Evaluating Mineral Contents of Selected Bread Wheat Landrace Pure Lines Derived from West Anatolia and Marmara Regions and Cultivars by GGE Biplot

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Bread wheat landraces are important resources for micronutritent improvement in plant breeding programs. This research aims to evaluate 9 macro and micronutrient contents (Fe, Zn, B, K, Mn, Cu, Mg, Ca, Mo) of 37 bread wheat pure lines derived from landraces of West Anatolia (Eskişehir and Kütahya) and Thrace (Edirne and Kırklareli) regions and compare with 11 bread wheat cultivars by using GGE Biplot. Field trials are conducted by incomplete block design with two replications in 2011-2012 growing season in Dardanos Agricultural Facility of Çanakkale Onsekiz Mart University. According to the biplot graphics, iron and zinc contents of genotypes were involved into the same section when boron and molibden contents were also highly correlated. Pure line L4 (TR57999/5) were the most prominent genotype for iron and zinc contents when L36 (TR38316/2) were superior by both boron and molibden contents. Copper contents of grains were found negatively correlated with iron and zinc contents. Results indicate notable variability among pure lines and lesser variability for cultivars for all micronutrients. Wheat cultivars had relatively higher Mo content while could be improved by their Fe, Zn, B, K and Ca contents. Possible candidates are introduced to be used in a future study.

Keywords: Bread wheat, landraces, GGE biplot, pure line, West Anatolia, mineral contents

Introduction

Wheat is a worldwide cultivated staple food and has always been one of the most widely practiced crops in plant breeding programs. Extensive breeding efforts have been made to improve older wheat lines and genotypes into modern high input cultivars with much higher yields from the beginning of 20th century. Reduced plant height increased plants resistance of lodging (especially grown under high nitrogen fertilization) and increased proportion of dry matter partition into the grain (Hedden, 2003). Today, high – yielding modern wheat cultivars are grown widely worldwide, replacing landraces that could no longer satisfy wheat farmers increasing expectations. This replacement almost caused extinction of landrace populations with a rapid reduction of wheat's natural germplasm that has been gradually reducing since the very beginning of its domestication (Reif et al. 2005, Cavanagh et al. 2013, Fu 2015).

Plant breeding programs usually requires high genetic variability among their material. Wheat landraces are considered as important sources of variation. (Kaya et al. 2006, Akçura et al. 2011, Hocaoglu and Akcura 2014). Previous studies showed that modern wheat cultivars tend to have lower mineral concentrations when compared to landraces or older cultivars (Fan et al. 2008, Ficco et al. 2009, Hussain et al. 2012, Akcura et al. 2013, Guzman et al. 2014, Akcura and Kokten 2017) which can be attributed to their significant reduction in quantity after the introduction of semi-dwarf cultivars (Zhao et al. 2009) or fertilization (Kirchmann et al. 2009, Martínez-Ballesta et al. 2010). Thus, improving important nutrient contents of bread wheat such as Fe, Zn, Cu, Ca would have great effects on human nutrition (Kashian and Fathivand 2015). Breeding more nutritious crops through plant breeding are essential (Ortiz-Monasterio et al. 2007, Bouis and Welch 2010) but nutrifiaction is only the beginning of an ongoing struggle to battle human malnutrition, which is growing to become an even bigger challenge with population growth and climate change (Godfray et al. 2010).

This study aims to evaluate macro and micronutrient contents of 37 bread wheat pure lines derived from landraces of West Anatolia and Thrace regions and compare with 11 registered cultivars.

Materials and Methods

37 bread wheat lines which are derived from landraces of West Anatolia (Eskişehir and Kütahya) and Thrace (Edirne and Kırklareli) regions are compared with commonly cultivated bread wheat cultivars of the same regions by their Fe, Zn, B, K, Mn, Cu, Mg, Ca and Mo contents (Table 1).

Table 1. Mineral concentrations (ppm) of bread wheat landrace derived pure lines and cultivars.

Genotype		Fe	Zn	B	K	Mn	Cu	Mg	Ca	Mo
L1	TR55155/6	48.12	34.17	8.96	2745.72	38.83	5.26	1243.75	409.99	0.98
L2	TR57999/6	48.35	34.30	9.71	2795.72	38.67	5.36	1167.91	490.66	1.00
L3	TR57999/2	36.92	25.00	10.46	5195.63	33.33	7.11	1620.41	429.32	1.09
L4	TR57999/5	51.68	44.00	10.96	4986.00	36.83	5.05	1554.16	433.98	1.05
L5	TR55154/4	46.25	30.17	12.96	3624.94	31.50	5.43	1533.75	346.64	1.00
L6	TR55155/2	42.29	33.16	9.71	2574.90	49.50	5.36	1559.16	434.64	0.97
L7	TR55164/2	40.96	30.92	8.17	4770.60	34.00	6.25	1530.41	472.64	0.94
L8	TR57999/3	38.00	26.42	8.08	4920.64	32.50	5.03	1636.25	454.64	1.05
L9	TR55140/5	46.04	30.17	12.96	2599.90	35.67	5.39	1521.66	483.32	1.24
L10	TR55138/6	48.33	34.25	9.50	3166.62	38.67	5.51	1342.50	461.98	1.05
L11	TR55148/3	38.00	24.50	9.83	2441.57	33.83	6.17	1033.75	437.31	0.97
L12	TR55149/6	36.00	24.33	9.62	4699.81	34.67	4.89	1564.58	411.32	0.93
L13	TR55125/6	43.75	29.17	9.79	3737.35	30.83	5.79	1517.91	441.32	1.09
L14	TR55142/1	42.29	33.17	9.75	2437.40	49.33	5.88	1576.25	440.65	0.92
L15	TR55174/3	48.75	34.66	8.96	2391.57	38.66	5.60	1565.00	433.32	0.93
L16	TR55125/1	42.92	32.33	10.42	2458.24	37.83	4.69	1082.92	432.65	1.10
L17	TR55146/7	40.73	33.00	9.62	3916.59	49.67	4.97	1378.75	473.99	0.94
L18	TR55142/3	48.00	34.08	10.46	3154.04	38.83	5.51	1344.29	496.65	1.00
L19	TR55144/3	39.17	26.50	9.67	3370.78	32.50	5.47	1249.58	441.32	1.09
L20	TR55167/1	39.58	28.68	8.96	3895.76	32.00	4.75	1158.75	551.00	1.05
L21	TR55148/4	42.08	33.33	9.83	3766.60	49.17	5.25	1591.66	443.31	0.94
L22	TR55128/2	50.00	35.91	12.96	4970.79	36.00	5.42	1514.58	469.98	1.08
L23	TR55127/1	42.29	33.00	11.04	3833.26	49.83	5.51	1356.66	424.65	0.92
L24	TR55146/4	39.71	33.00	9.75	4866.47	49.66	5.43	1278.75	443.98	0.90
L25	TR55212/2	43.75	29.25	10.96	4183.25	44.00	5.31	1144.58	477.30	0.94
L26	TR55143/5	43.65	29.08	10.46	4020.75	31.83	5.97	1330.41	486.61	0.97
L27	TR55174/5	41.00	32.33	11.21	4551.60	37.83	5.66	1514.58	335.97	1.08
L28	TR55167/2	41.46	31.92	10.29	4445.82	37.50	5.48	1550.00	489.98	0.94
L29	TR55141/2	43.33	26.00	10.96	3312.45	32.50	4.92	1593.75	405.99	1.00
L30	TR55144/5	49.37	35.33	10.50	4549.60	38.50	4.95	1608.33	499.31	0.94
L31	TR55166/6	44.87	29.83	9.79	4552.30	35.66	6.48	1076.25	479.99	1.00
L32	TR55138/5	38.00	26.42	10.46	4770.80	32.66	5.47	1175.41	401.32	1.09
L33	TR33419/2	42.58	32.50	8.04	4495.65	38.16	6.48	1555.41	482.64	1.05
L34	TR33257/3	40.42	31.08	8.46	2279.08	37.00	6.35	1356.25	503.98	0.97
L35	TR33419/5	35.50	24.33	10.46	3737.35	34.66	6.15	1509.58	416.65	0.89
L36	TR38316/2	44.17	29.33	14.25	2666.56	35.33	5.05	1464.16	434.65	1.23
L37	TR33521/3	45.42	30.08	10.96	2679.06	31.16	6.00	1512.50	414.65	0.92
ALTAY		33.00	24.33	7.71	3720.76	34.00	6.62	1610.00	423.98	1.09
FLAMURA		36.40	30.75	12.12	2391.57	32.33	5.10	1536.25	414.65	1.19
GELİBOLU		41.25	28.00	12.00	3466.53	34.33	6.40	1398.75	435.30	1.22
GEREK 79		38.00	28.58	9.00	5008.09	32.00	5.62	1527.50	483.31	1.05
HARMANKAYA		37.00	28.67	11.92	4179.08	32.16	4.20	1095.83	479.31	1.11
KIRAÇ		36.21	28.67	11.62	3420.78	33.66	4.50	1116.67	465.98	1.09
KIRGIZ		35.04	29.00	11.92	2799.89	33.33	4.82	1560.41	459.99	1.21
MÜFİTBEY		38.60	28.00	11.83	3029.05	37.00	5.87	1592.08	482.66	1.23
PEHLİVAN		39.70	24.65	8.42	4545.65	36.33	5.36	1476.66	437.99	1.23
SÖNMEZ		37.75	31.58	12.25	3724.93	37.17	5.27	1611.66	415.98	1.17
TEKİRDAĞ		41.25	31.75	12.21	2404.07	32.66	5.88	1468.75	419.32	1.20

Field trials are conducted by incomplete block design with two replications in 2011-2012 growing season in Dardanos Agricultural Facility of Çanakkale Onsekiz Mart University. Plots were 1.6 m^2 each and contained 4 rows with 20 cm space between lines; sown in 2 November 2011 with hand. Plant density were 550 plants per squaremeter. 2.7 kg da^{-1} N and 6.9 kg da^{-1} P_2O_5

fertilizer were applied with sowing, followed by 4.3 kg da^{-1} N application as topdress at the beginning of tillering phase. All agronomical procedures were in accordance with usual applications in wheat cultivation in Çanakkale, with the only exception of avoiding the use of herbicides and pesticides. Weeds around and within experiment area are controlled by hand. Plants were harvested by hand and threshed. Seed samples are grinded by using a laboratuary-type grinder. Obtained whole bread flour put under 0.05 cm sieve before chemical analysis. Mineral contents of seed samples are analysed by atomic absorption spectroscopy (Kacar and Inal, 2008).

GGE Biplot method is introduced to identify genotype, environment and genotype – environment interaction effects on multi-environmental data (Yan et al. 2000) which is projected on biplot graphic (Gabriel 1971). Ever since its development, GGE Biplot method gained popularity among plant breeders and agronomists for its capability of visualizing genotype performances on different environments by reducing the dimentionality of the data, making it possible to evaluate genotypes, variables and environments on the same graphic statistically. Furthermore, it is also used to rank genotypes and environments, provides information about stability of genotypes (Yan and Tinker 2006).

The GGE Biplot model used in this study is:

$$Y_{ij} - \mu - \beta_j = \lambda_1\, \xi_{i1}\, \eta_{1j} + \lambda_2\, \xi_{i2}\, \eta_{2j} + \varepsilon ij$$

Where Y_{ij} is the expected mineral j content of genotype i, μ is the grand mean, β_j is main effect of mineral j, λ1 and λ2 are the singular values of first and second principal components, ξ_{i1} and ξ_{i2} are eigenvectors of mineral j for PC1 and PC2, and εij is the residual effect for genotype i and mineral j. Biplot analysis was made and graphics were created in "GGEbiplot" software created by Weikai Yan (Yan et al. 2001).

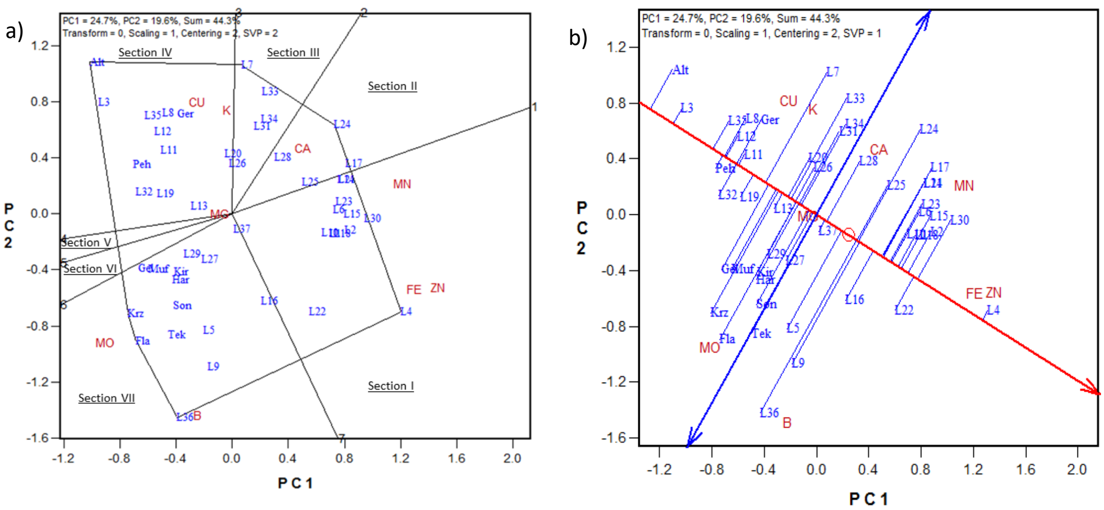

Figure 1. Polygon view of GGE Biplot – which is best for what (a) and Genotypes ranking based on average mineral axes (details of genotypes were given in Table 1) with genotype projections on AMC (Average mineral coordination) (b)

Results and Discussion

Polygon view of the biplot graphic is drawn by connecting the most distant genotypes from biplot origin to form a polygon, then drawing perpendicular lines from each side of this polygon to stop at the origin, which separates genotypes and environments into seven sections (Figure 1a). Vertex genotypes contributes overall variation most, delivering the most marjinal results that either the best or the worst (Yan and Tinker 2006).

In our study, L4, L30, L17, L24, L7, Altay, Kırgız, Flamura and L36 were the vertex genotypes. Vertex genotypes with each sector is considered having relatively higher mineral contents that is included in the same sector (Yan et al. 2000). Therefore, L4 was a possible candidate for both iron and zinc content when L24 for calcium and L36 for boron and molibden (Table 1).

High variation of mineral concentrations of pure lines can be seen in Figure 1a. Contrarily, cultivars except Altay, Pehlivan and Gerek seemed relatively closer to each other and placed in lower-left part of the biplot, showing much lesser variation compared to landrace pure lines. These cultivars also had remarkably higher molibden and lower calcium contents than the rest of the genotypes. Projections of genotypes on AMC (average mineral coordinate) are shown in Figure 1b. L4, L37 and Pehlivan had little variation for different mineral contents because they were located near the AMC when L36 had the most.

Biplot graphics suggests a high variation among genotypes by their mineral contents due to the distance of mineral vectors from biplot origin except magnesium (Figure 2a). Additionally, mineral vectors are scattered in almost every direction across the biplot, making acute and obtuse angles with each other (Figure 2a). High correlation of iron and zinc contents were explicit (figure 2a), due to acute angle between these two vectors indicates high positive correlation (Yan et al. 2000), which were also found in previous studies (Hussain et al. 2010, Moreira-Ascarrunz et al. 2016, Akcura and Kokten 2017). Iron and zinc concentrations of wheat genotypes had strong negative correlation with copper while as weak negative correlation with potassium, which were also positively correlated with each other. Another significant negative correlation is seen between molibden and calcium (figure 2a).

Mineral vectors which are located far away from the biplot origin also contribute greatly to overall variation, having higher discriminativeness than others. In Figure 2a, iron, zinc, boron and molibden were very good examples of discriminitiveness and followed by magnesium which is located on the edge of the last circle. Discriminativeness reduces with minerals such as copper, potassium and calcium respectively, which are placed in inner circles closer to the origin. Magnesium is located near the center of the origin, being the least discriminating mineral in our study, in a way that its contents among all landraces and cultivars contributes little to overall variation. Acute angle made by both iron and zinc with average environment axis indicated their high representetiveness which are followed by magnesium. It is clearly seen that iron and zinc contents were placed near AMC in figure 2a, which is an axis represents all mineral concentrations combined. Given that, iron and zinc were highly representetive for all mineral concentrations in addition to their high discriminitiveness, which means iron and zinc contents would make good criteria for selecting genotypes for generally good mineral contents (Yan and Tinker 2006).

In theory, the ideal genotype should be included by the concentric circle in figure 2b. Accordingly, L4 were placed near ideal genotype circle, suggesting L4 were the most desireable genotype to be selected by its overall mineral content. Other desireable genotypes were L22, L18 and L3 where cultivars were not more desireable than half of the landraces used in this study, which means landraces pure lines derived from West Anatolia and Thrace regions could contribute future breeding programs aimed to imrove seed mineral contents of winter wheat.

Conclusions

GGE Biplot provides insights and simplifies otherwise complicated two-way data, hovewer its statistical power in our study were limited due to combined rate of explained variation (PC1 and PC2) were 44,31%, which is under 50% (Yan et al. 2000). Still, explicit results such as L4's promising Zn and Fe content could be confirmed from Table 3. We believe presented biplot graphics provides information by its valuable visualization capabilities.

Results shows that registered cultivars had lesser variation among different mineral contents of landrace pure lines of northwest Anatolia and Thrace regions. These lines could provide candidates for biofortification of bread wheat. Landrace L4 were the most desirable genotype while having high mineral contents, especially iron and zinc. Landraces L22, L18 and L30 could also be candidates for future studies. L36, L24, L7 and L13 could be specifically used as plant materials to enrich boron, calcium, potassium and magnesium contents of future bread wheat cultivars, respectively. All registered cultivars had especially lower iron, zinc, manganese and calcium contents. This indicates importance of investigating and improving nutrification value of bread wheat in future.

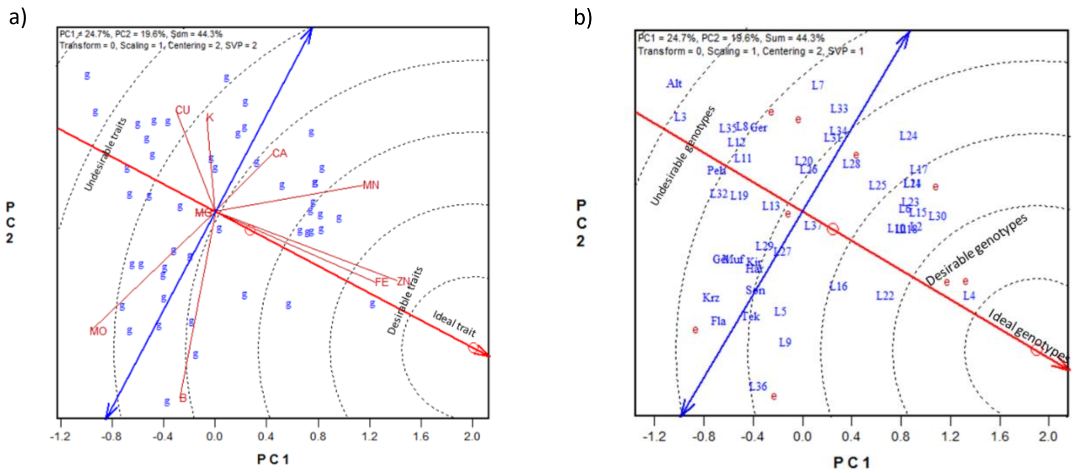

Figure 2. Ranking mineral concentrations on discriminating abilities and representativeness (a) and ranking genotypes based on their concentrations for all minerals altogether (b).

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