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Araştırma Makalesi

Evaluating the Element Contents of Durum Wheat Landraces Pure Lines in Çanakkale Conditions

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Abstract

Wheat landraces are often utilized in breeding programs for their potential to improve the grain quality of new varieties. Our goal is to evaluate thousand kernel weights (TKW), percentages of the yellowberry kernels (PYK), B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, P, S and Zn contents of 25 landraces derived durum wheat pure lines collected from the fauna of Turkey to identify promising candidates. Field trials were conducted in Çanakkale in 2015-2016 and 2016-2017 growing seasons and element contents of pure lines were determined by using ICP-OES. Differences between durum wheat landraces were found statistically significant by all traits ($p<0.01$). Correlation analysis demonstrated that Ca, Cu and Mg contents of pure lines were positively correlated to each other. Results suggested a valuable variability among durum wheat genotypes in terms of their element contents. Promising candidates were selected for future breeding programs.

Keywords: Durum wheat, element, Çanakkale, biofortification, Landraces

Çanakkale Koşullarında Yerel Makarnalık Buğday Hatlarının Çeşitli Element İçeriklerinin Değerlendirilmesi

Özet

Buğday ıslahında tane kalitesinin geliştirilmesi amcaıyla yerel buğdaylardan yaygın olarak yararlanılmaktadır. Bu çalışmada Türkiye faunasından toplanmış yerel makarnalık buğdaylardan elde edilen 25 adet yerel hat arasından bu potansiyele sahip hatları belirlemek amacıyla bin tan ağırlığı (BTA), dönmeli tane oranı (DTO) ile B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, P, S ve Zn içerikleri incelenmiştir. Araştırma Çanakkale'de 2015-2016 ve 2016-2017 yetiştirme mevsimlerinde yürütülmüş, parsellerden elde edilen tane örneklerinin element içerikleri ICP-OES yöntemi ile belirlenmiştir. İncelenen tüm özellikler bakımından makarnalık buğday hatları arasında gözlemlenen farklılıklar istatistiksel olarak önemli bulunmuştur ($p<0.01$). Korelasyon analizi sonucunda hatların Ca, Cu ve Mg içeriklerinin birbirleri ile olumlu ve önemli bir ilişki içerisinde bulundukları belirlenmiştir. Araştırma bulgularından yola çıkılarak makarnalık buğday yerel hatlarının element içerikleri bakımından dikkate değer bir çeşitlilik gösterdiği sonucuna ulaşılmıştır. Belirli elementler bakımından ümitvar hatlar seçilmiştir.

Anahtar Kelimeler: Makarnalık buğday, element, Çanakkale, biyofortifikasyon, yerel çeşitler

Introduction

Obtaining new genotypes with the prospect of higher performance and quality is a constant challenge in plant breeding. To this end, breeders and agronomists often study landraces and distant relatives of wheat with hopes to discover useful genotypes to associate in breeding programs. Due to its exceptional location where the Mediterranean and Middle east meet, significant genetic variation was reported among wheat landraces obtained from Turkey's flora (Karagöz and Zencirci, 2005; Altıntaş et al., 2008; Ateş Sönmezoğlu et al., 2012; Kabbaj et al., 2017).

In addition of their earlier use as breeding materials to improve grain yield disease and resistances in wheat, landraces derived pure lines are reported to have a particular potential for the enhancement of grain quality when compared to the cultivars (Gökgöl, 1939; Akçura, 2011; Nazco et al., 2012; Hocaoğlu and Akçura, 2014). A possible explanation for this phenomenon is "the bottleneck effect", which stands for a decrease of diversity among current breeding materials caused by the constant pressure of selecting for high-yielding genotypes. Continuous selection for grain yield causes a restriction in genotypic variability which resembles a bottleneck: genotypes that don't come forward by their high yields but may excel at different attributes are eliminated during the selection process. Losing genotypic variation limits the success of later breeding programs particularly by traits other than grain yield, such as grain quality and mineral content (Reif et al., 2005). Researches comparing wheat landraces to varieties often found that landraces populations or landrace derived plant materials had higher genetic diversity (Figliuolo et al., 2007) and higher contents of some microelements and protein in their grain (Konvalina et al., 2008; Zhao et al., 2009; Hocaoğlu and Akçura, 2014). Increasing the microelement content of wheat would lead to a significant contribution to human nutrition, because even though fruits and vegetables are considered as the essential sources of minerals in human diet (Martinez-Ballesta et al., 2010), mineral malnutrition is an important health problem today, which is often linked with carbonhydrate-rich unbalanced diets. This is especially common in the developing countries where severe health problems due to this type of malnutrition is caused by the lack of diversity of food substances (Welch, 2002). Although a permanent solution for this problem calls for a more comprehensive effort including social, economic and legal aspects of the situation, increasing mineral contents of staple foods may have an immediate effect and provide to be a short-term solution (White and Broadley, 2005). Mineral fertilization, increasing bioavailability of nutrients or breeding new varieties with increased capacity of mineral accumulation towards their edible organs are considered as valid solutions to reduce dietary malnutrition (White and Broadley, 2005). Therefore, monitoring landraces for quality related traits allows the identification of valuable germplasm to complement nutritional aspects of breeding programs.

This research aims to compare 25 landraces derived pure lines by their B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, P, S and Zn contents. In addition to the element contents and thousand kernel weights (TKW), percentages of yellowberry kernels of pure lines were also investigated to reveal insights about the current condition of growing landraces pure lines Çanakkale conditions. Yellowberry kernels in durum wheat is a physiological disorder where soft yellow stains occur on the grain due to the disruption of vitreous protein matrix by excessive starch accumulation. Therefore, presence of the yellowberry kernels decreases overall vitreousness and by doing so negatively effects the grain quality. Yellowberry kernels can be caused by climatic factors such as high air humidity/precipitation during the seed development or prolonged duration of seed development (Güleç et al., 2010). Therefore, identifying suitable durum wheat varieties for the climate of the growing are is important to reduce the percentages of yellowberry kernels (Pehlivan and İkincikarakaya, 2017).

Materials and Methods

Pedigree information and the registration codes of durum wheat genoptypes are given in Table 1. Field trials are designed according to the randomized complete block design with four replications and were conducted in 2015-2016 and 2016-2017 growing seasons in Çanakkale. Plots were arranged to be 0.8 m wide and 2 m long with 4 rows each. Sowing density was 500 seeds m^{-2}.8 kg da^{-1} $P_2 0_5$ and 15 $kgda^{-1}$ N fertilizer applied in total. Total dose of N fertilizer is divided into two doses for a better match with plant growth: first dose (10 kg da^{-1}) is applied during the sowing when the rest is applied by the beginning of stem erection. Weeds were controlled with commercial herbicide containing the active substance of chlorosulphuron.

Table 1. List of landrace-derived durum wheat pure lines

No	Landraces code and pedigree	Origin
1	YÇ-35 (Koca buğday MB-2005b-7-01)	Konya
2	YÇ-30 (Bulgurluk MB-2005-28-24)	Konya
3	YÇ-36 (Koca buğday MB-2005-43-11)	Konya
4	YÇ-47 (İri buğday MB-2005-72-03)	Konya
5	YÇ-33 (Arı buğdayı MB-2005-12-16)	Konya
6	YÇ- 29 (Koca buğday MB-2008-17-16)	Konya
7	YÇ-37 (Koca buğday MB-2008-01-20)	Konya
8	YÇ-28 (Koca buğday MB-2008-06-16)	Konya
9	YÇ-41 (Koca buğday MB-2008-05-23)	Konya
10	YÇ-1 (Bulgurluk MB-2009-13-08)	Eskişehir
11	YÇ-2 (Bulgurluk MB-2009-06-04)	Eskişehir
12	YÇ-3 (Bulgurluk MB-2009-03-19)	Eskişehir
13	YÇ-4 (Bulgurluk MB-2009-08-21)	Eskişehir
14	YÇ-5 (Bolavadin MB-2006-12-03)	Eskişehir
15	YÇ-7 (Sarı baş MB-2006-09-09)	Eskişehir
16	YÇ-8 (İri buğday MB-2006-05-09)	Eskişehir
17	YÇ-9 (Koca buğday MB-2006-08-24)	Eskişehir
18	YÇ-10 (Bulgurluk MB-2006-06-11)	Eskişehir
19	YÇ-12 (Bolavadin MB-2010-20-04)	Eskişehir
20	YÇ-13 (Sarı buğday MB-2010-17-16)	Eskişehir
21	YÇ-15 (Ak buğday MB-2010-11-22)	Eskişehir
22	YÇ-16 (Koca buğday MB-2010-10-14)	Eskişehir
23	DMB-63 (Bolavadin MB-2010-01-01)	Ankara
24	Yabani-67 (Buğday MB-2012-03-07)	Kayseri
25	YÇ-44 (Sarı buğday MB-2012-05-15)	Konya

All field applications are made by hand. Harvested plants were threshed with a stationary thresher. Seed counts and measurements for the assessments of the thousand kernel weights and percentages of yellowberry kernels were made in the laboratory. A set of grain samples were grinded. B, Ca, Cu, Fe, K, Mg, Mn, Na, Ni, P, S and Zn contents of 54 durum wheat genotypes are determined by ICP-OES (inductively coupled plasma - optical emission spectrometry). Sample preparations and ICP-OES readings are held in accordance with Akçura et al. (2019) and Mertens (2005).

Results are evaluated with ANOVA and the correlation analysis. Averages of both experiment years are represented as a heatmap for an easier evaluation (Table 3).

Results and Discussion

Combined ANOVA of two years results showed that genotype effects were significant for all traits at p<0.01 level (Table 2). Least significant difference (LSD) values, mean, minimum, and maximum of each trait are presented in the bottom of the heatmap given in Table 2.

Table 2. Variance analysis results of landraces genotypes

		Sources of variation							
DF		Year	Rep	Gn	Year*Gn	Error	Total	CV	R^2
		1	4	24	24	96	149		
Parameters	B	110.36	9.22	77.59**	11.50**	1.97	16.61	17.61	0.92
	Ca	6336.55	1703.9	49222.40**	25229.14**	483.78	12392.16	5.34	0.97
	Cu	9.78	0.62	10.10**	10.19**	0.26	3.52	8.69	0.95
	Fe	389.4	27.77	217.30**	191.93**	2.49	70.88	3.25	0.98
	K	9407317	164851	1443406**	900601**	12315	453055	2.87	0.98
	Mg	2329.40	8070.74	101904**	16181.02**	1250.59	20058.56	4.85	0.96
	Mn	13.56	46.12	201.38**	143.30**	3.14	58.87	6.64	0.97
	Na	1022.19	216.35	14155.27**	7677.66**	108.89	3599.54	6.67	0.98
	Ni	4.41	0.63	7.56**	1.38**	0.18	1.6	23	0.93
	P	593802	138812	971332**	818263**	17318	307126	3.57	0.96
	S	1188	99946	319982**	220133**	6554	93912	4.57	0.96
	Zn	884	15	148**	186**	3	62	3.73	0.97
	TKW	3852	263	89**	60**	5	60	5.63	0.95
	PYK	10.94	3.93	13.72**	18.15**	2.01	6.61	22	0.80

**: P<0.01, DF: Degree of Freedom, Gn: Genotype, CV: Coefficient of variation (%), R^2:R squared, B: Boron, Ca: Calcium, Cu: Copper, Fe: Iron, K: Potassium, Mg: Magnesium, Mn: Manganese, Na: Sodium, Ni: Nickel, P: Phosporus, S: Sulfur, Zn: Zinc, TKW: Thosand kernel weight (g), PYK: Percentage of yellowberry kernels (%).

Table 3. Heatmap of the averages of micro element contents (ppm), TKW (g) and PYK (%) of durum wheat genotypes

Genotype	B	Ca	Cu	Fe	K	Mg	Mn	Na	Ni	P	S	Zn	TKW	PYK
1	5.33	307	4.8	51.7	3296	492	31.3	120	0.95	3310	1185	47.3	44	6.5
2	12	454	6.58	53.8	4464	785	20.7	268	4.53	3692	1678	48.8	42.9	5.5
3	6.73	353	5.16	55.2	4057	843	22.1	68	1.45	4148	2079	43	39.9	7.75
4	13.8	376	5.14	52.1	4084	717	30.1	116	1.53	3924	1683	40.1	37.1	7.75
5	10.8	548	8.65	44.6	3779	860	21.9	152	2	3396	1882	43.9	42.3	5.25
6	4.86	337	6.74	35.5	3877	679	22.9	208	0.34	3516	1814	46.8	40.4	6.5
7	5.84	432	7.4	60.3	3710	714	30.8	155	0.59	3738	1566	51.6	40.9	7.5
8	7.97	569	5.94	41.1	3878	775	35.8	184	0.78	3642	1865	53.4	44.1	5.5
9	8.34	365	5.98	44.4	3779	679	25.3	195	0.38	3543	1742	47.2	42.6	2.75
10	9.33	275	5.38	53.8	3545	687	29.6	62.9	0.13	3482	1551	42.2	39.7	6
11	14.1	569	8.14	46.1	4482	1044	40.3	142	1.41	4297	2103	41.6	34.9	3.5
12	7.26	441	6.21	48.8	4144	654	19.9	157	3.92	3112	1809	31.4	39.3	5
13	6.75	578	6.2	53	4831	893	25.2	154	2.09	3914	1888	47.9	37.1	5
14	15.9	271	3.62	42.8	2862	615	26.8	132	3.02	3097	1629	45.1	41.4	6.25
15	8.5	374	4.77	42.4	4722	759	22.8	112	1.98	4008	1842	45.8	33.8	8
16	10.9	364	4.64	40	3965	681	34.5	170	1.51	4093	1911	47.6	38.4	6.75
17	3.79	373	4	56.2	3606	493	33.3	156	1.75	3297	1583	46	37.3	9
18	5.84	307	5.45	43.8	4380	703	16.3	196	0.34	3844	1592	51.4	35.3	7.75
19	2.61	410	5.91	50.3	3402	668	20	178	0.61	3115	1764	48	35.2	7
20	6.43	339	5.39	55	4018	707	28.9	170	0.15	4068	1682	48.5	36.7	6.75
21	10.9	390	3.22	51.2	3150	521	22.3	57.1	1.62	3297	1382	35.2	35.6	7.5
22	5.59	470	6.82	46.8	3872	838	26.8	185	1.97	3726	1952	43.6	28.6	8.5
23	2.01	500	6.62	41.9	3648	859	23.2	168	2.76	3921	2075	51.4	41.5	7.25
24	4.34	458	6.29	48.8	3880	882	31.3	87.3	1.69	4650	2205	43.5	44.9	5.75
25	9.26	437	6.83	49	3095	658	24.6	147	1.97	3314	1743	44.9	40.9	4.75
Mean	7.96	411.78	5.84	48.34	3861	728.17	26.66	149.52	1.58	3685	1768	45.44	38.9772	6.39
Max	15.86	577.98	8.65	60.29	4831	1043.5	40.33	268.15	4.53	4650	2204.7	53.39	44.88	9
Min	2.01	270.57	3.22	35.54	2862	491.7	16.31	57.09	0.13	3097	1185.1	31.41	28.55	2.75
LSD(0.01)	2.12	33.37	0.77	2.4	168.4	53.64	2.68	15.18	0.64	199	122	2.57	3.34	2.15

GN: Genotype number, TKW: Thosand kernel weight (g), PYK: Percentage of yellowberry kernels (%). Since durum wheat landraces genotypes with the higher element contents and lower PYK are considered to be more promising, better candidates for any given trait are indicated with the darker shades of green when darker shades of red indicates the opposite.

In Table 3, genotype performances can be compared against each other by using the cell color as an indicator: darker shade of green represent the preferability of a genotype which is associated with the higher microelement contents, higher TKW and lower percentages of yellowberry kernels. According to the heatmap, almost every durum wheat pure line had a unique element composition where selecting for a perfect genotype were not possible. Thus, choosing several genotypes as possible candidates for the biofortification of different microelements rather than selecting any pure line being prominent by all would be more accurate. Genotype 24 had highest P and S with a high TKW when genotype 2 had the highest averages of Na and Ni contents. Moreover, genotype 13 had the highest K and Ca contents when genotypes 14, 7 and 8 were prominent by B, Fe and Zn contents, respectively.

Highest average TKW were obtained from the genotypes 24, 9 and 1, all of which had a PYK (between %5.5 and 5.75) lower than the mean PYK of all genotypes (%6.39, Table 2). However, their element compositions varied greatly. Both genotypes 11 and 2 had reasonably high element compositions when genotype 2 would be preferable in terms of combining high TKW with lower PYK. (Table 3).

PYK averages of durum pure lines were found to be promising. According to the rate card declared from the Turkish Grain Board, 27% PYK is the upper limit for Group I durum wheat (Anonymous, 2019), meaning that the higher percentages of yellowberry kernels than this ratio causes financial loses for the farmers. Our results suggest that PYK of landrace derived pure lines differed between 2.75% - 9% (Table 3). Since genotype averages falls under 27% we conclude that durum wheat cultivation in Çanakkale province may be feasible in terms of meeting the quality requirements of the market.

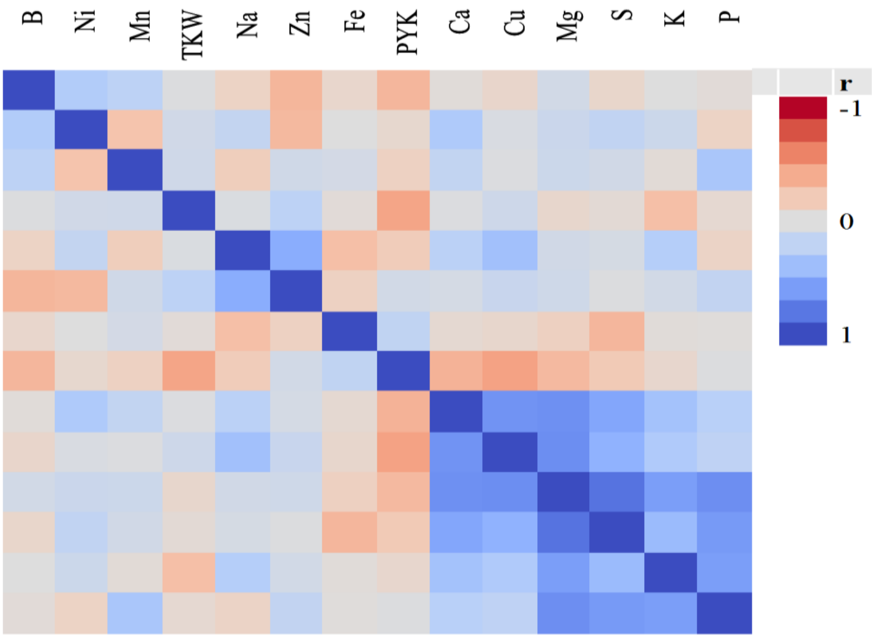

Figure 1. Color map of the correlation analysis

Table 4. Correlation coefficients between investigated parameters of pure lines

	B	Ca	Cu	Fe	K	Mg	Mn	Na	Ni	P	S	Zn	TKW
Ca	-0.15												
Cu	0.04	0.22											
Fe	0.10	-0.04	-0.03										
K	0.00	0.07	0.12	0.22									
Mg	0.10	0.42**	0.45**	-0.06	0.42**								
Mn	0.23	0.01	-0.23	-0.04	-0.16	0.02							
Na	0.02	-0.02	0.17	-0.18	0.13	-0.16	-0.05						
Ni	0.20	0.34**	0.03	0.14	0.03	0.10	-0.06	0.09					
P	-0.13	-0.01	0.24	0.28*	0.58**	0.45**	-0.01	-0.25	-0.20				
S	-0.19	0.28*	0.28*	-0.21	0.20	0.55**	-0.19	-0.12	0.22	0.30			
Zn	-0.01	-0.01	-0.07	0.27*	0.4**	0.09	0.09	0.38**	-0.08	0.41**	-0.18		
TKW	-0.07	0.04	0.04	0.04	-0.27	-0.02	-0.01	-0.11	0.14	0.04	0.23	-0.16	
PYK	-0.10	0.02	-0.23	0.10	-0.19	-0.36	0.04	-0.05	0.14	0.11	-0.21	0.43**	-0.04

* significant at p<0.05, ** significant at p<0.01.

Results of the correlation analysis revealed several significant relationships between various element contents (Table 4). Most significant relationships were observed between P and K (0.58) and Mg and S (0.55). Mg, Ca and Cu were also positively correlated with one other with varying correlation coefficients between 0.42 and 0.45. These relationships are more visible in the colored representation of the correlation table (Figure 1), where two bulks of positive and significant relationships can be observed. First bulk included Ca, Cu and Mg when a second bulk can be observed near the first, including Mg, S, P and K (Figure 1). Similar positive correlations among Mg, Ca and Cu contents were reported before on a set of old and modern durum wheat varieties (Ficco et al., 2009). Hakkı et al. (2014) confirmed positive correlations between

Mg, P an S but reported non-significant correlations among Mg, Ca and Cu contents of several Turkish durum wheat genotypes.

Correlation analysis did not reveal any significant relationships between TKW and other traits. Similarly, non-significant negative associations can be seen between many elements with PYK except for Zn, which were found to be positively and significantly correlated to PYK (0.43). TKW and PYK were negatively correlated but this relation was not statistically significant (Table 4).

In conclusion, given the importance of durum wheat products in Turkey, biofortification of durum grain by element contents would contribute to our nutrition. There are many studies underlining this issue, especially by Fe and Zn contents. Reports indicate that human diet often lacks sufficient amounts of Fe and Zn in the developing countries (Welch and Graham 2002). Element contents of crops can be increased through increasing the amount of mineral fertilization but depending on this alone will bring additional costs to the farmers and bring about the risk of pollution in both soil and groundwaters (Xu et al., 2011). Thus, plant breeding is considered as the foremost measure for biofortification which relies to the discovery of new genotypes with higher capability of metabolizing and storing elements (Cakmak et al., 2010). In our study, pure lines 24 and 2 can be recommended for cultivation in Çanakkale ecological conditions when all traits were considered. Additionally, genotypes 2, 7, 8, 11, 13, 14 and 24 were found to be promising candidates to increase element contents of durum wheat. Landrace derived pure lines were confirmed to contain a great variability, proving to be valuable assets to the future quality breeding programs.

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