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Grain mineral composition based-comparison of Miracle wheat (*T. turgidum* convar. *compositum*) with some landraces and modern wheat varieties

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Summary. Wheat landraces still maintain their value because of their importance in terms of genetic resource, attaining old tastes and natural nutrient contents as well as their use as a breeding material. Of the ancient wheats, miracle wheat is one of those about which speculations have been made at different points of time over the last few centuries. These speculations have been mainly based on yield. It is clear that, in its current form, it cannot be an alternative to modern wheats in terms of yield. However, as a breeding material, its characteristics need to be studied. In the study, protein contents of the varieties ranged from 9.6% to 18.3%. The lowest protein content was found in Zerun and the highest in Einkorn. Phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca), iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) concentrations of the varieties ranged between 2.6 and 4.6, 3.3 and 5.3, 1.5 and 1.9, 0.28 and 0.44 g kg^{-1}, 18.1 and 42.3, 4.3 and 8.8, 27.5 and 47.2, and 24.3 and 38.1 mg kg^{-1}, respectively. The highest P, K, Mg and Ca contents were found in Miracle wheat. Besides, miracle wheat was in the group with the highest values in terms of Fe, Cu, Mn, and Zn. In general, the varieties with the lowest mineral contents were Zerun and Emmer.

Key words: wheat, miracle wheat, branched spike, landraces, mineral contents

Introduction

The domestication of wheat dates back 10.000 years in the Fertile Crescent (1). Throughout the history, varieties have been moved between the Fertile Crescent and its neighboring regions, and new varieties have emerged. Egypt is one of these regions. Miracle wheat (*Triticum turgidum* L. convar. *compositum* (L.f.) A. Filat) is of Egyptian origin (2) and a variety of *T. turgidum* with a typical branched spike (3). It is taught to develop out of Emmer wheat through natural mutation (4). It has been long known and cultivated in some Mediterranean countries (5). This variety may be classified as soft red winter wheat. In spite of being bold in general, its grains may sometimes be hairy. Some have spikes with no branches, some have 3-5-7 branches on their spikes. Its grains are shorter, softer and bulgier than those of durum wheat (6). To a large extent, it resembles to tetraploid *T. durum* in structural terms (2).

There have been myths about it as Mummy wheat or Miracle wheat over the last few centuries (3). It has been known under many different names such as Khorasan Weizen, Miracle wheat, Egyptian wheat, Pharaoh's wheat, Osiris wheat, Alaska wheat, (Rivet, Cone or English wheat), wilder Emmer (German), Stoner, Many-headed, Many-spiked Miracle, Multiple-headed, Mummy, Keed, Seven-headed, Smyrna, and Syrian (6). It was introduced in the U.S. and England as Jerusalem wheat in the late 18^{th} and early 19^{th} centuries and, later on, reappeared with the name "Alaska". It was promoted with different names in different times, easily drew people's attention and gave rise to a large number of debates about its yield. Because of lacking in good qualities (yield, grain size, bread quality, etc.), it disappeared after a while (6). It still attracts attention from time to time.

Natural diet has become even more important as a result of the nutrition disorders that have developed in recent years, the chemical accumulation resulting from conventional farming and the increase in diseases thought to be related to it, and the increasing amount of genetically modified varieties in the market. Studies are being conducted that naturally existing (not bred by the hand of man) varieties and whole wheat flour (containing both bran and germ) are healthier (7) and more nutritious. It is stated that, of the wheat grain, bran is rich in fibers, minerals, vitamin B6, thiamine, folate and antioxidants (8) and contains 83% of the total phenolic compounds (9). In recent years, ancient and modern wheat varieties are compared to each other in respect of quality differences rather than yield differences. It is apparent that Miracle wheat is not a superior variety in terms of yield and bread quality. However, ancient wheats are thought to be a possible good genetic resource for enriching new and high-yielding varieties in microelements (10). This study was intended to compare Miracle wheat with other wheat landraces in terms of some mineral nutrient concentrations.

Material and Methods

The wheat seeds used in this study were planted with 3 replications in the experiment areas of Isparta University of Applied Sciences in the winter of 2017-2018. During planting, 200 kg "Super Ekin" (13-25-5 + 10 (SO_3) + 0.5 (Zn)) fertilizer was applied per hectare. In spring, it was split in two (Feekes 4 and 5) and 80 kg N (Ammonium Nitrate) was applied per hectare in total. The plants were drip irrigated twice – at the time of bolting and blooming. Table 1 shows the experiment areas' soil and climatic characteristics during the growing period. During the growing period, compared to long-term averages, a warmer and more arid climate was observed in the region. In spite of being a drier year, lack of rain did not have any negative effects on plant growth because of irrigation.

Registered or nonregistered landraces and some new varieties obtained from their crossbreeding (Table 2) were used in the experiment. The grains harvested at the end of the growing season were split into sets of 100 at a humidity rate of 13%, and thousand kernel weight (TKW) was determined. The samples were soaked in distilled water and then dried at 65°C. For homogenization, the samples were ground to achieve a particle size of <0.5 mm. 0.5 g sample was taken and dissolved by wet decomposition in a concentrated acid mixture (HNO_3: $HClO_4$, 4:1 v/v). The digests' macro- and micro-element concentrations were measured by atomic absorption spectrometer (Agilent AAS-FS 240). Nitrogen contents of the samples were determined by the Kjeldahl method, and the value obtained was multiplied by the coefficient of 5.7 (11) to calculate crude protein contents.

Descriptive statistics were performed in the dataset prior to one-way ANOVA test in SPSS environment. Mean separations of mineral composition of wheat grains were made by multiple comparison of Duncan's test.

Table 1. The soil properties of experimental field and some climatic data

Tex. class	$CaCO_3$ %	OM %	N %	Cu mg kg^{-1}	Mn mg kg^{-1}	Fe mg kg^{-1}	Zn mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}
L	29.4	1.6	0.1	1.5	5.4	1.7	0.75	15	108

Climatic factors	Years/ months	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	Means / Total
Mean temp. (°C)	2017-18	13.0	6.7	5.0	3.1	6.3	9.2	14.2	16.8	20.3	24.3	13.0
	Long term	12.9	7.4	3.5	1.9	2.9	6.2	10.7	15.6	20.2	23.6	10.4
Total precipitation (mm)	2017-18	36.3	38.5	68.7	24.1	54.9	2.9	40.3	36.8	4.0	13.3	319.8
	Long term	38.0	46.3	84.9	72.2	64.7	54.2	56.0	51.4	29.8	14.6	512.1

Table 2. The wheat varieties used in the trial

Common name	Botanical name	Ploidy level	Hulled or Free-threshing
Einkorn	*T. monococcum* L.	Diploid	Hulled
Zerun	*T. aestivum* L.	Hexaploid	Free-threshing
Emmer	*T. dicoccon* Schrank.	Tetraploid	Hulled
Karakılcık	*T. durum* Desf.	Tetraploid	Free-threshing
Miracle wheat	*T. turgidum* L.	Tetraploid	Free-threshing
Kunduru 1149	*T. durum* Desf.	Tetraploid	Free-threshing
Gökala	*T. durum* Desf.	Tetraploid	Free-threshing
Tosunbey	*T. aestivum* L.	Hexaploid	Free-threshing

Results and Discussion

The differences between the varieties were found to be at the level of p≤5% for the grain's P content and p≤1% for other traits investigated (Figure 1). The highest thousand kernel weight was obtained from Karakılçık wheat (50.6 g) and the lowest from Miracle wheat (17.1 g). One of the key indicators of yield potential is thousand kernel weight. Very low value of it makes competition in terms of yield with modern wheat varieties difficult for this variety. Protein content ranged from 9.6% (Zerun) to 18.3% (Einkorn). Protein content is affected by growing conditions (12), but the determining factor is genetic characteristics (13). In addition to Einkorn, Emmer wheat and Miracle wheat also have a high protein content potential.

The grain number per spike and thousand kernel weight are important yield components. In wheat, the number of grains per spike usually ranges between 35 and 44 (14, 15). In this study, the number of grains per spike in Miracle wheat was found to be 55 (personal unpublished data). The TKW was varied between 23.5-53.4 g in a research on many bread wheat landraces in Turkey (16). The acceptable thousand kernel weight for durum wheat is 35-40 g (17). In our study, TKW was found to be between these values for other durum wheat varieties (excluding Emmer) but nearly half for Miracle wheat (17.2 g). Such a low TKW indicates incomplete grain filling – i.e. wrinkled grains (18) –, suggesting that climatic conditions in this study were not suitable for Miracle wheat to reach its full yield potential.

Grain P contents ranged between 2.6 g kg^{-1} and 4.6 g kg^{-1}, and the mean was found to be 3.3 g kg^{-1}. The highest P content was obtained from Miracle wheat. Although there was no statistically significant difference between other varieties, Emmer had the lowest P content (2.6 g kg^{-1}). Potassium, Mg and Ca contents ranged between 3.3 (Zerun) - 5.3 g K kg^{-1} (Miracle wheat), 1.5 (Emmer) - 1.9 g Mg kg^{-1} (Miracle wheat) and 0.28 (Ze-

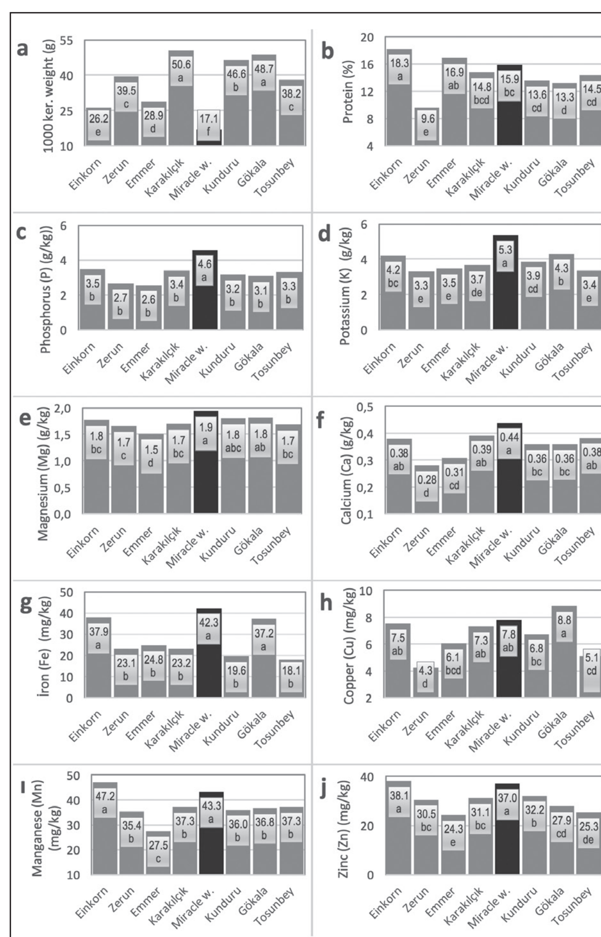

Figure 1. The TKW (a), protein (b), P (c), K (d), Mg (e), Ca (f), Fe (g), Cu (h), Mn (ı) and Zn (j) content of the wheat grain

run) - 0.44 g Ca kg^{-1} (Miracle wheat), respectively. These results seem to be close to those of the study conducted by Kokten and Akcura (19) on bread wheat landraces. The highest Cu and Mn contents were found in Gökala (8.8 mg kg^{-1}) and Einkorn (47.2 mg kg^{-1}) and the lowest in Zerun (4.3 mg kg^{-1}) and Emmer (27.5 mg kg^{-1}).

The most common nutrition disorder in the world is iron and zinc deficiency (20). Deficiency of iron and zinc affects both yield and quality. For this reason, micronutrient element studies are focused mainly on these two elements. In wheat, there is a positive correlation between zinc and iron concentrations (21) and a negative correlation between these two elements and yield (10, 21). The positive correlation between Fe and Zn is clearly seen in our study. The highest values were found in Einkorn and Miracle wheat and the lowest in Emmer.

There has been an increase in yield with the use of semi-dwarf wheats. As a result of this increase, grain Fe, Zn and P concentrations have decreased in bread wheats, although this fact is not apparent in the durum wheat (22). The results of our study run parallel with these findings (Table 3). In general, Zerun and Emmer were the varieties with the lowest mineral content. In wrinkled grains, endosperm content is lower than aleurone and embryo (23). Endosperm content was 66.6% in the grain with a TKW of 17.2 g but 81.1% in the grain with a TKW of 30.4 g. TKW has increased for approximately 2.2 g per decade from 1940s to 2000s and reached 44.6 g from 31.5 g (24). Today, endosperm content is about 81-84% (25). Endosperm contains a large amount of starch and proteins, whereas other sections (outer and germ layers) are rich in fibers, vitamins, minerals, and phytochemicals (25, 26). As reported by Zhang et al. (27), wheat flour contains 12 mg kg^{-1} Fe and 14 mg kg^{-1} Zn, and bran contains 151 mg kg^{-1} Fe and 111 mg kg^{-1} Zn. In this study, the probable cause of high micronutrient concentration of Miracle wheat is thought to be low endosperm ratio and high bran and germ ratios. Cakmak et al. (28) associated high zinc concentration in wild diploid wheats with its smaller grain size.

Table 3 shows the classification made by mean nutrient contents by wheat varieties. In spite of decreasing macronutrient concentrations (P, K, Mg, Ca) from diploid to hexaploid, this decrease was not found to be statistically significant. However, the decrease in micronutrient concentrations from diploid to hexaploid is considered to be statistically significant. This result is parallel with the opinions that micronutrient concentrations in ancient wheats is determined rather genetically (29) and that mineral concentrations in modern wheats are more affected by environmental factors (30). Besides, in cereals, plant nutrient concentrations change depending on fertilization (31). Cakmak et al. (28) found that the iron and zinc concentration in modern pasta and bread wheats was lower and more stable than that in ancient wheats. The reason was concluded to be that nutrient contents became rare in case of high yield. In spite of the general opinion that increasing yield leads to a decrease in the concentration of proteins and micronutrient elements (32), some researchers stated this was not always the case (33, 34).

Although kernel weight is basically determined by genetic characteristics, it can be increased by agronomic practices and is considered to be one of the key yield indicators (35, 36). In our study, the number of grains in Miracle wheat was consistently higher than that in other varieties. However, Miracle wheat appeared to have the lowest thousand kernel weight, suggesting that Miracle wheat cannot be superior in terms of yield.

Table 3. The TKW and mineral contentrations of wheat according to its ploidy level

	TKW g	Protein %	P g kg^{-1}	K g kg^{-1}	Mg g kg^{-1}	Ca g kg^{-1}	Fe g kg^{-1}	Cu g kg^{-1}	Mn g kg^{-1}	Zn g kg^{-1}
Diploid (Einkorn)	26.2 a*	18.3 a	3.5 a	4.2 a	1.8 a	0.38 a	37.9 a	7.5 a	47.2 a	38.1 a
Tetraploid (Emmer, Karakılcık, Miracle wheat, Kunduru, Gökala)	38.3 a	14.9 b	3.4 a	4.1 a	1.8 a	0.37 a	29.4 ab	7.4 a	36.2 b	30.5 b
Hexaploid (Zerun, Tosunbey)	38.8 a	12.0 b	3.0 a	3.3 a	1.7 a	0.33 a	20.6 b	4.7 b	36.3 b	27.9 b

*: Values with the different small letter in a column are significantly different according to the Duncan test at $P<0.05$

Conclusion

According to the results of our study, there are two probable reasons for the higher micronutrient concentrations of Miracle wheat: lower kernel weight and genetic potential. It would be useful for explaining the result to try Miracle wheat in the ecological environments where it can produce a higher yield. Some researches demonstrate that tetraploid wheat landraces can be a suitable genetic resource for increasing micronutrient elements. In this scope, Miracle wheat seems to be one of the landraces that can be used. Even though TKW is lower in Miracle wheat, the number of grains per spike is significantly higher. If this trait is improved by means of breeding methods, Miracle wheat can reach a considerable potential in terms of yield. If micronutrient concentrations decrease with the increasing yield, then increasing both yield and micronutrient elements seems to be one of the problems to be solved by fertilization practices. Wheat landraces are not capable of competing with modern varieties in yield characteristics. However, it is essential for our future to use them in breeding and to exercise due care for their existence.

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