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Effect of soil and foliar application of zinc on zinc content and uptake by of cauliflower (*Brassica oleracea* var. *botrytis* L.)

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Abstract
A field experiment entitled "Effect of soil and foliar application of zinc on growth and yield parameters of cauliflower (*Brassica oleracea* var. *botrytis* L.)" was conducted in the farmer's field during *kharif* 2018. The experiment was laid out in a Randomised complete block design with 9 treatments and 3 replications. The results revealed that a day prior to spray, treatment which received 8 kg of Zn ha^{-1} through $ZnSO_4$ as soil application along with RDF (150:100:125 N-P_2O_5-K_2O kg ha^{-1}) and FYM (25 t ha^{-1}) has recorded significantly higher zinc content (46.56 mg kg^{-1}) in cauliflower leaf. One week after spray, treatment T_9 which received 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5 per cent Zn through zinc sulphate as foliar spray along with RDF (150:100:125 N-P_2O_5-K_2O kg ha^{-1}) and FYM (25 t ha^{-1}) has recorded significantly higher zinc content(49.43%) in cauliflower leaf. Significantly higher zinc content in cauliflower leaves (35.16 mg kg^{-1}) and cauliflower curd (39.34 mg kg^{-1}) was recorded in the treatment T_9 which received 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5 per cent Zn through zinc sulphate as foliar spray along with RDF and FYM at harvest. Significantly higher uptake of zinc (139.73 g ha^{-1}) by cauliflower was recorded with the application of 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5 per cent Zn through zinc sulphate as foliar spray along with RDF and FYM followed by T_8. Lower uptake of zinc of 63.77 g ha^{-1} was recorded in T_1 (RDF + FYM).

Keywords: Zinc, content, uptake by cauliflower, zinc sulphate, foliar application

Introduction
The nutrients which are required in smaller quantities are called as micro or trace elements. Micronutrients although required in trace amount, play an important role in completion of life cycle of crop. They are essentially as important as that of macronutrients for achieving the better growth, yield and quality in plants.

Over the years, with intensive cultivation, Indian agriculture has moved from an era of single element deficiency to more complex multiple nutrient deficiencies. This is very true specially in case of micronutrients. Green revolution has greatly increased the food production in India, but continuous cultivation of high-yielding varieties have led to depletion of micronutrients in soils showing signs of fatigue for higher crop production. With the introduction of high yielding varieties of crops which was known to remove higher amount of nutrients and adoption of modern agricultural technology such as multiple cropping system, irrigation, intensive use of high analysis fertilizers with concomitant decrease in recycling of crop residues and use of animal manures, the widespread deficiency of micronutrients has increased. Among the micronutrients, zinc deficiency is more common in Karnataka soils followed by boron (Pujari, 2012) [15].

Zinc is a key nutrient for a plant to complete its life cycle. Zinc serves as an essential metal component of number of enzymes, *i.e*., dehydrogenase, carbonic anhydrase, super oxide dismutase etc. It is involved in synthesis of tryptophan, a precursor of IAA. Zinc has catalytic function and is essential for transformation of carbohydrate. It plays a vital role in metabolic processes of plant such as photosynthesis, respiration and other biochemical processes. It is required for normal cell division and other metabolic process. Zinc helps in formation of chlorophyll, the maintenance of the integrity of biological membranes and there by maintains the structural orientation of macromolecules and ion transport system. The interaction of zinc with phospholipids and sulphydryl groups of membrane proteins contributes for the maintenance of membranes (Cakmak, 2000) [8]. Zinc deficiency affects the growth of plant, shortened internodes, petioles, and small malformed leaves (little leaf) which results in the rosette symptom. Deficiency of zinc affect the protein and auxin synthesis and also causes interveinal chlorosis, reduced root growth, spikelet sterility and also adversely affect the quality of harvested products.

Deficiency of Zn noticed in most soils of Karnataka. Though some work has been done on the influence of these micronutrients in field and fruits crops (Babu and Singh, 2001 in Litchi) not much information is reported regarding their effect on vegetables especially cole crops. The literature pertaining to zinc nutrition on cole crops is very scanty. Keeping in view of the above facts a research work entitled "Effect of soil and foliar application of zinc on zinc content and zinc uptake by cauliflower (*Brassica oleracea* var. *botrytis* L.) Studied.

Material and Methods

Location of the experimental site

The experiment was carried out in the farmer's field at Konapalli, Chintamani Taluk, and Chickkaballapur District. The experimental farm is situated in Eastern Dry Zone (Zone 5) of Karnataka at 13.4020 º N latitude and 78.0551 º E longitude with elevation of 865 m above mean sea level. Initial physical and chemical parameters of soil given in Table 1.

Table 1: Initial physical and chemical properties of soil at experimental site

Sl. No.	Soil property	Content	Method followed
1.	Sand (%)	57.84	International pipette method (Piper, 1966)
	Silt (%)	7.69	
	Clay (%)	34.47	
	Textural class	Sandy clay	
2.	pH (1:2.5)	8.36	Potentiometry (Jackson, 1973)
3.	EC (1:2.5) (dS m^{-1})	0.22	Conductometry (Jackson, 1973)
4.	OC (%)	0.63	Wet oxidation method (Jackson, 1973)
5.	Available N (kg ha^{-1})	382.60	Alkaline permanganate method (Subbiah and Asija, 1956)
6.	Available P_2O_5 (kg ha^{-1})	32.30	Oleson's method (Jackson, 1973)
7.	Available K_2O (kg ha^{-1})	208.00	Neutral 1N ammonium acetate extraction & flame photometry method (Page *et al.*,1982)
8.	Exchangeble Ca [cmol (p^+) kg^{-1}]	6.75	Versenate titration method (Jackson,1973)
9.	Exchangeble Mg [cmol (p^+) kg^{-1}]	3.0	Versenate titration method (Jackson,1973)
10.	Available S (mg kg^{-1})	16.6	Turbidometry method (Black,1965)
11.	DTPA extractable Zn (mg kg^{-1})	0.46	DTPA extraction, atomic absorption spectrophotometer method (Lindsay and Norvel, 1978)
12.	DTPA extractable Fe (mg kg^{-1})	1.98	
13.	DTPA extractable Mn (mg kg^{-1})	1.95	
14.	DTPA extractable Cu (mg kg^{-1})	0.42	
15.	Available B (mg kg^{-1})	0.34	Hot water-soluble extraction method (Berger and Troug, 1939)

Detailed programme of work

The details of field experiment conducted are given below.

Test Crop	: Cauliflower
Variety	: Unnathi
Spacing	: 45 cm X 30 cm
Location	: Farmer's field, Chintamani, Eastern dry zone
Design	: RCBD
Plot size	: 3.6 X 3 m (10.8 m^2)
No. of treatments	: 9
No. of replications	: 3
Source of zinc	: Zinc sulphate
Foliar spray	: 30 DAT
Recommended dose of fertilizers ($N:P_2O_5:K_2O$ kg ha^{-1})	: 150:100:125
FYM (t ha^{-1})	: 25

Treatment details

Sl. No.	Treatment details
T_1	RDF + FYM
T_2	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application
T_3	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application
T_4	T_1+ 6 kg of Zn ha^{-1} through $ZnSO_4$ as soil application
T_5	T_1+ 8 kg of Zn ha^{-1} through $ZnSO_4$ as soil application
T_6	T_1+ 1 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray
T_7	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray
T_8	T_1+ 3 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray
T_9	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray

Fertilizer application

Recommended dose of fertilizers for cauliflower crop is 150:100:125 kg N, P_2O_5, K_2O ha^{-1} and FYM 25 t ha^{-1} and they were applied according to the treatment details. Nitrogen in the form of urea, P_2O_5 in the form of SSP, K_2O in the form of muriate of potash and zinc in the form of zinc sulphate were applied.

Foliar spray

As per the treatment details, the foliar spray of zinc @ 0.5% through zinc sulphate was taken at 30 days after transplanting.

Collection and preparation of plant samples
Plant samples were collected from randomly selected five plants in each treatment, cleaned with double distilled water, air dried and then dried in a hot-air oven at 65 °C for 18 hours. Dried samples were ground to fine powder and stored in polythene bags. These samples were used for analyzing zinc content.

Estimation of zinc (mg kg^{-1})
After making suitable dilution of di-acid extract (Nitric acid and perchloric acid), the samples were fed to the atomic absorption spectrophotometer using appropriate hallow cathode lamps to estimate the Zn, content of the plant samples were analyzed.

Zinc uptake by cauliflower
Uptake of zinc was calculated based on parts per million nutrient content in plant on dry weight. Uptake of zinc was worked out by using the formula mentioned below and is expressed in g ha^{-1}.

$$\text{Micronutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)}}{\text{Dry matter yield (kg ha}^{-1}\text{)}} \times 1000$$

Results and Discussion
Effect of soil and foliar application of zinc on zinc content of cauliflower leaf after harvest
The data on concentration of zinc in cauliflower leaves differed significantly due to soil and foliar application of zinc. The results are presented in Table 2. Zinc content in cauliflower leaves influenced significantly with soil and foliar application of zinc. Significantly higher zinc content (35.16 mg kg^{-1}) was recorded in the treatment combination of 4 kg of zinc ha^{-1} as soil application through zinc sulphate + 0.5% zinc as foliar spray through zinc sulphate along with RDF and FYM (T_9), and it was followed by treatment which received 3 kg zinc ha^{-1} as soil application + 0.5% zinc as foliar spray through zinc sulphate along with RDF (150 kg N: 100 kg P_2O_5: 125 kg K_2O) and FYM (T_8) which has recorded the zinc content of33.78 mg kg^{-1}. However, significantly lower zinc content (17.17 mg kg^{-1}) was recorded in the treatment combination of RDF (150 kg N: 100 kg P_2O_5: 125 kg K_2O) and FYM (T_1). Treatments which received zinc along with RDF (150 kg N: 100 kg P_2O_5: 125 kg K_2O) and FYM showed a significantly higher zinc content in cauliflower leaf compared to treatment which received only RDF (150 kg N: 100 kg P_2O_5: 125 kg K_2O) and FYM. This higher zinc content may be due to better absorption of zinc in zinc treated treatments which results in increased uptake of zinc in the cauliflower crop. The results were in agreement with the results obtained by Verma *et al*. (2017) [18], the application of zinc @ 7.5 kg ha^{-1} has significantly increased the zinc content in cauliflower crop.

The data with respect to concentration of zinc in cauliflower leaf before and after spray given in the Table 3. Zinc content a day before spray differed significantly with the zinc application. Significantly higher zinc content (46.56 mg kg^{-1}) was recorded in treatment which received 8 kg of zinc ha^{-1} through zinc sulphate as soil application along with RDF and FYM (T_5). It is followed by the treatment received T_1 + 6 kg of zinc ha^{-1} through zinc sulphate as soil application (T_4) which has recorded zinc content of 44.59 mg kg^{-1}. Treatments having zinc were recorded significantly higher zinc in cauliflower leaf as compared to T_1 which has received only FYM and RDF. The data presented in the Table 3 revealed that foliar application of zinc along with soil application has recorded significantly higher zinc content in cauliflower leaf. One week after spray, treatment with foliar application along with soil application of zinc has recorded significantly higher zinc content. A significantly higher zinc content (49.43 mg kg^{-1}) was recorded in treatment which received T_1 + 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray (T_9) followed by T_1 + 3 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray (T_8) which has recorded 47.15 mg kg^{-1}. A day before spray, T_5 has recorded higher concentration of zinc in cauliflower leaf which may be due to higher soil application of zinc in soil which has deficiency of zinc. At one week after spray, higher zinc content was recorded in T_9 which may be due to combined application of zinc as soil and foliar spray through zinc sulphate. Since the zinc sulphate is readily soluble in water and hence there is an increased absorption of zinc which resulted increased concentration of zinc in plant tissue. Similar results were reported by verma *et al*. (2017) [18] stated that application of 7.5 kg zinc ha^{-1} significantly increased the zinc content in cauliflower. The results were found similar with the results of Ranjtha (2017) in tomato. At harvest the zinc concentration was reduced which might be due to the utilization of zinc by cauliflower for various metabolic and catalytic activities during the crop growth. The results were found in line with findings of Pavithra (2018) [13].

Table 2: Effect of soil and foliar application of zinc on zinc content of cauliflower leaf

	Treatments	Zinc (mg kg^{-1})
T_1	RDF + FYM (150:100:125 N-P_2O_5 - K_2O kg ha^{-1} + 25 tons FYM ha^{-1})	17.17
T_2	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	20.56
T_3	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	26.17
T_4	T_1+ 6 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	29.35
T_5	T_1+ 8 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	30.27
T_6	T_1+ 1 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	21.17
T_7	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	28.16
T_8	T_1+ 3 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	33.78
T_9	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	35.16
S.Em±		0.823
CD (5%)		2.466

Table 3: Effect of soil and foliar application of zinc on zinc content of cauliflower leaf at one day before spray and one week after spray

	Treatments	Before spray	After spray
T_1	RDF + FYM (150:100:125 N-P_2O_5 - K_2O kg ha^{-1} + 25 tons FYM ha^{-1})	19.54	20.45
T_2	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	33.23	32.45
T_3	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	41.34	44.03
T_4	T_1+ 6 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	44.59	45.98
T_5	T_1+ 8 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	46.56	47.12
T_6	T_1+ 1 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	28.94	35.45
T_7	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	34.24	41.25
T_8	T_1+ 3 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	39.89	47.15
T_9	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	42.45	49.43
S.Em±		1.215	1.140
CD (5%)		3.644	3.419

Effect of soil and foliar application of zinc on zinc uptake (g ha^{-1}) by cauliflower leaf after harvest

The data with respect to zinc uptake by cauliflower as influenced by soil and foliar application of zinc at harvest is presented in Table 4. Zinc uptake by cauliflower differed significantly due to soil and foliar application of zinc at harvest. Zinc uptake by cauliflower was recorded significantly higher in T_9 (T_1 + 4 kg of zinc ha^{-1} through zinc sulphate as soil application + 0.5 per cent zinc through zinc sulphate as foliar spray) which recorded 139.73 g ha^{-1} followed byT_8 (T_1+ 3 kg of Zn ha^{-1}through $ZnSO_4$ as soil application + 0.5 per cent Zn through zinc sulphate as foliar spray) which was recorded 126.09 g ha^{-1}. Among all the treatments, T_1 (RDF + FYM) recorded lower zinc uptake 63.77 g ha^{-1}. Application of graded levels of zinc through soil and foliar application improved the uptake of zinc. This may be due to both soil and foliar application of zinc through zinc sulphate. Zinc sulphate is readily soluble in water, which led to the increased availability and absorption of zinc when applied to soil deficient in zinc and direct absorption of zinc through leaves by foliar application. Apoorva *et al*, 2017 reported that higher uptake of zinc was recorded with application of 20 kg Zn ha^{-1} along with RDF in rice. The results were found in line with Bhupender *et al*., 2013, reported that application of 9 kg Zn ha^{-1} significantly increased the total zinc uptake in mustad. Similar results were also reported by Basavaraj (2013) [4] in cauliflower and Ranjitha (2017) [16] in tomato, Keram *et al*., 2012 in wheat and Alok and Nayak (2008) [1] in cabbage.

Table 4: Effect of soil and foliar application of zinc on uptake of zinc by cauliflower

	Treatments	Uptake by curd (g ha^{-1})	Uptake by leaf (g ha^{-1})	Total uptake (g ha^{-1})
T_1	RDF + FYM (150:100:125 N-P_2O_5 - K_2O kg ha^{-1} + 25 tons FYM ha^{-1})	44.48	19.29	63.77
T_2	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	48.83	23.92	72.76
T_3	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	57.47	31.06	88.54
T_4	T_1+ 6 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	73.72	36.92	110.64
T_5	T_1+ 8 kg of Zn ha^{-1} through $ZnSO_4$ as soil application	81.18	40.07	121.25
T_6	T_1+ 1 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	60.18	24.25	84.44
T_7	T_1+ 2 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	67.10	33.95	101.06
T_8	T_1+ 3 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	82.99	43.10	126.09
T_9	T_1+ 4 kg of Zn ha^{-1} through $ZnSO_4$ as soil application + 0.5% Zn through $ZnSO_4$ as foliar spray	91.41	48.32	139.73
S.Em±		3.213	1.797	4.654
CD (5%)		9.411	5.3884	13.952

Conclusion

Application of 4 kg zinc ha^{-1} through zinc sulphate as soil application + 0.5 per cent foliar application of zinc through zinc sulphate along with recommended dose of NPK (150:100:125 N-P_2O_5-K_2O kg ha^{-1}) + FYM increased content and uptake of zinc in cauliflower. Soil and foliar application of zinc are more advantageous than soil application alone for cauliflower. Hence, application of Zn @ 4 kg ha^{-1} along with foliar application of zinc @ 0.5% zinc through zinc sulphate is economically viable to cauliflower yield.

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