Original Paper

Assessment of genetic diversity of Turkish maize landraces for phytic acid and total phenolic contents

Fatih KAHRIMAN[1]*, Fatma AKTAŞ[2], Gülizar PINAR[1], Umut SONGUR[1], Cem Ömer EGESEL[2]
[1]*Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Field Crops, Çanakkale, Turkey*
[2]*Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Agricultural Biotechnology, Çanakkale, Turkey*

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The breeding studies targeted to develop high yielding varieties in maize have led to a decrease in genetic variation in secondary biochemical components. Local maize landraces are important genetic sources for these components. The objective of this study was to examine the genetic variation for phytic acid and total phenolic compounds within 192 Turkish maize landraces. The plant material was grown during the summer season of 2017 in Çanakkale, with the inclusion of 7 check hybrids. The field trial used an Augmented Experimental Design, with 6 blocks, each one containing 32 landraces and 7 check hybrids. Phytic acid and total phenolics were detected spectrophotometrically in the seeds of landraces propagated by bulk pollination. The data were subjected to analysis of variance and some genetic estimations (coefficients of variation, heritability, genetic advance) were calculated for the observed traits. Results of data analysis suggest that there is a considerable genetic variation among the investigated genetic materials. The phytic acid content was found between 0.82–4.87 mg g^{-1} and the total phenolic content was between 0.03–1.99%. For both traits, genetic variation in local maize landraces was observed to be wider than check varieties. The promising materials among landraces may have potential use in the future breeding programs for manipulating the levels of phytic acid and phenolic compounds. According to the calculations made for the inheritance of the traits, it was determined that the heritability in phytic acid content was higher (56.2%) than those for the total phenolics. Genetic gain calculations showed that genetic improvement can be achieved by selection for both investigated traits.

Keywords: phytate, antinutrients, phenolic acids, *Zea mays*, genetic conservation

1 Introduction

The agricultural lands in the world areabout 1.5 billion hectares and approximately 712 million hectares of this area is devoted to the cultivation of cereals. Maize has a high proportion (25.7%) with 183 million hectares of this area (FAO, 2017; http://www.fao.org/faostat/en/#home). Maize, one of the major feed sources in animal production, is an important ingredient used in feed production for poultry, pigs and other animals (Abbassian, 2006; Chiangmai et al., 2011). Understanding the role of biochemical components found in maize grain and their effects in animal nutrition is essential. Phytic acid and phenolics are two of such components, that are well known to have effects on nutrition and health.

Phytic acid, also known as phytate, is a form of phosphorus that is stored in all grains and oilseeds (Jacela and Renter, 2010). In general, phytic acid in maize kernels has a high variability and it ranges from 0.68 mg g^{-1} to 14.2 mg g^{-1} (Kahriman et al., 2020). It has been reported that phytic acid content in maize kernel constitutes about 75–80% of the total phosphorus (Raboy et al., 2000). Approximately 90% of phytic acid in maize kernel accumulates in the embryo and about 10% in aleurone layers (Shi et al., 2003). Phytate is best known as an anti-nutrient substance that reduces mineral absorption, however, it has also been associated with potential benefits. It binds the majority of phosphorus as phytate phosphorus and it also forms complexes with minerals such as Fe, Ca, Zn. Reducing phytic acid content in seeds is a legitimate target for genetic improvement in many crops, including maize, rice, barley, wheat and soybean (Shi et al., 2003).

***Corresponding Author:** Fatih Kahrıman, Çanakkale Onsekiz Mart University, Faculty of Agriculture, Department of Field Crops, Çanakkale, Turkey. e-mail: fkahriman@hotmail.com

Phytic acid also plays an important role in animal nutrition. Since monogastric animals weakly digest phytic acid, phytate rich animal feeds are supplemented with inorganic phosphate to meet the phosphorus (Pi) requirement for animal growth (Cromwell and Coffey, 1991; Shi et al., 2003). Phytate interacts with proteins and reduces the benefits of such compounds for the animals as well as humans. In this respect, the phytic acid intake should be balanced in some groups carrying health risks (Özkaya et al., 2013).

Plant-derived foods contain phenolic phytochemicals and they provide powerful antioxidants to our body as well as contributing to body defence (Güleşci and Aygül, 2016). Phytochemicals showing antioxidant activity include flavonoids, phenolic compounds, nitrogenous compounds as well as tocopherols, carotenoids, and ascorbic acid. Phenolic compounds are the most active natural antioxidants that show useful effects such as binding free radicals and inhibiting the lipoxygenase enzyme. Many studies have suggested that the phytochemical content and antioxidant activity in phenolic compounds of plant-derived foods help preventing chronic and degenerative diseases (Heinonen et al., 1998; Record et al., 2001). In most of the cereals, seed and especially seed coat are rich in phenolic components (Nichenametla et al., 2006). The pigmented seeds of maize contain lots of secondary metabolites such as carotenoids and phenolics. Phenolic acids and flavonoids represent the most common form of phenolic compounds found in all maize kernels. Colouring pigments are mainly found in the aleurone layer or pericarp of the maize kernel, which greatly affect the colour of the kernels and they can be used as functional colorants (Žilić et al., 2012).

Several studies have been conducted on the variation of phytic acid and phenolic components in maize. Research focused on phytate accumulation in different parts of maize plant at different physiological development stages showed that there is no phytate accumulation in the vegetative parts of maize and the amount of phytate increases in kernels from flowering towards maturity (DeTurk et al., 1933; Earley and DeTurk, 1944). Different studies have addressed the variation of phytochemical components in different maize genotypes. Žilić et al. (2012) investigated the phenolic compounds, carotenoids, antioxidant capacity, and anthocyanin compositions in 10 different coloured maize genotypes. They suggested that the maize genotypes with naturally rich pigments had a potential to produce functional foods and functional food colorants (Žilić et al., 2012). In another study conducted in Philippines, 46 different maize landraces collected from Filipino farmers were screened in terms of their antioxidant potentials. This study showed that the contents of phytochemicals such as total phenols, flavonoids, and carotenoids have been found to be promising for the genetic improvement of grain quality characteristics (Purificacion et al., 2018). Dragičević et al. (2010) evaluated 28 maize populations for the genetic variability for phytic acid, inorganic phosphorus and soluble proteins. The results showed negative correlation between phytic acid and inorganic phosphorus in maize kernel and the highest mean yield was obtained from the low phytic populations. Five blue colored hybrids and two-coloured local varieties grown in Mexico have been evaluated for free and bound phenolics, antioxidant capacity and anthocyanin content. This study focused on evaluating the potential of elite blue-coloured maize hybrids in the nutraceutical industry as a natural source of antioxidant compounds. Results showed that elite blue maize hybrids can be an important source of antioxidant compounds with potential for the food or nutraceutical industries (Lugo et al., 2015).

Augmented Experimental Desing is one of the incomplete experimental designs for field trials. It was proposed by Federer (1956) and Federer (1961) and mostly preferred when the number of experimental material is high or the amount of seeds is limited. Augmented design is based on corrected data of test materials according to data obtained from check varieties with multiple times in such trials. Although there are some disadvantages of this design in terms of the capability of genetic estimations, it is commonly used in screening experiments with the high number of materials to be tested. This design gives indicative estimations about the inheritance of traits studied. Frank et al. (2026) and Chandana et al. (2018) calculated genetic components based on variance calculations obtained from augmented design (Frank et al., 2016; Chandana et al. 2018).

Literature review revealed that Turkish maize landraces have been screened for agro-morphological traits (Öner and Gülümser, 2014; Kızılgeçi et al., 2018) and some major and minor quality traits (Cömertpay et al., 2016; Ünlü et al., 2018) but they have not yet been evaluated in terms of phytic acid and phenolic compounds. Scientific literature also lacks information on the inheritance of these traits. From this point of view, the objectives of this study were i) to determine genetic variation among 192 local maize landraces collected from different regions of Turkey, ii) to investigate the genetic effects for the investigated traits to understand the inheritance of phytic acid and total phenolic compounds.

2 Material and methods

2.1 Plant material and field experiment

The experimental material consisted of 192 maize landraces previously collected from different regions of Turkey and conserved in National Gene Bank (Table 1). Also, seven commercial check hybrids (SYINOVE, HIDO, CALICIO, 75MAY75, RESERVE, and 72MAY80) were used as test genotypes. The study started with a seed increase in the first year to obtain enough kernels for the field trials. The landraces were planted into 2-row plots, with a plant density of about 70,000 plants ha^{-1} at the Plant Research and Experimental Unit of ÇOMÜ Agricultural Faculty Farm in 2017. To maintain genetic structure of the landraces, bulk pollination method was applied within each plot (The Maize Program, 1999).

In 2018, the field trial was set using an Augmented Experimental Design with six blocks, each containing 32 rows of landraces and 7 rows of check hybrids. Each hybrid existed in each block once as a single row plot. The field was fertilized with 170 kg ha^{-1} pure nitrogen and drip irrigated as needed. Weed control was carried out mechanically. The same pollination practices were applied as in the first year. Three to six ears from each row were harvested when the plants reached physiological maturity. The ears were shelled and kernels from one or two individual ears (depending on the number of ears from a plot) were sampled to make three experimental replicates. These samples were grinded using a laboratory mill (Fritsch pulverisette 14, Germany) with 0.5 mm sieve and stored at +4 °C until chemical analyses.

Table 1 The maize landraces used in current study

Code	Region	Code	Region	Code	Region	Code	Region
TR36986	Karadeniz	TR38101	Akdeniz	TR48461	Karadeniz	TR50798	Ege
TR37006	Ege	TR38104	Karadeniz	TR48477	Marmara	TR50816	Karadeniz
TR37105	Marmara	TR38128	Ege	TR48891	Ege	TR51719	Marmara
TR37115	Karadeniz	TR38141	Akdeniz	TR48893	D. Anadolu	TR51727	Karadeniz
TR37543	Karadeniz	TR38147	Karadeniz	TR49168	G. Anadolu	TR52003	Karadeniz
TR37573	G. Anadolu	TR38172	Ege	TR49171	Ege	TR53247	Marmara
TR37583	Karadeniz	TR38208	Karadeniz	TR49197	Karadeniz	TR53254	Marmara
TR37596	Marmara	TR38240	Karadeniz	TR49225	Karadeniz	TR54192	Karadeniz
TR37597	Marmara	TR38243	Ege	TR49234	Karadeniz	TR54193	Karadeniz
TR37600	Karadeniz	TR38256	Karadeniz	TR49245	İç Anadolu	TR54196	Karadeniz
TR37601	Marmara	TR38289	Marmara	TR49260	Karadeniz	TR54197	Ege
TR37603	Ege	TR38292	Marmara	TR49271	Karadeniz	TR54199	Marmara
TR37605	Karadeniz	TR38323	Karadeniz	TR49277	Marmara	TR54216	Marmara
TR37611	Karadeniz	TR38329	Karadeniz	TR49303	Marmara	TR54217	Karadeniz
TR37618	Karadeniz	TR38337	Marmara	TR49313	Karadeniz	TR54712	Karadeniz
TR37630	Karadeniz	TR38339	Marmara	TR49318	Marmara	TR55452	Karadeniz
TR37653	Marmara	TR38341	Akdeniz	TR49323	Karadeniz	TR55461	Karadeniz
TR37719	Karadeniz	TR38343	Marmara	TR49578	Marmara	TR55463	Karadeniz
TR37720	Ege	TR38350	Marmara	TR49579	Ege	TR55464	Karadeniz
TR37735	Marmara	TR38375	Marmara	TR50125	Marmara	TR55471	Karadeniz
TR37746	Karadeniz	TR38389	Karadeniz	TR50126	Marmara	TR55476	Ege
TR37754	Marmara	TR38401	Karadeniz	TR50130	Ege	TR55479	Ege
TR37810	Karadeniz	TR38422	Karadeniz	TR50131	Akdeniz	TR55480	Ege
TR37861	Karadeniz	TR38435	Marmara	TR50216	Ege	TR55481	Marmara
TR37876	Marmara	TR38439	Ege	TR50220	Karadeniz	TR55484	Karadeniz
TR37882	Karadeniz	TR38451	Ege	TR50250	Marmara	TR55485	Ege
TR37912	Karadeniz	TR38457	Karadeniz	TR50505	Marmara	TR55486	Ege
TR37918	G. Anadolu	TR40604	Marmara	TR50511	Marmara	TR55488	Karadeniz
TR37924	Ege	TR42576	Karadeniz	TR50513	Karadeniz	TR55491	Karadeniz

Continuation of table 1

Code	Region	Code	Region	Code	Region	Code	Region
TR37932	Marmara	TR42591	Marmara	TR50515	Karadeniz	TR55492	D. Anadolu
TR37940	Karadeniz	TR42641	Ege	TR50516	Karadeniz	TR55502	Karadeniz
TR37941	Karadeniz	TR42689	Marmara	TR50524	Marmara	TR55506	Ege
TR37953	Karadeniz	TR42703	Karadeniz	TR50547	D. Anadolu	TR55507	Karadeniz
TR37955	Ege	TR42712	Marmara	TR50549	Karadeniz	TR55508	Karadeniz
TR37958	Karadeniz	TR42725	G. Anadolu	TR50550	Karadeniz	TR55510	G. Anadolu
TR37969	Karadeniz	TR42750	Karadeniz	TR50551	Marmara	TR55513	Karadeniz
TR37970	Marmara	TR42856	Karadeniz	TR50555	Karadeniz	TR55518	Marmara
TR37974	Karadeniz	TR42868	Karadeniz	TR50558	Karadeniz	TR55521	Karadeniz
TR37984	Ege	TR42877	Ege	TR50559	Ege	TR55522	Karadeniz
TR37986	Ege	TR42948	Akdeniz	TR50564	Karadeniz	TR55527	Karadeniz
TR37995	G. Anadolu	TR42949	Karadeniz	TR50566	Marmara	TR55528	Marmara
TR37998	Karadeniz	TR42985	Karadeniz	TR50585	Marmara	TR55533	Karadeniz
TR38008	Karadeniz	TR44385	Karadeniz	TR50587	Marmara	TR55534	Marmara
TR38024	Marmara	TR44410	Marmara	TR50588	Marmara	TR55540	Marmara
TR38026	Karadeniz	TR44501	Marmara	TR50641	Marmara	TR55542	Marmara
TR38040	Karadeniz	TR45102	Ege	TR50642	Ege	TR55545	Ege
TR38064	İç Anadolu	TR48449	Marmara	TR50670	Karadeniz	TR57654	Karadeniz
TR38100	Marmara	TR48454	Ege	TR50683	Marmara	TR57658	Marmara

2.2 Total phenolic compounds (%)

The method of Galicia et al. (2009) was followed to quantify total phenolic compounds of the samples. For this purpose, 1.3 mL of 1.2 M HCl-Methanol solution was added to 20 mg ground sample and the tubes were shaken for 11 minutes at 1100 rpm and 42 °C. Then, the samples were left to cool down to room temperature and centrifuged at 14,000 rpm for 5 minutes. Five hundred microliters of supernatant were taken into a new eppendorf tube and the samples were dried in evaporator under nitrogen gas. The dried samples were dissolved in 1.3 mL of methanol and subjected to a colorimetric reaction. For this, 50 microliters of each sample were pipetted into a 96-well microplate. To each well, 40 microliters 25% Folin-Ciolalteu solution and 110 microliters 400 mM Na_2CO_3 were added. The 96-well microplate was taken to the microplate reader (BioTek, Vermont, US) after shaking for 10 seconds at 800 rpm. The device was incubated at 42 °C for 9 minutes and after cooling down to room temperature, absorbance values were taken at 765 nm. The phenolic contents of the samples were estimated with the help of standard curves constructed by standard gallic acid solution.

2.3 Phytic acid content (mg g^{-1})

For extraction of phytate, 0.5 g ground sample was shaken in a boiling water bath for 1 hour at room temperature using 10 mL of 0.2 N HCl. Then, 0.25 mL of extract was taken into a test tube, and 2.25 ml of 0.2 N HCL and 5 ml of iron solution were added. The tubes were kept in the boiling water bath for 30 minutes, then placed in an ice bath and kept until they reached to room temperature. After that, the tubes were centrifuged at 3,000 g for 20 minutes. 100 microliters were taken from the upper phase to 96-well plate and 150 microliters of H-L reagent (400 mg Bipyridine + 400 microliters TGA + 40 ml pure water) were added. The absorbance values of the samples were recorded at 519 nm using microplate reader (BioTEk, US). Phytic acid contents of samples were determined using the curves prepared with phytic acid standard according to Raboy et al. (2017).

2.4 Statistical analysis

The data were analysed in accordance with the Augmented Experimental Design. Variance analyses were performed in the R program (R Core Team, 2018) using the augmented RCBD package (Aravind et al., 2019). ANOVA was performed based on replicated check genotypes and the landraces values were corrected by the experimental error. All other analyses were performed on the corrected data for landraces. Phenotypic, genotypic, and environmental variances (σ_p^2, σ_g^2, and σ_e^2) were obtained from the ANOVA analysis to calculate the heritability values for the traits. Other

Table 2 The estimated parameters and their classification limits based on previous studies

Parameter	Equation	Evaluation limits	Reference
Phenotypic coefficients of variation (*PCV*) Genotypic coefficients of variation (GCV)	$PCV = \frac{\sigma_p^2}{\sqrt{\bar{x}}} \times 100$ $GCV = \frac{\sigma_g^2}{\sqrt{\bar{x}}} \times 100$	low = CV <10 moderate = 10≤ CV ≤20 high = CV ≥20	Burton, 1951, 1952 Sivasubramaniam and Madhavamenon, 1973
Broad sense heritability (H^2)	$H^2 = \frac{\sigma_g^2}{\sigma_p^2}$	low = H^2 <30 moderate = 30≤ H^2 ≤60 high = H^2 ≥60	Lush, 1940 Robinson, 1966
Genetic advance (*GA*) Genetic advance as per cent of mean (*GAM*)	$GA = k \times \sigma_g \times \frac{H^2}{100}$ $GAM = \frac{GA}{\bar{x}} \times 100$	low = GAM <10 moderate = 10≤ GAM ≤20 high = GAM ≥20	Johnson et al., 1955

$\bar{x}$ – mean, k at 5% selection intensity is 2.063

parameters estimated and their evaluation limits are shown in Table 2. Descriptive statistics (means, standard deviation, standard error, skewness, and kurtosis values) were calculated for each trait. Frequency distribution graphs were used to compare standard varieties and populations. Due to the large number of genotypes used, it was not possible to present the results of differences among the landraces and check varieties. A boxplot was created for each trait and Wilcoxon test was used to compare the differences between landraces and check varieties.

3 Results and discussion

3.1 Variance analyses for phytic acid and total phenolics

Results of variance analysis are shown in Table 3. When genotypes are ignored, block effect appears to be significant for both traits. The genotype effect (n = 199) appears to play an important role in the variation of phytic acid and phenolics. Significant differences were found between the averages of check varieties and landraces for both traits. There were significant differences among check varieties for phytic acid content (0.74, p <0.05), but not for total phenolics (p >0.05). The variation between averages of check varieties and maize landraces was significant for phytic acid content. Ignoring the check varieties, it was determined that there was a significant difference among maize landraces for phytic acid content (Table 3).

3.2 Genetic variability within maize landraces for phytic acid and total phenolics

For the landraces and check varieties, descriptive statistics of phytic acid and total phenolics are presented in Table 4. The average values of the genotype groups were similar for both phytic acid and total phenolic compounds. On the other hand, standard deviations with minimum and maximum values for both traits indicated that the variation in maize landraces is considerably higher than check varieties. Phytic acid contents of maize landraces ranged from 0.82% to 4.87%, while the standard varieties had a range from 1.63% to 2.49%. Similarly, total phenolics

Table 3 Analysis of variance for phytic acid and total phenolic contents according to augmented design

Source of variation	df	Phytic acid content	Total phenolic content
Block (ignoring Treatments)	5	1.33 **	0.56 **
Block (eliminating Treatments)	5	0.49 ns	0.07 ns
Treatment (eliminating Blocks)	198	0.54 **	0.09 ns
Treatment (ignoring Blocks)	198	0.56 **	0.10 *
Treatment: Test and Test vs. Check	192	0.54 **	0.09 *
Treatment: Check	6	0.74 *	0.02 ns
Treatment: Test vs. Check	1	6.75 **	0.04 ns
Treatment: Test	191	0.52 **	0.1 *
Residuals	30	0.22	0.05

ns – not significant at P >0.05; *, ** – significant at P ≤0.05, P ≤0.01, respectively

Table 4 Descriptive statistics of maize landraces and checks for phytic acid and total phenolics

Statistic	Phytic acid content		Total phenolics content	
	landraces	checks	landraces	checks
N	192	7	192	7
Mean	2.57	2.13	0.65	0.62
Minimum	0.82	1.63	0.03	0.54
Maximum	4.87	2.49	1.99	0.69
Std. deviation	0.72	0.35	0.32	0.06

of the landraces (0.03% and 1.99%) had a larger variation than the check varieties (0.54% and 0.69%) (Table 4).

Frequency analyses of the investigated traits are shown in Figure 1 and statistical comparisons of landraces versus checks are presented in Figure 2. Frequency plots indicate that phenolic content is skewed to the right, while the phytic acid data shows a distribution close to the normal distribution (Figure 1). Check varieties had narrower variation for phenolic contents than the variation in their phytic acid contents. SYINOVE and 75MAY75 had lower variation than the other check varieties for phytic acid content. 75MAY75 had the least variation for this trait. The number of maize landraces, which have high and low values compared to check varieties, can also be seen in Figure 1. It is seen that more than 80 landraces for phytic acid content and more than 60 landraces for phenolics content are higher than checks varieties. Also, it is seen that about 30 landraces have a lower value than the checks in terms of phytic acid content and 60 landraces have close values or lower than the standard varieties in terms of phenolic compounds.

In terms of the traits studied, the top 3 genotypes with the highest and lowest values for the check varieties and landraces can be seen in Figure 2. Although there is no statistically significant difference between checks and landraces in terms of phenolics, there is an important variation among the genotype groups for this trait. TR38337, TR38389 and TR520003 had as high as 2% phenolics, while TR48454, TR37653, TR55461 were with the lowest values. The highest phytic acid contents were detected in TR54199, TR37940 and TR54193, whereas TR50131, TR38323 and TR38104 were the populations with low phytic acid.

There are numerous studies focused on the phytochemical content and antioxidant capacity in different maize genotypes. In a study conducted in Serbia, maize genotypes with different kernel colours were compared and results showed that the total amount of anthocyanins and phenolic contents was higher in blue kernels (Žilić et al., 2012). Similar findings were reported in a study conducted in Mexico (Lopez-Martinez et al., 2009). In another study, Terao (1989) reported that the small or medium sized cereal grains had contain more phenolic components per unit dry matter because they had a higher ratio of aleurone and pericarp. The researcher suggested that the total anthocyanin and phenolic components were higher in the pericarps of coloured maize kernels, and those genotypes were promising in the development of functional foods. Velásquez-Ladino et al. (2016) collected twenty-five coloured and colourless maize landraces from different regions of Colombia and investigated their

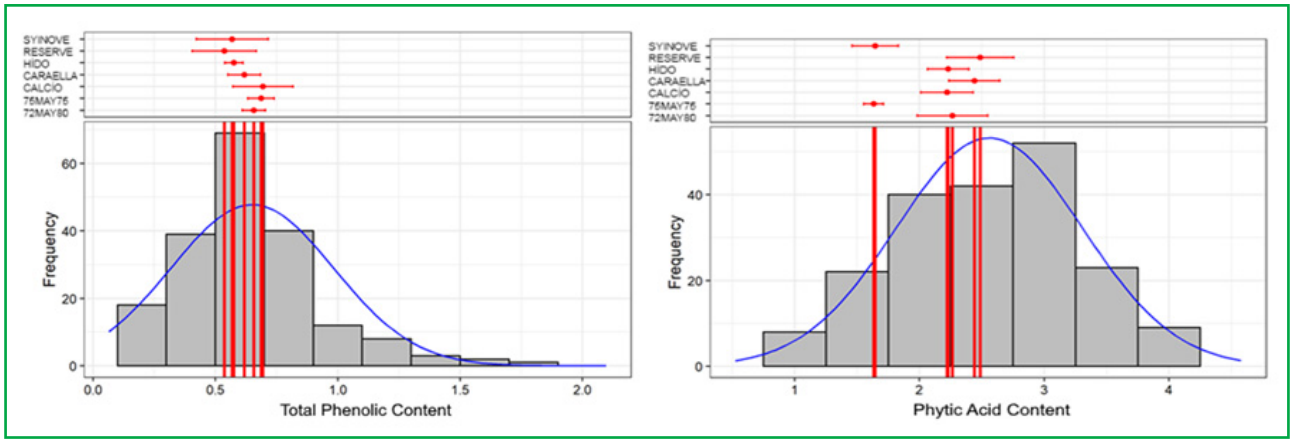

Figure 3 The frequency plots for total phenolics and phytic acid content

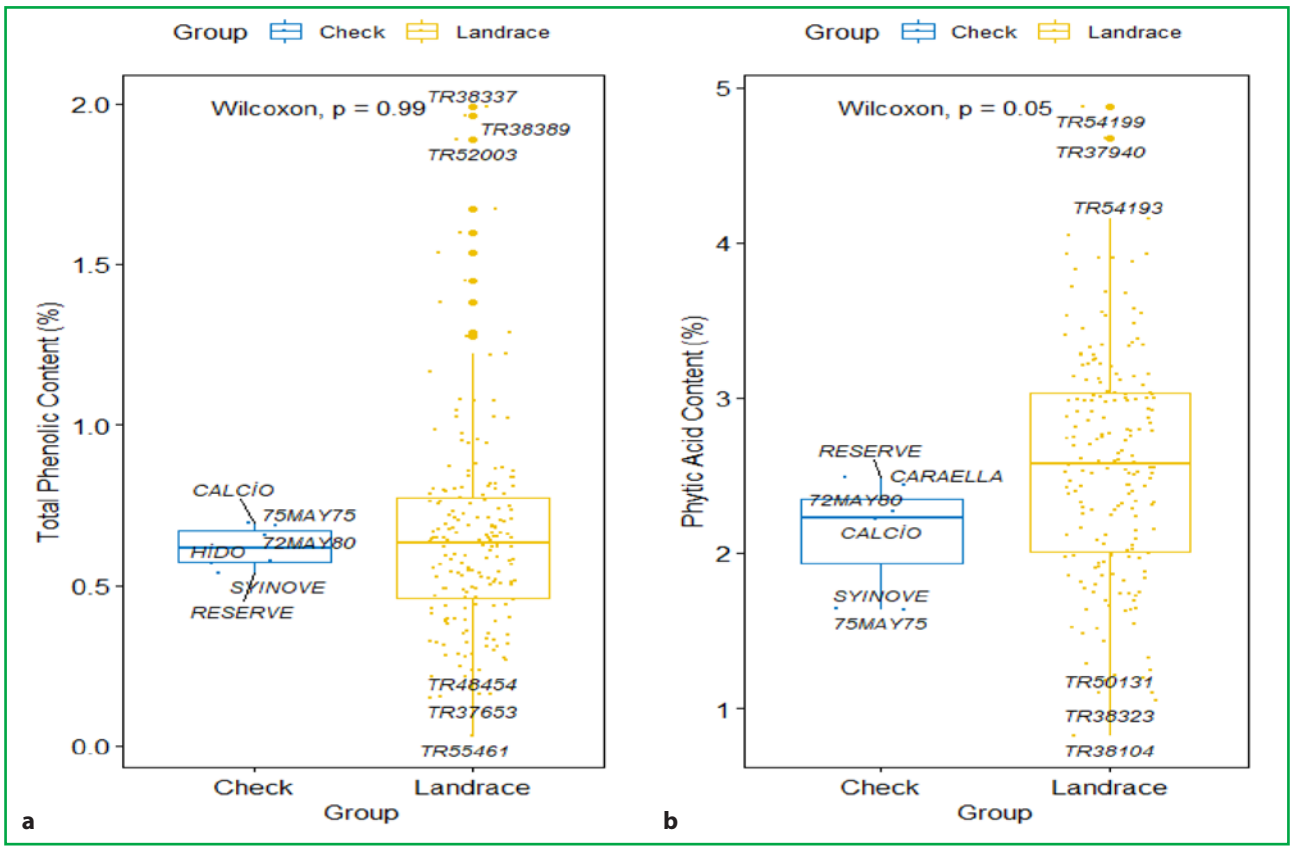

Figure 2 The box plot chart showing differences between checks and landraces for phenolics and phytic acid

total phenolic, flavonoid and anthocyanin contents. They argued that coloured maize genotypes could allow the expansion of the functional food industry in Colombia and other producer countries. They also pointed out that use of chemical evaluations together with multivariate analyses was a good approach for characterization of the coloured maize kernels.

Turkish landraces with the high levels of phenolics and phytic acid could be considered as useful sources for functional food industry.

3.3 Heritability and genetic estimations for phytic acid and phenolic compounds

Genetic and environmental variances along with the heritability and genetic advance values by the traits are presented in Table 5. For both traits, genotypic variance was found higher than environmental variance, thereby yielding higher GCV and ECV values. Heritability and genetic advance values calculated suggest that selection for total phenolics may be more successful than it is for phytic acid. The estimates of genetic advance over the

Table 5 Variance and genetic estimations for phytic acid content and total phenolics

Parameter	Phytic acid content	Total phenolic content
Mean (%)	2.56	0.65
Phenotypic variance	0.52	0.10
Genotypic variance	0.30	0.05
Environmental Variance	0.22	0.05
Genotypic coefficient of variation	21.42^{H}	34.34^{H}
Phenotypic coefficient of variation	28.31^{H}	49.35^{H}
Environmental coefficient of variation	18.51	35.43
Broad sense heritability	57.26^{M}	48.44^{M}
Genetic advance	0.86	0.32
Genetic advance over the mean	33.44^{H}	49.31^{H}

M – moderate, H – high

mean were calculated as 49.3% for phenolics and 33.4% for phytic acid content.

Studies on the heritability of secondary metabolites such as phenolic compounds in maize are rather limited as compared to yield and agronomic traits. Nevertheless, the inheritance of these compounds was studied on several materials using different statistical techniques. Da Rosa et al. (2020) found the genotypic variance higher for the total phenolic content in maize than the environmental variance, based on the results obtained by REML/BLUP calculations on inbred lines and their F1 offspring, and reported a broad-sense heritability value of 86%. Similarly, Mahan et al. (2013) reported that narrow-sense heritability was over 80%. In a maize breeding set created by the top cross method, the broad-sense heritability for phenolics was calculated as %12 by Carvalho et al. (2018).

Chandana et al. (2018) determined that the genetic variance had an important role in the variation of phytic acid content (*PV* = 7.35, *GV* = 7.29, *PCV* = 60.82, *GCV* = 60.34, h^2 = 99.21%, *GA* = 5.54, *GAM* = 45.85) in the F2 generation based on a study with three different maize breeding populations. In our study, although the calculated values for both phytic acid and phenolic compounds are within the limits mentioned above, our data are relatively lower than the reported results. The differences may be attributed to the experimental and statistical methods. Augmented design is an incomplete experimental design and it is preferred for trials conducted with many materials or when the amount of seeds to test is limited. Also, the cited studies here used special breeding genotypes (high or low) for the investigated traits, whereas our intention was to characterize the domestic landraces. Although they contain relatively lower concentrations, Turkish landraces has a considerable genetic variation for both traits, and appropriate breeding methods could be successfully utilized to alter the levels of these secondary metabolites in maize varieties. Another important source of differences among the results of scientific studies is the lab analysis method used. It was found that the analysis method interacts with the biochemical composition of the samples and it has important effect on the result of phytic acid analyses in maize (Kahriman et al., 2020). The differences between the results of current study and previous ones may come from above mentioned reasons.

4 Conclusions

It was determined that Turkish maize landraces tested in this study showed a remarkable variation in terms of phytic acid and phenolic contents. They had high genetic diversity compared to check varieties. Among the local maize populations evaluated, TR50131, TR38323 and TR38104 had low phytic acid content, while the TR38337, TR38389 and TR52003 had high phenolic components. Heritability estimates indicate that phytic acid and phenolic compound contents had moderate to high heritability values for the material used. The prominent maize landraces determined in this study can be used as source material in future studies. However, it would be wise to evaluate those genotypes with more informative experimental techniques before proceeding further.

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