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Effect of soil and foliar application of zinc on soil properties and quality of Knol Khol (*Brassica caulorapa* var *gongylodes*) in semi-arid region of Karnataka

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Abstract
The present field experiment was conducted in the farmer's field at Vijayapura, Bangalore Rural District, to study the effect of soil and foliar application of zinc on soil properties and quality of Knol Khol. The experiment was laid out in a randomized complete block design with ten treatments replicated thrice. The experimental results indicated that soil pH, electrical conductivity, organic carbon, calcium, magnesium, iron, manganese and copper did not significantly differ through the application of zinc. Whereas the nitrogen, phosphorus, potassium, sulphur and zinc content in soil differed significantly with soil and foliar application of zinc. Significant improvement in quality parameters like total soluble solids (8.83 °Brix) and ascorbic acid content (56.73 mg $100g^{-1}$) was observed with the combined soil and foliar application of zinc @ 4 kg and 0.14 per cent through zinc sulphate respectively, along with RDF and FYM (T_9).

Keywords: Zinc, Knol Khol, soil application, foliar application, soil properties, quality

Introduction
The knol-khol is a cole crop and belongs to family Cruciferaceae. Knol khol is characterized by formation of knob which arises from thickening of the stem tissue above the cotyledon. The knob is used for human consumption either as raw or cooked. The modified stem tuber is fairly rich in carbohydrates, proteins, minerals like calcium, magnesium, phosphorus, sodium, sulphur, antioxidants, vitamin A, C, E, carotene and dietary fibre. It also contains sulphoraphanes and other isothiocyanates which are believed to stimulate the production of protective enzymes in the body. A fresh raw 100 g edible portion of knol khol contains 91.7 per cent water, 23 kcal energy, 1.6 g protein, 0.2 g fat, 3.7 g carbohydrate, 2.2 g dietary fibre, 30 mg calcium, 10 mg magnesium, 35 mg phosphorus, 0.3 mg iron, 0.1 mg zinc, 0.11 mg thiamin, 0.3 mg niacin, 82 µg foliate, 43 mg ascorbic acid and traces of carotene and riboflavin (Holland *et al.*, 1991) [5].

Green revolution in India has led to intensive cultivation with the introduction of high yielding varieties of crops and adoption of modern agricultural technologies such as multiple cropping systems, irrigation and intensive use of high analysis fertilizers. This led to the removal of higher amount of nutrients resulting in multiple nutrient deficiencies especially the micronutrients and zinc in particular. Replenishment of micronutrients to soil has not received much attention, leading to their deficiency. Under these conditions application of zinc fertilizer is necessary for healthy crop growth and quality. Hence the present study was undertaken with an objective to find the effect of zinc on soil properties and quality of Knol Khol.

Materials and Methods
A field experiment was conducted in the farmer's field at Vijaypura, Bangalore Rural District, Karnataka during *kharif* 2017-18. The variety of Knol Khol chosen was White Vienna. The experiment was laid out in a Randomized Complete Block Design with ten treatments replicated thrice following 30 cm x 20 cm spacing with the individual gross plot size of 4.32 m^2. The treatment details include T_1= RDF (150:100:125 $N:P_2O_5:K_2O$ kg ha^{-1}) + FYM (12.5t ha^{-1}), T_2= T_1+ 2 kg of Zn through $ZnSO_4$ as soil application, T_3= T_1+ 4 kg of Zn through $ZnSO_4$ as soil application, T_4= T_1+ 6 kg of zinc through $ZnSO_4$ as soil application, T_5= T_1+ 8 kg of Zn through $ZnSO_4$ as soil application, T_6= T_1+ 1 kg of Zn through $ZnSO_4$ as soil application + 0.14% Zn through $ZnSO_4$ as foliar application, T_7= T_1+ 2 kg of Zn through $ZnSO_4$ as soil application + 0.14% Zn through $ZnSO_4$ as foliar application, T_8= T_1+ 3 kg of

Zn through $ZnSO_4$ as soil application + 0.14% Zn through $ZnSO_4$ as foliar application, T_9= T_1+ 4 kg of Zn through $ZnSO_4$ as soil application + 0.14% Zn through $ZnSO_4$ as foliar application and T_{10}= Farmer's practice (89.1:30:90 $N:P_2O_5:K_2O$ kg ha^{-1}). Zinc was applied in the form of zinc sulphate both as soil and foliar application. The soil application was done before transplanting whereas foliar spray was done 30 days after transplanting the crop. The soil properties and quality parameters were recorded by adopting standard procedures.

Results and Discussion

Initial Soil characteristics of the experimental site

The initial soil samples were collected from different sites of the experimental plot and a representative sample was prepared. The soil sample was analyzed for physical and chemical properties such as sand, silt, clay percentage, pH, EC, organic carbon, available nitrogen, phosphorous, potassium, exchangeable calcium, magnesium, available sulphur, DTPA extractable zinc, iron, copper and manganese. The details of the initial soil analysis are furnished in Table 1. The initial soil properties of soil indicated that the soil was sandy clay in texture and pH was slightly alkaline (7.8). The electrical conductivity of the soil was normal with 0.42 dSm^{-1}. The organic carbon content was medium with 0.56%. The available nitrogen, phosphorous and potassium contents was 282.4 kg ha^{-1}, 34.28 kg ha^{-1} and 266.4 kg ha^{-1} respectively. The DTPA extractable zinc was deficient with 0.48 mg kg^{-1}.

Effect of soil and foliar application of zinc on the nutrient content of soil after harvest of Knol Khol crop

Status of pH, electrical conductivity and organic carbon content of the soil

The data on pH, electrical conductivity and organic carbon in the soil after the harvest was not significantly influenced due to soil and foliar application of zinc. The results are presented in Table 2.

Status of primary and secondary nutrient content of the soil

The available nitrogen, phosphorus and potassium content of soil after the harvest of Knol Khol crop differed significantly due to soil and foliar application of zinc (Table 3). Significantly higher available nitrogen (294.68 kg ha^{-1}), phosphorous (38.15 kg ha^{-1}) and potassium (279.15 kg ha^{-1}) in soil at harvest was recorded in T_1 (RDF + FYM). The lowest available nitrogen (244.92 kg ha^{-1}), phosphorous (28.92 kg ha^{-1}) and potassium (248.48 kg ha^{-1}) was recorded in T_{10} (Farmer's practice) followed by T_9 (4 kg of Zn through $ZnSO_4$ as soil application + 0.14 per cent Zn through $ZnSO_4$ as foliar spray along with RDF and FYM).

The lowest available nitrogen, phosphorous and potassium content was recorded in T_{10} (Farmer's practice) due to the very low application of nitrogen, phosphorous and potassium to the soil compared to all other treatments. T_9 (T_1+ 4 kg of Zn through $ZnSO_4$ as soil application + 0.14 per cent Zn through $ZnSO_4$ as foliar spray) recorded lower nitrogen, phosphorous and potassium content in soil at harvest after T_{10} (Farmer's practice) which might be due to higher uptake of nutrients by plants and its further translocation to various plant parts including knob, besides being subjected to other losses. Similar results were also reported by Ravishankar (2011) [14] and Ranjitha (2017) [13].

Soil and foliar application of graded levels of zinc did not significantly influence exchangeable calcium and magnesium content in the soil after the harvest of Knol Khol crop (Table 3).

Available sulphur content of soil after the harvest of Knol Khol crop differed significantly due to soil and foliar application of zinc (Table 3). Significantly higher sulphur content of 13.16 mg kg^{-1} was recorded in T_5 (T_1+ 8 kg of Zn through $ZnSO_4$ as soil application) followed by T_4 (T_1+ 6 kg of Zn through $ZnSO_4$ as soil application) which recorded 12.92 mg kg^{-1}. This may be due to higher soil application of zinc through zinc sulphate which contributes sulphur to the soil. However, the lower sulphur content of 12.08 mg kg^{-1} was recorded in T_{10} (Farmer's practice) followed by T_1 (RDF + FYM) which recorded 12.18 mg kg^{-1}. The lower sulphur content in T_{10} (Farmer's practice) may be due to non-application of zinc sulphate. The results are in conformity with the findings of Ranjitha (2017) [13].

Status of micronutrient content of the soil

Available iron, manganese and copper content in soil were not significantly influenced with soil and foliar application of zinc (Table 4).

Available zinc content of soil after the harvest of Knol Khol crop differed significantly due to soil and foliar application of zinc. Significantly higher zinc content of 0.96 mg kg^{-1} was recorded in T_5 (T_1+ 8 kg of Zn through $ZnSO_4$ as soil application) followed by T_4 (T_1+ 6 kg of Zn through $ZnSO_4$ as soil application) which recorded 0.90 mg kg^{-1}. This may be due to higher soil application of zinc through zinc sulphate. Lower zinc content of 0.40 mg kg^{-1} was recorded in T_{10} (Farmer's practice) followed by T_1 (RDF + FYM) which recorded 0.45 mg kg^{-1}. The lower zinc content in T_{10} (Farmer's practice) may be due to non-application of zinc. The present results are corroborated with the findings of Ravishankar (2011) [14], Shrishail Arabhavi (2014) [18] and Ranjitha (2017) [13].

Effect of soil and foliar application of zinc on quality parameters

Total soluble solids (˚Brix)

The data on total soluble solids in Table 5 revealed that T_9 (T_1 + 4 kg of zinc through zinc sulphate as soil application + 0.14 per cent zinc through zinc sulphate as foliar spray) recorded significantly higher total soluble solids of 8.83 (˚Brix) followed by T_8 (T_1 + 3 kg of zinc through zinc sulphate as soil application + 0.14 per cent zinc through zinc sulphate as foliar spray) which recorded 8.61 (˚Brix). Lower total soluble solids of 6.17 (˚Brix) was recorded in T_{10} (Farmer's practice) followed by T_1 (RDF + FYM) which recorded 6.58 (˚Brix).

The significant increase in total soluble solids might be attributed to the significant role of Zn in carbohydrate metabolism. Davood *et al.* (2010) [3] reported that soil application of zinc improved the knol khol quality with respect to total soluble solids. The maximum total soluble solids was observed with the foliar application of zinc at 0.5% in cabbage (Ashok *et al.*, 2023) [1]. The results were in line with the findings of Kumar *et al.* (2012) [8], Mohsen Kazemi (2013) [10], Gajendra *et al.* (2014) [4], Zhao Yong-hou (2006) [21] and Shivran *et al.* (2017) [17].

Ascorbic acid (mg $100g^{-1}$)

The ascorbic acid content (Table 5) was recorded significantly higher due to graded levels of zinc as compared to control. Significantly higher ascorbic acid of 56.73 mg $100g^{-1}$ was recorded in T_9 which received 4 kg of zinc through zinc sulphate as soil application + 0.14 per cent zinc through zinc sulphate as foliar spray along with RDF (150:100:125 $N:P_2O_5:K_2O$ kg ha^{-1}) and FYM followed by T_8 (54.40 mg $100g^{-1}$) which received 3 kg of zinc through zinc sulphate as soil application and 0.14 per cent zinc through zinc sulphate as foliar spray along with RDF (150:100:125 $N:P_2O_5:K_2O$ kg ha^{-1}) and FYM. The lower ascorbic acid of 37.87 mg $100g^{-1}$ was recorded in T_{10} (Farmer's practice) followed by T_1 (RDF + FYM) which recorded 40.13 mg $100g^{-1}$.

A significant increase in ascorbic acid content may be due to the role of zinc as an activator of many enzymes particularly carbonic anhydrase and carboxylase that led to enhanced vitamin-C content in the knob. Davood *et al.* (2010) [3] recorded that with soil application of Zn at 15 kg ha^{-1} in Knol Khol improved the ascorbic acid content. Similar results were also reported by Salam *et al.* (2010) [16], Saha *et al.* (2014) [15], Kotecha *et al.* (2016) [7], Shivran *et al.* (2017) [17] and Verma *et al.* (2017) [20].

Table 1: Initial soil characteristics of the experimental site

Sl. No.	Soil property	Content	Method followed
1	Sand (%)	58.90	International pipette method (Piper, 1966) [12]
	Silt (%)	6.81	
	Clay (%)	33.70	
	Textural class	Sandy clay	
2	pH (1:2.5)	7.80	Potentiometry (Jackson, 1973) [6]
3	EC (1:2.5) (dS m^{-1})	0.42	Conductometry (Jackson, 1973) [6]
4	OC (%)	0.56	Wet oxidation method (Jackson, 1973) [6]
5	CEC [cmol (p^+) kg^{-1}]	14.38	Neutral 1N, NH_4OAc method (Jackson, 1973) [6]
6	Available N (kg ha^{-1})	282.4	Alkaline permanganate method (Subbiah and Asija, 1956) [19]
7	Available P_2O_5 (kg ha^{-1})	34.28	Olsen's method (Jackson, 1973) [6]
8	Available K_2O (kg ha^{-1})	266.4	Neutral 1N ammonium acetate extraction & flame photometry method (Page *et al.*,1982) [11]
9	Exchangeble Ca [cmol (p^+) kg^{-1}]	4.92	Versenate titration method (Jackson, 1973) [6]
10	Exchangeble Mg [cmol (p^+) kg^{-1}]	2.68	Versenate titration method (Jackson, 1973) [6]
11	Available S (mg kg^{-1})	12.24	Turbidometry method (Black, 1965) [2]
12	Available Zn (mg kg^{-1})	0.48	DTPA extraction atomic absorption spectrophotometer method (Lindsay and Norvel, 1978) [9]
13	Available Fe (mg kg^{-1})	3.28	
14	Available Mn (mg kg^{-1})	2.10	
15	Available Cu (mg kg^{-1})	0.78	

Table 2: Effect of soil and foliar application of zinc on pH, Electrical Conductivity (EC) and Organic Carbon (OC) of soil after the harvest of Knol Khol crop

Treatments	pH (1:2.5)	EC (dS. m^{-1})	OC (%)
T_1	7.78	0.43	0.58
T_2	7.76	0.42	0.57
T_3	7.78	0.45	0.56
T_4	7.80	0.45	0.54
T_5	7.80	0.47	0.52
T_6	7.74	0.43	0.51
T_7	7.72	0.46	0.50
T_8	7.76	0.47	0.48
T_9	7.80	0.48	0.45
T_{10}	7.78	0.41	0.42
S. Em ±	0.05	0.05	0.06
CD (5%)	NS	NS	NS

Table 3: Effect of soil and foliar application of zinc on primary and secondary nutrient status of soil after the harvest of Knol Khol crop

Treatments	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Ca (cmol (p^+) kg^{-1})	Mg (cmol (p^+) kg^{-1})	S (mg kg^{-1})
T_1	294.68	38.15	279.15	4.86	2.61	12.18
T_2	290.56	37.26	276.54	4.85	2.60	12.56
T_3	284.46	35.89	271.88	4.84	2.59	12.78
T_4	281.39	34.98	269.77	4.83	2.58	12.92
T_5	272.65	33.40	264.92	4.81	2.56	13.16
T_6	287.27	36.82	274.02	4.84	2.59	12.48
T_7	276.99	34.11	266.94	4.82	2.57	12.54
T_8	268.49	32.07	261.98	4.81	2.56	12.66
T_9	262.34	30.58	258.66	4.80	2.55	12.78
T_{10}	244.92	28.92	248.48	4.87	2.62	12.08
S. Em ±	1.36	0.27	0.82	0.04	0.03	0.03
CD (5%)	4.07	0.80	2.44	NS	NS	0.09

Table 4: Effect of soil and foliar application of zinc on micronutrient status of soil after the harvest of Knol Khol crop

Treatments	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
T_1	3.24	2.07	0.74	0.45
T_2	3.23	2.06	0.73	0.69
T_3	3.22	2.05	0.72	0.82
T_4	3.21	2.04	0.71	0.90
T_5	3.19	2.02	0.69	0.96
T_6	3.22	2.05	0.72	0.62
T_7	3.20	2.03	0.70	0.68
T_8	3.19	2.02	0.69	0.72
T_9	3.18	2.01	0.68	0.80
T_{10}	3.25	2.08	0.75	0.40
S. Em ±	0.04	0.03	0.03	0.01
CD (5%)	NS	NS	NS	0.04

Table 5: Effect of graded levels of zinc on quality parameters of Knol Khol crop

Treatments	Total soluble solids (°Brix)	Ascorbic acid (mg 100g $^{-1}$)
T_1	6.58	40.13
T_2	6.81	41.40
T_3	7.31	45.65
T_4	7.63	46.41
T_5	8.22	52.39
T_6	7.10	43.77
T_7	7.82	50.71
T_8	8.61	54.40
T_9	8.83	56.73
T_{10}	6.17	37.87
S. Em ±	0.06	0.62
CD (5%)	0.18	1.85

Conclusion

The soil and foliar application of zinc significantly differed the available nitrogen, phosphorus, potassium, sulphur and zinc content in soil. The application of RDF (150:100:125 $N:P_2O_5:K_2O$ kg ha^{-1}) and 12.5 t of FYM per hectare and 4 kg of Zn through $ZnSO_4$ as soil application along with 0.14 per cent Zn through zinc sulphate as foliar spray significantly increased the quality parameters such as total soluble solids of (8.83 °Brix) and ascorbic acid content (56.73 mg $100g^{-1}$).

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