Effect of zinc application on quality traits of barley in semi arid zones of Turkey

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ABSTRACT

Field experiments were carried out to study effects of zinc application on quality traits of barley in 1994–1996. The treatments were applied as 0 and 23 kg/ha of zinc sulphate and incorporated into soil before sowing. The experimental design was split plot with four replications. Barley genotypes responded differently to zinc application in relation to thousand grains weight, protein content and starch content. A significant increase was determined for thousand grain weight in cultivars Tokak 157/37 and Cumhuriyet 50, for protein content in Orza, Bülbül 89 and Anadolu 86, for starch content in Karatay 94 and Cumhuriyet 50, while a significant decrease has been found for thousand grain weight in Karatay 94 and Obruk 86 and for protein content in Karatay 94, Cumhuriyet 50 and Tarm 92. When feeding and malting quality are considered together, Karatay 94 and Cumhuriyet 50 are the most suitable cultivars for growing in zinc-applied soils of semi arid areas.

Keywords: barley; Zn-deficiency; quality; semi arid; zinc application

A global investigation of FAO has brought to light that zinc is the most widely deficient micronutrient, especially in the soils of semi arid zones in the world. It is therefore considered as the most serious part of hidden hunger of plants. About 50% of the soils used for cereal production in the world contain low levels of plant-available Zn, which reduces not only grain yield, but also nutritional quality (Graham et al. 1992, Çakmak et al. 1996, Graham and Welch 1996). Unlike the other micronutrients, it is a common feature of both cold and warm climates and acid, alkaline, heavy or light soils (Graham et al. 1992). During an FAO investigation, 250 wheat soil and 50 maize soil samples, well distributed over the agriculturally important areas of the country, were collected in Turkey. Results of analysis of these samples showed that the most evident micronutrient disorders in Turkey are caused by deficiency of zinc (Sillanpaa 1982). There is a significant evidence showing that zinc deficiency is a critical nutritional problem in cultivated areas of Turkey and more seriously in majority of dryland zones of Central Anatolian soils, where more than 50% of wheat and barley production of Turkey is obtained (Chaudary and Kacar 1980, Çakmak et al. 1996, Eyüpoğlu 1998, Çakmak 2000). Zinc deficiency is particularly widespread in calcareous soils (Çakmak et al. 1997). The FAO investigation showed that zinc deficiency was associated with high pH, low organic matter, low total or extractable Zn content in soil and $CaCO_3$ in soil with high evaporation and low annual precipitation (Takkar and Walker 1993). Majority of soils in rain-fed areas of Turkey carry these characteristics. A number of research have indicated that zinc deficiency in plants can be corrected fairly readily by application of inorganic zinc salts such as $ZnSO_4$ to the soil (Marschner 1995). The rate 2.5–25 kg/ha Zn for an application below seeds before planting was proved as the most effective in ameliorating zinc deficiency in field (Murph and Walsh 1972, Takkar and Walker 1993).

In Turkey, barley production is the second biggest after wheat, with growing area over 3–4 million hectares and yield about 7–8 million tones. It is used as animal feed or consumed after processing into beverages (Kinaci and Dönmez 1998). In general, low water supply is known to be the main reason for limitation of grain yield of barley in semi arid soils, but zinc also affects various agronomic characters of barley grown in rain-fed areas (Kinaci et al. 1995, Aydin et al. 1998, Kanbaev and Sade 2002). Studies on quality features of barley produced in semi arid soils of Turkey in relation with the effect of zinc are limited.

This work was carried out to determine (i) the effect of Zn application on quality characters of barley, (ii) the response of barley genotypes to Zn application in the semi arid areas.

MATERIAL AND METHODS

This research was done in Konya, the largest barley growing province in semi arid Central Anatolian Region of Turkey. Field experiments were conducted at research farm of the Bahri Dağdaş International Winter Cereals Research Center during 1994–1995 and 1995–1996 cropping seasons. Soil of the experiment site was characteristic for the majority of Central Anatolian semi arid areas (Table 1). The soil samples were air-dried, passed through a 4 mm sieve and analysed for pH, $CaCO_3$, organic matter and texture using standard procedures (Black 1965). Plant available concentrations of Zn, Fe, Mn and Cu in soils were determined according to the method of Lindsay and Norvell (1978) by extraction with DTPA (diethylenetriamine pentaacetic acid) using a soil-solution ratio of 1:2 and shaking time of two hours. Extracted micronutrients were determined by atomic absorption and spectrophotometry.

The long-term average of total annual precipitation is 326.3 mm, however, during the 1994–1995 and 1995–1996 cropping seasons it was exceptionally high as 365.5 and 425.9 mm, respectively.

Two rows of winter barley (*Hordeum vulgare* L.) genotypes were used as a material in this research. These were Yesevi, Bülbül 89, Tokak 157/37, Tarm 92, Anadolu 86, Obruk 86, Hamidiye 85, Cumhuriyet 50, Orza and Karatay 94 varieties and variety candidate YEA 1868 (recently released as Kalayci 97) which are improved and released for rain-fed conditions.

In this study, zinc was applied as 0 and 23 kg/ha using Zinc Sulphate Hepta Hidrate in crystalline form and incorporated into the soil before sowing. 120 kg/ha Diamonium Phosphate (18% N–46% P_2O_5) and 40 kg/ha Amonium Sulphate (21% N) were applied with sowing and 140 kg/ha Amonium Sulphate were given as foliar treatment in early spring, which are recommended rates for barley production under rain-fed conditions in the Central Plateau. The experimental design was split-plot with four replications. Zn treatments (with and without 23 kg Zn/ha applied as $ZnSO_4$) were established as main plots and arranged in a randomized complete-block design. Cultivars were randomized as subplots.

Grain samples were collected after maturation from each variety and sampled for evaluations of grain quality. Thousand grain weight, protein and starch content were determined by following procedures: Thousand grains weight (TGW) was determined individually from each replicates by multiplying the weight of 100 grains by 10. Prior to determination of protein and starch, representative samples (100 g) of grains were individually milled into flour with a laboratory mill. All analyses were carried out in duplicate and reported on a dry matter basis.

Flour protein and starch content were estimated by the NIR analysis using a Dickey –John GAC III. It was calibrated according to Kjeldahl protein determination to estimate protein content (Anonymous 1983). The starch content was estimated according to Ewers (Williams and Norris 1987).

Analyses of variance were conducted for each variety. Relationships between zinc treatment and quality characters were described using a regression analysis for each variety. Measurements of quality characters employed in regression analyses were values of all replications in all years of all treatments.

Table 1. Soil properties of the experimental area

Soil properties	Range
Soil pH	7.2–8.4
Organic matter (%)	0.12–1.45
$CaCO_3$ (%)	35–39
Soil texture	Silty loam – clayed loam
DPTA-extractable	
Zn (mg/kg soil)	0.12
Fe (mg/kg soil)	3.2
Mn (mg/kg soil)	3.4
Cu (mg/kg soil)	0.4

Table 2. Analysis of variance for TGW in zinc applied barley genotypes

	Year	Zinc	Year × zinc	Error
Yesevi	16.4*	1.44	0.81	2.21
YEA 1868	10.7**	2.48	0.35	0.96
Bülbül 89	38.1*	10.08	0.27	4.08
Tokak	16.4*	13.32*	0.82	1.75
Tarm	17.85**	1.50	0.02	0.86
Anadolu	24.01**	3.43	0.01	1.1
Obruk	32.8**	16.2**	2.45	1.21
Hamidiye	60.09**	7.1	1.02	3.28
Cumhuriyet	27.57**	6.25**	0.81	0.51
Karatay	40.33**	7.03*	1.31	1.27
Orza	22.57**	3.43	0.55	1.47

*significant at 5% level, **significant at 1% level

Table 3. Mean values, reduction and increase of TGW in zinc applied barley genotypes

Cultivars	1994–1995			1995–1996			Mean of two years		
	–Zn	+Zn	% RD-IN	–Zn	+Zn	% RD-IN	–Zn	+Zn	% RD-IN
Yesevi	53.8	52.7	–2.04	55.4	55.2	–0.40	54.6	54.0	–1.1
YEA 1868	52.6	51.5	–2.09	54.0	53.5	–0.90	53.3	52.5	–1.5
Bülbül 89	45.2	47.0	3.98	48.5	49.8	2.68	46.8	48.4	3.42
Tokak	54.6	56.9	4.21	57.1	58.5	2.45	55.9	57.7	3.22
Tarm	52.3	51.8	–0.96	54.5	53.8	–1.28	53.4	52.8	–1.12
Anadolu	53.9	54.8	1.67	56.3	57.3	1.78	55.1	56.0	1.63
Obruk	55.6	52.8	–5.04	57.7	56.5	–2.08	56.6	54.6	–3.53
Hamidiye	39.6	37.7	–4.80	42.9	42.1	–1.86	41.3	39.9	–3.39
Cumhuriyet	51.4	53.1	3.31	54.5	55.3	1.47	53.0	54.2	2.3
Karatay	52.2	51.4	–1.53	55.9	54.0	–3.40	54.0	52.7	–2.41
Orza	52.5	51.2	–2.48	54.5	53.9	–1.10	53.5	52.6	–1.68

RESULTS AND DISCUSSION

In relation with quality traits, significant differences were determined among barley genotypes that received zinc application in two years. TGW values were affected either positively or negatively by Zn, related to genotype. Significant effect in TGW was determined in Tokak 157/37, Cumhuriyet 50, Obruk 86 and Karatay 94 (Table 2). Estimated increases in TGW values in two years average were 3.22% in Tokak 157/37 and 2.3% in Cumhuriyet 50 while the decreases were 3.53% in Obruk 86 and 2.41% in Karatay 94 (Table 3). These levels of increase in TGW may mean that by zinc application there can be obtained 23–32.6 kg/t more from Cumhuriyet 50 and Tokak 157/37. On the other hand, the same treatment can cause the 24–35 kg/t reduction of production in Karatay 94 and Obruk 86.

These results are quite important for farmers growing barley as a subsistent crop or on large and small scale as a cash crop. Besides, if the grain sown back into the zinc-deficient soils, as is commonly done by Turkish farmers, seeds with high zinc content will have a major effect on seedling vigour of next generation. In contrast, seedlings from seed with low zinc content are susceptible to various soil-borne pathogens and thus to winterkill (Graham and Webb 1991, Graham et al. 1992, Graham and Rengel 1993). Barley with higher seed zinc content also produces bigger roots and shoots during early growth (Rengel 2001). Greater root mass would be beneficial in later growth stages for nutrients and water uptake when plants face water shortage in case of early drought periods that are fairly often during springs in semi arid areas.

Variation accounted to zinc application changed between 4–28%. Statistically significant variations due to zinc treatment were estimated as 28% in Tokak 157/37 and 26% in Obruk 86. Important and positive correlation was found between TGW and zinc treatment in Tokak 157/37, while this correlation was significantly negative in Obruk 86. With each kg of zinc treatment, the TGW increased by 0.79 g in Tokak 157/37. In contrast, each kg of zinc treatment caused 0.88 g decrease in Obruk 86 (Table 8).

Zinc has a critical role in synthesis of protein and metabolism of DNA and RNA. Protein content of a Zn deficient plant is dramatically reduced (Valle and Falchuk 1993). Protein concentration affects the

Table 4. Analysis of variance for PC

	Year	Zinc	Year × zinc	Error
Yesevi	1.26**	0.0	0.0	0.12
YEA 1868	0.14*	0.14*	0.01	0.02
Bülbül 89	1.16**	0.46*	0.07	0.09
Tokak	1.21*	0.0	0.0	0.002
Tarm	0.52**	0.10*	0.01	0.012
Anadolu	1.44**	0.49*	0.01	0.07
Obruk	6.25**	0.25	0.04	0.13
Hamidiye	3.81**	0.0	0.0	0.07
Cumhuriyet	1.62**	0.45*	0.11	0.07
Karatay	0.49**	0.31**	0.01	0.02
Orza	1.10**	1.44**	0.01	0.06

Table 5. Mean values, reduction and increase of PC in zinc applied barley genotypes

Cultivars	1994–1995			1995–1996			Mean of two years		
	–Zn	+Zn	% RD-IN	–Zn	+Zn	% RD-IN	–Zn	+Zn	% RD-IN
Yesevi	14.1	14.1	0	14.7	14.7	0	14.4	14.4	0
YEA 1868	14.4	14.5	0.7	14.5	14.8	2.1	14.5	14.6	0.7
Bülbül 89	13.3	13.8	3.8	14.0	14.2	1.4	13.6	14.0	2.9
Tokak	14.3	14.3	0	14.9	14.9	0	14.6	14.6	0
Tarm	14.1	13.9	–1.4	14.4	14.3	–0.7	14.3	14.1	–1.4
Anadolu	13.9	14.3	2.9	14.5	14.9	2.8	14.2	14.6	2.8
Obruk	13.8	13.6	–1.4	15.1	14.8	–2.0	14.5	14.2	–2.1
Hamidiye	13.5	13.5	0	14.5	14.5	0	14.0	14.0	0
Cumhuriyet	14.1	13.9	–1.4	14.9	14.4	–3.4	14.5	14.2	–2.1
Karatay	14.0	13.8	–1.4	14.4	14.1	–2.1	14.2	14.0	–1.4
Orza	14.0	14.6	4.3	14.5	15.1	4.1	14.2	14.8	4.2

quality of barley for making beer. The delivery of low or high protein grain affects the downstream processing of the barley grain in the malt house and the brewery, including efficiency, throughout times and profitability. High protein grains are generally less uniform in their germination, which affects the degree of converting the starch in the grain into malt extract. On the other hand, fermentation can be limited due to the low protein content (Paynter 1999). Recently, the negative effect on ileal starch digestibility of chicks and cocks, when fed with high protein barley has been recognised (Almirall et al. 1995). This leads to the conclusion that high protein barley is inappropriate for malting and feed purposes (Molina-Cano et al. 1997).

As to protein content, there were significant differences among cultivars in response to Zn treatment (Table 4). Zinc application had positive and considerably high effect on PC in Orza, Bülbül 89, Anadolu 86 with an average of 4.2%, 2.9% and 2.8%, respectively (Table 4). Zinc application caused reduction in PC in Cumhuriyet 50 with the average of 2.1%, Karatay 94 and Tarm 92 with the average of 1.4% (Table 5).

Variation accounted to zinc application changed from 3% to 45%. There were significantly positive correlations between zinc application and PC in YEA 1868 and Orza and significantly negative correlations in Karatay 94. For each kg of zinc treatment PC rate increased by 26% in Orza and 8% in YEA 1868 (presently Kalayci 97) but decreased by 12% in Karatay 94 (Table 8).

In this investigation, various amounts of starch content increase were obtained by zinc applications (Table 7). Zinc application significantly affected starch content of Karatay 94 by 1.8% and Cumhuriyet 50 by 0.8% (Table 6). Malting barley must have a high starch content that is modified to soluble fermentable sugars (Williams et al. 1988). Extract yield (primary malting parameter) show significant positive correlation with starch content. This correlation reflects the energy value of barley for both malting and feeding. Reed (1940), Jyung et al. (1975), and Sukhija et al. (1987) reported the starch formation reduction under zinc deficiency in some crops. In this investigation, various amounts of starch content increase were obtained by zinc applications. This is again a relatively important aspect for brewery but also for feeding, where energy is one of the major requirements. A positive

Table 6. Analysis of variance for SC in zinc applied barley genotypes

	Year	Zinc	Year × zinc	Error
Yesevi	8.7**	0.64	0	0.55
YEA 1868	27.8**	0.001	0.01	0.36
Bülbül 89	19.36**	4.62	2.72	1.74
Tokak	14.24**	0.0	0.58	0.54
Tarm	5.76*	1.96	0.0	1.12
Anadolu	16.41**	0.0	0.0	0.36
Obruk	12.60**	0.72	0.26	1.14
Hamidiye	18.07**	0.81	0.49	1.09
Cumhuriyet	15.6**	1.11*	0.29	0.18
Karatay	11.39**	5.18**	0.33	0.42
Orza	18.49**	0.0	0.0	0.41

Table 7. Mean values, reduction and increase of SC in zinc applied barley genotypes

Cultivars	1994–1995			1995–1996			Mean of two years		
	–Zn	+Zn	% RD-IN	–Zn	+Zn	% RD-IN	–Zn	+Zn	% RD-IN
Yesevi	59.8	60.2	0.67	61.3	61.7	0.65	60.5	60.9	0.66
YEA 1868	58.9	59.0	0.2	61.6	61.7	0.16	60.3	60.4	0.17
Bülbül 89	58.1	60.0	3.3	61.2	61.4	0.3	59.6	60.7	1.80
Tokak	59.4	59.4	0.0	61.3	61.3	0.0	60.3	60.3	0.0
Tarm	59.7	60.4	1.2	60.9	61.6	1.2	60.3	61.0	1.2
Anadolu	59.5	59.5	0.0	61.5	61.5	0.0	60.5	60.5	0.0
Obruk	59.4	60.1	1.18	61.4	61.6	0.3	60.4	60.8	0.7
Hamidiye	58.7	59.5	1.36	61.2	61.3	0.2	60.0	60.4	0.7
Cumhuriyet	59.0	59.8	1.36	61.3	61.5	0.3	60.2	60.7	0.8
Karatay	59.7	61.1	2.35	61.7	62.5	1.3	60.7	61.8	1.80
Orza	59.7	59.7	0	61.8	61.8	0.0	60.8	60.8	0.0

correlation was reported between the metabolizable energy (primary nutritional trait) and the starch content by Molina-Cano et al. (1997).

Variation accounted to zinc application for SC value changed from 2 to 15%. Correlation between the zinc application and SC was positive for most genotypes but not significant (Table 8).

When feeding and malting quality of varieties are considered together, i.e for dual purposes, Cumhuriyet 50 and Karatay 94 should be sown in Zn applied soil. On the other hand, Tokak 157/37 increased its TGW values after zinc treatment but no changes occurred in other traits. Although it was not significant statistically, Bülbül 89 showed various degrees of increase for all quality traits that were investigated in this study.

In most zinc deficient soils of semi-arid areas, principal crops are cereals. They are grown in rotation in rain-fed agriculture. Residual effect of zinc continues 4–5 years after its incorporating into the soil, therefore every crop would be treated by zinc at least one year in a three or four year rotational system. Farmers who produce barley according to the market preference will have opportunity to

Table 8. Relationship between zinc application (x) and quality characters in barley genotypes

	TGW			PC			SC		
	$Y = a + bx$	R	r	$Y = a + bx$	R	r	$Y = a + bx$	R	r
Yesevi	$54.6 - 0.26x$	0.04	–0.20	$14.4 + 0.01x$	$4.3.10^{-4}$	0.02	$60.5 + 0.17x$	0.04	0.21
YEA 1868	$53.3 - 0.34x$	0.11	–0.33	$14.4 + 0.08x$	0.27	0.52*	$60.3 + 0.02x$	2.710^{-4}	0.02
Bülbül 89	$46.8 + 0.69x$	0.12	0.34	$13.6 + 0.15x$	0.19	0.43+	$59.6 + 0.47x$	0.11	0.32
Tokak	$55.9 + 0.79x$	0.28	0.53*	$14.58 + 0x$	0	0	$60.3 + 0x$	0	0
Tarm	$53.4 - 0.27x$	0.05	–0.23	$14.3 - 0.07x$	0.13	–0.36	$60.3 + 0.30x$	0.15	0.39
Anadolu	$55.1 + 0.40x$	0.08	0.28	$14.6 + 0.15x$	0.18	0.43+	$60.5 + 0x$	0	0
Obruk	$56.6 - 0.88x$	0.26	–0.51*	$14.5 - 0.11x$	0.03	–0.18	60.5 + 0.14	0.02	0.13
Hamidiye	$41.3 - 0.58x$	0.07	–0.27	$14 + 0x$	0	0	$60 + 0.20x$	0.03	0.16
Cumhuriyet	$53.0 + 0.54x$	0.15	0.40	$14.5 - 0.15x$	0.16	–0.41	$60.2 + 0.23x$	0.05	0.23
Karatay	$54 - 0.58x$	0.11	–0.33	$14.2 - 0.12x$	0.29	–0.54*	$60.7 + 0.49x$	0.15	0.39
Orza	$53.5 - 0.40x$	0.08	–0.29	$14.2 + 0.26x$	0.45	0.67**	$60.8 + 0x$	0	0

+$P < 0.10$, *$P < 0.05$, **$P < 0.01$

select cultivars to grow in zinc-applied soils. On the other hand, a variation among barleys to zinc can be used to generate sources to use in breeding programmes to improve barleys for different purposes.

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ABSTRAKT

Vliv hnojení zinkem na kvalitu ječmene v semiaridních oblastech Turecka

V letech 1994–1996 byl v polních pokusech s dělenými dílci sledován vliv hnojení zinkem na kvalitativní znaky jedenácti odrůd ječmene. V odezvových variantách bylo při předseťové přípravě zapraveno do půdy 23 kg Zn/ha ve formě síranu zinečnatého. Jednotlivé odrůdy na hnojení zinkem reagovaly rozdílně. U odrůd Tokak 157/37 a Cumhuriyet 50 byla zjištěna významně vyšší hmotnost tisíce zrn. Dále byl stanoven významně vyšší obsah bílkovin u odrůd Orza, Bülbül 89 a Anadolu 86 a obsah škrobu u odrůd Karatay 94 a Cumhuriyet 50. Naopak byl zaznamenán významný pokles hmotnosti tisíce zrn u odrůd Karatay 94 a Obruk 86 a obsahu bílkovin u odrůd Karatay 94, Cumhuriyet 50 a Tarm 92. Z hlediska krmné a rovněž sladovnické kvality ječmene jsou pro pěstování v semiaridních oblastech na půdách hnojených zinkem nejvhodnější odrůdy Karatay 94 a Cumhuriyet.

Klíčová slova: ječmen; deficit zinku; kvalita; semiaridní podmínky; hnojení zinkem

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