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Zinc Contents of Soils and Plants in the Çukurova Region of Turkey

S. IRMAK*, A.K. SURUCU† and S. AYDIN‡
Institute of Cukurova Agricultural Research, Adana, Turkey
Tel: (90)(322)3340030, Fax: (90)(322)3340357
E-mail: seyyidirmak@hotmail.com.tr

Soil, leaf and grain samples were collected from wheat (*Triticum* spp) fields in Cukurova region of Turkey and the soil samples taken from the root area of plants where the leaf and grain samples were obtained was analyzed for zinc content. The leaf samples taken during the stem elongation and the grain samples taken at the time of maturation were also analyzed for zinc content. The correlation analysis between soil-zinc contents and leaf and grain-zinc contents was performed to determine the relationship among the variables. The analysis findings revealed that the zinc content of soil of Cukurova region was quite low. The zinc content of the soil samples collected in 2005 and 2006 was between 0.16 and 1.10 ppm; 0.16 and 0.88 ppm, respectively. The zinc content of the majority of soil samples was observed below the critical level which is 0.5 ppm. The zinc content of the leaf samples was ranged from 6.10 to 46.10 ppm in 2005 and 15.25 to 25.42 ppm in 2006, whereas the zinc content of the grain samples was ranged from 38.47 to 80.02 ppm in 2005 and 9.24 to 100.31 ppm in 2006. The zinc content of the leaf samples was observed lower than normal, but for grain samples, the findings were relatively better comparing to leaf samples. The zinc content of the leaf and grain samples was directly correlated with the zinc content of the soil. Correlation between zinc content of soil and zinc content of leaf in 2005 is significant at the 0.01 level according to statistical analysis. The extractable P_2O_5 content of the soil and P content of the grain was, however, inversely correlated with the zinc content of the grain in this study. Correlation between zinc content of grain and P content of grain is significant at the 0.05 level according to statistical analysis.

Key Words: Soil characteristic, Zinc, Micronutrient elements, Zinc deficiency.

†Institute of Soil and Water Resources Research, Sanliurfa, Turkey.
‡Department of Crop Science, Faculty of Agriculture, University of Sutcu. Imam, K. Maras, Turkey.

INTRODUCTION

During the 20th century, plant breeding and improved crop management techniques successfully increased the grain yield of bread wheat[1-3] and, in doing so, effectively reduced food shortages and malnutrition. The future poses a similar challenge: by 2020, the demand for wheat is expected to be 40 % greater than its current level of 552 million tons per year[4]. However, a unique opportunity exists for agriculture to invest more nutrient-dense staple food crops for developing[5] that could help reduce not only energy, but also nutrient malnutrition. Welch and Graham[6] proposed a new balanced nutrition paradigm for crop production. They point out that although, the world's food supply in recent years has been sufficient, it does not promote an adequate nutritional balance[7-9].

As staple crops contribute substantially to daily caloric intake among people in developing countries, there has been a resurgence of interest in addressing human malnutrition through breeding of staple crops, specifically to address micronutrient malnutrition[10-13].

Human zinc deficiency is a widespread condition prevalent in people consuming grain and legume based diets. Dry beans (*Phaseolus vulgaris* L.) are frequently the major protein source in such diets. One way to reduce the incidence of zinc deficiency may be through the development of high zinc dry beans. Large variation for zinc concentration in dry bean seed exists, which would aid in the development of zinc-rich cultivars[14].

In Turkey, zinc deficiency is a critical nutritional problem in plants. Through analysis of 1511 soil samples collected from different parts of Turkey, it was found that about 50 % of arable soils are zinc deficient[15]; this is equivalent to 14 million hectares of cropped land in Turkey. Zinc deficiency is particularly widespread in Central Anatolia, which is major wheat growing area of Turkey[16,17]. Nearly 45 % (4.5 million hectares) of the wheat producing area in Turkey is located in Central Anatolia Region. This region is the driest region of Turkey with a high proportion of calcareous soils. The combination of high pH, $CaCO_3$ and heavy soil texture together with low levels of organic matter and soil moisture has been discussed as major factors lowering zinc availability to plant roots[16].

Zinc deficiency in plants reduces not only grain yield, but also nutritional quality of grains. As in soils and plants, zinc deficiency is also a common nutritional problem in humans, particularly in developing countries. High consumption of cereal-based foods with low levels and poor bioavailability of zinc is thought to be a major causal factor for widespread occurance of zinc deficiency in humans[17-19].

In recent years, the studies showed the important role of micro elements in human and plant nourishment. The studies made especially on zinc, point out that the problem of zinc deficiency is in serious condition in Turkey.

Insufficient content of micronutrient elements in soil has a negative impact on the development of crops, which, in turn, affects human health. Micro element deficiencies like zinc and iron bring out some serious health problems especially in children at developing age. In this aspect, micronutrient elements exhibit a profound significance for the condition of human health as much as they do for a successful production of crops. The objectives of this study: (i) was to determine the soil zinc content of wheat production field in Cukurova region; (ii) was to assess the effect of soil zinc content on zinc content of leaf and grain.

EXPERIMENTAL

This study is carried out in the Çukurova region in the East Mediterranean Region of Turkey. The study area is characterized by xeric climate and lies between 37º03' and 36º37' N latitudes and 35º 12' and 36º 02' E longitudes with altitude ranging between 20 and 80 m above MSL. The average amount of annual rainfall is 670.8 mm and potential total evaporation is 1536.0 mm. The mean annual air temperature is 19.1. The mean annual soil temperature at 50 cm depth is 20.8 ºC. All the soils are xeric. The vegetation in the study area are grasses, cereal and leguminous crops. The vegetation was dominated by cereal and leguminous grasses. Wheat, cotton, maize, grape, friut and soybean have been growing as commonly in Cukurova region.

In this study, 23 leaves samples, 23 grain samples and 23 soil samples in 2005 and 30 leaves samples, 30 grain samples and 30 soil samples in 2006 were investigated. Plants were sampled during growing (heading) to determine zinc content of leaves. Grain samples were taken in the harvest season to determine zinc content of grains. Soil samples were taken from 0-30 from roots region for laboratory analysis. Disturbed soil samples for laboratory analysis were collected from 0-30 cm depth and air dried to pass a 2 mm siever. Soil samples for laboratory analysis were collected from 0-30 cm depth and air dried, ground to pass a 2 mm sieve. The particle size distribution of each sample was determined by the pipette method[20] after removal of organic matter and carbonates. The pH was measured on saturation extracts (Radiometer PHM 82 standard pH meter. Organic C was measured by using a modified Walkley-Black procedure[21]. Carbonate content was determined by the Scheibler calcimeter method[22]. Cation-exchange capacity by Mg saturation followed by NH_4 substitution[20]. Available P_2O_5 analysis were carried out following methods[23]. Extractable zinc by the citrate dithionite-bicarbonate method and total chemical analysis were carried out by the HF fusion method[24]. Statistics analysis carried out between data of zinc content of soil, leaf and grain and P content of grain according to correlation analysis.

RESULTS AND DISCUSSION

The findings of chemical analysis of soil samples from 2005 were given in Table-1, respectively. According to results from analysis of soil samples collected in 2005, the $CaCO_3$ and organic matter content were observed between 12 and 20 %, and 1.32 and 2.70 %, respectively. The cation exchange capacity (CEC) values change between 21.32 and 34.76 cmol kg^{-1}. Soil pH has changed between 7.50 and 7.99. Utilizable P_2O_5 content of soils collected in 2005 change between 31 and 178 kg ha^{-1}. The maximum amount of utilizable P_2O_5 content was observed in sample number 1 as 178 kg ha^{-1} appeared to be quite high. The optimum amount of soil P_2O_5 content to provide favourable growing condition for plants is about 110 kg ha^{-1}. High P_2O_5 content may be attributed to excess application nutrient to soil. The excess amount of utilizable P_2O_5 content seems to have a disadvantage for zinc uptake from soil[13,25].

TABLE-1
SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN 2005

Sample no.	$CaCO_3$ (%)	Org. matter (%)	CEC (cmol kg^{-1})	pH (1/1)	P_2O_5 (kg ha^{-1})	Particle-size < 2 mm		
						Clay (%)	Silt (%)	Sand (%)
1	16.0	2.48	33.33	7.45	178	35.9	42.2	21.9
2	17.0	2.14	29.26	7.59	156	34.1	46.2	19.8
3	16.0	2.70	30.67	7.57	78	38.5	41.5	19.7
4	16.0	2.58	34.76	7.59	74	42.8	43.4	13.8
5	16.0	2.23	31.66	7.59	46	32.1	45.3	22.6
6	15.0	2.07	29.68	7.75	44	32.7	46.2	21.1
7	14.0	1.96	28.22	7.60	59	32.5	39.5	27.8
8	17.0	1.44	22.67	7.74	78	22.5	29.1	48.4
9	13.0	1.51	23.44	7.77	64	23.7	29.5	46.9
10	20.0	1.60	32.98	7.92	31	32.8	51.8	15.4
11	16.0	1.22	21.32	7.65	70	19.8	24.9	55.3
12	16.0	2.29	24.80	7.51	121	27.5	38.0	34.5
13	17.0	1.98	28.14	7.64	73	30.5	45.4	24.1
14	17.0	1.95	26.25	7.57	92	30.5	45.0	24.4
15	17.0	1.51	28.14	7.71	137	33.7	44.4	22.0
16	12.0	1.63	32.32	7.74	68	38.2	50.4	11.5
17	17.0	1.54	27.56	7.75	115	35.4	41.9	22.7
18	17.0	1.73	28.87	7.82	102	33.8	42.7	23.5
19	17.0	1.85	31.66	7.76	67	39.2	42.5	18.2
20	16.0	2.14	29.02	7.68	70	38.6	45.2	16.2
21	18.0	1.63	32.32	7.71	55	38.2	47.2	14.6
22	16.0	1.32	30.26	7.70	52	33.8	48.4	17.8
23	17.0	1.48	28.22	7.75	46	32.7	44.7	22.0

Some selected physical and chemical properties of soils sampling in 2006 were presented in Table-2. $CaCO_3$ and organic matter content of soil samples from 2006 were observed between 16 and 21 %, and 1.46 and 2.33 %, respectively. The cation exchange capacity (CEC) values change between 21.24 and 38.02 cmol kg^{-1}. Also soil pH has changed between 7.50 and 7.99. The lowest utilizable P_2O_5 content was observed in sample number 23 as 16 kg ha^{-1}. The highest amount of utilizable P_2O_5 was 179 kg ha^{-1} in sample number 6 while the amount of utilizable P_2O_5 changes

TABLE-2
SELECTED PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN 2006

Sample no.	$CaCO_3$ (%)	Org. matter (%)	CEC (cmol kg^{-1})	pH (1/1)	P_2O_5 (kg ha^{-1})	Particle-size < 2 mm		
						Clay (%)	Silt (%)	Sand (%)
1	16	2.33	26.04	7.50	125	31.9	43.0	25.1
2	17	2.05	28.66	7.64	49	31.1	46.1	22.8
3	16	2.02	29.77	7.71	51	30.6	44.8	24.6
4	16	1.83	25.04	7.58	130	32.2	41.9	25.9
5	16	1.71	29.63	7.62	70	33.2	43.7	23.1
6	16	1.49	21.24	7.57	179	23.1	25.3	51.6
7	19	1.90	38.02	7.69	64	34.4	49.2	16.4
8	21	1.83	30.62	7.75	68	32.2	45.9	21.9
9	18	1.73	32.22	7.76	47	40.8	48.7	10.5
10	21	1.90	30.83	7.73	65	38.7	49.7	11.6
11	19	2.08	30.87	7.68	25	37.1	51.7	11.2
12	18	2.08	29.94	7.71	66	37.1	52.3	10.6
13	18	2.14	30.91	7.74	38	39.5	47.9	12.6
14	17	2.24	35.50	7.64	122	40.2	48.6	11.2
15	18	2.21	33.08	7.71	122	39.1	49.7	11.2
16	18	1.96	34.75	7.66	74	39.1	49.2	11.7
17	18	2.17	36.33	7.65	69	40.8	48.2	11.0
18	18	1.74	34.72	7.76	66	41.4	48.9	9.7
19	18	1.99	33.08	7.68	81	39.6	49.3	11.1
20	17	1.99	33.55	7.72	105	37.2	50.5	12.3
21	18	1.90	33.80	7.71	49	41.7	48.3	10.0
22	18	1.86	33.66	7.77	56	41.8	47.5	10.7
23	19	1.99	30.88	7.74	16	39.0	48.2	12.8
24	21	2.05	30.80	7.72	72	34.7	50.6	14.7
25	20	1.71	33.30	7.67	60	37.3	48.9	13.8
26	21	1.46	31.72	7.63	29	38.4	53.7	7.9
27	21	1.65	31.63	7.50	46	35.1	50.5	14.4
28	21	1.27	31.51	7.59	60	36.4	52.0	11.6
29	18	1.65	32.60	7.99	51	36.1	47.2	16.7
30	17	1.68	31.60	7.72	31	36.1	44.0	19.9

between 16 and 179 kg ha^{-1}. It is believed that the excess amount of utilizable P_2O_5 in soil caused by overdose application of fertiliser. It is also stated that high amount of utilizable P_2O_5 and lime content, high soil pH and insufficient amount of organic matter content make zinc uptake difficult by crops[25].

Zinc contents of soils

Zinc contents of soil samples collected in 2005 were given in Table-3. Zinc content of soil samples was determined as low ranging from 0.16 to 1.10 ppm according to results of chemical analysis. Zinc content of all samples, except sample number 1, 2, 3, 4 and 12, appeared to be lower than zinc critical level being 0.5 ppm. The sample number 10 have had the lowest amount of zinc content being 0.16 ppm and the sample number 1 have had the highest amount of zinc content being 1.10 ppm. The low zinc content may be associated with chemical composition of parent material.

TABLE-3
ZINC CONTENT OF SOIL, PLANT AND GRAIN IN 2005

Sample no.	Zn in soil (ppm)	Zn in leaf (ppm)	Zn in grain (ppm)	P in the grain (%)	Texture
1	1.10	46.10	42.41	0.42	CL
2	0.80	19.70	49.93	0.42	SiCL
3	1.02	39.10	61.16	0.32	SiCL
4	0.74	19.40	58.12	0.41	SiC
5	0.48	19.80	46.67	0.38	CL
6	0.24	9.40	50.12	0.29	CL
7	0.34	16.80	50.45	0.33	CL
8	0.18	6.10	45.12	0.29	L
9	0.26	8.90	71.67	0.33	L
10	0.16	7.00	38.47	0.27	SiCL
11	0.34	16.10	64.30	0.37	SL
12	0.72	22.70	68.07	0.36	CL
13	0.34	14.00	80.02	0.34	CL
14	0.22	10.40	75.26	0.32	CL
15	0.22	9.70	41.69	0.31	CL
16	0.36	14.30	46.54	0.32	SiCL
17	0.32	13.60	67.87	0.36	CL
18	0.36	13.60	59.46	0.40	CL
19	0.32	15.30	43.07	0.32	SiCL
20	0.34	19.30	45.26	0.36	SiCL
21	0.22	7.30	67.22	0.35	SiCL
22	0.26	10.40	74.68	0.39	SiCL
23	0.28	13.90	80.02	0.37	CL

Zn analyses results of soil samples from 2006 was given in Table-4. Like in 2005, zinc content of soil samples in 2006 was determined as low ranging from 0.16 to 0.88 ppm. Zinc content of all samples except sample number 24 was lower than critical level (0.5 ppm). Insufficient amount of zinc content of soil might have a relation with chemical composition of soil parent material. It is known that soil parent material has an effect on chemical properties of soil[26].

TABLE-4
ZINC CONTENT OF SOIL, LEAF AND GRAIN AND P IN GRAIN IN 2006

Sample no.	Zn in soil (ppm)	Zn in leaf (ppm)	Zn in grain (ppm)	P in the grain (%)	Texture
1	0.26	19.45	16.83	0.27	CL
2	0.20	17.57	17.91	0.31	CL
3	0.16	17.58	9.24	0.31	CL
4	0.24	17.65	17.14	0.34	CL
5	0.22	20.94	16.72	0.31	CL
6	0.22	18.25	44.94	0.27	L
7	0.26	15.25	100.31	0.34	SiCL
8	0.18	16.54	15.47	0.35	CL
9	0.24	19.69	27.65	0.33	SiC
10	0.22	14.21	39.86	0.30	SiCL
11	0.16	20.36	25.65	0.27	SiCL
12	0.26	18.70	47.96	0.37	SiCL
13	0.26	24.59	62.74	0.34	SiCL
14	0.32	16.42	52.69	0.37	SiC
15	0.32	20.75	54.54	0.34	SiCL
16	0.24	21.17	54.57	0.32	SiCL
17	0.26	20.66	56.26	0.34	SiC
18	0.20	20.13	54.24	0.36	SiC
19	0.20	25.42	56.39	0.32	SiCL
20	0.24	20.82	57.13	0.34	SiCL
21	0.24	24.59	60.39	0.33	SiC
22	0.22	21.75	25.32	0.36	SiC
23	0.16	17.98	25.10	0.28	SiCL
24	0.88	19.51	22.89	0.33	SiCL
25	0.16	22.30	29.84	0.35	SiCL
26	0.24	23.03	27.03	0.32	SiCL
27	0.16	15.93	21.12	0.29	SiCL
28	0.24	13.54	25.39	0.32	SiCL
29	0.20	19.07	60.21	0.36	SiCL
30	0.24	22.40	90.29	0.37	SiCL

The first and most characteristic reaction of plants to zinc deficiency in the field was the decrease in shoot elongation and leaf size. Decrease in shoot elongation was evident already at early seedling growth and pronounced at the tillering and stem elongation stages. Leaf symptoms such as light green colour of leaves and whitish-brown necrotic on leaf blades were observed after the decrease in shoot growth. Appearance of these symptoms varied considerably among the cereals[25].

Zinc contents of leaves

Zinc contents of leaf samples collected in 2005 were given in Table-3. Zinc content of leaf samples was varied between 6.10 and 46.10 ppm according to results of chemical analysis. Zinc content of all samples, except sample number 1, 3 and 12, appeared to be lower than zinc critical level being 20 ppm. Zinc content appeared to be high in soil sites where the leaf samples containing zinc content above the critical level was taken from Table-2. Zinc content of leaf sample number 1 was determined as the highest (46.10 ppm). Zinc content of soil sample number 1 was also determined as the highest (1.10 ppm). On the other hand, zinc content of sample number 8 was determined as the lowest (6.10 ppm). Zinc content of soil sample number 8 was also determined as the lowest. Insufficiency of zinc content seen in leaf samples is directly related with insufficiency of zinc content of soils. As seen in the study, zinc content of soils have a direct effect on zinc content of leaf. The correlation between zinc content of soil and zinc content of leaf is significant at the 0.01 level according to statical analysis (Table-5).

Zinc contents of leaf collected in 2006 were presented in Table-4. Zinc content of the leaf samples changing between 15.25 ppm and 25.42 ppm in 2006 was relatively higher compared with values of 2005. Although, zinc content of soil samples taken from root area of plants that the leaf samples was collected below the critical level, most of the leaf samples contained zinc content equal or above the critical level. Therefore, moisturized soil during the development stage of plants enhances bio-utility of zinc content in soil[11,14]. The relation between zinc content of soil and leaf in that condition might be explained by the uniformity of rainfall regime and higher amount of precipitation received during the intensive development stage of plants in 2006.

Zinc contents of grains

Zinc content of grain samples collected in 2005 was given in Table-3 respectively. The amount of zinc content in grain samples was between 38.47 and 80.02 ppm in 2005. Sample number 10 contained the lowest amount of zinc and sample number 13 and 23 contained the highest amount of zinc. Zinc content of sample number 10 is 38.47 ppm. On the other

TABLE-5
CORRELATIONS BETWEEN ZINC CONTENT OF SOIL, LEAF AND GRAIN IN 2005 ACCORDING TO STATISTICAL ANALYSIS

Descriptive statistics			
	Mean	Std. Deviation	N
Zn in soil	0.4183	0.26662	23
Zn in leaf	16.2130	9.55626	23
Zn in grain	57.7209	13.40308	23
P in grain	0.3491	0.04220	23

		Zn in soil	Zn in leaf	Zn in grain	P in grain
Zn in soil	Pearson correlation	1	0.924**	0.199	0.545**
	Sig. (2-tailed)	–	–	0.590	0.007
	N	23	23	23	23
Zn in leaf	Pearson correlation	0.924**	1	0.158	0.455*
	Sig. (2-tailed)	–	–	0.473	0.029
	N	23	23	23	23
Zn in grain	Pearson correlation	0.119	0.158	1	0.215
	Sig. (2-tailed)	0.590	0.473	–	0.324
	N	23	23	23	23
P in grain	Pearson correlation	0.545**	0.455*	0.215	1
	Sig. (2-tailed)	0.007	0.029	0.324	–
	N	23	23	23	23

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

hand, zinc content of sample number 13 is 80.02 ppm. Zinc content of soil sample collected from the root area of plants having the lowest amount of zinc content in grain was also determined as the lowest one and it is 0.16 ppm (Table-3).

It is stated that zinc content of grain was affected by zinc content of soil, accordingly, when the amount of zinc increases in soil, the amount of zinc in grain also increases[13,25]. According to this statement, content of grain sample number 1 collected in 2005 supposed to be higher compared to other grain samples because zinc content of soil sample corresponding to grain sample number 1 was higher than the other soil samples. Zinc content of grain sample 1 was, however, observed quite low compared to zinc content of other grain samples. The case in zinc content of grain sample 1 does not comply with above statement. This can be explained by the relation between zinc content and utilisable P_2O_5 content of soil. Table-1 shows that utilisable P_2O_5 content of soil sample 1 seems to be quite high (178 kg ha^{-1}). High amount of utilisable P_2O_5 in soils generates a disadvantage in terms of zinc uptake and interacts with zinc to limit zinc uptake by plants[25]. High P_2O_5 content of grain also impede zinc storage in grain by fitin acid that is a storage form of P_2O_5 in grain. Similar results were observed in other samples and when the utilizable P_2O_5 content of soils increases, zinc content of grain decreases and *vice-verse*. It can be stated that there is a inverse correlation between utilizable P_2O_5 content of soil and zinc content of grain.

Zinc content of grain samples collected in 2006 was given in Table-4, respectively. Zinc content of grain sample in 2006 has changed from 9.24 to 100.31 ppm. The lowest amount of zinc content was found in sample number 3 and soil sample taken from root area of grain sample 3 also contained the lowest amount of zinc content that was 0.16 ppm. There was a direct relation between zinc content of grain and soil samples, there was a inverse relation between zinc content of grain and P content of grain in 2006. Correlation between zinc content of grain and P content of grain is significant at the 0.05 level according to statistical analysis (Table-6). It is stated that there is a inverse correlation between phosphorus and zinc content in grain and fitin acid that is a storage form of phosphorus in grain affix zinc to impede its utility in grain[13].

TABLE-6
CORRELATIONS BETWEEN ZINC CONTENT OF SOIL, LEAF AND GRAIN IN 2006 ACCORDING TO STATISTICAL ANALYSIS

Descriptive statistics

	Mean	Std. Deviation	N
Zn in soil	0.2467	0.12685	30
Zn in leaf	19.5417	2.99059	30
Zn in grain	40.5273	22.56669	30
P in grain	0.3270	0.02996	30

		Zn in soil	Zn in leaf	Zn in grain	P in grain
Zn in soil	Pearson correlation	1	0.019	0.011	0.145
	Sig. (2-tailed)	–	0.920	0.954	0.444
	N	30	30	30	30
Zn in leaf	Pearson correlation	0.019	1	0.244	0.178
	Sig. (2-tailed)	0.920	–	0.193	0.347
	N	30	30	30	30
Zn in grain	Pearson correlation	0.011	0.244	1	0.450
	Sig. (2-tailed)	0.954	0.193	–	0.013*
	N	30	30	30	
P in grain	Pearson correlation	0.145	0.178	0.450	1
	Sig. (2-tailed)	0.444	0.347	0.013	–
	N	30	30	30	30

*Correlation is significant at the 0.05 level (2-tailed).

Conclusion

Zinc content of soils in study area appears to be quite low and pH, lime and phosphorus content of soils also make zinc uptake difficult for plants. Application of zinc fertilizer is, therefore, required to achieve intended yield gain in Cukurova region where there is a great potential for wheat production. Zinc fertilizer should be applied directly to plant leaves to get more benefits from because of chemical composition of soil making zinc uptake more difficult for plants. If zinc fertilizer is applied to the soil directly, the adverse chemical composition of soil would make zinc uptake difficult for plants. For that reason, laef fertilizer application of zinc is more beneficial for plant production.

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