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# Biofortification of Coriander (*Corianderum sativum*) Variety with Sulphur and Zinc for Higher Productivity

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**The present study was aimed to examine the effect of two varieties (RCr-436 and RCr-435), four levels of sulphur (0, 20, 40 and 60 kg S/ha) and four levels of zinc (0, 2.5, 5.0 and 7.5 kg Zn/ha) making 32 treatment combination under split plot design with three replications. Results showed that significantly increased dry matter accumulation and seed (1409 kg/ha), stover yield, nitrogen, sulphur, zinc concentration, essential oil content, oil yield, protein content and net returns (Rs 39396/ha) were obtained with coriander variety RCr-436 as compared to vareity RCr-435. Whereas, coriander varieties RCr-435 recorded significantly higher plant height as compared to RCr-436. The variety RCr-436 recorded 13.1 and 24.2% higher seed yield and net returns as compared to RCr-435. Sulphur application at 40 kg/ha increased significantly higher plant height, dry matter accumulation, seed (1406 kg/ha), stover yield, nitrogen, sulphur, zinc concentration, essential oil content, oil yield and protein content and net returns Rs 39175/ha over control and 20 kg S/ha. The sulphur at 40 kg/ha registered 20.8 and 7.5% higher seed yield and 39.0 and 12.7% more net returns over control and 20 kg/ha, respectively. Significantly increased higher plant height, dry matter accumulation, seed (1436 kg/ha), stover yield, nitrogen, sulphur, zinc concentration, essential oil content, oil yield, protein content and net returns( Rs 39309/ha) were obtained with 5.0 kg Zn/ha over control and 2.5 kg Zn/ha. Zinc application @5.0 kg/ha recorded significantly more seed yield by 30.3 and 10.5 % and net returns by 35.2 and 10.4 %, respectively.**

**Keywords:** Biofortification, Sulphur, Zinc and Productivity.

Coriander (*Coriandrum sativum* L.) popularly known as "dhania" is one of the oldest seed spice used by the mankind. It is the most widely used condiment throughout the world. It is mainly grown for its aromatic and fragrant seed which is botanically a cremocarpic fruit. The fresh green stem, leaves and fruits of coriander have a pleasant aromatic odour. The pleasant aroma in the plant is due to an essential oil called "coriandrol" range from 0.1 to 1.3 per cent in dry seeds. The oil of coriander seeds is a valuable ingredient in perfumes, cosmetic products, soup, candy, cocoa, chocolate, meat products, soft drinks and alcoholic beverages. Good quality oleoresin can be extracted from coriander seed which is used for flavouring beverages, sweets pickles, sausages, shacks, etc coriander bark oil has high germicidal activity and can be used as fungicides (Krishna, 1999). The entire young plant is used for flavouring curried dishes of all sorts and chutney. Coriander leaves are also rich source of vitamin C (125-250 mg/100 g) and vitamin A (5200 IU/100g). In medicines, its seed is used as a carminative, refrigerant and diuretic. The dry seeds of coriander contain 0.3 per cent essential oil, 19.6 per cent non-volatile oil, 24 per cent carbohydrates, 5.3 per cent mineral matter and 175 IU/100 vitamin A. Recently 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

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for crop plays a multiple role in nutrition. It helps in chlorophyll formation and also a constituent of amino acids like cystine, cysteine and methionine. Sulphur is also responsible for synthesis of certain vitamins (biotin and thiamine), proteins, fats and metabolism of carbohydrates (Tondon, 1991). Zinc is most deficient among all the micronutrients in Indian soils. In many parts of India, zinc as a plant nutrients now stands third in importance next to nitrogen and phosphorus (Takkar and Randhawa, 1980). It is a constituent of several enzyme systems which regulates various metabolic reactions in plant, for example oxidation reduction reactions in the formation of chlorophyll etc. It acts as an activator of dehydrogenase and proteinage enzymes directly or indirectly in the synthesis of carbohydrates and protein. Therefore, the present investigation carried out to study the effect of sulphur and zinc on yield, nutrient uptake and quality of coriander varieties.

## MATERIALS AND METHODS

The two year field experiment comprising 32 treatment combinations replicated three times, was laid out in split split design with two varieties ( RCr-435 and RCr-436) and four levels of sulphur (0, 20, 40 and 60 kg/ha) in main plots and four level of zinc (0, 2.5, 5.0 and 7.5 kg/ha) in sub plots. It was conducted at S.K.N. College of Agriculture, Jobner (Rajasthan) during *rabi* seasons of 2012-13 and 2013-14 situated at latitude of $27^0$ 05' N, longitude of $75^0$ 28' E and at an altitude of 427 m above mean sea level. The soil of experimental field was loamy sand, low in organic carbon (0.18%), available N (128.4 kg/ha), phosphorus (17.18 kg/ha), zinc (0.43 ppm) and medium in potassium (173.40 kg/ha) with alkaline (pH 8.4) in reaction having 1.60 $Mg/m^3$ bulk density, 2.63 $Mg/m^3$ particle density, 11.95% field capacity and 42.35% porosity at the beginning of the experiment. The crop variety RCr-436 and RCr-435 were sown in rows 30 cm apart with seed rate of 12 kg/ha. Uniform dose of nitrogen (60 kg/ha) through urea and phosphorus (40 kg/ha), potassium (20 kg/ha) and soil application of zinc and sulphur as per treatments through MOP, DAP, zinc chloride and gypsum, respectively were drilled at the time of sowing. During the crop season need based cultural and plant protection operations were taken up to harvest good crop during both the years of experimentation. Five random plants were selected from each plot for taking observations on yield attributes and for yield, the net plots were harvested. Nutrient uptake was calculated using following expression: uptake of N/S/Zn (kg/ha) = per cent N/S/Zn in seed x seed yield (kg/ha) + per cent N/S/Zn in stover x stover yield (kg/ha) / 100. To ascertain the economic feasibility of different treatments, economics of treatments was worked out on the basis of prevailing market prices of inputs and outputs and expressed in terms of net profit per hectare so that most remunerative treatment could be recommended. Regular analysis of variance was performed for each trait for both the seasons and the pooled analysis over seasons after testing error variance homogeneity was carried out according to the procedure outlined by (Gomez and Gomez, 1984).

## RESULTS AND DISCUSSION

### Growth and yield parameters

#### Effect of variety

Coriander variety RCr-435 recorded significantly higher plant height at 60, 90 DAS and at harvest over variety RCr-435 during both years of experimentation and in pooled data (Table 1). The percent increase in plant height was 11.1, 7.4 and 7.5% respectively, over RCr-436 on pooled mean basis. Variety RCr-436 recorded significantly increased dry matter accumulation at 30, 60, 90 DAS and at harvest during both the years and in pooled data over RCr-435. The variety RCr-436 indicated an increase of 16.6, 11.7, 12.2 and 13.1% respectively over RCr-435. It is an established fact that growth, development and yield potential of crop/variety is an outcome of genomic, environmental and agronomic interaction. Since, both the varieties were grown under identical agronomic (management) practices and environmental condition, the observed variation in overall growth of varieties seems to be due to their genetic milieu. The improvement in these growth parameters might be due to more interception and absorption of radiant energy, resulting into greater photosynthesis and finally dry matter accumulation. The better growth and development of RCr-436 compared to many other varieties and local checks were reported by Balai and Keshwa (2010) in coriander. The variety of

**Table 1.** Effect of variety, sulphur and zinc fertilization on yield attributes and yield of coriander

| | Umbels/plant | | | Umbellets/umbel | | | Seeds/umbel | | | Test weight (g) | | | Seed yield (kg/ha) | | | Stover yield (kg/ha) | | | Biological yield (kg/ha) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled |
| | 20.27 | 18.50 | 19.38 | 5.41 | 4.89 | 5.15 | 24.85 | 24.41 | 24.63 | 9.81 | 9.92 | 9.87 | 1298 | 1193 | 1245 | 1960 | 1845 | 1902 | 3258 | 3038 | 3148 | 39.77 | 39.18 | 39.48 |
| | 22.07 | 20.21 | 21.14 | 5.88 | 5.30 | 5.59 | 27.58 | 26.79 | 27.19 | 10.07 | 10.16 | 10.11 | 1465 | 1352 | 1409 | 2107 | 2015 | 2061 | 3572 | 3367 | 3469 | 40.94 | 40.09 | 40.52 |
| | 0.23 | 0.25 | 0.17 | 0.06 | 0.06 | 0.04 | 0.33 | 0.34 | 0.23 | 0.12 | 0.12 | 0.08 | 17 | 15 | 11 | 25 | 23 | 17 | 44 | 41 | 30 | 0.51 | 0.54 | 0.37 |
| | 0.71 | 0.75 | 0.52 | 0.19 | 0.21 | 0.14 | 0.99 | 1.02 | 0.72 | NS | NS | NS | 53 | 45 | 35 | 75 | 71 | 52 | 135 | 125 | 94 | NS | NS | NS |
| els (kg/ha) | | | | | | | | | | | | | | | | | | | | | | | | |
| | 18.32 | 16.69 | 17.51 | 4.96 | 4.48 | 4.72 | 22.73 | 22.42 | 22.58 | 9.56 | 9.67 | 9.62 | 1210 | 1118 | 1164 | 1831 | 1731 | 1781 | 3041 | 2850 | 2945 | 39.73 | 39.16 | 39.45 |
| | 20.86 | 19.05 | 19.95 | 5.59 | 5.03 | 5.31 | 25.89 | 25.28 | 25.59 | 9.90 | 9.96 | 9.93 | 1362 | 1254 | 1308 | 2007 | 1897 | 1952 | 3369 | 3152 | 3260 | 40.36 | 39.72 | 40.04 |
| | 22.52 | 20.63 | 21.58 | 5.94 | 5.40 | 5.67 | 27.88 | 27.06 | 27.47 | 10.10 | 10.23 | 10.17 | 1464 | 1347 | 1406 | 2132 | 2018 | 2075 | 3597 | 3365 | 3481 | 40.63 | 39.96 | 40.30 |
| | 22.97 | 21.04 | 22.01 | 6.09 | 5.48 | 5.79 | 28.36 | 27.65 | 28.00 | 10.19 | 10.30 | 10.25 | 1489 | 1370 | 1430 | 2162 | 2074 | 2118 | 3652 | 3444 | 3548 | 40.71 | 39.71 | 40.21 |
| | 0.33 | 0.35 | 0.24 | 0.09 | 0.09 | 0.06 | 0.46 | 0.48 | 0.33 | 0.17 | 0.17 | 0.12 | 25 | 21 | 16.08 | 35 | 34 | 25 | 63 | 58 | 43 | 0.71 | 0.76 | 0.52 |
| | 1.01 | 1.06 | 0.74 | 0.26 | 0.27 | 0.19 | 1.39 | 1.44 | 1.02 | 0.51 | 0.51 | 0.37 | 74 | 63 | 50 | 106 | 100 | 74 | 191 | 177 | 132 | NS | NS | NS |
| | 7.67 | 8.81 | 9.09 | 7.53 | 8.66 | 8.81 | 8.59 | 9.09 | 8.66 | 8.33 | 8.28 | 8.31 | 8.7 | 8.0 | 8.39 | 8.35 | 8.41 | 8.38 | 9.05 | 8.94 | 8.99 | 8.72 | 9.44 | 9.02 |
| (kg/ha) | | | | | | | | | | | | | | | | | | | | | | | | |
| | 18.00 | 16.50 | 17.25 | 4.72 | 4.29 | 4.51 | 22.32 | 21.97 | 22.15 | 9.42 | 9.63 | 9.53 | 1156 | 1048 | 1102 | 1759 | 1657 | 1708 | 2915 | 2705 | 2810 | 39.60 | 38.70 | 39.15 |
| | 20.77 | 18.97 | 19.87 | 5.57 | 5.01 | 5.29 | 25.78 | 25.27 | 25.53 | 9.90 | 10.07 | 9.99 | 1351 | 1246 | 1299 | 1994 | 1892 | 1943 | 3345 | 3138 | 3242 | 40.33 | 39.67 | 40.00 |
| | 22.66 | 20.74 | 21.70 | 6.09 | 5.48 | 5.79 | 28.07 | 27.47 | 27.77 | 10.17 | 10.20 | 10.19 | 1490 | 1381 | 1436 | 2168 | 2056 | 2112 | 3658 | 3437 | 3548 | 40.68 | 40.14 | 40.41 |
| | 23.24 | 21.21 | 22.23 | 6.21 | 5.61 | 5.91 | 28.69 | 27.70 | 28.20 | 10.26 | 10.26 | 10.26 | 1529 | 1415 | 1472 | 2212 | 2115 | 2164 | 3741 | 3530 | 3636 | 40.82 | 40.04 | 40.43 |
| | 0.30 | 0.31 | 0.22 | 0.08 | 0.09 | 0.06 | 0.39 | 0.40 | 0.28 | 0.13 | 0.13 | 0.09 | 23 | 19 | 15.40 | 33 | 32 | 23 | 53 | 53 | 38 | 0.64 | 0.66 | 0.46 |
| | 0.87 | 0.89 | 0.61 | 0.24 | 0.25 | 0.17 | 1.11 | 1.14 | 0.78 | 0.37 | 0.37 | 0.26 | 67 | 55 | 43 | 99 | 93 | 67 | 150 | 151 | 105 | NS | NS | NS |
| | 7.05 | 7.91 | 7.66 | 7.18 | 8.54 | 7.90 | 7.29 | 7.66 | 8.54 | 6.34 | 6.27 | 6.33 | 8.33 | 7.42 | 8.03 | 8.44 | 8.29 | 8.33 | 7.63 | 8.10 | 7.85 | 7.70 | 8.12 | 7.95 |

RCr-436 produced significantly higher seed (1409 kg/ha), stover (2061 kg/ha) yield during both the years of experimentation and in pooled analysis and registered an increase of 13.1 and 8.3 % higher seed and stover yield over RCr-435, respectively. Since coriander yield formation is a complex process and governed by interaction between source (photosynthesis and availability of assimilates in leaves etc.) and sink component storage organs. Balai and Keshwa (2010) in coriander.

**Effect of sulphur**

Significant increase in growth of coriander was observed due to the application of sulphur upto 40 kg/ha with respect to plant height at 60, 90 DAS during both the years and in pooled mean data (Table 1). The percent increase due to 40 kg S/ha was to the extent of 18.3 and 6.5 at 60 DAS, 14.0 and 4.7 at 90 DAS, 20.0 and 6.7 % at harvest over control and 20 kg S/ha, respectively. Application of 40 kg S/ha significantly increased the dry matter accumulation over control at 30 DAS during both the years. On the basis of pooled mean, the treatment 20 kg S/ha showed its superiority over control enhancing the dry matter accumulation by 4.13%. The percent increase brought about by 40 kg S/ha on pooled basis was 18.2 and 6.8 at 60 DAS, 18.4 and 6.9 at 90 DAS, 23.7 and 9.1% at harvest over control and 20 kg S/ha, respectively. It may be attributed to the fact that application of sulphur improved not only availability of sulphur but other nutrients also which are considered vitally important for growth and development of plants. The application of sulphur through gypsum which contains sulphur in readily available form ($SO_4^{-2}$-S), enhanced the concentration of sulphur in soil solution for plants absorption. Besides, it also reduced the soil pH which was responsible for greater availability and mobility of nutrients. Similar findings were also observed by Nawange *et al.* (2011). Application of sulphur upto 40 kg/ha significantly increased seed (1406 kg/ha), stover (2075 kg/ha) and biological (3481 kg/ha) yields of coriander during both the years and in pooled data. The percent increase due to 40 kg S/ha was recorded to the tune of 20.8, 7.5%, 16.5, 6.3% and 18.2, 6.8% over control and 20 kg S/ha, respectively. The seed, stover and biological yields primarily being a function of cumulative response of growth and yield attributing characters increased remarkably with increase in sulphur levels (Patel *et al.,* 2013).

**Effect of zinc**

The plant height was remained unaffected significantly with zinc application at 30 DAS, however, at 60 DAS and at harvest during both the years and in pooled data and at 90 DAS in pooled data plant height increased significantly upto 5.0 kg Zn/ha. The plant height increased significantly only upto 2.5 kg Zn/ha at 90 DAS during individual years of experimentation (Table 1). The per cent increase in plant height on pooled data basis with 5.0 kg Zn/ha was 16.8 and 6.1% at 60 DAS, 13.1 and 3.5 at 90 DAS and 21.4 and 6.3% at harvest over control and 2.5 kg/ha, respectively. Application of 5 kg Zn/ha significantly increased the dry matter accumulation over control at 30 DAS during 2012-13 as well as in pooled mean and increase in dry matter accumulation due to 5 kg Zn/ha over control was 3.88 % on pooled basis. However at 60, 90 DAS and at harvest, application of 5 kg Zn/ha significantly improved the dry matter accumulation over control and 2.5 kg Zn/ha during both the years and in pooled analysis. The per cent improvement by 5 kg Zn/ha on pooled basis was 20.0 and 7.6 at 60 DAS, 25.6 and 9.4 at 90 DAS, 30.0 and 10.2% at harvest over control and 2.5 kg Zn/ha, respectively. The application of 5 kg Zn/ha significantly increased seed (1436 kg/ha) and stover yield of coriander during both the years as well as in pooled analysis and represented an increased seed by 30.3, 10.5% yield over control and 2.5 kg Zn/ha, respectively. The applied as well as native zinc helped to improve overall availability in the rhizosphere resulting into greater uptake by the plant consequently leading to a favourable stimulus effect on physiological and metabolic processes of the plant (Chauhan *et al.,* 2013). The favourable influence of applied zinc on these characters may be explained to its catalytic or stimulatory effect on most of the physiological and metabolic processes of plant. Application of zinc might have increased the availability and steady supply of nutrients for plant metabolism and photosynthetic activity resulting into optimum growth and development of the crop. In addition, zinc is important in the synthesis of tryptophan, a component of some proteins and a compound needed for production of growth hormones (auxins) like indol-acetic acid. Such improvement under

**Table 2.** Effect of variety, sulphur and zinc on total nutrient uptake, quality and net returns of coriander

| Treatments | Total N uptake(kg/ha) | | | Total S uptake(kg/ha) | | | Total Zn uptake(g/ha) | | | Protein content (%) | | | Essential oil content (%) | | | Oil yield (kg/ha) | | | Net returns (Rs/ha) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled | 2012-13 | 2013-14 | Pooled |
| Varieties | | | | | | | | | | | | | | | | | | | | | |
| RCr-435 | 61.98 | 55.41 | 58.70 | 5.96 | 5.70 | 5.83 | 416.89 | 356.28 | 386.59 | 19.72 | 18.97 | 19.34 | 0.356 | 0.329 | 0.343 | 4.65 | 3.96 | 4.30 | 34211 | 29235 | 31723 |
| RCr-436 | 70.86 | 63.17 | 67.02 | 6.73 | 6.45 | 6.59 | 463.54 | 402.08 | 432.81 | 20.41 | 19.34 | 19.88 | 0.372 | 0.343 | 0.357 | 5.49 | 4.66 | 5.08 | 42020 | 36772 | 39396 |
| SEm± | 0.68 | 0.76 | 0.51 | 0.08 | 0.09 | 0.06 | 5.70 | 5.78 | 4.06 | 0.27 | 0.28 | 0.19 | 0.004 | 0.003 | 0.002 | 0.07 | 0.07 | 0.05 | 496 | 516 | 358 |
| CD (P=0.05) | 2.07 | 2.31 | 1.58 | 0.24 | 0.26 | 0.18 | 17.28 | 17.53 | 12.50 | NS | NS | NS | 0.011 | 0.010 | 0.008 | 0.20 | 0.20 | 0.15 | 1506 | 1566 | 1104 |
| Sulphur levels (kg/ha) | | | | | | | | | | | | | | | | | | | | | |
| 0 | 54.87 | 48.70 | 51.79 | 4.85 | 4.51 | 4.68 | 377.89 | 322.90 | 350.39 | 18.39 | 17.30 | 17.84 | 0.334 | 0.305 | 0.320 | 4.06 | 3.42 | 3.74 | 30347 | 26007 | 28177 |
| 20 | 64.96 | 57.95 | 61.46 | 6.16 | 5.88 | 6.02 | 432.48 | 370.84 | 401.66 | 19.89 | 19.05 | 19.47 | 0.363 | 0.337 | 0.350 | 4.96 | 4.24 | 4.60 | 37310 | 32230 | 34770 |
| 40 | 71.93 | 64.37 | 68.15 | 7.03 | 6.78 | 6.90 | 470.66 | 405.57 | 438.11 | 20.83 | 20.05 | 20.44 | 0.377 | 0.349 | 0.363 | 5.54 | 4.72 | 5.13 | 41923 | 36428 | 39175 |
| 60 | 73.93 | 66.13 | 70.03 | 7.35 | 7.13 | 7.24 | 479.85 | 417.41 | 448.63 | 21.14 | 20.23 | 20.69 | 0.382 | 0.352 | 0.367 | 5.71 | 4.85 | 5.28 | 42882 | 37349 | 40116 |
| SEm± | 0.96 | 1.08 | 0.72 | 0.11 | 0.12 | 0.08 | 8.06 | 8.17 | 5.74 | 0.38 | 0.40 | 0.27 | 0.005 | 0.005 | 0.003 | 0.10 | 0.10 | 0.07 | 702 | 730 | 506 |
| CD (P=0.05) | 2.93 | 3.27 | 2.23 | 0.34 | 0.37 | 0.26 | 24.43 | 24.79 | 17.68 | 1.15 | 1.21 | 0.85 | 0.016 | 0.014 | 0.011 | 0.29 | 0.29 | 0.21 | 2129 | 2215 | 1561 |
| CV (%) | 7.12 | 8.92 | 8.11 | 8.72 | 9.96 | 9.41 | 8.96 | 10.56 | 9.81 | 9.24 | 10.21 | 9.69 | 7.18 | 6.60 | 6.93 | 9.19 | 10.80 | 10.08 | 9.0 | 10.8 | 9.86 |
| Zinc levels (kg/ha) | | | | | | | | | | | | | | | | | | | | | |
| 0 | 52.55 | 46.07 | 49.31 | 5.22 | 4.96 | 5.09 | 345.84 | 294.85 | 320.34 | 18.38 | 17.38 | 17.88 | 0.354 | 0.325 | 0.340 | 4.11 | 3.42 | 3.77 | 31601 | 26537 | 29069 |
| 2.5 | 64.33 | 57.62 | 60.97 | 6.18 | 5.92 | 6.05 | 425.14 | 365.55 | 395.35 | 19.88 | 19.06 | 19.47 | 0.362 | 0.334 | 0.348 | 4.92 | 4.18 | 4.55 | 38058 | 33129 | 35594 |
| 5.0 | 73.02 | 65.51 | 69.26 | 6.89 | 6.60 | 6.74 | 484.78 | 418.26 | 451.52 | 20.81 | 19.94 | 20.38 | 0.369 | 0.340 | 0.355 | 5.53 | 4.72 | 5.12 | 41874 | 36745 | 39309 |
| 7.5 | 75.80 | 67.96 | 71.88 | 7.10 | 6.82 | 6.96 | 505.12 | 438.06 | 471.59 | 21.19 | 20.25 | 20.72 | 0.372 | 0.345 | 0.359 | 5.72 | 4.91 | 5.31 | 40929 | 35605 | 38267 |
| SEm± | 0.89 | 0.92 | 0.64 | 0.09 | 0.09 | 0.06 | 5.58 | 5.64 | 3.97 | 0.26 | 0.27 | 0.19 | 0.005 | 0.004 | 0.003 | 0.08 | 0.08 | 0.05 | 619 | 602 | 432 |
| CD (P=0.05) | 2.54 | 2.62 | 1.80 | 0.25 | 0.25 | 0.18 | 15.88 | 16.02 | 11.13 | 0.75 | 0.78 | 0.53 | 0.014 | 0.011 | 0.009 | 0.22 | 0.22 | 0.15 | 1760 | 1711 | 1211 |
| CV (%) | 6.59 | 7.62 | 7.12 | 6.92 | 7.22 | 7.11 | 6.21 | 7.28 | 6.84 | 6.46 | 7.02 | 6.85 | 6.85 | 5.81 | 6.29 | 7.50 | 8.82 | 8.22 | 8.02 | 8.91 | 8.41 |

increased availability of zinc in rhizosphere might have resulted in greater uptake by the plant consequently leading to a favourable effect on various processes of plant. These favourable influences resulted into greater meristematic activities and apical growth, thereby improving plant height, branches/plant and dry matter accumulation/plant at all the stages. Zinc being an essential component of enzymes, responsible for assimilation of nitrogen, helps in the formation of chlorophyll. Zinc has been an instrumental in increased chlorophyll synthesis in plant leaves. The higher chlorophyll content and greater uptake of nutrients might have increased the process of photosynthesis and carbohydrate synthesis and its distribution to different plant parts especially to panicle. The results obtained in present investigation are in line*s* with the findings of Lal *et al.* (2014).

**Nutrient concentration**

**Effect of variety**

**C**oriander varieties failed to differ significantly in their nitrogen concentration in seed during 2014. However, variety RCr- 436 showed significantly higher nitrogen concentration in seed over RCr-435 during 2013 and pooled mean basis and registered an increase of 2.9% in seed on pooled basis. Nitrogen concentration in stover, sulphur and zinc concentration in seed and stover was not influenced due to varieties during both the years as well as in pooled mean basis (Table 2). The higher nitrogen concentration in RCr-436 may be due to its genetic milieu. Nutrient uptake is dependent on concentration and dry matter production, hence, inspite of marginal improvement in nutrient concentration. The results of the present investigation indicated differential behavior of coriander varieties with respect to nutrient concentration and quality is in close conformity with findings of other workers (Balai and keshwa, 2011).

**Effect of sulphur**

Application of 40 kg S/ha recorded significantly higher nitrogen and zinc concentration in seed over control and 20 kg S/ha during both the years and pooled analysis (Table 2). Enhancement in nitrogen concentration due to 40 kg S/ha over control and 20 kg S/ha was 14.3, 5.1and 10.6, 4.0% respectively on pooled basis. Whereas application of 60 kg S/ha significantly increased the sulphur concentration in seed over control, 20 and 40 kg S/ha during both the years and in pooled mean. In respect of stover, application of sulphur upto 40 kg/ha recorded significantly higher sulphur concentration during both the years of experimentation and in pooled analysis of data. On pooled basis, the magnitude of increase in sulphur concentration of seed due to 60 kg S/ha was 28.9, 11.3 and 4.2%, respectively over control, 20 and 40 kg/ha. The increases in stover with application of 40 kg S/ha was 23.7 and 7.1% over control and 20 kg, respectively in pooled mean data. Nitrogen and zinc concentration in stover was not influenced significantly due to sulphur fertilization during both the years of experimentation as well as on the basis of pooled analysis of data. The increased availability of nutrients in the root zone coupled with increased metabolic activity at the cellular level probably might have increased the uptake of nutrient and their accumulation in vegetative plant parts. Increased accumulation of nutrients specially N, Zn and S in vegetative plant parts concomitant with improved metabolism led to greater translocation of these nutrients to reproductive structures of the crop. Thus, N, Zn and S concentration in seed and stover increased significantly due to sulphur fertilization. Similar results of increased concentration of nutrients with sulphur application were also observed by Kumawat (2001).

**Effect of zinc**

Application of 5 kg Zn/ha recorded significantly higher nitrogen, sulphur and zinc concentration in seed over control and 2.5 kg Zn/ha during both the years of experimentation (Table 2). However, nitrogen and sulphur concentration in seed on the basis of pooled mean data significantly increased upto 7.5 kg Zn/ha. Enhancement in nitrogen concentration due to 7.5 kg Zn/ha over control, 2.5 and 5.0 kg/ha was 16.8, 6.4, 1.8 and 13.2, 6.7, and 2.0%, respectively on pooled basis in pooled analysis zinc application bring significant increase in sulphur concentration only upto 2.5 kg/ha that bring improvement of 2.8% over control. In respect of stover application of 5 kg Zn/ha recorded significantly higher zinc concentration over control and 2.5 kg Zn/ha during pooled. On pooled basis, the magnitude of increase due to 5 kg Zn/ha was 11.6 and 4.1% respectively over control and 2.5 kg Zn/ha in stover. Nitrogen, sulphur concentration in stover was not influenced significantly due to zinc fertilization during 2012-13 and 2013-14 as well as on basis of pooled mean of observed data over two years. Application of zinc to deficient soil increased the availability of zinc in rhizosphere at a level below where the optimum requirement of crop is fulfilled. The beneficial role of zinc in increasing CEC of roots helped in increasing absorption of nutrients from the soil. Further, the beneficial role of zinc in chlorophyll formation, regulating auxin concentration and its stimulatory effect on most of the physiological and metabolic processes of plant might have helped the plants to absorb greater amount of nutrients from the soil. Thus, the favourable effect of zinc on photosynthesis and metabolic processes augmented the production of photosynthates and their translocation to different plant parts including seed, which ultimately increased the concentration of nutrients in the seed. Similar results were also reported by Upadhay *et al.* (2012) in mustard.

**Quality**

**Effect of variety**

Variety RCr-436 showed significantly higher essential oil content in seed and oil yield of coriander over RCr-435 during both the years and in pooled analysis and represented an increase of 4.1% and oil yield by 18.1% as compared to RCr-435.

**Effect of sulphur**

Application of 20 kg S/ha estimated the highest oil content and remaind superior to control. However, on the basis of pooled mean, the treatment $S_{40}$ showed its superiority over $S_0$ and $S_{20}$ enhancing the oil content by 13.4 and 3.7%, respectively. Increasing levels of sulphur application upto 40 kg/ha significantly increased the oil yield during both the years of study and in pooled analysis of data. The percent increase in oil yield due to 40 kg S/ha was 37.2 and 11.5% in coriander over control and 20 kg S/ha respectively on pooled mean basis. This might be due to the fact that sulphur concentration in seeds increased under sulphur application, which has significant bearing on synthesis of oil and its participation in carbohydrate metabolism of plants. It is believed that in absence of sulphur, the carbohydrates are not fully utilized in the formation of oils. The protein content was significantly increased with application of 40 kg/ha over preceding levels and remained at par to 60 kg/ha. The per cent improvement was 14.6 and 5.0 with 40 kg S/ha over control and 20 kg/ha, respectively (Table 2). Nitrogen is the main ingredients of protein content in seed and increase in their availability increase the utilization of nitrogen for the synthesis of protein. Sulphur synthesized some sulphur containing amino acid like cystine, cysteine and methionine and resulted increase in protein content in seeds of coriander. The similar results have been reported by partap *et al.* (2003) in fennel.

**Effect of zinc**

The zinc application @ 5 kg/ha recorded significantly increased essential oil content over control and remained at par with 7.5 kg Zn/ha during both the years as well as in pooled analysis. The enhanced in oil content brought about by 5 kg Zn/ha over control was to the tune of 4.4% on pooled data. However, oil yield increased significantly up to 7.5 kg Zn/ha. This level registered an increase of 40.8, 16.7 and 3.7 per cent over control, 2.5 kg and 5.0 kg Zn/ha, respectively (Table 2). It might be because of the fact that zinc is recognized as an essential component in several hydrogenases, proteinases and peptidases and plays an important role in auxin formation and other enzyme system. The increase in oil yield was due to corresponding increase in oil content and seed yield. The result are corroborated the findings of Said *et al.* (2009). The significantly increasing trend of nitrogen content in seed resulted in significantly increased the protein content in seed of coriander upto 5 kg/ha during both the years as well as in pooled data analysis. The mean increase in protein content of seed on basis of pooled data analysis was 14.0 and 4.7 per cent over control and 2.5 kg/ha, respectively (Table 2). Positive effect of zinc application on nitrogen content may be due to activation of physiological processes because zinc acts as a catalyst and/or co-enzyme. The increase in protein content of coriander due to application of zinc has also been reported by Jakhar *et al.* (2013) in fenugreek.

**Economics**

**Effect of variety**

The data in table 2 indicated that variety RCr-436 recorded higher net returns of ‘ 39396/ha, representing an increase of ‘ 7673/ha over RCr-435

(‘31723/ha). Despite the same cost of cultivation for both the varieties, the higher seed yield recorded under variety RCr-436 have led to increased net returns as compared to RCr-435. These results are also supported by the findings of Balai and Keshwa (2010).

**Effect of sulphur**

The net returns (‘ 39175/ha) were increased significantly with increasing levels of sulphur upto 40 kg/ha by ‘10998 and 4405/ha over control and 20 kg S/ha, respectively (Table 2). This was mainly due to the increased seed yield with comparatively lesser cost of sulphur under this treatment. Similar results were also reported by Lal *et al.* (2014).

**Effect of zinc**

The economic evolution (Table 2) shows that in coriander, the application of zinc at the rate of 5.0 kg/ha exhibited maximum net returns (‘ 39309/ha) which was significantly higher by ‘ 10240 and ‘ 3715 over control and 2.5 kg Zn/ha, respectively. The cost involved under the treatment was comparatively lower than its additional income due to high yield, which led to more returns under these treatments. These results also substantiated by Lal *et al.* (2014).

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