International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 2479-2483

Received: 05-07-2018
Accepted: 07-08-2018

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Effect of sulphur and zinc on growth, yield and quality of coriander (*Coriandrum sativum* L.) *cv.* RCr-436

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Abstract
A field experiment was conducted during *rabi* season 2017-18 at the Horticulture Research Farm, College of Horticulture, Mandsaur (M.P.) to study the response of sulphur and zinc on growth, yield and quality of Coriander. The experiment was laid out in factorial RBD with three replications including four levels of sulphur (0, 15, 30 and 45 kg S/ha) and four levels of zinc (0, 2, 4 and 6 kg Zn/ha). Results showed that sulphur application at 45 kg/ha significantly increased leaf area index, leaf area duration, specific leaf area, crop growth rate, relative growth rate, seeds umbel^{-1}, biological yield, seed yield (16.93 q/ha), seed index (g), chlorophyll content (SPAD) essential oil and dry matter content in seed (%) over control and 15 kg S/ha. significantly leaf area index, leaf area duration, specific leaf area, crop growth rate, relative growth rate, seeds umbel^{-1} biological yield, seed yield (17.19 q/ha) seed index (g), chlorophyll content (SPAD Value) essential oil and dry matter content in seed (%) were obtained with application of 6 kg of Zn/ha over control and 2 kg Zn/ha. Therefore, the application of 45 kg S/ha and 6 kg Zn/ha gave maximum growth, yield and quality of Coriander.

Keywords: Coriander, sulphur, CGR, RGR and zinc

Introduction
Coriander is the dried fruit of *Coriandrum sativum* L., an aromatic spice crop belong to family Umbelliferae or Apiaceae. It is a native of Mediterranean region. It is a cross pollinated. It is very old flavoring substance and its usage both for its leaves, stems as well as fruits has been mentioned in Egyptian. The plant is a smooth, erect annual herb, 30-90 cm high, with conspicuously enlarged nodes and hollow internodes. The fruit is a schizocarp, globular, yellow in colour with brown ribs. The size of the seed is about 3 mm in diameter and ripe seeds are aromatic. At dehiscence, the 2 carpels called mericarps separate, each containing a single seed with a copious endosperm and a minute embryo (Farooqi *et al*., 2004) [2].

Sulphur deficiency has been aggravated in soils due to continuous crop removal under intensive cropping system and use of sulphur free high analysis NPK fertilizers. Sulphur which has now emerged as the third most important plant nutrient for crop plays a multiple role in nutrition. It helps in chlorophyll formation and also a constituent of amino acids like cysteine, cysteine and methionine. Sulphur is also responsible for synthesis of certain vitamins (biotin and thiamine), proteins, fats and metabolism of carbohydrates (Tondon, 1991) [14]. Sulphur is essential for production of protein, fats and oils, promotes enzyme activity and helps in chlorophyll formation, improves root growth and grain filling resulting in vigorous plant growth and resistance to cold. Its deficiency causes interveinal chlorosis with a very distinct reddish color of the veins and petioles (Shanyn and Lucy, 1999) [10].

Zinc plays an important role as a constituent of alcohol dehydrogenase and carbonic anhydrase in both microorganisms a higher plant. It helps the utilization of phosphorus and nitrogen in plants (Singh *et al*., 2002) [12]. Thus looking to the situation, there is an urgent need to augment supplies of customised fertilisers supplying secondary and micronutrients to sufficiently support, the integrated need of nutrient in coriander production. Considering the above facts, the studies on effect of different levels of sulphur and zinc on growth, yield and quality of coriander was undertaken.

Materials and Methods

The experiment was laid out at the "Horticulture Research Field of the Department of Plantation, Spices, Medicinal and Aromatic Crops", College of Horticulture, RVSKVV, Mandsaur (M.P.) during *Rabi* season of 2017-18. The soil of the experimental field was light black loamy in texture with low nitrogen (192 kg/ha), low phosphorus (7.6 kg/ha), medium potassium (145.0 kg/ha) soil having (pH 8.36) and EC (0.18 dS/m). The field experiment comprising 16 treatment combinations with three replication was laid out in factorial randomized block design with two factors. The experiment consisted of four levels of sulphur (0, 15, 30 and 45 kg S/ha) and four levels of zinc (0, 2, 4 and 6 kg Zn/ha). The crop variety RCr-436 were sown in spacing 30x10 cm with seed rate of 15 kg/ha. Uniform dose of nitrogen (40 kg/ha) through urea and phosphorus (30 kg/ha), potassium (20 kg/ha) as per treatments through MOP, DAP and soil application of zinc and sulphur. Data was statistically analyzed using the method of analysis of variance as described by Panse and Sukhatme (1985) [7].

Leaf area index (LAI):

$$LAI = \frac{\text{Total leaf area}}{\text{Land area}}$$

$$LAI = \frac{(LA_2 + LA_1)}{2P}$$

Where , the LA_1 and LA_2 represent the leaf area during two consecutive intervals and 'P' unit ground area (Watson, 1974) [15].

Leaf area duration (LAD)

$$LAD = \frac{(LA_2 + LA_1)}{2} \times (t_2 - t_1)\ (cm^2\ day^{-1})$$

Where, LA_1 and LA_2 represent the leaf area at two successive time intervals (t_1 and t_2) (Watson, 1952) [15].

Specific leaf area (SLA):

$$SLA = \frac{(LA_2 / LW_2 + LA_1 / LW_1)}{2}\ (cm^2\ g^{-1})$$

Crop growth rate (CGR)

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}\ (g\ cm^{-2}\ \text{of ground area}\ day^{-1})$$

Where, W_1 and W_2 are the dry weight of the plants at time t_1 and t_2 and P is land area.

Relative growth rate (RGR)

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}\ (g\ g^{-1}\ day^{1})$$

Where, $\log_e W_1$ and $\log_e W_2$ are the natural logs of dry weight at time t_1 and t_2.

Results and Discussion

Effect of sulphur

The increasing levels of sulphur significantly influenced the growth, yield and quality attributes of coriander. In growth attributes progressive increase in sulphur at 45 kg ha^{-1} significantly recorded higher leaf area index (0.887, 2.753 and 3.178), leaf area duration (79.91, 247.73 and 344.01 $cm^2\ day^{-1}$), specific leaf area (219.89, 160.79 and 156.38 $cm^2\ g^{-1}$), crop growth rate (0.501, 0.110 and 0.136 $g\ cm^{-2}\ day^{-1}$) and relative growth rate (0.090, 0.037 and 0.043 $g\ g^{-1}\ day^{-1}$) at 30-60 DAS, 60-90 DAS and 90 DAS-at harvest growth over the control. In yield attributes progressive increase in sulphur levels at 45 kg ha^{-1} significantly recorded maximum number seeds $umbel^{-1}$ (39.71), biological yield (40.35 q/ha), seed yield (16.93 q/ha) and seed index (1.29 g) over the control. In quality attributes progressive increase in sulphur levels at 45 kg ha^{-1} significantly recorded maximum chlorophyll content (SPAD) (33.42, 44.43, 25.88 and 1.49) at 30, 60, 90 DAS and at harvest, essential oil content in seed (0.43%) and dry matter content in seed (88.64%) over control. The increase in these growth attributing characters might be due to the important role in sulphur in energy transformation, activation of number of enzymes and also in carbohydrate metabolism, supply of sulphur in adequate and appropriate amount helps in flower primordial initiation for its reproductive part, The favorable influence of applied sulphur on these growth parameters may be ascribed to catalystic or stimulatory effect of sulphur on most of the physiological and metabolic processes of the plant at successive growth stages due to adequate availability, mobilization and influx into the plant tissue owing to increased sulphur application (Balai, 2005) [1]. Sulphur also plays an important role in lowering the soil pH where most of the nutrients in soil remains in range of availability. Similar findings were also reported by (Patel *et al.*, 2013) [9] and (Kumawat *et al.*, 2009) [5].

Effect of zinc

Growth attributes progressive increase in zinc levels at 6 kg ha^{-1} significantly recorded higher leaf area index (0.803, 2.587 and 3.052), leaf area duration (71.97, 232.84 and 326.55 $cm^2\ day^{-1}$), specific leaf area (197.27, 161.15, and 158.58 $cm^2\ g^{-1}$), crop growth rate (0.471, 0.098, and 0.120 $g\ cm^{-2}\ day^{-1}$) and relative growth rate (0.088, 0.034 and 0.037 $g\ g^{-1}\ day^{-1}$) at 30-60 DAS, 60-90 DAS and 90 DAS-at harvest growth over control. In yield attributes progressive increase in zinc levels at 6 kg ha^{-1} significantly recorded maximum number seeds $umbel^{-1}$, (39.55) biological yield, (41.43 q/ha), seed yield (17.19 q/ha) and seed index (1.26 g) over control. In quality attributes progressive increase in zinc levels at 6 kg ha^{-1} significantly recorded maximum chlorophyll content (SPAD Value) (32.28, 42.41, 24.53 and 1.43) at 30, 60, 90 DAS and at harvest, essential oil content in seed (0.39%) and dry matter content in seed (86.80%) over control. Zinc has been suggested to play a role in regulating the auxin concentration in plant and also in the synthesis of nucleic acid and protein. It helps the utilization of phosphorus and nitrogen in plants (Singh *et al.*, 2002) [12]. The positive effect of zinc with respect to plant vegetative growth and yield with its attributes is due to the fact that zinc favors the enzyme system, auxin and protein synthesis and seed production directly or indirectly (Sharma *et al.*, 1999) [11]. (Khattab and Umer, 1999) [4] in fennel and (Pariari *et al.*, 2009) [8] in fenugreek also recorded and increased plant growth and yield with zinc application.

Interaction of sulphur and zinc

The combined effect both nutrients S_3Z_3 were significantly influenced maximum leaf area index (1.210, 3.394 and 3.749) at all stages of growth attributes compared to control S_0Z_0. Maximum leaf area duration significantly influenced (108.99, 305.50 and 397.48 cm^2 day^{-1}) at 30-60 DAS, 60-90 DAS except 90 DAS - at harvest increased at higher dose of sulphur ad zinc compared to control S_0Z_0. Maximum specific leaf area significantly influenced on soil application of sulphur and zinc levels (239.74, 172.41 and 165.77 cm^2 g^{-1}) at 30-60 DAS, 60-90 DAS except 90 DAS - at harvest compared to control S_0Z_0. Maximum crop growth rate significantly influenced on soil application of sulphur and zinc levels (0.589 and, 0.137 and 0.171 g cm^{-2} day^{-1}) at 30-60 DAS except 60-90 DAS and 90 DAS - at harvest compared to control S_0Z_0. Maximum relative growth rate non-significantly influenced on soil application of sulphur and zinc levels (0.096, 0.046 and 0.048 g g^{-1} day^{-1}) at all stages of growth compared to control S_0Z_0. Combined effect of sulphur and zinc levels showed significantly influenced on yield attributes of Coriander. Due to sulphur and zinc levels in combination and maximum number seeds $umbel^{-1}$, (42.94) biological yield, (44.96 q/ha) seed yield (19.59 q/ha) and seed index (1.40 g) was recorded under S_3Z_3 treatment combination compared to control S_0Z_0. Combined effect of sulphur and zinc levels showed significantly influenced on quality attributes of Coriander. however non- significantly influenced on SPAD value (36 and 1.56) at 30 DAS and at harvest. Due to sulphur and zinc levels in combination maximum chlorophyll content (SPAD Value) (47.15 and 27.32) at 60 and 90 DAS, essential oil content in seed (0.47%) and dry matter content in seed (91.33%) was recorded under treatment combination S_3Z_3 compared to control S_0Z_0.The positive influence of soil 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 play vital role in various biochemical processes (Hussain *et al*., 2006) [3]. The increase in yield may be attributed to increased plant height, maximum number of branches, maximum number umbellets which was positively affected by the application of micronutrients. Also reported that yield attributes, seed and oil yield and oil content were all enhanced by the application of N, S and Zn fertilizers (Manure *et al.*, 2000) [6].

Table 1: Effect of different levels sulphur and zinc on growth attributes of coriander

Treatments	Leaf area index			Leaf area duration			Specific leaf area		
	30-60 DAS	60-90 DAS	90 DAS- at harvest	30-60 DAS	60-90 DAS	90 DAS- at harvest	30-60 DAS	60-90 DAS	90 DAS- at harvest
Sulphur									
S_0	0.424	1.740	2.257	37.91	156.58	240.30	143.46	137.39	145.16
S_1	0.533	2.012	2.533	47.93	181.05	274.52	151.77	148.22	151.05
S_2	0.691	2.336	2.762	62.43	210.27	295.40	189.26	153.21	154.38
S_3	0.887	2.753	3.178	79.91	247.73	344.01	219.89	160.79	156.38
S.Em ±	0.024	0.044	0.047	2.59	4.58	8.57	2.61	0.64	2.25
CD at 5%	0.071	0.128	0.135	7.47	13.22	24.76	7.54	1.85	6.49
Zinc									
Z_0	0.474	1.834	2.299	42.75	165.03	248.16	150.70	136.91	141.24
Z_1	0.586	2.106	2.575	53.06	189.55	278.83	172.21	146.58	150.78
Z_2	0.672	2.314	2.805	60.40	208.20	300.70	184.20	154.97	156.37
Z_3	0.803	2.587	3.052	71.97	232.84	326.55	197.27	161.15	158.58
S.Em ±	0.024	0.044	0.047	2.59	4.58	8.57	2.61	0.64	2.25
CD at 5%	0.071	0.128	0.135	7.47	13.22	24.76	7.54	1.85	6.49
Interaction									
S_0Z_0	0.313	1.432	1.917	28.33	128.84	201.29	123.38	126.39	136.45
S_0Z_1	0.432	1.727	2.215	38.85	155.37	243.08	141.47	134.57	144.42
S_0Z_2	0.448	1.839	2.393	40.31	165.49	251.53	150.74	140.47	148.42
S_0Z_3	0.503	1.963	2.505	44.13	176.62	265.30	158.24	148.13	151.33
S_1Z_0	0.421	1.717	2.223	37.88	154.52	245.61	139.39	135.87	142.58
S_1Z_1	0.533	1.996	2.497	47.98	179.64	268.44	148.47	146.40	150.62
S_1Z_2	0.569	2.119	2.664	51.20	190.68	282.55	154.36	152.01	154.64
S_1Z_3	0.607	2.215	2.747	54.65	199.34	301.48	164.85	158.60	156.35
S_2Z_0	0.516	2.016	2.487	46.44	181.40	260.88	160.28	141.27	145.50
S_2Z_1	0.627	2.185	2.571	57.45	196.69	276.76	173.30	145.74	152.61
S_2Z_2	0.730	2.367	2.784	65.73	213.07	302.05	197.20	160.39	158.53
S_2Z_3	0.890	2.777	3.208	80.10	249.90	341.92	226.27	165.46	160.86
S_3Z_0	0.648	2.171	2.569	58.34	195.36	284.86	179.74	144.10	140.42
S_3Z_1	0.751	2.516	3.016	67.95	226.48	327.02	225.61	159.61	155.47
S_3Z_2	0.940	2.929	3.379	84.34	263.58	366.66	234.49	167.03	163.87
S_3Z_3	1.210	3.394	3.749	108.99	305.50	397.48	239.74	172.41	165.77
S.Em ±	0.049	0.089	0.094	5.17	9.15	17.15	5.22	1.28	4.50
CD at 5%	0.141	0.256	0.271	14.95	26.44	NS	15.09	3.70	NS

Table 2: Effect of different levels sulphur and zinc on growth attributes of coriander

Treatments	Crop growth rate			Relative growth rate		
	30-60 DAS	60-90 DAS	90 DAS- at harvest	30-60 DAS	60-90 DAS	90 DAS- at harvest
Sulphur						
S_0	0.285	0.060	0.067	0.071	0.019	0.021
S_1	0.364	0.070	0.080	0.079	0.024	0.029
S_2	0.432	0.086	0.099	0.085	0.029	0.033
S_3	0.501	0.110	0.136	0.090	0.037	0.043
S.Em ±	0.001	0.009	0.013	0.0004	0.003	0.003
CD at 5%	0.003	0.026	0.037	0.001	0.008	0.010
Zinc						
Z_0	0.310	0.061	0.065	0.074	0.019	0.023
Z_1	0.379	0.080	0.084	0.080	0.027	0.029
Z_2	0.423	0.087	0.112	0.084	0.030	0.035
Z_3	0.471	0.098	0.120	0.088	0.034	0.037
S.Em ±	0.001	0.009	0.013	0.0004	0.003	0.003
CD at 5%	0.003	0.03	0.04	0.001	0.008	0.010
Interaction						
S_0Z_0	0.225	0.048	0.055	0.064	0.012	0.019
S_0Z_1	0.269	0.062	0.064	0.069	0.020	0.021
S_0Z_2	0.298	0.064	0.072	0.073	0.022	0.022
S_0Z_3	0.349	0.067	0.078	0.078	0.023	0.022
S_1Z_0	0.281	0.062	0.061	0.071	0.020	0.020
S_1Z_1	0.353	0.070	0.068	0.079	0.024	0.023
S_1Z_2	0.388	0.073	0.085	0.082	0.025	0.035
S_1Z_3	0.432	0.074	0.104	0.085	0.026	0.038
S_2Z_0	0.340	0.065	0.069	0.077	0.022	0.023
S_2Z_1	0.410	0.081	0.073	0.084	0.026	0.030
S_2Z_2	0.464	0.083	0.125	0.088	0.029	0.043
S_2Z_3	0.513	0.112	0.128	0.091	0.040	0.037
S_3Z_0	0.392	0.068	0.076	0.082	0.024	0.032
S_3Z_1	0.484	0.106	0.131	0.089	0.037	0.043
S_3Z_2	0.540	0.127	0.166	0.093	0.042	0.047
S_3Z_3	0.589	0.137	0.171	0.096	0.046	0.048
S.Em ±	0.002	0.018	0.026	0.001	0.006	0.007
CD at 5%	0.01	NS	NS	NS	NS	NS

Table 3: Effect of different levels sulphur and zinc on yield and quality attributes of coriander

Treatments	Yield and Quality attributes						SPAD value		Essential oil content (%)	Dry matter content (%)
	Seeds/ umbel	Biological yield q/ha	Seed yield q/ha	Seed index (g)	SPAD 30 DAS	SPAD 60 DAS	90 DAS	at harvest		
Sulphur										
S_0	35.16	35.41	14.19	1.08	27.65	36.79	19.63	1.25	0.28	82.25
S_1	36.99	37.15	15.06	1.11	29.49	39.20	22.43	1.31	0.33	83.98
S_2	38.05	39.40	16.06	1.23	31.49	40.96	24.13	1.43	0.38	85.62
S_3	39.71	40.35	16.93	1.29	33.42	44.43	25.88	1.49	0.43	88.64
S.Em ±	0.23	0.24	0.19	0.01	0.44	0.23	0.08	0.01	0.00	0.28
CD at 5%	0.67	0.68	0.55	0.03	1.26	0.68	0.23	0.03	0.01	0.81
Zinc										
Z_0	34.97	34.21	13.81	1.10	28.85	37.60	21.08	1.29	0.32	83.07
Z_1	36.96	37.51	15.25	1.16	29.97	40.04	22.79	1.36	0.35	85.11
Z_2	38.44	39.16	15.99	1.20	30.95	41.34	23.68	1.39	0.37	85.51
Z_3	39.55	41.43	17.19	1.26	32.28	42.41	24.53	1.43	0.39	86.80
S.Em ±	0.23	0.24	0.19	0.01	0.44	0.23	0.08	0.01	0.00	0.28
CD at 5%	0.67	0.68	0.55	0.03	1.26	0.68	0.23	0.03	0.01	0.81
Interaction										
S_0Z_0	31.83	31.06	12.28	1.04	25.74	34.89	17.67	1.20	0.26	80.15
S_0Z_1	35.53	36.16	14.50	1.07	27.54	36.67	19.24	1.23	0.27	82.72
S_0Z_2	36.27	36.34	14.63	1.09	28.47	37.33	20.05	1.25	0.29	82.94
S_0Z_3	37.00	38.06	15.37	1.12	28.86	38.28	21.57	1.30	0.30	83.17
S_1Z_0	35.57	32.93	13.23	1.08	27.73	36.88	20.00	1.26	0.29	82.64
S_1Z_1	37.12	37.78	15.32	1.10	29.38	38.45	22.20	1.31	0.32	83.93
S_1Z_2	37.35	38.76	15.74	1.12	29.92	40.32	23.40	1.33	0.34	84.21
S_1Z_3	37.93	39.12	15.97	1.15	30.94	41.13	24.13	1.35	0.36	85.15
S_2Z_0	35.67	36.44	14.79	1.11	30.55	38.53	22.93	1.32	0.35	84.56
S_2Z_1	37.23	37.09	15.07	1.21	30.65	40.07	23.94	1.41	0.38	85.02
S_2Z_2	39.00	40.52	16.54	1.25	31.42	42.19	24.55	1.45	0.40	85.37

S_2Z_3	40.32	43.57	17.84	1.35	33.33	43.07	25.10	1.52	0.42	87.54
S_3Z_0	36.80	36.41	14.96	1.17	31.37	40.10	23.73	1.39	0.37	84.94
S_3Z_1	37.97	39.02	16.12	1.28	32.31	44.98	25.77	1.47	0.44	88.75
S_3Z_2	41.14	41.02	17.05	1.31	34.00	45.50	26.70	1.53	0.45	89.52
S_3Z_3	42.94	44.96	19.59	1.40	36.00	47.15	27.32	1.56	0.47	91.33
S.Em ±	0.46	0.47	0.38	0.02	0.87	0.47	0.16	0.02	0.01	0.56
CD at 5%	1.34	1.37	1.10	0.06	NS	1.35	0.45	NS	0.02	1.62

Conclusion

On the basis of one year research It could be concluded that application of sulphur and zinc influence the growth, yield and quality of coriander can be increased by application of S_3Z_3 (45 Kg S/ha + 6 Kg Zn/ha) should be advocated for coriander seed production.

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