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Variations in Grain Yield and Quality Traits of Bread Wheat Genotypes by Zinc Fertilization

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Abstract: This study was carried out to investigate variation in grain yield and some quality traits of 12 bread wheat cultivars grown in zinc-deficient soil under rainfed conditions. Zinc fertilization was applied at the rate of 23 kg Zn ha^{-1}, as $ZnSO_4.7H_2O$. Zinc application resulted in significant increase in grain yield and thousand kernel weight on average of 184 and 17% respectively, while resulting in grain protein and gluten content (3.5%) decreases. Correlation analysis indicated that, with zinc application, grain yield and protein content, thousand kernels weight and protein content had negative significant relationship, whereas protein content and gluten content had positive significant relationship.

Key words: Bread wheat, zinc fertilization, grain yield, quality traits

Introduction

Zinc deficiency is a critical nutritional problem in Central Anatolia, substantially limiting wheat production. A large plant and soil sampling program was carried out in the farmers' fields in Central Anatolia by some researchers (Cakmak *et al.*, 1998; Yilmaz *et al.*, 1998). The results showed that 90% of soil samples were Zn deficient and almost 80% of the plant samples suffered from Zn deficiency. Wheat plants grown in soils containing less than 0.2 mg kg^{-1} DTPA-Zn significantly respond to soil Zn applications. Zinc fertilization resulted in dramatic increases in grain yield, providing substantial economic savings to farmers in Central Anatolia (Yilmaz *et al.*, 1998).

Zinc deficiency in human beings is a prevalent micro-nutrient deficiency in many countries. It has been estimated that more than 2 billion people in the world suffer from micro-nutrient deficiencies including Zn (Graham and Welch, 1996). A higher proportion of cereal-based foods in the diet was suggested to be one major reason for Zn deficiency in humans, especially in developing countries. Wheat, maize and rice consumed by people in developing countries comprise about 90% of the average diet (Graham and Welch, 1996). Also in Turkey, where cereal-based foods dominate in the diet, Zn deficiency is widespread in humans (Prasad, 1982).

Several works have been carried out concerning the effect of zinc fertilization on yield of different wheat cultivars under field conditions in Central Anatolia. Ekiz *et al.* (1997) reported that increase in grain yield by Zn application ranged from 5 to 55%, depending on genotype, soil properties such as group, pH, $CaCO_3$, organic matter and clay, and annual precipitation. Brown *et al.* (1993) found that pollen grain development in Zn-deficient wheat plants was largely impaired, possibly as a result of reduced levels of indole acetic acid and proteins. These results indicate that in Central Anatolia, in order to increase grain yield, Zn application is necessary.

Unfortunately, in Turkey, a few studies have been conducted on interactions between quality traits and Zn application in various wheat cultivars, in spite of more research on grain yield. Besides grain yield, it is necessary to know how much changes, if any, does happen in quality traits because of zinc deficiency or existence. Kinaci (1997) reported that by zinc application to wheat cultivars, some variations were determined in sedimentation volume and damaged starch among quality features.

The objective of this study was to (I) determine variation in grain yield and quality traits of 12 bread wheat cultivars in Zn-deficient and Zn-sufficient soil under rain-fed conditions (ii) monitor how to deviate relationships between and within grain yield and quality traits by Zn application.

Materials and Methods

Twelve bread wheat cultivars (Süzen-97, Atlas-66, İkizce-96, Bolal-2973, Aytin-98, Gerek-79, Kiraç-66, Kutluk-94, Gün-91, Dagdas-94, Kirgiz-95, and 4/11) were grown in Zn-deficient and Zn sufficient soils under rain-fed conditions in the experimental field of the Bahri Dagdas International Winter Cereals Research Center, Konya, during 2000-2001 growing season. Just prior to planting, zinc fertilizer was applied to soil surface by spraying as a solution of $ZnSO_4.7H_2O$ (23 kg Zn ha^{-1}) and incorporated into 0-10 cm depth of soil by a rotatiller. Sowing was done in mid-October 2000 in 1.2 x 7 m^2 plots by an experimental drill. Seeding rate was 550 seeds m^{-2}. Fertilizer application was made as 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} at the planting, and 40 kg N ha^{-1} at stem elongation stage. Harvesting was done in mid-July 2001 in 1.2 x 5 m^2 plots by experimental combine. Total precipitation during the vegetation period was about 210 mm below normal (about 320 mm).

Soil in the experimental field showed a clayey loam texture. pH was 8.06 to 8.16. Lime content was high, (31 to 48%). Saline content was low, 0.08 to 0.79%. Soil was poor in organic matter content, ranging from 0.87 to 1.79% and the level of available Zn in the soil was 0.13 to 0.20 ppm below critical level (0.50 ppm).

Grain yield (kg ha^{-1}) was obtained by converting the grain yields obtained from plots to hectares. Thousand kernel weight (g) was calculated by randomly sampling four hundred kernels four times, then by weighing and multiplying with 2.5. Protein content (%) and gluten content (%) were measured by NIRS (near-infrared reflectance spectroscopy) (Williams *et al.*, 1988).

SAS software (1996) was used to perform factorial analysis of variance on the values of grain yield and quality components obtained per plot. Means of cultivars with and without Zn fertilization were compared by (LSD) test at 5% probability level. To determine relationship between features and treatments, correlation analysis was applied to the means of grain yield and quality traits.

Results and Discussion

Differences among genotypes were statistically significant for all traits except grain yield, while Zn application was significant for grain yield, protein content, thousand kernels weight and gluten content (Table 1). However, interaction between genotypes and Zn application was significant for all traits.

Grain yield without Zn application ranged from 518 kg ha^{-1}, for Kiraç-66, to 1057 kg ha^{-1}, for Dagdas-94, resulting in an average grain yield of 739 kg ha^{-1} (Table 2). With Zn application, grain yield ranged from 1653 kg ha^{-1}, for 4/11, to 2823 kg ha^{-1}, for Dagdas-94, with an average of 2081 kg ha^{-1}. In this experiment, Dagdas-94 was found to be the highest yielding variety under both conditions. Among 12 cultivars, grain yields under Zn deficient and Zn applied conditions showed large deviations in accordance with Cakmak *et al.* (1998), who reported that wheat

Table 1: F-statistic values for traits observed with and without Zn fertilization

S.O.V	DF	Grain yield	Protein content	Thousand Kernels weight	Gluten content
Replication	2	0.06	0.46	0.98	0.33
Genotype (G)	11	1.27	6.43**	5.96**	5.03**
Treatment (T)	1	345.00**	4.42*	80.45**	4.19*
GxT	11	1.92	1.06	1.87	0.78
CV		25.25	5.34	7.23	5.64
R^2		0.89	0.65	0.78	0.59

* $P<0.05$, ** $P<0.01$

Table 2: Differences (%) between Zn deficient and Zn efficient conditions for traits

Cultivars	Grain Yield (kg ha^{-1}) -Zn	Grain Yield (kg ha^{-1}) +Zn	Difference (%)	Protein content (%) -Zn	Protein content (%) +Zn	Difference (%)	Thousand Kernel Weight (g) -Zn	Thousand Kernel Weight (g) +Zn	Difference (%)	Gluten Content (%) -Zn	Gluten Content (%) +Zn	Difference (%)
Süzen-97	596	2310	306	14.53	13.10	-10	24.40	29.87	22	11.63	10.58	-10
Atlas-66	520	1777	242	15.33	15.47	1	21.80	24.97	15	13.13	13.27	1
İkizce-96	709	2470	248	14.03	13.23	-6	24.73	29.40	19	11.87	11.03	-7
Bolal-2973	872	1983	127	13.08	13.77	-1	24.33	32.27	33	11.63	11.60	-1
Aytin-98	854	1970	131	14.47	14.53	1	23.00	26.27	14	12.00	12.00	0
Gerek-79	930	1983	113	14.57	13.63	-6	22.03	27.53	25	11.53	10.83	-6
Kiraç-66	518	2350	354	15.87	15.10	-5	22.87	25.13	10	12.57	12.00	-5
Kutluk-94	646	1720	166	15.20	15.50	2	25.90	25.47	-2	12.00	12.17	2
Gün-91	573	2030	254	13.83	13.43	-3	21.03	25.07	19	11.70	11.27	-4
Dagdas-94	1057	2823	167	14.03	13.20	-6	26.17	31.53	21	11.87	11.20	-6
Kirgiz-95	941	1903	102	14.60	13.83	-5	24.33	27.93	15	11.60	11.10	-5
4/11	684	1653	142	15.20	16.00	5	24.93	27.63	11	12.10	12.67	5
Mean	739	2081	184	14.62	14.23	-3.5	23.79	27.75	17	11.97	11.64	-3.5
LSD $_{0.05}$	472	767		0.72	1.72		2.41	3.39		0.61	1.50	

Table 3: Correlation coefficients calculated for traits with and without Zn

Traits	Treatment	Grain yield	Protein content	Thousand kernels weight
Protein content	-Zn	-0.325		
	+Zn	-0.660*		
Thousand kernel weight	-Zn	0.205	-0.062	
	+Zn	0.500	-0.590*	
Gluten content	-Zn	-0.580*	0.694*	-0.252
	+Zn	-0.554	0.899**	-0.507

*P<0.05, ** P<0.01

cultivars possessed differential Zn efficiency and abilities to utilize the applied Zn.

Differences between Zn-deficient and sufficient conditions for grain yield ranged from 102% for Kirgiz-95, to 354% for Kiraç-66, resulting in an average increase of 184% (Table 2). Zn application affected grain yields of Kiraç-66, Süzen-97, and Gün-91 more than those of Kirgiz-95, Gerek-79 and Bolal-2973. It is suggested that the former are more sensitive to Zn deficiency than the latter. These results are similar to the findings of Cakmak *et al*. (1998), who conducted a study concerning the effect of Zn fertilization on yield of different wheat cultivars under field conditions.

In the growing season, total precipitation was about 210 mm below long term average value (about 320 mm). Therefore, cultivars were subjected to a severe drought stress besides Zn deficiency. It was possibly a severe drought stress, which caused drastic reduction in grain yields, especially together with Zn deficiency.

Protein contents under Zn deficiency ranged from 13.08% for Bolal-2973 to 15.87% for Kiraç-66, with an average of 14.62%. With Zn application, the range was from 13.10% for Süzen-97 to 16.00% for 4/11, with an average protein content of 14.23%. 4/11 and Kiraç-66 were the highest protein containing varieties under conditions with and without Zn, while Süzen-97 and Bolal-2973 were the lowest under both conditions (Table 2).

Protein contents of most cultivars showed sharp decreases with zinc fertilization (Table 2). Interestingly, some varieties such as 4/11, Kutluk-94, Aytin-98 and Atlas-66 had a slightly reverse interaction between protein content and Zn application (Table 2). However, Kinaci (1997) determined no variation in protein content with Zn application. Ekiz *et al*. (1997) (unpublished data), observed that protein contents of bread wheat cultivars decreased with Zn application. Conversely, Malakouti (1998) found that Zn application considerably increased the grain protein content.

In order to better understand the decrease in protein content with Zn fertilization, it is essential that more attention be paid for differences in Table 2. Varieties Süzen-97, Gerek-79, Dagdas-94 and İkizce-96 exhibited the highest variations in protein contents. The mean of protein contents decreased with Zn application.

One of the contributing characteristics of grain yield, thousand kernels weight (TKW) without Zn ranged from 21.03 g for Gün-91 to 25.90 g for Kutluk-94, resulting in an average TKW of 23.79 g. With Zn, the range was between 24.97 g for Atlas-66 and 32.27 g for Bolal-2973, giving an average TKW of 27.75 g. Consequently, the highest TKWs with and without Zn were obtained for Bolal-2973 and Kutluk-94, respectively while under both conditions Gün-91 and Atlas-66 exhibited the lowest TKWs. Hemantaranjan and Garg (1988) implied that significant effect of zinc application was observed on TKW. Correspondingly, increases in TKWs by Zn fertilization occurred in the majority of genotypes. Except demonstrating negative effect of 1.70%, for Kutluk-94, Zn application showed positive effect on TKWs of all varieties, with an average of 16.60% (Table 2).

Without Zn fertilization gluten content ranged from 11.53% for Gerek-79 to 13.13% for Atlas-66, with an average of 11.97%. With Zn, range was between 10.58% for Süzen-97 and 13.27% for Atlas-66, giving an average gluten content of 11.64%. As a consequence, it was found that cultivars with +Zn showed lower gluten contents than those of -Zn application. Similar to protein contents, gluten contents also decreased with Zn fertilization, probably due to close structural relationship between them. The average gluten content was negatively affected with Zn fertilization (Table 2).

Correlation analysis indicated, the highest negative relationship (r=-0.660*) between grain yield and protein content, whereas gluten content and protein content exhibited the highest positive correlation (r=0.899**).

Grain yield with and without Zn was negatively correlated with protein content and gluten content. Association between protein content and grain yield, when Zn was not applied, was negative, but non significant. Of the other traits, negative correlation between gluten content and grain yield was significant without Zn, in spite of non significantly negative with Zn.

Based on these results, the interactions between grain yield and some of quality traits were almost negatively influenced by Zn fertilization. Several works indicated that there was a negative linear relationship, which was nearly constant, between grain yield and protein content. This may force us to consider the insufficient use of some nutrients, such as P_2O_5 and N, under increasing yield levels.

Protein content was positively correlated with gluten content in case of Zn application. However, protein content and TKW possessed negative significant association under the same conditions. By Zn application, increase in protein content was in accordance with the increase in gluten content, probably due to a strong linkage between protein content and gluten content, especially indicating that protein had a structural relation to gluten, excluding that this linkage could be destroyed by biotic and abiotic stresses such as sunny bug damage.

TKW, which enhanced increase in grain yield, and protein content had negative significant correlation. Despite the fact that it is evaluated as a quality trait, TKW behaved as a yield component and considerably contributed to increase the grain yield.

Consequently, protein content and TKW had negative significant correlation with Zn application.

In Zn-deficient soil under rain-fed conditions, Zn fertilization can encourage increases in grain yield, even if it shows negative effect on quality traits. Zinc application resulted in significant increases in grain yield and thousand kernel weight, 184 and 17%, while it resulted in decreases in protein and gluten contents, 3.5%, respectively.

Negative significant correlation for grain yield and grain protein content can be accelerated drastically by Zn fertilization. Correlation analysis indicated that grain yield and protein content, thousand kernel weight and protein content had negative significant, whereas protein and gluten contents possessed positive significant correlations, with Zn.

References

Brown, P.H., I. Cakmak and Q. Zhang. 1993. Form and function of zinc in plants In: Zinc in Soils and Plants. A. D. Robson (Ed.). Kluwer Academic Publishers, The Netherlands. pp 93-106.

Cakmak, I., M. Kalayci, H. Ekiz, A. Yilmaz, B. Torun and H.J. Braun. 1998. Selection and characterization of cereal genotypes with high Zn efficiency and evaluation of bio-availability of Zn in wheat for the Central Anatolia Region. NATO Science for Stability Programme. The Kemal Printing Com. Adana, Turkey.

Ekiz, H., A. Yilmaz, I. Gultekin, S.A. Bagci, B. Torun and I. Cakmak, 1997. Field experiments concerning zinc deficiency problem in cereals in Konya region. In: 1st National Zinc Congress, Eskisehir, Turkey, pp: 115-123.

Graham, R.D. and R.M. Welch, 1996. Breeding for staple food crops with high micro-nutrient density. Working Papers on Agricultural Strategies for Micro-nutrients, No: 3. International Food Policy Institute, Washington D.C.

Hemantaranjan, A. and O.K. Garg, 1988. Iron and zinc fertilization with reference to the grain quality of *T. aestivum* L. J. Pl. Nut., 11: 6-11, 1439-1450.

Kinaci, G., 1997. Effect of different types and quantities of zinc containing fertilizers on yield, yield components and quality in wheat cultivars. In: 1st National Zinc Congress, Eskisehir, Turkey. pp 251-256.

Malakouti, M.J., 1998. Increasing grain and community's health through the use of $ZnSO_4$ in wheat fields. Soil and Water J., 12: 1, 34-43.

Prasad, A.S., 1982. Clinical and biochemical spectrum of zinc deficiency in human subjects. In: Clinical, Biochemical, and Nutritional Aspects of Trace Elements.: Alan R Liss, New York, pp: 3-62.

SAS Institute, 1996. SAS/STAT User's Guide, 2nd ed., SAS Institute Inc., Cary. NC.

Williams, P., F.J. Haramein, H. Nakkoul and S. Rihawi, 1986. Crop Quality Evaluation Methods and Guidelines. Technical Manual No: 14, ICARDA, Aleppo, Syria.

Yilmaz, A., H. Ekiz, I. Gultekin, B. Torun, H. Barut, S. Karanlik and I. Cakmak, 1998. Effect of seed zinc content on grain yield and zinc concentration of wheat grown in zinc deficient calcareous soils. J. Pl. Nut., 21: 10, 2257-2264.