ICP-OES Multi-element Analysis of Wheat Grown in Southeastern Turkey

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INTRODUCTION

Cereals are an important source of nutrition and lack of micronutrients affects the health of all living things. The metabolism of all cells depends on a balanced diet containing carbohydrates, proteins, and lipids (1). Most of the trace elements come from daily intake of food, especially grains (2), which play important roles in different metabolic processes (3). In excess or a lack thereof may disturb the normal biochemical functions of the body (4). During the last decades, the demand for nutritional safety levels has stimulated research regarding the risks associated with the consumption of food and water contamination by trace metals or toxins (5). Some trace elements, such as Cr, Cu, Ca, Na, K, Fe, Zn, Mn, and Se, are essential for all life. In high concentrations, they can create toxicity in soil, humans, animals, and plants (3, 6). Trace elements, such as Cd, As, Hg and Pb, are not essential but pose health risks when they enter the food and water chain (7, 8). Contaminants in nutrition typically do not lead to rapid mortality; however, they accumulate and cause chronic health effects (9). For example, Pb, Cd, Hg, and As can cause acute and chronic poisoning of the liver, kidneys, heart, the vascular and immune systems (11). Iron and Ca are micronutrient elements that play an important role for hemoglobin formation, oxygen, electron transfer, teeth, the

ABSTRACT

The bread and durum wheat varieties grown in Southeastern Turkey are the main source of food consumed by the Turkish population and serve as bread and pasta. In this study, 12 kinds of durum wheat and 5 kinds of bread wheat samples registered by the International Agricultural Research and Training Centre of Turkey (IARTC, Turkey) were investigated for their multi-elemental concentrations (Ca, K, Mg, Fe, Zn, Mn, Si, Sn, Cu, Cr, Cd, Ni, V, Pb, As, and Se). The samples were microwave-digested and the elements determined by ICP-OES. The results were in good agreement with the certified values. This study shows that the elements Si, Fe, Zn, Cd, Cr, Cu, Sn, and Pb in durum wheat were higher than in bread wheat. Both wheat species were found to be rich in terms of Ca, Mg, and K. The multi-element content of some bread wheat and durum wheat was also in good agreement with the maximum allowable levels of the Food and Agriculture Organization (FAO) World Health (WHO).

muscular system, bones, and heart functions (14, 15). The elements Zn, Se, Mg, and Cu are essential and support a wide range of biological functions including the enzymatic and redox systems (10).

In several studies (12, 13), wheat has been reported to show a substantial variation in trace element concentrations. Therefore, the concentration of microelements should be properly regulated through agro-

nomic, biochemical, and physical processes by decontamination programs (16). The FAO/WHO report (17) states that it is the accountability of national authorities to guarantee that food, water, grain, and cereal products do not contain toxic chemical substances in concentrations that would affect the health status of humans. Table I lists some of the trace elements and their maximum allowable levels in air, food, and water, human intake per day of the metal, toxic quantities, and normal quantities in the body as approved by WHO (17) and the Turkish Standard Institution (18). In Turkey, the daily energy requirement of a person is met on average by an intake of 40% wheat products. Wheat is a carbohydrate that is ground into flour and is used for making bread and other products such as bulgur, pasta, biscuits, and many other food products (15).

According to a study by the International Agricultural Research and Training Centre (IARTC, Turkey), an increase in planting more wheat will result in an increase in the production of cereals and other foods and thus contribute to enhancing the economic development program for the provinces of Urfa, Diyarbakir, Gaziantep, Adiyaman, and Mardin (located in the basins of the Euphrates and the Tigris River in Upper Mesopotamia). The main purpose of the IARTC project is to help increase the standard of living of the farming community and all people involved in producing the cereals (wheat 34%), barley, grains, and cotton. At present, these goals have been tripled due to irrigation

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from the Ataturk Dam. The farmers of the Harran plains feel very encouraged and also experiment by planting new varieties of fruits, vegetables, and nuts (19, 20).

The main objective of the present study was to investigate the variation in the micronutrient con-

tent of a wide range of wheat grains used for bread and durum wheat products. The samples were obtained from different areas and include 12 kinds of durum wheat and 5 kinds of bread wheat. These samples were analyzed by using plasma-based spectrochemical tech-

niques to assess whether these grains contain toxic levels of trace elements.

EXPERIMENTAL

Instrumentation

For this study, a model ICAP™ 6300 inductively coupled plasma optical emission spectrometer (ICP-OES) (Thermo Fisher Scientific, USA) was used to determine the elements in bread and durum wheat varieties. The most sensitive lines without spectral interferences in the sample matrix were used for the analysis (21). The instrumental and operating parameters are listed in Table II.

Standard Solutions and Reagents

The standard solutions and their elemental concentrations were in the range of 50–400 mg/L for Ca, Na, K, and Mg; 2.5–40 mg/L for Fe, Zn, Mn, Ni, Sn, Cd, Cr, Cu, and Pb; and 0.05–1.0 mg/L for V. They were prepared by diluting an ICP multi-element stock solution at 1000 mg/L (High-purity Standards, Charleston, SC, USA). Arsenic and selenium were studied by using a hydride system (Thermo Fisher Scientific, Waltham, MA, USA) mounted on the ICP-OES. The As and Se standard solutions (10, 20, 40, 60, and 100 µg/L) were prepared by adding a 1.0-mL mixture of ascorbic acid and KI (by dissolving 5.0 g ascorbic acid and 5.0 g of KI in 100 mL ultrapure water), then diluting with 10% HCl. The same procedure was applied to the wheat samples. The concentration of each element was calculated using calibration curves that were prepared from the standard solutions. The standard curves were found to be linear with a correlation coefficient of 0.999.

The limit of detection (LOD) and limit of quantification (LOQ) for each element were determined by using analytical curves performed

TABLE I
Maximum Standard Elemental Values for Wheat and Daily Consumption Through Nutrient, Air, Food, and Water (3, 17, 18)

Elements	Food and Water (m/g daily)	Air (m/g daily)	Toxic Effects (m/g daily)	Levels in Body (m/g daily)	Max. Standard Levels in Wheat (mg/kg)
Sb	1.000	0.0017	100	7.9	NS
Cu	1.325	0.0014	250-500	72.0	0.1-5.0
Ba	0.735	0.030	200	22	0.7
Be	0.012	0.00004	NS	0.03	NS
Bi	0.020	0.00076	NS	0.23	NS
Hg	0.0025	NS	NS	NS	0.006
Zn	14.500	0.0168	NS	2300	20
Fe	15.000	0.084	NS	4200	1.5-20
Ag	0.600	NS	60	1.0	NS
Cd	0.016	0.0074	3	50	0.005
Sn	7.300	0.0006	2000	17	150-250
Co	0.390	0.00012	500	1.5	NS
Pb	0.300	0.046	NS	12.0	0.1-2.0
Cr	0.245	0.0011	200	1.8	NS
Mn	4.400	0.0288	NS	12	0.2
Mo	0.335	0.006	NS	9.3	NS
Ni	0.600	0.00236	NS	10	NS
Ti	1.375	0.0014	NS	9	NS
U	0.050	NS	NS	0.7	NS
V	0.116	0.00916	NS	22	NS
Zr	0.490	NS	NS	420	NS

NS : Indicates that no standard exists.

TABLE II
Instrumental Operating Conditions Using Model ICAP 6300 ICP-OES

Parameters	Normal	Hydride System
Power	1150 W	1350 W
Pump Speed	50 rpm	30 rpm
Purge Gas	Argon	Argon
Coolant Gas Flow	12 L/min	16 L /min
Auxiliary Gas Flow	0.5 L/min	0.5 L/min
Torch	Axial, Radial	Axial
Autosampler	Cetac ASX-260	

with 10 independent analyses of a blank solution spiked with the metal at a level of lower concentration. The LOD and LOQ were calculated from the standard deviation (α) of the determinations ($\text{LOD} = 3 \times \alpha$ and $\text{LOQ} = 10 \times \alpha$), and the analytical results are listed in Table III.

Samples and Sample Preparation

In this study, 12 durum wheat and 5 bread wheat samples were obtained from the Department of Field Grain, located near the Tigris

River, registered by IARTC. The types and names of the different durum wheat samples used were Güney Yildizi, Zühre Eyyubi, Artuklu, Sahinbey, Saricnak-98, Altintoprak-98, Firat-93, Aydin-93, Harran-95, Ceylan-95, and Diyarbakir-81. The bread wheat samples were Karacadag-98, Aday-13, Nurkent, Dinç, and Cemre. In order to preserve the original quality of the wheat, the samples were stored at ambient temperature in sealed plastic bags prior to any conditioning. The wheat samples were washed with

pure water in a beaker in order to separate the impurities. The samples were dried in an oven at 70 °C for 24 hours, then ground to 300 mesh with a flour mill (Lab Mill 3100, Perten Hågersten, Sweden). An amount of 0.25 g of the dried and ground wheat samples was accurately weighed into the digestion vessels, and 10 mL of 65% HNO_3 and 2 mL of 30% H_2O_2 were added. The vessels were closed and heated in a MWS-3 Berghof microwave oven (Berghof, Germany) as listed in Table IV.

The vessels were removed and vented in a fume hood after cooling to room temperature in a water bath. The reaction mixture was subjected to an evaporation procedure by using the evaporation module to remove the acids after digestion. Then, the samples were filtered and diluted to 25 mL with Milli-Q® ultra-pure water (Millipore Corporation, USA).

Accuracy of the Method

The certified standard reference material (CRM) GBW 10010 Wheat (General Administration of Quality Supervision, Langfang, P.R. China) was used to assess the accuracy and precision of the method. The CRM sample was analyzed in triplicate by ICP-OES. The results were in good agreement with the certified values and are listed in Table V.

RESULTS AND DISCUSSION

In this study, the concentrations of Ca, K, Mg, Fe, Zn, Mn, Si, Sn, Cu, Cr, Cd, Ni, V, Pb, As, and Se in 12 kinds of durum wheat and 5 kinds of bread wheat samples were analyzed. The wheat samples were acid-digested in the microwave digestion system (Table II). The procedure used for the sample preparation and digestion of the plant matrices was performed by adding 10 mL of H_2O_2 to HNO_3 . This increases the oxidation power of HNO_3 during the digestion and

TABLE III
Detection and Quantification Limits
of Elemental Analytical Wavelengths

Elements	Wavelength (nm)	LOD (mg/kg)	LOQ (mg/kg)
Ca	(317.933)	0.031	0.103
K	(766.440)	0.040	0.133
Mg	(279.553)	0.009	0.028
Fe	(259.940)	0.220	0.733
Zn	(213.856)	0.003	0.010
Sn	(189.989)	0.093	0.310
Mn	(257.610)	0.018	0.060
Cr	(205.560)	0.002	0.007
Cu	(224.754)	0.001	0.005
Cd	(214.438)	0.001	0.005
Si	(251.611)	0.046	0.153
Ni	(221.647)	0.002	0.008
V	(292.402)	0.002	0.006
Pb	(220.353)	0.002	0.008
As	(189.042)	0.020	0.066
Se	(196.090)	0.004	0.015

LOQ: Limit of quantification.

LOD: Limit of detection.

TABLE IV
Temperature Program of Microwave Digestion System
for Wheat Samples

Step	1	2	3	4
T (°C)	160	170	100	100
T (min) ^a	10	5	1	1
Time (min) ^b	15	10	10	0

^a Waiting time at desired temperature.

^b Time between the two sequential temperatures.

enhances the dissolution of the organic material present in the sample before ICP-OES measurements (22-25).

The limit of detection (LOD) and the limit of quantification (LOQ) for each element were determined. The detection limits were within acceptable limits for all elements except As which was < 0.002 mg/kg (Table III). A certified reference material was used in order to verify the accuracy of the method. The results obtained from the study were in good agreement with the certified values (Table V).

The results of the analyses listed in Table VI were compared with the values as provided by the Turkish Standard Institution (18), WHO (17), and other studies (Table I).

Calcium (Ca)

The values of Ca were found to be 480 ± 6 to 742 ± 20 mg/kg in the durum wheat sample and 420 ± 4 to 625 ± 54 mg/kg in the bread wheat

sample (Table VI). According to Ereifej et al. (26), the Ca values in durum wheat from Jordan, Morocco, and the FAO were found as 29.5 ± 0.6 , 40.1 ± 0.5 and 55.8 mg/100 g, respectively. Hongxing and Kui (2012) (27) reported the Ca values as 200.63 μ g/g, which is lower than those obtained in the present study.

Magnesium (Mg)

The Mg values found were between 526 ± 62 and 856 ± 14 mg/kg in durum wheat and from 762 ± 8 to 883 ± 23 mg/kg in bread wheat, which indicates that the Mg concentrations were higher in bread wheat. Ereifej et al. (26) reported Mg values in Jordanian and Moroccan durum wheat as 85.1 ± 4 and 137 ± 2 mg/100 g, respectively. According to Hongxing and Kui (27), the Mg value was 321.11 μ g/g for Peking wheat. It can be seen that the Mg concentration determined in this study is higher than those in the literature.

Potassium (K)

The K values were found to be between 1988 ± 52 and 2868 ± 100 mg/kg in durum wheat and between 1896 ± 70 and 2954 ± 13 mg/kg in bread wheat. These values are higher than those of the Peking wheat (1569.34 mg/kg) as reported by Hongxing and Kui (27).

Iron (Fe)

The Fe values were determined to be between 41.0 ± 0.2 and 57 ± 0.2 mg/kg in durum wheat and between 34.7 ± 0.25 and 47.6 ± 5 mg/kg in bread wheat. Al-Gahri et al. (28) reported values of 51.06 ± 0.13 , 57.63 ± 0.12 , and 60.54 ± 0.09 μ g/g, respectively, for wheat grain samples grown in Yemen, Austria, and the U.S.

Zinc (Zn)

The Zn values obtained were between 18.8 ± 0.2 to 34.8 ± 0.2 mg/kg in durum wheat and 18.4 ± 0.09 to 27.1 ± 1.7 mg/kg in bread wheat. According to Al-Gahri et al. (28), the Zn values in wheat from Yemen, Austria, and the U.S. were found to be 16.96 ± 0.09 , 11.55 ± 0.13 , and 17.13 ± 0.12 μ g/g, respectively, for wheat grain samples, and was lower than those found in the present study.

Silicon (Si)

The Si values obtained were in the range of 41.4 ± 2 to 97.5 ± 1.3 mg/kg in the durum wheat and 34.2 ± 0.7 to 65.5 ± 4 mg/kg in the bread wheat.

Manganese (Mn)

The Mn values obtained were between 33.2 ± 0.6 and 50.5 ± 0.04 mg/kg in durum wheat and 34.1 ± 1 to 45.3 ± 0.9 mg/kg in bread wheat. No significant difference was found between the results of the present study and those reported by Al-Gahri et al. (28) and Ereifej et al. (26). In the Peking wheat, the Mn value was reported as 6.69 μ g/g (27).

TABLE V
Accuracy Assessment of Analysis of CRM GBW 10010 Wheat
(n = 3, dry weight)

Elements	CRM (mg/kg)	Found (mg/kg)	Recovery (%)
Ca	340 ± 20	348 ± 16	102
Mg	450 ± 25	437 ± 32	97
K	1400 ± 60	1370 ± 78	94
Si	80 ± 4.15	92 ± 4.31	97
Fe	18.5 ± 3.1	17.4 ± 3.8	94
Zn	11.6 ± 0.70	11.8 ± 0.74	102
Mn	5.4 ± 0.30	5.5 ± 0.42	102
Ni	0.060 ± 0.02	0.062 ± 0.03	103
Cd	0.180 ± 0.04	0.185 ± 0.05	102
Cr	0.096 ± 0.013	0.092 ± 0.020	96
Cu	2.70 ± 0.20	2.65 ± 0.18	98
Pb	0.065 ± 0.024	0.066 ± 0.027	101
V	0.034 ± 0.012	0.035 ± 0.014	103
As	0.031 ± 0.005	0.030 ± 0.006	97
Se	0.053 ± 0.007	0.054 ± 0.009	102

n = replicate.

TABLE VI
Trace Element Concentrations in Durum Wheat and Bread Wheat (mean $\pm$ S.D, n = 3) (mg/kg, dry weight)

Samples	Ca	Mg	K	Fe	Si	Mn	Zn	Sn
Durum Wheat								
Güneyyildizi	629 ^a $\pm$ 27 ^b	766 $\pm$ 25	2537 $\pm$ 86	44.4 $\pm$ 6	46.1 $\pm$ 4.7	35.5 $\pm$ 10	29.4 $\pm$ 0.06	30.0 $\pm$ 10
Zühre	595 $\pm$ 12	784 $\pm$ 15	2580 $\pm$ 51	57 $\pm$ 0.2	72.5 $\pm$ 0.8	35.7 $\pm$ 0.6	23.83 $\pm$ 0.2	31.4 $\pm$ 10
Eyyubi	605 $\pm$ 5	526 $\pm$ 62	2405 $\pm$ 14	49.2 $\pm$ 1	44.3 $\pm$ 2.2	33.3 $\pm$ 3	26.6 $\pm$ 0.08	22.4 $\pm$ 7
Artuklu	681 $\pm$ 64	851 $\pm$ 20	2703 $\pm$ 58	48.3 $\pm$ 5	62.3 $\pm$ 5	42.7 $\pm$ 5	33.4 $\pm$ 4.0	23.1 $\pm$ 4
Sahinbey	624 $\pm$ 2.4	843 $\pm$ 9.5	2741 $\pm$ 38	50 $\pm$ 0.7	97.5 $\pm$ 1.3	46.9 $\pm$ 0.6	34.8 $\pm$ 0.2	13.4 $\pm$ 0.8
Sarıcanak-98	704 $\pm$ 11	856 $\pm$ 14	2868 $\pm$ 86	52.1 $\pm$ 5	55.4 $\pm$ 19	48.2 $\pm$ 4	31.2 $\pm$ 0.1	23.1 $\pm$ 4
Altıntoprak-98	670 $\pm$ 2.6	789 $\pm$ 11	2506 $\pm$ 59	72.8 $\pm$ 0.3	55.0 $\pm$ 0.4	50.5 $\pm$ 0.04	32.7 $\pm$ 0.1	27 $\pm$ 1.5
Firat-93	480 $\pm$ 6	828 $\pm$ 9	2486 $\pm$ 24	49.2 $\pm$ 4	78.3 $\pm$ 8	43.5 $\pm$ 3	21.6 $\pm$ 0.1	33.9 $\pm$ 13
Aydin-93	742 $\pm$ 20	819 $\pm$ 15	2626 $\pm$ 32	41.0 $\pm$ 0.2	49 $\pm$ 13	43.5 $\pm$ 7.3	29.3 $\pm$ 0.2	15.7 $\pm$ 1.7
Harran-95	652 $\pm$ 17	740 $\pm$ 82	2695 $\pm$ 102	43.1 $\pm$ 0.9	49.3 $\pm$ 3	33.2 $\pm$ 0.6	23.5 $\pm$ 0.2	16.5 $\pm$ 4
Ceylan-95	720 $\pm$ 26	587 $\pm$ 41	1988 $\pm$ 52	50.3 $\pm$ 1.8	41.4 $\pm$ 2	42.1 $\pm$ 1.56	23.0 $\pm$ 0.08	15.6 $\pm$ 3.3
Diyarbakir-81	718 $\pm$ 8	829 $\pm$ 7.5	2752 $\pm$ 38	44.2 $\pm$ 0.6	85.5 $\pm$ 1.3	44.2 $\pm$ 0.6	18.8 $\pm$ 0.2	13.1 $\pm$ 0.8
Ref. (26)	29.5-40.1	85.1 $\pm$ 4						
Ref. (27)	200.63	321.11	1569.34					
Ref. (28)				51.06-60.54			11.55-17.13	
Bread Wheat								
Cemre	487 $\pm$ 11	883 $\pm$ 23	2514 $\pm$ 121	47.6 $\pm$ 5	56.4 $\pm$ 5	41.5 $\pm$ 1	20.7 $\pm$ 0.1	21.2 $\pm$ 2
Nurkent	625 $\pm$ 54	842 $\pm$ 3	2954 $\pm$ 13	44.1 $\pm$ 7	65.5 $\pm$ 4	42.7 $\pm$ 5.2	27.1 $\pm$ 1.7	20.3 $\pm$ 3.9
Karacadag-98	454 $\pm$ 11	856 $\pm$ 21	2504 $\pm$ 16	43.3 $\pm$ 1	34.3 $\pm$ 3	45.3 $\pm$ 0.9	26.4 $\pm$ 0.05	15.4 $\pm$ 1.7
Dinç	420 $\pm$ 4	762 $\pm$ 8	1974 $\pm$ 10	38.2 $\pm$ 4	44.8 $\pm$ 2	39.4 $\pm$ 3	18.4 $\pm$ 0.09	16.2 $\pm$ 1.6
Aday-13	495 $\pm$ 7	778 $\pm$ 20	1896 $\pm$ 70	34.7 $\pm$ 0.25	34.2 $\pm$ 0.7	34.1 $\pm$ 1	19.2 $\pm$ 0.09	13.6 $\pm$ 1

^a = mean ^b = sd

Table VI cont'd. on next page

Mean Elemental Composition of Samples

A study of the mean elemental composition of the durum wheat and the bread wheat samples showed that the Ca, Mg, and K values were the most abundant elemental species. The Pb values were higher in durum wheat, whereas the V values were higher in bread wheat. The concentration of Si was higher in both wheat products because of the high amount of silica content in the soil. However, based on the WHO and Turkish standards, the Mg, Ca, K, Pb, V, and Si values were not at toxic levels. The concentrations of metal ions found in the present study and those reported in the literature show no significant differences.

CONCLUSION

This study revealed that the concentrations of Ca, Si, Fe, Zn, Cd, Cr, Cu, Sn, and Pb in durum wheat were generally higher than in bread wheat. In general, the metal concentrations determined follows the order of K > Mg > Ca > Fe > Si > Mn > Zn > Sn > Cu > Cr > Ni > Pb > Se > V > Cd > As. Based on the allowable limits established by FAO/WHO and the Turkish Food Codex, all of these elements studied are not present at toxic levels. The results of this study also show that the wheat grains grown in Turkey contain non-toxic mineral concentrations. These grains are mostly used for food and food products, are very important for human nutrition, and thus make it an unpolluted and safe source of nutrition.

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TABLE VI (continued)
Trace Element Concentrations in Durum Wheat and Bread Wheat (mean $\pm$ S.D, n = 3) (mg/kg, dry weight)

	Cu	Cd	Cr	Ni	V	Pb	As	Se
Durum Wheat								
Güneyyildizi	7.75 $\pm$ 2.0	0.041 $\pm$ 0.003	0.82 $\pm$ 0.25	0.72 $\pm$ 0.009	0.042 $\pm$ 0.01	0.210 $\pm$ 0.01	< 0.002	0.312 $\pm$ 0.01
Zühre	4.22 $\pm$ 0.02	0.011 $\pm$ 0.002	1.41 $\pm$ 0.02	0.62 $\pm$ 0.007	0.090 $\pm$ 0.02	0.171 $\pm$ 0.05	< 0.002	0.250 $\pm$ 0.08
Eyyubi	10.5 $\pm$ 0.3	0.042 $\pm$ 0.001	1.03 $\pm$ 0.02	0.93 $\pm$ 0.03	0.091 $\pm$ 0.01	0.242 $\pm$ 0.08	< 0.002	0.260 $\pm$ 0.11
Artuklu	10.5 $\pm$ 0.3	0.042 $\pm$ 0.001	1.03 $\pm$ 0.02	0.93 $\pm$ 0.03	0.091 $\pm$ 0.01	0.242 $\pm$ 0.08	< 0.002	0.260 $\pm$ 0.11
Sahinbey	7.83 $\pm$ 1.5	0.010 $\pm$ 0.001	0.12 $\pm$ 0.01	0.85 $\pm$ 0.008	0.062 $\pm$ 0.02	0.163 $\pm$ 0.01	< 0.002	0.374 $\pm$ 0.06
Sarıçanak-98	5.11 $\pm$ 2.0	0.006 $\pm$ 0.002	1.02 $\pm$ 0.04	0.11 $\pm$ 0.03	0.072 $\pm$ 0.01	0.111 $\pm$ 0.0	< 0.002	0.337 $\pm$ 0.09
Altıntoprak-98	7.15 $\pm$ 0.02	0.014 $\pm$ 0.003	1.05 $\pm$ 0.01	0.98 $\pm$ 0.02	0.04 $\pm$ 0.009	0.124 $\pm$ 0.09	< 0.002	0.344 $\pm$ 0.11
Firat-93	5.20 $\pm$ 0.4	0.052 $\pm$ 0.005	1.21 $\pm$ 0.02	0.89 $\pm$ 0.009	0.060 $\pm$ 0.01	0.162 $\pm$ 0.01	< 0.002	0.293 $\pm$ 0.06
Aydin-93	8.70 $\pm$ 1.2	0.021 $\pm$ 0.003	0.85 $\pm$ 0.00	0.71 $\pm$ 0.005	0.040 $\pm$ 0.01	0.181 $\pm$ 0.02	< 0.002	0.385 $\pm$ 0.03
Harran-95	13.2 $\pm$ 0.2	0.030 $\pm$ 0.003	1.08 $\pm$ 0.02	0.72 $\pm$ 0.01	0.102 $\pm$ 0.02	0.160 $\pm$ 0.06	< 0.002	0.400 $\pm$ 0.03
Ceylan-95	14.7 $\pm$ 0.6	0.061 $\pm$ 0.0005	1.42 $\pm$ 0.04	0.72 $\pm$ 0.04	0.09 $\pm$ 0.008	0.220 $\pm$ 0.03	< 0.002	0.312 $\pm$ 0.08
Diyarbakir-81	4.91 $\pm$ 0.1	0.060 $\pm$ 0.001	1.63 $\pm$ 0.01	0.54 $\pm$ 0.01	0.05 $\pm$ 0.006	0.091 $\pm$ 0.01	< 0.002	0.398 $\pm$ 0.05
Bread Wheat								
Cemre	6.2 $\pm$ 1	0.011 $\pm$ 0.001	0.81 $\pm$ 0.01	0.9 $\pm$ 0.02	1.483 $\pm$ 0.1	< 0.0025	< 0.002	0.324 $\pm$ 0.02
Nurkent	5.5 $\pm$ 0.9	0.002 $\pm$ 0.0004	0.52 $\pm$ 0.03	0.78 $\pm$ 0.07	0.051 $\pm$ 0.02	0.041 $\pm$ 0.01		
Karacadag-98	5.2 $\pm$ 0.1	0.021 $\pm$ 0.003	0.66 $\pm$ 0.05	0.72 $\pm$ 0.02	1.212 $\pm$ 0.10	< 0.0025	< 0.002	0.322 $\pm$ 0.07
Dinç	4.4 $\pm$ 0.1	0.008 $\pm$ 0.0005	0.97 $\pm$ 0.01	0.56 $\pm$ 0.01	1.041 $\pm$ 0.34	0.022 $\pm$ 0.001	< 0.002	0.350 $\pm$ 0.04
Aday-13	4.4 $\pm$ 0.1	0.032 $\pm$ 0.003	0.52 $\pm$ 0.009	0.57 $\pm$ 0.03	1.351 $\pm$ 0.11	0.044 $\pm$ 0.01	< 0.002	0.344 $\pm$ 0.06

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