Asian Journal of Chemistry Vol. 19, No. 1, (2007), 627–635

Effect of Zinc Containing Fertilizers in Organic and Inorganic Forms on the Yield of Barley Crop and Uptake of Nutrients

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This study was conducted to investigate the effect of treatment of the barley crop (Karatay-94) with zinc ontaining fertilizer under field conditions on two locations. The study was designed according to a randomised complete block experimental design in three replicates and at five different sources of zinc (Zn-gluconate, Zn-pyruvate, ZnO, $ZnSO_4$, Zn-EDTA) and were applied on the leaf in three different doses (0–0.75–1.50 kg/da Zn). The highest grain yield in the study was obtained from ZnO, $ZnSO_4$ and Zn-pyruvate applications on both locations. Although significant increases occurred in yield when zinc sources were applied in different doses on the first location ($P < 0.05$), no statistical differences were observed among zinc sources. On both locations in the study, significant differences were observed in regard to phosphorus and zinc contents of the flag leaf, zinc content in the grain and zinc taken up by the grain. Since no statistical differences were observed among zinc sources on both locations ($P < 0.05$), a dose of 0.75 kg Zn/da of $ZnSO_4$ can be recommended due to its economic criteria.

Key Words: Zinc, Zinc source, Barley, Organic zinc.

INTRODUCTION

Barley is a crop that is second to wheat in respect of cultivation area among field crops in Turkey; it is grown in all regions like wheat. Nearly all of the barley grown is consumed domestically. 76% of the production is used as animal feed (both as an additive in mixed feed and as mere feed by itself) and the remaining 24% is used as raw material in beer making. According to the data of the year 2004, barley cultivation fields were 3.5×10^6 ha and the production was 9×10^6 tonnes[1]. In Konya, where the study was conducted[2], cultivation area was 391.516 ha, the production was 984.536 tonnes and yield was 2546 kg ha^{-1}. Since barley farming is conducted mostly in dry conditions in Turkey, yield is quite low[3]. In raising yield in farming of cereals, meeting the micronutrient needs of the crop is as significant as meeting the macronutrient needs of the crop. Micronutrients have been known to increase the yield and improve the quality of different cereals including barley. In Turkey, approximately 49.8% of the arable soils (14 billion ha) were found to contain less than 0.5 mg/kg DTPA-extractable zinc[4]. In Central Anotolia, where nearly 45% of Turkey's wheat production is located, more than 90% of soils contain less than 0.5 mg kg^{-1} DTPA-extractable zinc, which is widely considered to be the critical deficiency concentration of zinc for plants grown on calcereous soils[5, 6]. Deficient levels of zinc in crop plants have been shown to reduce yield and crop quality in the US and throughout the world[7]. Zinc application increased grain yield 60% in the Great Konya Basin soils and medium grain yield[8] was approximately 14%. Zinc applications also increased significantly both wheat and barley yields[9–11]. In the field experiments on six locations in Central Anatolia, application of 23 kg Zn ha^{-1} increased grain yield on all locations. Relative increases in wheat grain yield resulting from zinc application ranged[12] between 5 to 554% with a mean of 43%.

In experiments conducted in Central Anatolia, it was found that barley came after durum wheat and bread wheat among cereals in regard to sensitivity to zinc deficiency and significant increases were achieved in barley yield when the amount of extractable zinc in the soil[13] was 0.3 mg kg^{-1}. According to the results of these studies, it is a requirement that zinc containing fertilization be applied on soils of Konya, which has calcareous and high pH soils that are deficient in organic substances and which are in a semi-dry climatic zone. There are differences among zinc chelates in eliminating zinc deficiency, as differences between plant species and genotypes in respect of zinc uptake. Some researches had demonstrated the chelating agents to modify the solubilization and transport of micronutrients to plant roots[14, 15]. The most common zinc sources used to correct zinc deficiencies are $ZnSO_4$ and ZnO, although zinc oxysulfates, inorganic zinc complexes, synthetic chelates and natural organic complexes are also used[16].

However, there are various zinced fertilizers on the market to meet the zinc demands of the plants. The chemical forms and application doses of zinc contained in these fertilizers are different. Hence, the purpose of this study is to investigate the effect of different zinc sources applied at various doses on barley (*Horeum vulgare* cv. Karatay-94) and its effect on grain yield and uptake of nutrient materials by plant.

EXPERIMENTAL

The study was conducted in dry conditions on calcareous soils of Konya plain on two locations under field conditions in the year 1999–2000. In fact, the experiment had been planned to be established on the same location for two years, but since it proved to be impossible to set up the experiment on the same location and since zinc application had been performed before, the second experiment had to be established on another location 10 km away. Soils of the experiment field were hydromorphic alluvial. Annual average precipitation in the experiment fields was 355.4 mm on location A (1999) and 176.1 mm on location B (2000). Average temperature on both locations on vegetation periods[17] was 12.2°C. The results of the physical and chemical analyses of the soils where the experiment was conducted are given in Table-1.

TABLE-1
CHEMICAL AND PHYSICAL PROPERTIES OF THE EXPERIMENT LOCATION SOILS

Location	pH	EC (mmho/cm)	$CaCO_3$ (%)	Org. matter (%)	P (mg kg^{-1})	K (mg kg^{-1})	DTPA-Zn (mg kg^{-1})	Texture			
								Sand (%)	Silt (%)	Clay (%)	Texture class
A	7.90	0.34	12.87	1.03	6.41	359.96	0.64	73.05	17.27	9.68	SL
B	7.18	0.43	9.03	2.03	5.81	837.42	0.83	15.01	29.63	55.36	CL

The research was carried out using a randomized complete block experimental design with three replicates at five different organic and chemical sources of zinc [$ZnSO_4$ (23% Zn), Zn-gluconate (3.68% Zn), Zn-pyruvate (4.17% Zn), ZnO (99% Zn) and Zn-EDTA (15% Zn)] and in three different doses (0–0.75–1.50 kg Zn da^{-1}). 0.75 kg Zn da^{-1} and 1.50 kg Zn da^{-1} pulverized on leaf corresponded to 0.18% and 0.36%, respectively. The zinc solution was applied in March, when the plant was in the stage of comprising 3–4 leaves (GS 13). Barley (*Hordeum vulgare* cv. Karatay-94) was used as experimental plant in the research. Bred for dry conditions, seeds of this type of barley were obtained from Bahri Dağdaş Institute of International Agricultural Research, Turkey. 10 kg DAP da^{-1} were applied on 12 m^2 experiment plots during sowing. Ammonium nitrate 33% was applied in the same plots in order to supply the nitrogen requirements of barley (5.6 kg da^{-1}) in tilling stage in April. Flag leaf samples (60 pieces) were randomly selected from barley plants in each plot. During harvest, plant height and ear height of the grain and the weight of a thousand grains were determined.

The selected samples were rinsed with 0.01 N HCl once and twice with distilled water and then dried in ambient conditions. Barley was harvested in the last week of July by a combined plot harvester. Collected flag leaves and grain samples were dried at 65 ± 5°C and then milled and wet-digested by sulfuric acid and hydrogen peroxide[18]. Phosphorus contents of these samples were determined by spectrophotometer (UV-160 Shimadzu), potassium contents by flame photometer (Jenway PFP-7) and zinc contents by atomic absorption spectrophotometer (GBC-902). The data were analyzed by using MINITAB and then subjected to LSD test by using Mstat C.

RESULTS AND DISCUSSION

Grain yield: In the study, in the experiment conducted on location A, grain yield of the barley plant demonstrated considerable increases when different zinc sources were applied ($P < 0.05$) (Table-2). In the study conducted on location B, on the other hand, although yield increased, compared with control plots, when zinc sources were applied, these increases were not statistically significant (Table-2).

Increases achieved in yield on location A were observed especially in 0.75 kg Zn da^{-1} dose of zinc sources and the order according to increase in yield is as follows: ZnO > Zn-EDTA > Zn-pyruvate > $ZnSO_4$ > Zn-gluconate. However, there are no statistical differences between applications in respect of grain yield in this order. The difference between locations in regard to reaction to zinc applications may

TABLE-2
EFFECTS OF DIFFERENT ZINC SOURCES ON BARLEY (KARATAY-94) PLANT AND SOME OF ITS PROPERTIES

Sources	Zinc doses (kg da^{-1})	Grain yield (kg da^{-1})	A thousand grain weight (g)	Plant height (cm)	Ear height of the grain (cm)
		Location A			
Zn-pyruvate	0.75	375.11 a	37.68	65.64	7.08
	1.50	344.44 a	32.99	68.22	7.03
Zn gluconate	0.75	321.09 ab	32.72	61.83	7.21
	1.50	310.30 ab	34.98	63.83	6.83
$ZnSO_4$	0.75	367.71 a	34.67	64.65	7.26
	1.50	358.17 a	37.23	65.55	7.38
ZnO	0.75	427.62 a	34.18	60.94	7.11
	1.50	310.03 ab	34.13	61.05	6.88
Zn-EDTA	0.75	405.42 a	31.93	60.94	7.21
	1.50	93.99 ab	34.23	60.00	7.09
Control		164.72 b	32.13	61.76	6.47
LSD value, $P < 0.05$		161.6	ns	ns	ns
		Location B			
Zn-pyruvate	0.75	432.83	50.50	94.30	8.72
	1.50	377.17	33.81	84.17	8.03
Zn-gluconate	0.75	387.61	44.88	95,53	8.31
	1.50	358.67	49.60	88.83	8.97
$ZnSO_4$	0.75	345.89	46.72	89.00	8.46
	1.50	453.17	49.15	98.90	8.11
ZnO	0.75	413.73	47.85	95.97	8.27
	1.50	429.78	48.83	91.93	8.05
Zn-EDTA	0.75	417.89	49.08	91.37	8.21
	1.50	425.95	52.24	95.57	8.27
Control		375.89	47.64	93.90	7.60
LSD value, $P < 0.05$		ns	ns	ns	ns

result from the fact that zinc contents of the experiment soils are respectively 0.64–0.83 ppm, that there is a difference of 0.19 ppm between them and that there is a difference between values of precipitation on locations in the experiment conducted in dry conditions. Çekiç *et al.*[19] indicated a dose of 0.5 kg Zn/da for wheat and barley in some areas where Zn deficiency was not severe. Although the relative effect of different zinc chelates on the increase of dry substance in corn under greenhouse conditions appeared in the order of Zn-FYM > Zn-FA (soil) > Zn-FA (compost) > Zn-DTPA > Zn-EDTA > $ZnSO_4$, total dry substance yield in wheat did not change with zinc sources apart from Zn-FYM[20]. Likewise, it was observed that increased zinc application to Tarm-92 and Hamidiye barley types augmented plant growth[21]; increases in grain yield of ten barley types in Eskişehir were respectively 54, 15, 11, 12 and 10% from 1991–92 to 1995–96 as a result of zinc fertilization[22]. It was further noticed that zinc applications on soils of Central Anatolian Region increased the yield of different cereal types[23, 24]

A thousand grain weight, plant height and ear height of the grain: On both locations, no statistical differences were observed between different zinc sources in respect of a thousand grain weight, plant height and height of the ear grain and doses of zinc applications (Table-2). It was reported that zinc application to barley types of Tokak 157/37, Erginel-90, Obruk-86, Bülbül-89, Cumhuriyet-80 and BDMA-13 did not change the weight of a thousand grains, but there were marked differences among types in regard to plant height[10], that there was not a significant difference between zinc application in barley and a thousand grain weight[25]that the highest plant height was achieved in plots where zinc was applied[26, 27], that maturity on durum wheat, increasing rates of zinc application increased a thousand grain weight[28].

Phosphorus contents of leaf and grain: In the study, the phosphorus content of the leaf changed remarkably with the application of zinc sources on both locations ($P < 0.05$). While the phosphorous content of the leaf increased with zinc application on location A, there was not much increase on location B (Table-3). In the same research, the phosphorus content of leaf and grain in Kiziltan durum wheat did not change with different zinc application forms, while the phosphorus content of grain significantly ($P < 0.05$) changed with the same application in the second year[29]. On the other hand, with the application of zinc in doses more than 5 mg kg^{-1} the phosphorus uptake of the Japanese mint plant decreased[30]. The phosphorus content of the grain did not change with the application of different zinc sources (Table-3).

Zinc contents of leaf and grain: The zinc contents of the leaf increased considerably ($P < 0.05$) on both locations compared with the control with the application of zinc sources (Table-3). In greenhouse experiments, which were conducted to evaluate the relative efficiency of synthetic and natural chelates for supplying zinc to wheat in a zinc deficient alkaline soil, per cent utilization of applied zinc by wheat plants was highest with Zn-DTPA and lowest with $ZnSO_4$.[20] The application of zinc complexes (Zn-phenolate, Zn-EDDHA, Zn-EDTA, Zn-lignosulphate, Zn-polyflavonoid and Zn-heptagluconate) significantly increased zinc uptake by maize compared with that in the control soil[31].

Similarly, the zinc contents of the grain displayed significant ($P < 0.05$) increases on both locations compared with the control with the application of zinc sources but no differences were observed between zinc doses applied (Table-3). The other study carried out to assess the varieties collected from different countries reveals that the lowest zinc concentrations (34.7% μg g^{-1}) were found[32] in the Turkish variety CBWF-96-151. Foliar application of zinc in inorganic or organic form is equally suitable in providing adequate zinc nutrition to wheat[33].

Potassium contents of leaf and grain: The potassium contents of leaf and grain did not display a statistically significant change on both locations with the application of different zinc sources (Table-3).

Zinc uptake by grain: Zinc uptake by grain increased markedly on both locations with the application of different zinc sources ($P < 0.05$). These increases were observed on location A in dose 0.75 kg Zn/da of organic Zn-pyruvate and Zn-gluconate and on location B in the same zinc sources again and in dose 0.75 kg Zn/da of Zn-EDTA (Table-3). Therefore, we can state that a dose 0.75 kg Zn/da of

TABLE-3
EFFECTS OF DIFFERENT ZINC SOURCES APPLIED IN DIFFERENT ZINC DOSES ON NUTRIENT CONTENTS OF BARLEY (KARATAY-94) PLANT

Zinc sources	Zinc doses (kg da^{-1})	Leaf P (mg kg^{-1})	Leaf Zn (mg kg^{-1})	Leaf K (%)	Grain P (mg kg^{-1})	Grain Zn (mg kg^{-1})	Grain K (%)	Zn uptake in grain (g da^{-1})
				Location A				
Zn-pyruvate	0.75	980.0 cd	41.51 ab	2.06	2055.5	35.23 ab	0.754	14.811 a
	1.50	1104.4 abc	53.52 a	2.27	2067.9	30.33 abc	0.740	10.194 abc
Zn gluconate	0.75	1242.5 a	39.73 ab	2.18	2117.4	41.77 a	0.719	14.354 a
	1.50	1216.6 a	30.67 ab	2.24	2074.1	24.78 abc	0.692	7.742 abc
$ZnSO_4$	0.75	1150.4 ab	24.49 b	2.18	1783.0	19.96 bc	0.713	7.204 abc
	1.50	1018.1 bcd	32.52 ab	2.17	1937.8	35.90 ab	0.714	13.405 ab
ZnO	0.75	1098.7 abc	24.70 b	2.16	1972.2	23.44 abc	0.748	10.071 abc
	1.50	1092.9 abc	39.11 ab	2.20	1987.4	15.21 c	0.728	4.678 bc
Zn-EDTA	0.75	1190.7 a	53.40 a	2.27	2036.9	22.65 bc	0.752	9.144 abc
	1.50	1012.4 bcd	35.61 ab	2.03	2111.2	22.99 bc	0.707	6.061 abc
Control		914.6 d	18.73 b	2.13	1962.6	12.74 c	0.720	1.960 c
LSD value ($P < 0.05$)		170.1	22.97	ns	ns	18.78	ns	9.624

Zinc sources	Zinc doses (kg da^{-1})	Leaf P (mg kg^{-1})	Leaf Zn (mg kg^{-1})	Leaf K (%)	Grain P (mg kg^{-1})	Grain Zn (mg kg^{-1})	Grain K (%)	Zn uptake in grain (g da^{-1})
Location B								
Zn-Pyruvate	0.75	1825.3 b	30.49 bc	2.84	4150.9	27.35 bcde	0.190	11.839 abcd
	1.50	4254.0 a	26.12 c	2.58	3908.7	26.64 bcde	0.190	10.055 bcd
Zn Gluconate	0.75	1876.9 b	22.50 c	2.69	4567.0	26.96 bcde	0.205	10.579 abcd
	1.50	2413.2 b	44.48 a	2.85	4335.3	26.35 bcde	0.192	9.366 bcd
Zn- SO_4	0.75	1846.0 b	27.35 c	2.97	3878.6	20.28 e	0.191	6.971 d
	1.50	1747.9 b	26.06 c	2.85	4361.3	22.27 cde	0.206	10.157 bcd
ZnO	0.75	2217.2 b	28.66 c	2.48	4609.2	30.85 abcd	0.215	12.724 abcd
	1.50	1866.6 b	34.19 abc	2.53	4371.5	32.43 abc	0.208	13.582 abc
Zn-EDTA	0.75	2640.1 ab	31.32 abc	3.13	4508.7	33.93 ab	0.203	15.090 ab
	1.50	1722.2 b	43.97 ab	2.64	4504.4	38.74 a	0.206	16.546 a
Control		2351.3 b	24.70 c	2.85	4073.8	20.96 de	0.203	7.876 cd
LSD value ($P < 0.05$)		1635	14.54	ns	ns	10.22	ns	5.987

zinc increased the zinc uptake of grain. The application of Zn at 5 kg ha^{-1} level resulted in significantly higher uptake of both native and applied Zn by wheat grain and straw[34]. In the study conducted on soil whose zinc content that can be extracted with DTPA is 1.5 mg kg^{-1}, uptake of zinc by maize increased with the rate of applied zinc, with slightly higher values for powdered ZnO than powdered $ZnSO_4$ at each zinc rate[35].

Conclusion

In conclusion, significant increases took place with the application of zinced fertilizer to the barley crop compared with the control. However, these increases were more obvious in the experiment on location A, which contained less zinc on soil than location B and statistically significant (P). We can state that this resulted from a difference of 0.19 ppm between the zinc contents of the soils and the increase achieved in yield by zincs of more than 0.5 mg Zn kg^{-1}, which is the upper limit for soils, was less. Although differences were observed between zinc applications on both locations with regard to other properties studied, when the results of both experiments are taken into consideration, we can say that the dose 0.75 kg Zn da^{-1} of $ZnSO_4$ should be preferred by virtue of its being the most economical of the zinc sources. Similarly, it was reported that zinc had a significant effect on yield and zinc uptake of wheat and that zinc sulphate was more effective compared with zinc oxide[36] and that the application of 3 kg $ZnSO_4 \cdot 7H_2O$ can be recommended for cereals[17].

ACKNOWLEDGEMENT

Part of this research was supported by Selcuk University Coordination Office for Scientific Research Projects (BAP) in Konya.

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(*Received*: 10 January 2006; *Accepted*: 30 June 2006) AJC-4988