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Effect of Zinc on Some Grain Quality Parameters in Bread and Durum Wheat Cultivars

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Abstract This research was conducted in Isparta, Turkey ecological condition to investigate the effects of different zinc application doses on some quality parameters of bread (Gün-91, Altay-2000) and durum (Kızıltan-91, Kunduru-1149) wheat cultivars. The experiment was set up with three replications according to the randomized complete block design with a split-plot design. The cultivars took place in the main plots whereas the zinc application doses (0, 9, 18, 27 and 36 kg ha^{-1} Zn) were in the sub-plots. Phosphorus and nitrogen fertilizers providing 40 kg ha^{-1} of P_2O_5 and 80 kg ha^{-1} of N were applied to the plots. According to the result of variance analysis, different zinc application in wheat cultivars had significant effect on the grain quality parameters. But zinc fertilization had no effect on test weight. The effect of Zn treatment found statistically important on sedimentation and wet gluten content of flour, Zn, P and crude protein contents of bran and flour. In all cultivars, Zn application increased sedimentation, wet gluten content, protein, Zn content and P content in bran. However, the Zn application decreased the amount of P in flour. Also, protein, Zn and P contents were higher in the bran than in the flour. In the research results, it was found that Zn application had a positive effect on quality parameters, but high Zn doses affected both grain yield and quality parameters negatively.

Keywords Wheat, Zinc, Test Weight, Flour, Bran, Quality

1. Introduction

Bread and other cereal products are the main staples for Turkish people. Approximately 50 % of the daily energy need is supplied from wheat products [1]. In Turkey, the average wheat yield increased approximately up to 3000 kg ha^{-1} in recent years. Approximately half (49.8 %) of the agricultural land in Turkey has zinc deficiency and this is more prominent in Central Anatolia region [2]. It is considered that Zn content of the cultivated plants normally varies between 20 and 100 mg kg^{-1} on dry matter basis and Zn critical level is 10-15 mg kg^{-1} in many types of grain [3]. In a study conducted to determine the zinc content of the soil, available zinc content in Isparta province soils was found as 0.10 ppm [4]. On the other hand, soil containing less than 0.5 mg kg^{-1} zinc are considered as weak soils [5]. Considering these data, it can be said that Isparta and the surrounding area has lack of zinc in the soil.

The effect of environmental conditions on grain quality mentioned in previous works focused largely on the effects of macronutrients [6]. On the other hand, it was demonstrated that the micronutrients have effect on grain quality shown by flours derived from Cu and Zn deficient wheat produced dough [7]. Increase in available Zn can increase grain protein concentration [8], which may preferentially accumulate in gluten. Starks and Johnson [9] indicated that Zn is associated with the seed storage proteins of wheat. Gluten is the major component of flour protein that determines processing quality.

The purpose of this study was to examine the effects of the zinc fertilization in different wheat cultivars on test weight, sedimentation value and wet gluten amount in flour; (ii) on protein, zinc and phosphorus contents in different parts (the flour and bran) of grain.

2. Materials and Methods

The field experiments were carried out at the Experimental Area of the Faculty of Agriculture, Süleyman Demirel University, Isparta (37° 45' N; 30° 33' E; and 1050 m), Turkey, under rainfed conditions. In the field experiment, two bread wheat cultivars (Gün-91 and Altay-2000) and two durum wheat cultivars (Kızıltan-91 and Kunduru-1149) were used. The experiment included five zinc application rates (0, 9, 18, 27 and 36 kg ha^{-1} Zn). The study was carried out on 4 wheat cultivars on split-plot design in a randomized complete block with 3 replications. The varieties were placed on main plots whereas zinc application rates were placed on sub-plots. Sowing was done by plot sowing machine providing 500 seeds per m^2. The basal fertilizer applications were 40 kg ha^{-1} P_2O_5 and 80 kg ha^{-1} N as triple superphosphate and ammonium sulphate, respectively. All of the phosphorus fertilizers were applied with sowing. Nitrogen fertilization was applied in two equal doses, during sowing in autumn (October) and in early spring (March) when plants were at the tillering stage. Zinc sulphate was used as zinc fertilizer and was applied with sowing. Plot sizes were 9.6 m^2 (1.2 m x 8 m), with 6 rows and a row spacing of 20 cm. The wheat samples obtained from each plot after harvest in the research was stored at 4-10 ° C. The wheat grains were ground in 2013. It was separated into bran and flour. Milled flour samples were sieved 212 µ diameter and the bran and flour were separated again. The bran on the sieve was mixed the former bran. In the research, sedimentation and wet gluten content of flour samples in Zn application were determined according to Özkaya and Özkaya [10]. In bran and flour samples, concentrations of Zn were determined by atomic absorption spectrometry after ashing samples at 550°C and dissolving ash in 3.3 % HC1 [2], P by the vanadate–molybdate colorimetric method [11]and the protein content was calculated by multiplying the Kjeldahl N by 6.25.

The soil of the research areas had a low water-holding capacity, was alkaline (pH 7.9-8.3) and Lime (25.5-30% $CaCO_3$), and contained a low amount of organic matter (1.15-1.34 %). The P_2O_5, N and Zn contents were 192-197 mg kg^{-1}, 0.4-0.17% and 0.52-0.79 ppm, respectively.

The weather conditions during the two years were different [12]. The long-term average temperature from September to June was 9.5 °C. Precipitation was 453.4 mm for the same period. The growing seasons (from October to June) in 2009-2010 and 2010-2011 had average temperatures of 10.7 and 9.8°C, total precipitation of 620.2 and 459.3 mm respectively. During the 2010-2011 growing season, there was quite a lot of rainfall during germination. In contrast, the 2009-2010 seasons were warmer during the seed filling stage.

2.1. Statistical Analysis

Averages of two years were pooled and according to the average of two-year results, statistical analysis was carried out using MSTAT-c statistical package program. The calculated mean values were compared using Duncan's multiple range test.

3. Results

3.1. Test Weight

The effect of the cultivar and dose of zinc applications was not significant. According to the average of two-year results, test weight (weight of 100 liter) changed among doses 80.65-81.86 kg, cultivars 80.91-81.72 kg (Table 1). On the other hand, variety x dose interaction was significant. The effect of Zn applications on varieties was different and comparing to control (0 kg Zn ha^{-1}) the increase ratio in test weight in Altay-2000 was significant, whereas test weight in other wheat cultivars was not significant. The maximum test weight in Altay-2000 was obtained from 36 kg ha^{-1} zinc application (82.85 kg), followed by 27 kg ha^{-1} zinc application. But the test weight in 18, 27 and 36 kg ha^{-1} zinc applications was similar to each other and was not significant. This showed that sensitivity of varieties to Zn deficiency was different.

3.2. Wet Gluten Content

Both cultivar and Zn applications significantly affected wet gluten content in bread and durum wheat cultivars ($P \leq 0.01$; Table 2). As general average, content of wet gluten of durum wheat was more than those in bread wheat. The different response of varieties to Zn applications showed variety x Zn interaction.

As two-year average, the highest content of wet gluten was in Kunduru-1149 (31.45%), whereas the lowest was in Gün-91 (27.06%) and compared to others Kunduru had higher value than others (Table 2). Wet gluten content of Gün-91 and Altay-2000 was similar to each other. Different Zn applications in wheat cultivars had a positive effect on amount of wet gluten. But in the experiment the amount of wet gluten had variations depending on the genotypes. While the lowest amount of wet gluten in all cultivars was obtained from control, the highest values was found in Altay-2000 (28.88%), Gün-91 (30.43%) and Kunduru-1149 (37.33%) varieties in 36 kg ha^{-1} Zn application, and Kızıltan-91 (31.70%) variety had highest wet gluten at 27 kg ha^{-1} Zn application.

Table 1. The effect of zinc fertilization on the test weight (kg) according to the average two-year results in bread and durum wheat varieties.

Cultivar	Zinc Application (kg ha^{-1})					Average
	0	9	18	27	36	
Altay-2000	79.32 *b*[1]	79.82 *b*	81.61 *ab*	81.84 *ab*	82.85 *a*	81.09
Gün-91	79.86	80.47	81.47	81.90	80.83	80.91
Kızıltan-91	83.09	81.31	82.00	81.09	81.15	81.72
Kunduru-1149	80.32	81.11	82.37	82.01	79.67	81.10
Average	**80.65**	**80.68**	**81.86**	**81.71**	**81.12**	
Variety(a),2.452 ns ; Zn Dose (b),1.124 ns; A x B, 2.783 * ; CV(a) = 1.75 %; CV(b) = 2.22 %						

[1]Means with different superscript in the same row differ ($P<0.05$); ns: Non significant

Table 2. The effect of zinc fertilization on content of wet gluten (%) according to the average two-year results in bread and durum wheat varieties

Cultivar	Zinc Application (kg ha^{-1})					Average
	0	9	18	27	36	
Altay-2000	26.28b[1]	26.08b	26.34b	28.34a	28.88a	27.18
Gün-91	22.53d	26.08c	27.87b	28.41b	30.43a	27.06
Kızıltan-91	27.58c	29.50b	31.32a	31.70a	29.59b	29.94
Kunduru-1149	23.76d	30.95c	32.75b	32.47b	37.33a	31.45
Average	**25.04**	**28.72**	**29.57**	**29.67**	**31.56**	
Variety(a),182.829**; Zn Dose (b),160.135 ** ; AxB, 33.359 ** ;CV(a) = 2.46 %; CV(b) = 2.63 %						

[1]Means with different superscript in the same row differ (P<0.01) ; **: significant at 1% levels of probability

3.3. Sedimentation

Genotypes, Zn applications and their interactions on sedimentation values were significant (P≤0.01; Table 3). As general average, sedimentation values of bread wheat cultivars (Altay-2000, 26.00 ml; Gün-91, 29.80 ml) were more than those in durum wheat varieties (Kızıltan-91, 16.75 ml; Kunduru-1149, 15.15 ml). The highest values of sedimentation (except Kızıltan-91) were found at highest Zn application dose (36 kg ha^{-1}). The lowest values were found in control.

Table 3. The effect of zinc fertilization on sedimentation (ml) according to the average two-year results in bread and durum wheat varieties

Cultivar	Zinc Application (kg ha^{-1})					Average
	0	9	18	27	36	
Altay-2000	23.50c[1]	24.75b	25.25b	25.50b	31.00a	26.00
Gün-91	28.50b	29.25b	28.50b	29.00b	33.75a	29.80
Kızıltan-91	15.50c	16.50b	18.00a	16.25bc	17.50a	16.75
Kunduru-1149	14.00c	14.25c	16.00ab	15.25b	16.25a	15.15
Average	**20.38**	**21.63**	**22.00**	**21.50**	**24.13**	
Variety(a),1704.817 ** ; Zn Dose (b), 81.559 **; AxB, 28.520 **CV(a) = 3.51 %;CV(b) = 2.77 %						

[1]Means with different superscript in the same row differ (P<0.01); **: significant at 1% levels of probability

3.4. Crude Protein Content

Zinc applications increased crude protein content in both bran and flour significantly (P≤0.01). Also it was found that crude protein percent was lower in flour than in bran in all varieties (Table 4).

Table 4. The effect of zinc fertilization on protein content in bran and flour according to the average two-year results in bread and durum wheat varieties

Zinc doses (kg ha^{-1})	Altay-2000 Protein %		Gün-91 Protein %		Kızıltan-91 Protein %		Kunduru-1149 Protein %	
	Bran	Flour	Bran	Flour	Bran	Flour	Bran	Flour
0	12.17c[1]	9.63c	12.49c	10.02c	12.56c	8.10c	13.20c	9.39c
9	14.13a	10.39ab	14.45a	11.48ab	13.60ab	10.89a	15.22a	11.96a
18	13.09b	10.50a	14.21a	11.62a	13.80a	10.46a	14.55b	11.70a
27	12.42c	9.89bc	13.16b	10.96b	13.58ab	8.90b	12.74d	10.04b
36	12.26c	9.71c	13.02b	10.16c	13.24b	8.89b	12.41d	9.70bc
Average	**12.81**	**10.03**	**13.47**	**10.85**	**13.35**	**9.45**	**13.62**	**10.56**
Bran: Variety(a),23.255 ** ; Zn Dose (b), 97,840 **; AxB, 9.135 ** ;CV(a) = 2.44%; CV(b) = 2.35%								
Flour: Variety(a),39.281 **; Zn Dose (b), 70.611 **; AxB, 4.237 **; CV(a) = 4.3 %; CV(b) = 4.01 %								

[1]Means with different superscript in the same column differ (P<0.01); **: significant at 1% levels of probability

Protein content increased up to 18 kg ha^{-1} zinc application after which applying higher Zinc doses significantly reduced protein content in the all varieties. The lowest values of protein content in flour and bran were found in control. In this study, it was found that Gün-91 and Kunduru-1149 varieties had better zinc use efficiency and nutrients in soil are better utilized.

3.5. Zinc (Zn) Concentrations

Zinc applications affected Zn concentrations of cultivars. Cultivar, Zn treatments and their interactions on Zn concentrations of bran and flour were significant ($P \leq 0.01$; Table 5), while effect of year was not significant. According to the two years means, Zn concentrations significantly increased both in bran and flour of cultivars. The lowest Zn concentrations of bran and flour were obtained from control group. Generally, Zn concentrations of grain were increased by increasing Zn applications (Table 5).

Although Zn concentration of bran was higher than flour, Zn applications relatively increased Zn concentration in flour more than those in bran (the increase rates in flour compared to control (0 kg ha^{-1}) were 82, 61, 85 and 89 % for Altay-2000, Gün-91, Kızıltan-91, Kunduru-1149, respectively). The average Zn concentrations of bran of bread wheat (Altay-2000, 70.8 mg kg^{-1}; Gün-91, 72.9 mg kg^{-1}) were higher than durum wheat cultivars (Kızıltan-91 36.4 mg kg^{-1}; Kunduru-1149, 40.1 mg kg^{-1}).

3.6. Phosphorus (P) Concentrations

Zinc treatments, cultivars and their interaction significantly affected the P concentrations of bran and flour ($P \leq 0.01$; Table 6). Zinc treatments decreased the P concentration in flour but increased in bran for all the wheat cultivars. The bran P concentration of bread wheat (Altay-2000, 0.3%; Gün-91, 0.4%) was higher than the flour P concentration of durum wheat (Kızıltan-91, 0.18%; Kunduru-1149, 0.19%). The P concentration of bran of bread wheat increased up to 27 kg $ha^{-1}$of Zn application. The lowest P concentration of bran of bread wheat was obtained from control group. The P concentration of bran of durum wheat increased up to 9 kg $ha^{-1}$of Zn application (Kızıltan-91, 0.42%; Kunduru-1149, 0.45%), however difference between control and 9 kg ha^{-1} was not significant. The P concentrations of both bran and flour of all cultivars significantly decreased at 36 kg ha^{-1} Zn treatment (Table 6).

Table 5. The effect of zinc fertilization on zinc (Zn) content according to the average two-year results in bread and durum wheat varieties

Zn doses (kg ha^{-1})	Altay-2000 Zn mg kg^{-1}		Gün-91 Zn mg kg^{-1}		Kızıltan-91 Zn mg kg^{-1}		Kunduru-1149 Zn mg kg^{-1}	
	Bran	**Flour**	**Bran**	**Flour**	**Bran**	**Flour**	**Bran**	**Flour**
0	66.75e[1]	11.61d	60.71e	12.95e	32.19d	11.92e	38.25e	12.49d
9	70.32c	15.94c	72.67c	16.00d	36.52c	18.96c	40.70c	21.61b
18	72.03b	17.24b	78.16b	18.55b	37.79b	22.17a	42.55b	20.90c
27	76.91a	21.12a	82.54a	20.88a	40.93a	19.60b	43.60a	23.58a
36	67.80d	12.10d	70.17d	16.67c	37.30bc	14.58d	39.46d	21.50b
Ave.	**70.76**	**15.60**	**72.85**	**17.01**	**36.94**	**17.44**	**40.91**	**20.02**
Bran: Variety(a),8560,099 ** ; Zn Dose (b), 719,390 **;AxB, 82,158 **; CV(a) = 1,66%; CV(b) = 1,16%								
Flour:Variety(a),364,335 ** Zn Dose (b), 1087,818 **; AxB, 80,558 **; CV(a) = 2,92%; CV(b) = 2,14%								

[1]Means with different superscript in the same column differ ($P<0.05$); **: significant at 1% levels of probability

Table 6. The effect of zinc fertilization on phosphorus (P) content in bran and flour according to the average two-year results in bread and durum wheat varieties

Zinc doses(kg ha^{-1})	Altay-2000 P (%)		Gün-91 P (%)		Kızıltan-91 P (%)		Kunduru-1149 P (%)	
	Bran	**Flour**	**Bran**	**Flour**	**Bran**	**Flour**	**Bran**	**Flour**
0	0.458c[1]	0.165 a	0.510c	0.163a	0.395ab	0.198a	0.430ab	0.210a
9	0.555b	0.156ab	0.553b	0.163a	0.415a	0.188ab	0.453a	0.205a
18	0.553b	0.153ab	0.570b	0.158ab	0.398ab	0.183bc	0.440a	0.170b
27	0.605a	0150b	0.648a	0.148b	0.358bc	0.183bc	0.433a	0.180b
36	0.485c	0.125c	0.435d	0.118c	0.338c	0.170c	0.390b	0.180b
Ave.	**0.531**	**0.150**	**0.543**	**0.149**	**0.380**	**0.184**	**0.428**	**0.189**
Bran:Variety(a), 159,220 **; Zn Dose (b), 30,363 **; AxB, 8,619 **;CV(a) = 4,95 %; CV(b) = 5,16 %								
Flour: Variety(a),66,578 ** ; Zn Dose (b), 25,860 **; AxB, 6,772 **; CV(a) = 3,92 %; CV(b) = 4.49 %								

[1]Means with different superscript in the same column differ ($P<0.05$), **: significant at 1% levels of probability

4. Discussion

Test weight, on the quality of wheat is one of the traits that are effective, and it is required to be above 80 kg [13]. Test weight can be affected by factors such as; variety, environmental conditions, cultural practices, pests and diseases [14].In this study, the effect of the varieties and dose of zinc applications was not significant. But test weight of durum wheat, compared to bread wheat was higher and zinc application had significant increase on particularly bread wheat varieties. Test weight was around 79 kg in control, and it increased up to 80 kg with zinc applications. In this study, sensitivity of varieties to Zn deficiency was different. The response of varieties to Zn deficiency could be related with the ability of taking Zn from the soil and using at different efficiency in plant tissues [15].On the other hand, it was reported that high Zn concentration reduced plant growth, seed number and seed weight [16].In our study, high doses of zinc application negatively affected the test weight, whereas this difference between control and 36 kg ha^{-1} was not significant. Previous research showed similar results to our results indicating that Zn application had no significant effect on test weight [17].

Grain protein content and protein quality is the most important one of the traits in wheat. The amount and composition of endosperm storage protein has influence on the rheological properties of dough made from flour of bread wheat [7].It was shown that the environmental conditions, genotypic variation and cultural applications has effect to grain protein content [7, 18].In our research, variety and Zn applications significantly affected crude protein content. As general average, crude protein content of durum wheat was more than those in bread wheat.

In determining the bread quality, gluten quantity and sedimentation value are important. The reduction in dough strength is associated with a decrease in gluten content in flour and an increase in the gliadin:glutenin ratio [7].Mineral nutrition had a major role in determining grain quality. Most of previous works concentrated on the effects of macro elements. The effectiveness of microelement received little attention. In this study it was found that genetic properties and zinc application are effective on wet gluten content, sedimentation value, protein content. Similar results were obtained by different researchers [19, 20].On the other hand, it was shown that variety was more effective on sedimentation value than environmental conditions [21].In this study, bread wheat sedimentation value was higher than durum wheat. This result showed that heredity has more effect than environment. Mineral analysis of the genotypes showed a large genetic variation for Zn, P and protein concentrations under Zn application.

In another study, it was found that there is a positive relation between gluten and protein content [19],also zinc content and protein content [22] in wheat. Additionally, Peck et al. [7]showed that Zn nutrition can alter protein composition and effects of Zn may interact with grain filling temperatures. Increasing available Zn increased grain protein content by gluten accumulation [8].

In this study, protein, zinc and phosphorus contents were higher in bran than in flour. This data showed that most of zinc in seed accumulated in embryo and aleuron layer, but less of it was in endosperm. Öztürk et al. [23]reported that zinc content of wheat in embryo and aleuron layer was 150 mg kg^{-1} but 15 mg kg^{-1} in endosperm.

In this study, it was found that except phosphorus content in flour, zinc application positively affected other examined characters. Protein and zinc contents significantly decreased in control and high zinc application doses. Otherwise, phosphorus content in flour in all varieties decreased by zinc application and the highest phosphorus content was in control group. It has been reported that phosphorus content in seed decreased in different plant varieties depending on zinc application [24, 25]

The nutritive quality and content of wheat grain is very important because daily calorie needs of our country are mostly supplied from the bread. In developing countries, it has been reported that daily Zn intake varies between 9-11 mg for an average person but this value is below than 15-20 mg which has been recommended for an adult [26].Microelement deficiency such as Zn negatively affects the human health [27]. Thus the production of cereals enriched with Zinc content is necessary.

5. Conclusions

According to the two-year results, Zn applications increased the grain yield and quality both of bread and durum wheat. For this reason, Zn applications should be recommended in Zn deficient fields to increase the yield and quality of wheat. This research indicated that the grain parts used in making bread are very important. Also, adding bran to flour at certain percentages would increase nutritional value of the bread.

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