_1	26.93	28.13	36.53	30.53	1.41	1.57	1.65	1.54
A_1B_2	27.27	29.13	37.07	31.16	1.40	1.62	1.66	1.56
A_1B_3	25.53	26.00	32.73	28.09	1.38	1.52	1.58	1.49
A_1B_4	25.40	25.73	32.60	27.91	1.36	1.50	1.58	1.48
A_2B_1	28.73	29.53	37.27	31.84	1.29	1.69	1.69	1.55
A_2B_2	28.93	29.93	39.73	32.87	1.33	1.75	1.73	1.60
A_2B_3	26.07	26.67	34.00	28.91	1.58	1.54	1.60	1.57
A_2B_4	25.73	26.20	33.80	28.58	1.31	1.53	1.60	1.48
A_3B_1	26.60	27.00	35.27	29.62	1.45	1.55	1.62	1.54
A_3B_2	26.93	28.07	36.33	30.44	1.31	1.57	1.65	1.51
A_3B_3	24.67	25.13	31.47	27.09	1.35	1.48	1.54	1.46
A_3B_4	23.73	24.73	31.20	26.56	1.33	1.48	1.52	1.44
A_4B_1	26.53	27.00	34.47	29.33	1.37	1.54	1.61	1.51
A_4B_2	26.80	27.20	36.20	30.07	1.27	1.57	1.64	1.49
A_4B_3	24.93	25.20	32.27	27.47	1.37	1.50	1.58	1.48
A_4B_4	23.13	24.40	30.27	25.93	1.52	1.46	1.50	1.49
S. Em.+	1.48	1.56	2.74	1.16	0.07	0.07	0.08	0.04
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Control	22.67	23.27	28.00	24.64	1.40	1.44	1.50	1.45
C.V. %	9.91	10.12	13.94	12.06	8.46	7.76	9.19	8.52
	S. Em.+	C.D. at 5%			S. Em.+	C.D. at 5%		
Treatment	1.16	3.26			0.04	NS		
Y × T	2.01	NS			0.07	NS		
Y × A	1.01	NS			0.04	NS		
Y × B	1.01	NS			0.04	NS		
Y × A × B	2.01	NS			0.07	NS		
Cont vs. rest	0.85	2.38			0.03	NS		
Y × Cont vs. rest	2.01	NS			0.07	NS		

The results presented in Table 3 revealed that soil application micronutrient as well as foliar application of micronutrient exhibited significant differences for seed yield per plot in 2018-19 and on pooled basis. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher seed yield per plot (3.15 kg) was recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over control and amongst the foliar

Table 3. Effect of micronutrient application on seed yield per plot (kg) and seed yield (kg/ha) in coriander

Treatments	Seedyield per plot (kg)				Seed yield (kg/ha)			
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
A_1	2.78	2.97	3.30	3.02	1847.58	1976.67	2199.17	2007.81
A_2	2.88	3.07	3.51	3.15	1910.92	2048.89	2339.44	2099.75
A_3	2.64	2.82	3.08	2.85	1754.25	1877.78	2054.72	1895.58
A_4	2.61	2.80	3.10	2.84	1731.08	1866.11	2067.78	1888.32
S. Em.+	0.14	0.13	0.09	0.07	77.22	87.18	62.11	44.00
C.D. at 5%	NS	NS	0.27	0.20	NS	NS	178.90	123.50
B_1	2.85	3.05	3.42	3.11	1896.08	2033.33	2282.78	2070.73
B_2	2.95	3.14	3.57	3.22	1955.42	2094.44	2380.00	2143.29
B_3	2.58	2.77	3.05	2.80	1717.42	1843.33	2030.28	1863.68
B_4	2.53	2.70	2.95	2.73	1674.92	1798.33	1968.06	1813.77
S. Em.+	0.14	0.13	0.09	0.07	77.22	87.18	62.11	44.00
C.D. at 5%	NS	NS	0.27	0.20	222.44	NS	178.90	123.50
Y_1	-	-	-	2.72	-	-	-	1810.96
Y_2	-	-	-	2.91	-	-	-	1942.36
Y_3	-	-	-	3.25	-	-	-	2165.28
S. Em.+	-	-	-	0.06	-	-	-	36.96
C.D. at 5%	-	-	-	0.17	-	-	-	103.76
A x B Interaction								
A_1B_1	2.94	3.14	3.49	3.19	1961.00	2091.11	2326.67	2126.26
A_1B_2	2.97	3.17	3.55	3.23	1985.67	2113.33	2365.56	2154.85
A_1B_3	2.65	2.84	3.12	2.87	1764.33	1895.56	2076.67	1912.19
A_1B_4	2.57	2.71	3.04	2.77	1679.33	1806.67	2027.78	1837.93
A_2B_1	2.98	3.18	3.65	3.27	1994.33	2120.00	2433.33	2182.56
A_2B_2	3.16	3.35	4.05	3.52	2088.00	2235.56	2697.78	2340.44
A_2B_3	2.68	2.88	3.20	2.92	1784.00	1920.00	2133.33	1945.78
A_2B_4	2.68	2.88	3.14	2.90	1777.33	1920.00	2093.33	1930.22
A_3B_1	2.76	2.95	3.29	3.00	1832.00	1968.89	2193.33	1998.07
A_3B_2	2.85	3.05	3.36	3.08	1895.00	2031.11	2237.78	2054.63
A_3B_3	2.48	2.66	2.85	2.66	1650.67	1775.56	1900.00	1775.41
A_3B_4	2.47	2.60	2.83	2.63	1639.33	1735.56	1887.78	1754.22
A_4B_1	2.73	2.93	3.27	2.98	1797.00	1953.33	2177.78	1976.04
A_4B_2	2.80	3.00	3.33	3.04	1853.00	1997.78	2218.89	2023.22
A_4B_3	2.51	2.67	3.02	2.73	1670.67	1782.22	2011.11	1821.33
A_4B_4	2.41	2.60	2.80	2.60	1603.67	1731.11	1863.33	1732.70
S. Em.+	0.29	0.26	0.19	0.14	154.44	174.36	124.21	87.99
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS
Control	2.40	2.32	2.45	2.39	1603.33	1544.44	1631.11	1592.96
C.V. %	18.25	15.74	10.08	14.66	14.87	15.74	10.08	
	S. Em.+	C.D. at 5%			S. Em.+	C.D. at 5%		
Treatment	0.14	0.40			87.99	247.01		
Y × T	0.25	NS			152.41	NS		
Y × A	0.12	NS			76.20	NS		
Y × B	0.12	NS			76.20	NS		
Y × A × B	0.25	NS			152.41	NS		
Cont vs. rest	0.10	0.29			64.13	180.04		
Y × Cont vs. rest	0.25	NS			152.41	NS		

application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher seed yield per plot (3.22 kg) over control. The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait. The results also revealed that soil application micronutrient exhibited significant differences for seed yield in 2018-19 and on pooled basis, while foliar application of micronutrient registered significant effect for seed yield in 2016-17, 2018-19 and on pooled basis. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher seed yield (2099.75 kg/ha) was recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over $CuSO_4$ @ 25 kg/ha + RDF (1895.58 kg/ha), $MnSo_4$ @ 25 kg/ha + RDF (1888.32 kg/ha) and control (1592.96 kg/ha), and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher seed yield (2143.29 kg/ha) over $CuSO_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF (1863.68 kg/ha), $MnSo_4$ @ 0.5% + 0.25% Calcium Carbonate at 30 & 45 DAS + RDF) (1813.77 kg/ha) and control (1592.96 kg/ha). The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait (Table 3). These findings were supported by the finding of [4, 1]. The yield improvement may be attributed to higher yield attributing components such as increased plant growth, maximum number of umbels and seeds, which were positively affected by the foliar application of iron. Iron improves photosynthesis and assimilates transportation to sinks and finally increased seed yield [11]. [12] reported that application of Fe, Mn and Zn significantly increased grain yield and yield components of wheat.

Among the seed quality characters, soil application micronutrient as well as foliar application of micronutrient exhibited significant differences for germination in individual years as well as on pooled basis, except soil application of micronutrient in 2017-18. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher germination (85.66 %) was recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over control and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher germination (87.16 %) over control. The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait (Table 4).The results presented in Table 4 also revealed that soil application micronutrient as well as foliar application of micronutrient exhibited significant differences for root length in individual years, but the results were significant on pooled basis in both the types of applications. The interaction effect of soil and foliar application of micronutrients was significant in 2016-17 and 2017-18. The treatment combination of soil application of $FeSO_4$ @ 25 kg/ha + RDF and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher root length of 1.86 cm and 4.95 cm in 2016-17 and 2017-18, respectively over control. These findings were supported by the finding of [5, 1].

Soil application micronutrient as well as foliar application of micronutrient exhibited significant differences for shoot length in individual years as well as on pooled basis. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher shoot length (4.24 cm) was recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over control and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher shoot length (4.37 cm) over control. The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for this trait (Table 5).

The results also revealed that soil application micronutrient as well as foliar application of micronutrient exhibited significant differences for seed Vigour index (length) in individual years as well as on pooled basis. Based on pooled data, among the soil application treatments of micronutrients, significantly the higher seed Vigour index (length) (603.39) was recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over control and amongst the foliar application treatments, foliar application of FeSO @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher seed Vigour index (length) (643.36) over control. The interaction effect of soil and foliar application of micronutrients was significant in 2016-17 and on pooled basis. The treatment combination of soil application of $FeSO_4$ @ 25 kg/ha + RDF and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher seed Vigour index (length) of 384.80 and 715.33 in 2016-17 and on pooled basis, respectively over control (Table 5). The increase

Table 4. Effect of micronutrient application on germination (%) and root length (cm)in coriander

Treatments	Germination (%)				Root length (cm)			
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
A_1	85.39	92.50	72.50	83.46	1.46	3.12	3.23	2.59
A_2	88.22	93.33	75.42	85.66	1.60	3.79	3.38	2.91
A_3	79.72	91.58	68.50	79.94	1.39	2.80	3.05	2.41
A_4	79.05	91.42	67.08	79.19	1.36	2.74	3.00	2.36
S. Em.+	0.96	0.83	0.75	1.10	0.02	0.04	0.04	0.12
C.D. at 5%	2.76	NS	2.17	3.81	0.05	0.12	0.11	NS
B_1	87.89	93.33	75.83	85.69	1.54	3.73	3.37	2.88
B_2	89.72	93.83	77.92	87.16	1.64	4.13	3.50	3.08
B_3	78.80	91.08	66.00	78.63	1.35	2.37	2.97	2.22
B_4	75.97	90.58	63.75	76.78	1.27	2.21	2.82	2.10
S. Em.+	0.96	0.83	0.75	1.76	0.02	0.04	0.04	0.25
C.D. at 5%	2.76	2.38	2.17	6.10	0.05	0.12	0.11	NS
Y_1	-	-	-	83.11	-	-	-	1.43
Y_2	-	-	-	92.21	-	-	-	3.11
Y_3	-	-	-	70.88	-	-	-	3.16
S. Em.+	-	-	-	0.41	-	-	-	0.02
C.D. at 5%	-	-	-	1.16	-	-	-	0.05
A x B Interaction								
A_1B_1	90.38	93.67	78.33	87.46	1.64	3.95	3.47	3.02
A_1B_2	90.40	94.00	78.67	87.69	1.56	4.01	3.53	3.03
A_1B_3	82.07	91.33	67.00	80.13	1.29	2.35	2.99	2.21
A_1B_4	78.73	91.00	66.00	78.58	1.28	2.15	2.91	2.11
A_2B_1	91.73	94.67	81.00	89.13	1.61	4.03	3.61	3.08
A_2B_2	94.40	95.00	82.00	90.47	1.86	4.95	3.69	3.50
A_2B_3	83.73	92.00	71.33	82.36	1.40	3.21	3.16	2.59
A_2B_4	83.08	91.67	67.33	80.69	1.40	2.98	3.05	2.48
A_3B_1	85.08	92.67	72.33	83.36	1.50	3.49	3.22	2.74
A_3B_2	87.07	93.33	77.67	86.02	1.50	3.90	3.47	2.96
A_3B_3	73.73	90.33	62.67	75.58	1.30	1.93	2.83	2.02
A_3B_4	73.08	90.00	61.33	74.80	1.20	1.87	2.69	1.92
A_4B_1	84.40	92.33	71.67	82.80	1.40	3.43	3.17	2.67
A_4B_2	87.10	93.00	73.33	84.48	1.50	3.67	3.31	2.82
A_4B_3	75.70	90.67	63.00	76.46	1.30	1.99	2.90	2.06
A_4B_4	69.10	89.67	60.33	73.03	1.20	1.85	2.63	1.89
S. Em.+	1.91	1.66	1.51	0.98	0.04	0.08	0.08	0.06
C.D. at 5%	NS	NS	NS	NS	0.10	0.23	NS	NS
Control	51.40	88.00	58.67	66.02	0.80	1.73	2.54	1.69
C.V. %	4.08	3.12	3.72	3.63	4.35	4.59	4.28	4.64
	S. Em.+	C.D. at 5%			S. Em.+	C.D. at 5%		
Treatment	2.72	7.84			0.25	0.72		
Y × T	1.70	4.78			0.07	0.19		
Y × A	0.85	2.39			0.03	0.09		
Y × B	0.85	2.39			0.03	0.09		
Y × A × B	1.70	NS			0.07	0.19		
Cont vs. rest	5.78	NS			0.18	NS		
Y × Cont vs. rest	1.70	4.78			0.07	0.19		

Table 5. Effect of micronutrient application on germination (%) and seed vigour index I (length) in coriander

Treatments	Shootlength (cm)				Seed vigour index I (length)			
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
A_1	2.23	5.10	4.89	4.07	314.69	761.63	591.89	556.06
A_2	2.44	5.19	5.10	4.24	327.77	839.49	642.90	603.39
A_3	2.00	4.89	4.74	3.89	279.24	705.66	537.63	507.51
A_4	1.99	4.61	4.62	3.74	265.27	673.04	514.19	484.16
S. Em.+	0.03	0.07	0.07	0.03	3.75	9.77	8.75	13.27
C.D. at 5%	0.09	0.20	0.19	0.09	10.81	28.15	25.22	45.91
B_1	2.44	5.20	5.07	4.24	329.67	834.13	641.33	601.71
B_2	2.53	5.44	5.15	4.37	356.39	898.88	674.80	643.36
B_3	1.92	4.60	4.53	3.69	259.11	635.04	496.72	463.62
B_4	1.78	4.54	4.60	3.64	241.80	611.76	473.75	442.43
S. Em.+	0.03	0.07	0.07	0.05	3.75	9.77	8.75	25.57
C.D. at 5%	0.09	0.20	0.19	0.18	10.81	28.15	25.22	88.47
Y_1	-	-	-	2.17	-	-	-	296.74
Y_2	-	-	-	4.95	-	-	-	744.95
Y_3	-	-	-	4.84	-	-	-	571.65
S. Em.+	-	-	-	0.03	-	-	-	3.82
C.D. at 5%	-	-	-	0.08	-	-	-	10.73
A x B Interaction								
A_1B_1	2.50	5.55	5.03	4.36	348.20	890.87	666.30	635.12
A_1B_2	2.50	5.60	5.23	4.44	365.60	903.56	688.69	652.62
A_1B_3	2.00	4.65	4.69	3.78	274.80	638.54	514.81	476.05
A_1B_4	1.90	4.59	4.63	3.71	270.10	613.53	497.74	460.46
A_2B_1	2.60	5.63	5.42	4.55	366.50	914.39	731.73	670.87
A_2B_2	2.80	5.71	5.44	4.65	384.80	1012.56	748.63	715.33
A_2B_3	2.30	4.72	4.82	3.95	282.10	729.27	569.45	526.94
A_2B_4	2.10	4.67	4.70	3.82	277.70	701.74	521.80	500.41
A_3B_1	2.40	4.89	4.93	4.07	321.80	777.53	589.31	562.88
A_3B_2	2.40	5.45	4.97	4.27	345.30	872.48	655.93	624.57
A_3B_3	1.70	4.51	4.30	3.50	226.80	581.79	447.00	418.53
A_3B_4	1.61	4.69	4.78	3.69	223.10	590.83	458.26	424.06
A_4B_1	2.30	4.73	4.90	3.98	282.20	753.74	577.99	537.98
A_4B_2	2.40	5.01	4.96	4.12	329.90	806.93	605.96	580.93
A_4B_3	1.80	4.52	4.33	3.55	252.70	590.54	455.63	432.96
A_4B_4	1.49	4.18	4.29	3.32	196.20	540.93	417.18	384.77
S. Em.+	0.06	0.14	0.13	0.07	7.50	19.55	17.51	9.10
C.D. at 5%	NS	NS	NS	NS	21.61	NS	NS	25.54
Control	1.09	3.74	3.87	2.90	128.57	481.21	375.31	328.36
C.V. %	4.87	4.84	4.74	5.05	4.53	4.64	5.41	5.19
	S. Em.+	C.D. at 5%			S. Em.+	C.D. at 5%		
Treatment	0.08	0.24			26.68	76.86		
Y × T	0.11	0.32			15.76	44.24		
Y × A	0.06	NS			7.88	22.12		
Y × B	0.06	0.16			7.88	22.12		
Y × A × B	0.11	NS			15.76	NS		
Cont vs. rest	0.05	0.14			20.05	122.00		
Y × Cont vs. rest	0.11	NS			15.76	44.24		

in seed quality parameters may be due to the participation of micronutrients (Zn, Fe, Cu and Mn) in catalytic activity and breakdown of complex substances into simple forms like glucose, amino acids and fatty acids. These in turn were reflected on enhanced germination, elongation of root and shoot of coriander seedling. These findings were supported by the finding of [13] reported while working with tomato.

The economic analysis was done to find out the gross and net return and the benefit cost ratio (BCR) and it is presented in Table 6. The highest gross return (280853 ₹/ha), net return (221849 ₹/ha) as well as benefit cost ratio (BCR) (3.76) was obtained from the seed harvested from treatment combination of soil application of $FeSO_4$ @ 25 kg/ha + RDF and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF.

Overall, the results presented revealed that on pooled basis, soil application of micronutrient as well as foliar application of micronutrient exhibited significant differences for seed yield, yield attributes and quality parameters studied except 100 seed weight in types of micronutrient applications and root length in soil application. Based on pooled data, among the soil application treatments of micronutrients, significantly the

Table 6. Economics of coriander seed production

Treatments	A	B	Treatment Cost (Rs.)	Fixed Cost (Rs.)	Total Cost (Rs.)	Seed yield (kg/ha)	Gross Return (Rs.)	Net Return (Rs.)	BCR
A_1	3000	0	3000	56829	59829	2007.81	240937	181108	3.03
A_2	675	0	675	56829	57504	2099.75	251970	194466	3.38
A_3	5250	0	5250	56829	62079	1895.58	227470	165391	2.66
A_4	2125	0	2125	56829	58954	1888.32	226598	167644	2.84
B_1	0	2250	2250	56829	59079	2070.73	248488	189409	3.21
B_2	0	1500	1500	56829	58329	2143.29	257195	198866	3.41
B_3	0	3000	3000	56829	59829	1863.68	223642	163813	2.74
B_4	0	1500	1500	56829	58329	1813.77	217652	159323	2.73
A_1B_1	3000	2250	5250	56829	62079	2126.26	255151	193072	3.11
A_1B_2	3000	1500	4500	56829	61329	2154.85	258582	197253	3.22
A_1B_3	3000	3000	6000	56829	62829	1912.19	229463	166634	2.65
A_1B_4	3000	1500	4500	56829	61329	1837.93	220552	159223	2.60
A_2B_1	675	2250	2925	56829	59754	2182.56	261907	202153	3.38
A_2B_2	675	1500	2175	56829	59004	2340.44	280853	221849	3.76
A_2B_3	675	3000	3675	56829	60504	1945.78	233494	172990	2.86
A_2B_4	675	1500	2175	56829	59004	1930.22	231626	172622	2.93
A_3B_1	5250	2250	7500	56829	64329	1998.07	239768	175439	2.73
A_3B_2	5250	1500	6750	56829	63579	2054.63	246556	182977	2.88
A_3B_3	5250	3000	8250	56829	65079	1775.41	213049	147970	2.27
A_3B_4	5250	1500	6750	56829	63579	1754.22	210506	146927	2.31
A_4B_1	2125	2250	4375	56829	61204	1976.04	237125	175921	2.87
A_4B_2	2125	1500	3625	56829	60454	2023.22	242786	182332	3.02
A_4B_3	2125	3000	5125	56829	61954	1821.33	218560	156606	2.53
A_4B_4	2125	1500	3625	56829	60454	1732.70	207924	147470	2.44
Control	0	0	0	56829	56829	1592.96	191155	134326	2.36

Factor A: Soil application

A_1=$ZnSo_4$ @ 25 kg/ha = ₹ 3000

A_2=$FeSO_4$ @ 25 kg/ha = ₹ 675

A_3=$CuSO_4$ @ 25 kg/ha = ₹ 5250

A_4=$MnSo_4$ @ 25 kg/ha = ₹ 2125

Factor B: Foliar application (5 kg)

B_1= $ZnSo_4$ @ 0.5%+0.25% Calcium Carbonate at 30 & 45 DAS = ₹ 2250

B_2= $FeSO_4$ @ 0.5%+0.1% Citric Acid at 30 & 45 DAS = ₹ 1500

B_3= $CuSO_4$ @ 0.5%+0.25% Calcium Carbonate at 30 & 45 DAS = ₹ 3000

B_4=$MnSo_4$ @ 0.5%+0.25% Calcium Carbonate at 30 & 45 DAS = ₹ 1500

higher seed yield (2099.75 kg/ha) was recorded in soil application of $FeSO_4$ @ 25 kg/ha + RDF over control and amongst the foliar application treatments, foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded significantly the higher seed yield (2143.29 kg/ha) over control. More or less, the same trend was observed for other yield attributes and quality parameters. The interaction effect of soil and foliar application of micronutrients was non-significant in individual years as well as on pooled basis for seed yield, yield attributes and quality parameters studied. However, on mean basis, the treatment combination of soil application of $FeSO_4$ @ 25 kg/ha + RDF and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF recorded the high means for seed yield, yield attributes and quality parameters. The highest gross return (280853 ₹/ha), net return (221849 ₹/ha) as well as benefit cost ratio (BCR) (3.76) was obtained from the seed harvested from treatment combination of soil application of $FeSO_4$ @ 25 kg/ha + RDF and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid at 30 & 45 DAS + RDF.

CONCLUSION

Coriander responds well to nutrients. Foliar micronutrient application was more advantageous then soil application of micronutrients. It is advantageous to apply $FeSO_4$ @ 25 kg/ha as soil application at the time of planting and foliar application of $FeSO_4$ @ 0.5% + 0.1% Citric Acid (75 g/10 liter) at 30 & 45 DAS along with recommended dose of fertilizer to obtain higher seed yield with high germination and seedling vigour.

REFERENCES

1. KALIDASU G, C SARADA AND YT REDDY (2008). Influence of micronutrients on growth and yield of coriander (*Coriandrum sativum*) in rain fed vertisols. *Journal of Spices and Aromatic Crops*, **17(2)**: 187-189.

2. NAGA SK, SK SWAIN, VV SANDEEP AND B RAJU (2013). Effect of foliar application of micronutrients on growth parameters of tomato (*Lycopersicon esculentum* Mill). *Journal of Agriculture and Food Sciences*, **1**: 146-151.

3. NASIRI Y, ZS SAEID, N SAFAR, N NOSTATOLLAH AND GG KAZEM (2010). Effect of foliar application of micronutrients (Fe and Zn) on flower yield and essential oil of chamomile (*Matricaria chamomilla* L.). *Journal of Medicinal Plants Research*, **4(17)**: 1733-1737.

4. JOYNUL AM, AM NURUL, HM JAMAL, AA NURE, M KAZI AND H FAISAL (2012). Effect of micronutrients on growth and yield of onion under calcareous soil environment. *International Journal of Biosciences,* **2**: 95-101.

5. MAZAHERI M, B FAKHERI, I PIRI AND A TAVASSOLI (2013). The effect of drought stress and micronutrient of Zn and Mn on yield and essential oil of cumin (*Cuminum cyminum*). *The Journal of Novel Applied Sciences*, **2**: 350-356.

6. KALIDASU G, C SARADA AND RT YELLAMANDA (2008). Influence of micronutrients on growth and yield of coriander (*Coriandrum sativum* L.) in rainfed vertisols. *Journal of Spices and Aromatic Crops*, **17**: 187-189.

7. SINTA I, A VIJAUKUMAR AND P SRIMATHI (2015). Effect of micronutrient application in coriander (*Coriandrum sativum* L.) cv. CO4. *African Journal of Agricultural Research*, **10(3)**: 84-88.

8. JACKSON MI (1973). Soil Chemical Analysis. Prentice Hall Indian private Ltd. New Delhi pp: 200-250.

9. ISTA (2003). International Rules for Seed Testing, Zurich, Switzerland. ISTA

10. ABDUL-BAKI AA AND JB ANDERSON (1973). Vigour determination of soybean seeds by multiple criteria, *Crop Science,* **13**:630-633.

11. EBRAHIMIAN E ANDB AHMAD (2011). Effect of iron foliar fertilization on growth, seed and oil yield of sunflower grown under different irrigation regimes. *Middle-East Journal of Scientific Research,* **9**: 621-627.

12. ZEIDAN MS, MF MOHAMED ANDHA HAMOUDA (2010). Effect of foliar fertilization of Fe, Mn and Zn on wheat yield and quality in low sandy soils fertility. *World Journal of Agricultural Sciences*, **6**: 696-699.

13. SANTOSH K (2012). Effect of micronutrients on quality of fruit and seed in tomato (*Solanum lycopersicum* L.). *International Journal of Farm Sciences*, **2**:43-46.