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Effects of Different Zinc Doses on Zinc and Protein Contents of Barley

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This study aimed to investigate the effects of different zinc doses and application methods on zinc and protein contents and some yield components of barley (cv. Sahin 91) grown under the semi-arid conditions of south-eastern Anatolia. Foliar and soil application and seed dressing methods at varying levels were tested. Teprosyn F-2498 (600 g Zn L^{-1}) was dressed on seeds with four doses (0, 3, 6, 9 l ton^{-1}). Four doses (0, 10, 20, 30 kg ha^{-1}) of $ZnSO_4{\cdot}7H_2O$ fertilizer were applied into soil at sowing time and four doses (0.0, 0.1, 0.3 and 0.5 %) (0.0, 110, 330, 550 g Zn ha^{-1}) of $ZnSO_4{\cdot}7H_2O$ solution were sprayed three times on to the plants at 15 d intervals, starting from stem elongation onward. Seed dressing affected significantly the protein content of grain, spike length and kernel weight in barley. Soil zinc applications affected spike length and protein content of grain. Foliar Zn applications significantly affected grain weight and the Zn content of barley. Second and third doses of all application methods affected the grain yield, yield components and Zn content of the plants significantly. It was determined that the application of 30 kg $ZnSO_4{\cdot}7H_2O$ ha^{-1} to the soil or the application of 6 L ton^{-1} Teprosyn F-2498 to the seed or 0.3 % of $ZnSO_4{\cdot}7H_2O$ solution to the plants should be more efficient in terms of their economically feasible aspects and yield increases.

Key Words: Barley (*Hordeum vulgare* L.), Fertilization, Zinc, Protein, Yield components.

INTRODUCTION

The Southeastern Anatolia region, being one of the gene origins of barley, provides 15 % of the barley production of Turkey. The southeastern Anatolia region project covers about 3.2 million hectares of cultivable land. The project is among the most ambitious of all integrated regional development efforts in the world. Barley cultivation area will hold a considerable

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place in crop varieties in the area of 1.7 million hectares, which may be opened for irrigation in near future with the southeastern Anatolia Project[1]. It has been reported that more than 50 % of the cultivated area in southeastern Anatolia region had zinc deficiency because of the soils of the province contain high clay and lime in a climate of low precipitation and over evaporation[2]. A range of health problems resulting from an insufficient zinc level in human diets consisting mainly of grain crops has been described[3].

Grain yield of cereal species grown under zinc deficiency conditions decreased[4] *ca.* 35 %. Aydin *et al.*[5] reported that grain yield of 'Tokak' barley cultivar increased by 5 kg Zn ha^{-1} application. According to Raghbir *et al.*[6], 5 mg kg^{-1} zinc application to soil in a pot experiment, increased grain total protein, grain nitrogen and sulphur content of barley. However, grain yield of barley was not affected by zinc containing fertilizers in irrigated and rainfed conditions of Harran Plain. Significant differences in response to zinc were found among barley cultivars by Cölkesen *et al.*[7]. Taban *et al.*[8] determined that zinc applications increased grain yield and 1000 grain weight. In a study of three different zinc application methods[9] on the grain yield of bread and durum wheat, increased yield by 76 % soil fertilization, 61 % foliar spraying and 52 % seed dressing, respectively.

This study was carried out to determine the effects of application methods and different rates of the fertilizers $ZnSO_4 \cdot 7H_2O$ and Teprosyn F-2498 seed dressing on the zinc levels of the plants, yield and yield components of 'Sahin 91' barley cultivar grown in the province of Diyarbakir, where zinc deficiency of soils is wide-spread.

EXPERIMENTAL

The field experiments were carried out at the Experimental and Research Station of Faculty of Agriculture of Dicle University, Diyarbakir in the years 2001 and 2002 crop season under rainfed conditions. The barley cultivar 'Sahin 91' was used as material in the experiment. Annual precipitation levels in the first year and second year of the experiment were 537 and 474 mm, respectively. The long-term average precipitation level[1] in the province Diyarbakir is 490 mm. Seeding rate was 450 seeds m^{-2} and plot sizes were 4.8 m^2, an interval of 0.5 m was left to prevent the interaction of the fertilizer among the plots. Application rates of fertilizers were 60 kg P_2O_5 ha^{-1} and 120 kg N ha^{-1} to the soil, half of the nitrogen at the sowing time, the other half at stem elongation onward and phosphorus as whole at the sowing time. Four rates (0, 10, 20, 30 kg ha^{-1}) of the fertilizer $ZnSO_4 \cdot 7H_2O$ were applied to the soil at sowing time and four rates (0.0, 0.1, 0.3, 0.5 %) (0.0, 110, 330, 550 g Zn ha^{-1}) of the solutions prepared from the fertilizer $ZnSO_4 \cdot 7H_2O$ were applied three times to leaves in intervals of 15 d starting from the period of stem elongation onward. Four rates (0, 3, 6, 9 L ton^{-1} seed grain) of commercial fertilizer so-called Teprosyn F-2498 solution were used when dressing the seed grain.

10 Plants from each plot at the period of the spike formation were chosen to determine the zinc contents of the plants. Plants were cut at the height of 10 cm from the ground, by using a non-rusting steel scissors[10]. The samples were prepared for the analysis according to the method by Cakmak *et al.*[11] and the zinc contents of the plants were determined after dry ashing by AAS. The protein content in the grain measured by Mark Leco FP-528 protein/nitrogen analyzer apparatus, the plant height, the spike length, kernels per spike and the grain weight per spike, the 1000 grain weight, the grain yield were determined at maturity according to Genc[12].

Texture of soil was determined by using the hydrometer method[13]; pH by Beckman pH-meter in the saturated soil paste, lime content by Scheibler calcimeter, organic matter was determined by Walkley-Black wet oxidation[14] and available P was determined according to Murphy and Riley[15], extracting the soil by 0.5 N $NaHCO_3$ (pH = 8.5)[16]. Soil samples for available K were treated with 1 N ammonium acetate (pH = 7) and quantified by atomic absorption spectrophotometer[17] zinc was extracted with DTPA-TEA in the filtered soil solution and determined[18] by AAS. The soil, classified as a clayey loam, contained an average of 19 and 7.8 g kg^{-1} organic matter and lime, respectively and had pH 7.77. Soil samples were found to have 7.5, 290 and 0.37 mg kg^{-1} for P, K and Zn, respectively.

The experimental design was a split plot design with three replications. Differences among means and treatments were compared by the least significant differences (LSD) at $p < 0.05$ and $p < 0.01$ by using MSTAT-C software program.

RESULTS AND DISCUSSION

The effects of the zinc rates and the application methods on grain yield, yield components, protein contents and the zinc contents are presented in Tables 1-3. Compared to the control treatment, all zinc rates significantly increased grain yield, yield components, protein contents and zinc contents of barley plants, while zinc application methods significantly affected only spike length, grain weight per spike, zinc content of plant and protein per grain. There were differences between years for all traits except thousand grain weight, grain yield and protein rate per grain. This results from the similarity of rainfall and mean temperature conditions in both years at the heading stage of barley. Also, the differences in Zn content may be the result of the unexpected rain after the third application of $ZnSO_4{\cdot}7H_2O$ solution to the plant (Tables 1-3). The effect of zinc rates on grain yield was statistically significant. Compared to controls, the yield increases obtained with Zn_2 was about 17.5 %, while those of Zn_3 and Zn_1 were 16.5 and 10.4 %, respectively. Grain yield increased up to 5325 kg ha^{-1} (Table-3) by the application rate of 30 kg ha^{-1} $ZnSO_4{\cdot}7H_2O$ to soil.

TABLE-1
EFFECTS OF FERTILIZERS CONTAINING ZINC ON PLANT HEIGHT, SPIKE LENGTH OF BARLEY AT MATURITY

Treatments		Plant height (cm)			Spike length (cm)		
		2001	2002	Means	2001	2002	Means
Seed	Zn_0	109	115	112	8.70	7.84	8.27
	Zn_1	110	119	114	8.90	8.09	8.50
	Zn_2	111	123	117	9.17	8.45	8.81
	Zn_3	114	122	118	9.13	8.62	8.88
Soil	Zn_0	107	113	110	8.77	6.61	7.69
	Zn_1	108	117	113	8.93	7.64	8.29
	Zn_2	108	119	114	9.50	7.84	8.67
	Zn_3	109	120	114	9.07	7.83	8.45
Leaf	Zn_0	107	115	111	8.43	7.05	7.74
	Zn_1	107	118	112	8.57	7.19	7.88
	Zn_2	109	121	115	8.93	8.14	8.54
	Zn_3	108	120	114	9.23	7.70	8.47
Application × doses		LSD	n.s.		0.372*		
Means of applications		Seed	115		8.61 a		
		Soil	113		8.27 ab		
		Leaf	113		8.15 b		
		LSD	n.s.		n.s.		
Means of doses		Zn_0	111 b		7.90c		
		Zn_1	113 ab		8.22bc		
		Zn_2	115 a		8.67a		
		Zn_3	115 a		8.60ab		
		LSD	2.453**		0.378**		

*p < 0.05, **p < 0.01; n.s. = Non-significant, a, b, c = The differences among the groups with different letters in the same column and line are significant.

The highest results for spike length and grain weight per spike were obtained by zinc application to seed. Zinc application methods and Zn_1, Zn_2 and Zn_3 doses increased the zinc contents up to the optimum level. As expected zinc content was increased by foliar zinc application twice higher than seed and soil application than.

The present findings corresponding to the findings of those showing the yield increase at the rate of 17.2 % increasing from 2650 to 3200 kg ha^{-1} by the zinc application rate of 22 kg ha^{-1} $ZnSO_4 \cdot 7H_2O$ in the plot of plant control in a study carried out with the plant wheat in a soil containing 0.35 mg kg^{-1} zinc level[19]. It can be said that soil application of Zn was economical and had long-term effects for enhancing grain yield of cereals grown on

TABLE-2
EFFECTS OF FERTILIZERS CONTAINING ZINC ON KERNELS PER SPIKE, GRAIN WEIGHT PER SPIKE AND THOUSAND GRAIN WEIGHT

Treatments		Kernels per spike			Grain weight per spike (g)			Thousand grain weight (g)		
		2001	2002	Mean	2001	2002	Mean	2001	2002	Mean
Seed	Zn_0	26.9	25.4	26.2	1.42	1.36	1.39	52.6	51.7	52.2
	Zn_1	27.8	25.5	26.7	1.57	1.40	1.48	57.1	56.3	56.7
	Zn_2	28.8	26.7	27.8	1.66	1.47	1.57	59.4	58.7	59.1
	Zn_3	28.5	26.9	27.7	1.75	1.56	1.65	62.0	60.0	61.0
Soil	Zn_0	27.0	25.1	26.1	1.31	1.32	1.32	49.1	55.4	52.3
	Zn_1	27.7	26.6	27.2	1.36	1.25	1.30	51.7	58.0	54.8
	Zn_2	29.3	28.2	28.8	1.51	1.49	1.50	57.8	58.3	58.0
	Zn_3	29.9	27.5	28.7	1.63	1.52	1.58	63.3	60.1	61.7
Leaf	Zn_0	25.7	24.7	25.2	1.39	1.26	1.33	56.8	53.4	55.1
	Zn_1	26.3	25.5	25.9	1.55	1.33	1.44	61.2	55.8	58.5
	Zn_2	28.4	26.7	27.6	1.61	1.48	1.54	63.7	58.3	61.0
	Zn_3	28.8	26.1	27.5	1.66	1.38	1.52	65.1	56.9	60.9
Application × Doses				LSD	n.s.			n.s.		n.s.
Means of applications				Seed	27.1			1.52 a		57.2
				Soil	27.7			1.42 b		56.7
				Leaf	26.5			1.46 ab		58.9
				LSD	n.s			0.0698*		n.s
Means of doses				Zn_0	25.8 b			1.34 b		53.2 c
				Zn_1	26.6 ab			1.41 b		56.7 bc
				Zn_2	28.0 a			1.54 a		59.4 ab
				Zn_3	28.0 a			1.58 a		61.2 a
				LSD	1.802**			0.1073**		3.818**

*p < 0.05, **p < 0.01, n.s. = Non-significant, a, b, c = The differences among the groups with different letters in the same column and line are significant.

zinc deficient soils. The increased zinc application rates significantly increased grain yield in barley[5,20]. Nevertheless, Cölkesen *et al.*[7] could not find any significant relationship between zinc and grain yield.

Increasing zinc application rates increased the length of spike and kernels per spike (Table-2). Resulting positive correlations of the increasing zinc application rates on the grain number and weight per spike might result from the positive correlations among the spike traits[21].

Optimum zinc content of barley at the heading time[10] is between 20 and 70 mg kg^{-1}; all application methods, especially foliar application increased the zinc contents of the plants up to the optimum level[11,22,23].

TABLE-3
EFFECTS OF FERTILIZERS CONTAINING ZINC ON GRAIN YIELD AND GRAIN PROTEIN CONTENT AT MATURITY AND ZINC CONTENTS OF BARLEY PLANTS AT SPIKE FORMATION

Treatments		Grain yield (kg ha^{-1})			Grain protein content (%)			Zinc contents of the plants (mg kg^{-1} D.W.)		
		2001	2002	Mean	2001	2002	Mean	2001	2002	Mean
Seed	Zn_0	4130	4660	4395	12.5	12.1	12.3	18.1	19.9	19.0 c
	Zn_1	4510	4860	4685	13.2	12.5	12.8	26.9	19.4	23.7 c
	Zn_2	4920	5110	5015	13.4	12.5	12.9	22.4	21.3	21.8 c
	Zn_3	4660	5020	4840	13.2	12.8	13.0	17.8	22.0	19.4 c
Soil	Zn_0	4250	4530	4390	12.1	11.8	11.9	17.3	20.5	18.9 c
	Zn_1	4950	4770	4860	12.4	12.4	12.4	23.9	21.6	22.7 c
	Zn_2	5120	5160	5140	12.6	12.5	12.5	22.7	23.8	23.3 c
	Zn_3	5310	5340	5325	12.6	12.9	12.7	26.4	23.1	24.8 c
Leaf	Zn_0	4180	4530	4355	11.9	11.6	11.7	15.5	23.5	19.5 c
	Zn_1	5130	4810	4970	12.0	11.8	11.9	37.9	45.8	41.8 b
	Zn_2	5340	5240	5290	12.5	12.4	12.4	45.9	62.5	54.2 b
	Zn_3	5240	5050	5145	12.3	12.0	12.1	48.7	92.2	70.4 a

		Grain yield	Grain protein content	Zinc contents
Application × Doses	LSD	n.s.	n.s.	12.42**
Means of applications	Seed	4734	12.8 a	21.0 b
	Soil	4929	12.4 ab	22.4 b
	Leaf	4940	12.1 b	46.5 a
	LSD	n.s	0.4231*	10.10**
Means of doses	Zn_0	4380 b	12.0 b	19.1 c
	Zn_1	4838 a	12.4 ab	29.4 b
	Zn_2	5148 a	12..6 a	33.1 ab
	Zn_3	5103 a	12.6 a	38.2 a
	LSD	447.4**	0.4713*	7.17**

*p < 0.05, **p < 0.01), n.s. = Non-significant, a, b, c = The differences among the groups with different letters in the same column and line are significant.

Zinc contents of plants were significantly greater in leaf applied treatments than other applications, whereas protein content was greater in seed application. However, there was no significant difference between zinc application methods for plant height, kernel number, grain yield and thousand grain weight.

Short plant height is one of the most common symptoms of an insufficient Zn level[11]. The present findings correlated 111-115 cm well with the findings[20] of those showing increases in plant height from 66.3 to 83.3 cm and zinc application on the spike length[24], which increased from 6.45 cm (control) to 7.30 cm (18 kg Zn ha^{-1}) in the experimental of years[20] spike length are longer 7.9-8.6 cm.

The positive effects of seed zinc applications on spike length may result from easy uptake of zinc in the germination. Zinc application to leaves may not affect early spike development due to low translocation of zinc in plant tissues and late application times.

The increase of thousand grain weight by increasing zinc application rates might be the result of adequate rainfall and sufficient amount of the nutrients in soil at the vegetative stage[25]. The present findings (Table-2) does not correspond with the findings of Kenbaey and Sade[20], reporting a decrease of 1000 grain weight from 50.8 to 47.9 g in barley at the increasing application rates and the insignificant effect on thousand grain weight by the increased zinc application rates[9].

The positive effects of Zn_2 and Zn_3 application rates (Tables 1 and 2) on plant height, spike length, grain weight per spike and thousand grain weight of barley might result from the effect of zinc on the synthesis of plant growth hormone Auxin and on the efficient use of other plant nutrients[21,26].

The increased protein content of grain as a result of the increased application rates of zinc to barley plants might result from the consequent protein synthesis of the positive effects of zinc on the amino acid synthesis[26]. The present findings coincide with the findings of those reporting[20] the increase of grain protein content from the level of 13.5 to 14.2 % in 6 barley varieties at the increased application rates of fertilizer $ZnSO_4·7H_2O$ by the application method of soil fertilization and the highest level of the protein rate at the application rate of 27 kg ha^{-1} $ZnSO_4·7H_2O$ and accordingly, considerable increases in the total protein contents of grains at the increased application rates of zinc[6].

The rate of 0.1 % of the foliar solution of $ZnSO_4·7H_2O$ was applied to the plants three times and the zinc contents of the plants increased from 19 to 42 ppm. Instead of that application, only one application with a 0.3 % solution at stem elongation may be a more economical way with the same result.

The best increases in grain yield, yield components and zinc content of the plants were obtained by the application rate of 30 kg ha^{-1} of the fertilizer $ZnSO_4·7H_2O$ applied to soil at sowing or the application rate of 6 L ton^{-1} of Teprosyn F-2498 by seed dressing or foliar spray with 0.3 % of $ZnSO_4·7H_2O$ solution. However, soil applications would contributed residual and available zinc for the consecutive crop.

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