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Full Length Research Paper

Pattern of variation for seed characteristics in Turkish populations of *Cucurbita moschata* Duch.

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Pumpkins are one of the most important *Cucurbit* crops in Turkey. For this research, 40 populations of pumpkin, *Cucurbita moschata* Duch., were collected from different regions of Turkey and variation in seed characters was assessed. The present collection showed appreciable genotypic variation in color, shape, brightness, dimension, and weight of seed. With regard to seed dimensions, populations showed a range of 13.8 - 24.3 mm for seed length, 7.5 -15.3 mm for seed width, and 1.6 - 4.7 mm for seed thickness. For seed length to thickness ratio and seed width to thickness ratio, populations showed a range of 3.7 - 10.8 and 2.1 - 6.4, respectively. Data were analyzed using principal component analysis (PCA). The first two factor axes explained 72.6% of the total multivariate variation. Data were also subjected to cluster analysis. Cluster analysis established the existence of eight groups. A dendrogram was prepared to evaluate seed characters among populations. Each cluster had some unique characteristics and revealed high variation in this study. As a conclusion, the populations evaluated in this study display a wide diversity of seed characters for selection and combination of interesting genotypes for important seed characters in order to obtain improved varieties.

Key words: Pumpkin, population, seed dimension, variation, multivariate analysis, Turkey.

INTRODUCTION

The *Cucurbitaceae* consists of two well defined subfamilies, eight tribes representing varying degrees of circumscriptive cohesiveness and about 118 genera and 825 species (Jeffrey, 1990). *Cucurbita* is a New World genus. There are three economically important *Cucurbita* species, namely *C. pepo* L., *C. maxima* Duch., and *C. moschata* Duch., which have different climatic adaptations and are widely distributed in agricultural regions worldwide (Robinson and Decker-Walters, 1997; Pitrat et al., 1999; Wu et al., 2007). Pumpkin (*C. moschata* Duch.) is mostly used to refer to cultivars with round fruits which are used when mature in baking or feeding livestock (Ferriol and Pico, 2008). Cultivation of pumpkins and squash has a long history, and it can be said that cucurbits are associated with the origins of agriculture in South and Central America (Whitaker and Robinson, 1986). The geographical distribution of the known archaeological remains of *C. moschata* indicates that it has been cultivated for more than 5000 to 6000 years (Robinson and Decker-Walters, 1997). It has spread to other countries rapidly.

The most common cultivated species of the *Cucurbitaceae* family in Turkey are *Citrullus lunatus* Thunb., *Cucumis flexuosus* L., *Cucumis sativus* L., *Cucurbita maxima*, *Cucurbita moschata*, and *Cucurbita pepo.* In almost all regions of Turkey *Cucurbitaceae* land-races are still grown by farmers and are highly variable in morphology and taste and also used as vegetable or pickling (Kucuk et al., 2002; Balkaya and Karaagac, 2005; Sari et al., 2008). The current production of *C moschata* is based on local cultivars and is for home consumption or sold in local markets in Turkey.

These traditional landraces are an important genetic resource for plant breeders because of their considerable genotypic variation. This variation is favored and

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Figure 1. Provinces names and numbers from Table 1 correspond to the numbers in this figure.

maintained by deliberate selection for specific traits by farmers (Balkaya et al., 2009). Mature and young fruits, male flowers, seeds, and young tips of the vines are consumed in pumpkins. In Turkey, pumpkin is utilized at the immature and mature fruit stages, and is a major ingredient of several vegetable dishes. Pumpkin, when used at the ripening stage or after storage, provides a valuable source of the carotenoids and ascorbic acid that have a major role in nutrition as antioxidants in the form of pro-vitamin A and vitamin C, (Whitaker and Robinson, 1986; Pandey et al., 2003). Pumpkin seeds are consumed throughout the world and are increasing in popularity, but the commercial market for pumpkin seeds is still relatively small (Cascio, 2007). Pumpkin seeds have also been used in traditional medicine as a vermifuge, and are among several food plants and herbs containing fatty acids and phytosterols that are used for the treatment of benign prostatic hyperplasia (Zhang et al., 1994; Dvorkin and Song, 2002). In Turkey, pumpkin seeds are used to treat tapeworm, where the dried seeds are eaten on an empty stomach. With respect to variation in characters among populations, cluster analysis has been used by several research groups for identifying morphological variability in different crop species (Decker and Wilson, 1986; Cartea et al., 2002; Balkaya et al., 2005; Balkaya and Ergün, 2008). In analyzing genetic variation among populations and determining the most important variables contributing to this variation, it seems that principal component analysis (PCA) is most useful (Ozdamar, 2004). Genetic diversity in pumpkins has been reported (Babu et al., 1996; Kale et al., 2002; Kumar et al., 2006), and fruit size, shape and color vary greatly among cultivated cucurbits (Whitaker and Bemis, 1975; Robinson and Decker-Walters, 1997). Cucurbitaceae is one of the most important families with significant genetic resources in Turkey. To date, there has been no detailed investigation of variation in seed traits in Turkish pumpkin populations. Therefore, the aim of the present investigation was to analyze genotypic variation among 40 populations of pumpkin seeds collected from different sites in Turkey.

MATERIALS AND METHODS

Pumpkin populations used in this study were collected before and during harvest time between September 2004 and February 2006. The geographical distribution of pumpkin populations was follow as: 5 populations from Bolu, 4 populations from Samsun and Hatay, 3 populations from Amasya and Çorum, 2 populations from Trabzon, Tokat, Sinop, and Artvin provinces, and 1 population from Adana and Giresun provinces. Five pumpkin accessions are part of the pumpkin collection preserved at the Turkish seed Genebank (AARI). Additionally, six pumpkin populations were provided by the University of Çukurova in Adana. In total, 40 populations were investigated (Table 1 and Figure 1). In this study, 10 - 20 accessions were collected from each village and then 12 plants were raised from the seeds of single representative accession. Morphologically similar genotypes were determined in the first selection. From some villages, more accessions were used for this study. The other accessions from each population are preserved at -20°C for long term storage in the Turkish seed gene bank (AARI) for use in future breeding programs. The field component of this study was carried out in Bafra county, Samsun province. In April 2006, the seeds of all populations were sown into plug trays containing peat, organic manure and sand, mixed at the ratio of 4:2:1. The seedlings were transplanted in May 2006 at the 4 - 5 leaf stage and at a field spacing of 2.8 × 2.0 m. The accessions were grown in a non replicated trial. Unfortunately, there is no standard pumpkin variety in Turkey (TTSM, 2008). For this reason, control variety did not use in this study. The soil of the experimental area was sandy loam with a pH of 6.5. Standard fertilization and weed control cultural practices were applied. The fruits were harvested manually at full maturity from the end of October and the middle of November. The mean value for each character was determined on

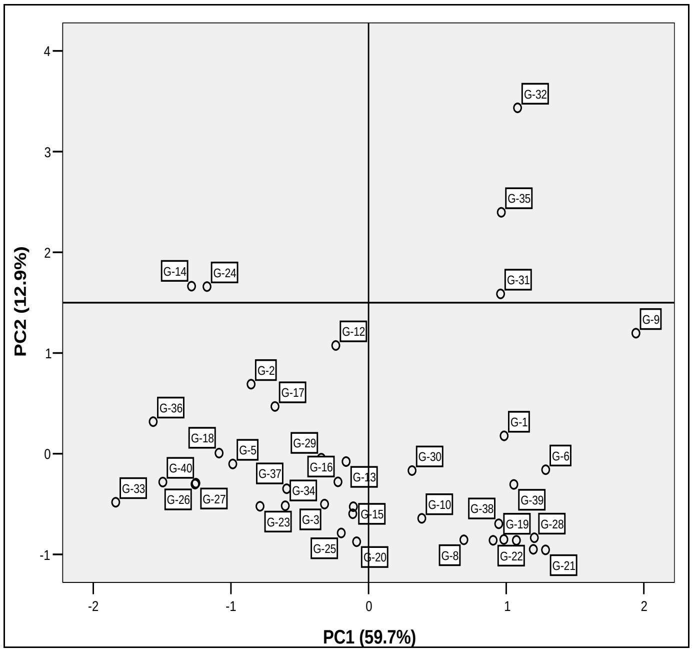

Figure 2. Scatter plot based on the first two principal component (PC) axes, and number of represent populations and refer to the “work codes” of Table 1.

plants per population and 50 seeds per plant. Seed color (1. white, 2. light cream, 3. cream, 4. dark cream, 5. tawny, 6. brown), seed shape (1. narrow-elliptic, 2. elliptic, 3. wide-elliptic), and seed brightness (1. mat, 2. intermediate bright, 3. very bright) were determined using a standardized UPOV descriptor list (Anonymous, 1998). To standardize interpretation of seed traits, the same researcher did all the classifications. The data for this experiment were collated by measuring the length (L), width (W) and thickness (T) of a total of 600 seeds (50 seeds × 12 fruit from each of 12 plants) from the 40 populations. Length to width (L/W), length to thickness (L/T), and width to thickness (W/T) ratios were computed from those measurements for each seed. Seed weight was determined by weighing 400 air-dried seeds (100 seeds × 4 replicates for each plant). The following seed weight categories were established: (1)small (20 - 30 g), (2) medium (30 - 40 g), (3) large (40 - 50 g) or (4) very large (>50 g) (Anonymous, 1998).

Data analysis

Statistical analysis was performed using the statistical program SPSS (13.0 for Windows). Firstly, the characters were recorded on a quantitative scale (e.g. seed length) and a nominal scale (e.g. seed shape). Secondly, nominal scale values was transformed in the Z-values. Finally, principal component analysis (PCA) was used to determine traits that explain the variation among populations. Those principal components (PC) with Eigen values >1.0 were selected and those characters with load coefficient values >0.6 were considered highly relevant characters scored for that PC (Jeffers, 1967). The results of PCA are presented in tables and graphically. To develop a better insight into the diversity of their pumpkin populations, the authors also used cluster analysis.

Hierarchical cluster analyses were performed using Ward’s criteria, minimizing the total sum of squared distances of objects to cluster centers. Ward’s criteria were preferred because they tend to produce desirable compact clusters (Zewdie and Zeven, 1997).

Standard deviation within clusters was calculated for all characters. Furthermore, the graphic produced in the study represents “relationship among the characters”.

RESULTS

The accession number and some seed characteristics of the pumpkin populations are given in Table 1. There was variability in terms of seed color. The most of the pumpkin populations had cream tones. Seed color of populations was cream (30.0%), tawny (25.0%), dark cream (17.5%), light cream (17.5%) and brown (10.0%). In this research, widely elliptic seeds were the most common, with 90% among populations. Mat was the most common form of seed brightness (72.5%) (Table 1). In terms of seed dimensions (length, width and thickness), there were wide differences among the populations. Average population seed length varied from 13.8 to 24.3 mm (Table 2). The highest value was registered in the populations G9 (24.3 mm) and G22 (23.1 mm), and the lowest was in G26 (13.8 mm). For seed width, populations varied from 7.5 to 15.3 mm (Table 2). Seed thickness measurements ranged between 1.6 and 4.7 mm. With regard to relative dimensions, considerable variability was also encountered in this study (Table 2). Relative dimensions showed a range of 1.3 - 2.1 for seed length/seed width, 3.7-10.8 for seed length/seed thickness, and 2.1 - 6.4 for seed width/seed thickness (Table 2). Average population seed weight (100 seeds) ranged from 8.5 to 50.9 g. The populations showed great differences for this trait. G-9 was the only very large seeded population (2.5%), with a weight of 100 seeds >50 g. Thirty five percent of the populations had a weight of <20.0 g per 100 seeds, and were classified as very small. Thirteen populations (32.5%) had a 100 seed weight of 20.0 - 30.0 g and were classed as small.

PCA used for revealing general distances between genotypes as numerical values indicate which traits could be used to differentiate genotypes. The relative magnitude of the coefficients of each trait related to the first two principal components from the component analysis can often provide a seed traits interpretation for each component axis (Table 3). The first PC axis accounts for 59.7% of the total multivariate variation (Table 3 and Figure 2), while the second accounts for 12.9%. The high degree of variation in the two PC axes indicates a high degree of variation for these characters (Figure 2). Though clear guidelines do not exist to determine the significance of a character coefficient, one rule of thumb is to treat coefficients >0.6 as having a large enough effect to be considered important (Jeffers, 1967). When comparing PC coefficients of variation, seed length (0.85), seed width (0.91), seed thickness (0.78), 100 seed weight (0.96), seed number 1^{-1} g (0.90), and seed shape (0.73) had higher coefficients on the first PC axis (Table 3). Characters with high coefficients in the first PC should be considered more important, since these

Table 1. Seed traits of pumpkin (*Cucurbita moschata*) populations from Turkey.

Work code	Population	District/province	L. no.	Seed color	Seed shape	Seed brightness
G-1	55 BA 01	Bafra/ Samsun	1	Brown	Elliptic	Brightly
G-2	55 ÇA 04	Çarşamba/ Samsun	1	Brown	Elliptic	Mat
G-3	55ÇA06	Çarşamba/ Samsun	1	Brown	Elliptic	Mat
G-4	55ÇA07	Çarşamba/ Samsun	1	Dark cream	Wide elliptic	Mat
G-5	05 AM 02	Merkez/ Amasya	3	Dark cream	Wide elliptic	Light brightly
G-6	05 AM03	Merkez/ Amasya	3	Dark cream	Wide elliptic	Light brightly
G-7	05ME04	Merzifon/ Amasya	3	Brown	Wide elliptic	Mat
G-8	14 YE02	Yeniçağ/Bolu	6	Tawny	Wide elliptic	Mat
G-9	14YE01	Yeniçağ/Bolu	6	Cream	Wide elliptic	Mat
G-10	14BO01	Merkez/Bolu	6	Cream	Wide elliptic	Mat
G-11	14GE03	Gerede/Bolu	6	Cream	Wide elliptic	Mat
G-12	14DÖ02	Dörtdivan/ Bolu	6	Cream	Wide elliptic	Mat
G-13	08AR01	Merkez/ Artvin	7	Cream	Wide elliptic	Light brightly
G-14	31ER01	Erzin/Hatay	11	Tawny	Wide elliptic	Mat
G-15	28Gİ01	Merkez/ Giresun	8	Tawny	Wide elliptic	Mat
G-16	08Fİ01	Fındıklı/ Artvin	7	Light cream	Wide elliptic	Mat
G-17	19İS01	İskilip/ Çorum	5	Dark cream	Wide elliptic	Light brightly
G-18	19İS02	İskilip/ Çorum	5	Dark cream	Wide elliptic	Light brightly
G-19	19İS03	İskilip/ Çorum	5	Cream	Wide elliptic	Mat
G-20	61MA02	Maçka/ Trabzon	9	Cream	Wide elliptic	Mat
G-21	61MA01	Maçka/ Trabzon	9	Dark cream	Wide elliptic	Mat
G-22	60Zİ02	Zile/Tokat	4	Cream	Wide elliptic	Mat
G-23	60Zİ01	Zile/Tokat	4	Cream	Wide elliptic	Mat
G-24	01KA01	Kadirli/ Adana	10	Cream	Wide elliptic	Mat
G-25	31AN01	Antakya/ Hatay	11	Cream	Wide elliptic	Mat
G-26	31AN02	Antakya/ Hatay	11	Cream	Wide elliptic	Mat
G-27	31 ER02	Erzin/Hatay	11	Tawny	Wide elliptic	Mat
G-28	TR65269	AARI Gene Bank	12	Light cream	Wide elliptic	Mat
G-29	TR71675	AARI Gene Bank	14	Tawny	Wide elliptic	Light brightly
G-30	TR71676	AARI Gene Bank	15	Light cream	Wide elliptic	Mat
G-31	TR37068	AARI Gene Bank	5	Tawny	Wide elliptic	Brightly
G-32	TR37069	AARI Gene Bank	13	Tawny	Wide elliptic	Mat
G-33	ÇU01	Univ. of Çukurova		Light cream	Wide elliptic	Mat
G-34	ÇU02	Univ. of Çukurova		Tawny	Wide elliptic	Light brightly
G-35	ÇU03	Univ. of Çukurova		Dark cream	Wide elliptic	Mat
G-36	ÇU04	Univ. of Çukurova		Tawny	Wide elliptic	Brightly
G-37	ÇU06	Univ. of Çukurova		Light cream	Wide elliptic	Mat
G-38	ÇU09	Univ. of Çukurova		Tawny	Wide elliptic	Light brightly
G-39	57Sİ07	Merkez/ Sinop	2	Light cream	Elliptic	Mat
G-40	57Sİ22	Merkez/ Sinop	2	White	Wide elliptic	Mat

axes explain more than half of the total variation (Table 3). In this study, eight groups were clustered as a result of the cluster analysis. The related dendogram is shown in Figure 3. The means and standard deviations of the traits for each cluster are given in Table 4.

- Group A: This group included 13 populations and five subgroups which were collected from different locations in Turkey. The average seed width of this group was 12.6 mm. This value was higher than for all other groups, except Group C (Table 4). The average population seed weight (100 seeds) was 33.5 g. The seeds of populations were medium size, with widely elliptic shape. In addition, seed color was in white tones, and seed brightness was generally mat.

- Group B: This group contained two subgroups, with two populations from the Turkey Seed Gene Bank in the first and the population from the University of Çukurova in the second subgroup. The majority of the seeds were medium

Table 2. Dimensions, weight 100 seeds and ratios of pumpkin seeds (L, Length; W, Width; T, thickness).

Work code	L	W	T	L/W	L/T	W/T	Weight 100 seeds (g)
G-1	20.5	13.5	3.5	1.5	5.9	3.9	33.8
G-2	16.4	7.7	2.8	2.1	5.9	2.8	23.3
G-3	17.0	9.7	2.8	1.8	6.1	3.5	22.6
G-4	19.1	10.0	3.0	1.9	6.4	3.3	21.0
G-5	15.0	8.9	2.5	1.7	6.0	3.6	14.3
G-6	20.0	15.3	3.8	1.3	5.3	4.0	40.6
G-7	20.7	12.7	3.8	1.6	5.4	3.3	28.6
G-8	18.9	12.5	3.8	1.5	5.1	3.3	28.2
G-9	24.3	14.4	4.7	1.7	5.2	3.1	50.9
G-10	19.8	10.9	4.4	1.8	4.5	2.5	23.9
G-11	22.8	12.7	3.5	1.8	6.5	3.6	37.8
G-12	17.1	10.8	2.8	1.6	6.0	3.8	21.1
G-13	20.2	9.9	3.6	2.0	5.7	2.8	19.4
G-14	14.4	7.5	3.6	1.9	4.0	2.1	12.4
G-15	15.1	10.1	4.0	1.5	3.7	2.5	20.6
G-16	21.9	10.4	2.8	2.1	7.9	3.8	20.4
G-17	16.4	8.4	3.7	2.0	4.4	2.3	15.5
G-18	17.5	9.9	2.9	1.8	6.1	3.4	8.5
G-19	21.5	12.5	3.8	1.7	5.7	3.3	32.4
G-20	18.8	10.9	3.3	1.7	5.7	3.3	23.6
G-21	22.6	13.6	3.5	1.7	6.4	3.8	40.3
G-22	23.1	11.9	4.1	1.9	5.7	2.9	35.8
G-23	18.1	9.1	2.7	2.0	6.6	3.3	16.7
G-24	14.7	7.5	3.1	2.0	4.7	2.4	12.9
G-25	15.7	7.9	2.9	2.0	5.4	2.7	24.3
G-26	13.8	7.9	3.1	1.7	4.5	2.6	12.1
G-27	14.4	7.5	3.1	1.9	4.6	2.4	11.3
G-28	20.8	13.2	3.9	1.6	5.3	3.4	38.0
G-29	18.4	9.1	3.5	2.0	5.3	2.6	20.6
G-30	21.6	10.1	3.5	2.1	6.2	2.9	26.8
G-31	19.9	11.8	4.6	1.7	4.3	2.6	35.6
G-32	20.4	12.8	4.3	1.6	4.8	3.0	37.2
G-33	14.7	8.0	1.8	1.8	8.1	4.4	8.13
G-34	16.1	9.4	2.6	1.7	6.3	3.7	16.0
G-35	22.8	12.5	4.1	1.8	5.5	3.0	30.0
G-36	14.5	8.5	2.4	1.7	6.0	3.5	9.3
G-37	18.8	11.5	1.8	1.6	10.5	6.4	14.5
G-38	19.3	12.4	4.3	1.6	4.5	2.9	31.0
G-39	20.6	12.0	4.6	1.7	4.5	2.6	40.1
G-40	17.7	9.3	1.6	1.9	10.8	5.6	9.2

size. In addition, seeds had tawny and dark cream tones and were intermediate bright (Table 4). - Group C: Together with Groups E and H, this was the smallest group and composed one population (G-9) collected from Yeniçağ, Bolu provinces. The seed dimensions (of this population were the largest of all groups (Table 4). Average population seed weight (100 seeds) was the highest (50.9 g) in all groups, and seed size of this population was classified as very large.

- Group D: This largest group comprised 17 populations. The shape of seeds was narrow elliptic or elliptic. The seed color of populations was in light cream and cream tones. The majority of the seeds were very small and small (Table 4).

Table 3. Principal component (PC) coefficients of each seed trait in pumpkin (*Cucurbita moschata*) populations. Proportions of variations are associated with first two PC axes, which correspond to eigenvalues greater than 1. Characters with high coefficients in the PC axes should be considered more important, thus eigenvectors above 0.60 are shown in bold.

	PC axis	
	PC1	PC2
Eigen-values	5.373	1.162
Explained proportion of variation (%)	59.7	12.9
Cumulative proportion of variation (%)	59.7	72.6
Character	**Eigen vector**	
Seed length	0.85	-0.33
Seed width	0.91	-0.36
Seed thickness	0.78	0.22
100 seed weight	0.96	0.54
Seed number / 1g	0.90	0.40
Seed shape	0.73	0.51
Seed colour	-0.14	0.78
Seed brightness	0.17	0.71

Table 4. Mean trait values used in pumpkin (*C. moschata* Duch.) population group identification.

	Groups							
Traits	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Seed length	21.0 ± 1.3	21.0 ± 1.5	24.3 ± 1.8	17.0 ± 2.2	14.4 ± 1.4	15.9 ± 1.7	16.2 ± 2.2	18.8 ± 1.6
Seed width	12.6 ± 1.3	12.4 ± 0.6	14.4 ± 1.2	9.1 ± 1.1	7.5 ± 0.9	9.1 ± 2.3	8.6 ± 0.9	11.5 ± 1.3
Seed thickness	3.9 ± 0.4	4.3 ± 0.2	4.7 ± 0.3	3.0 ± 0.5	3.6 ± 0.3	3.0 ± 0.2	1.7 ± 0.1	1.8 ± 0.2
100 seed weight	33.5 ± 5.5	34.3 ± 3.8	50.9 ± 2.8	17.5 ± 5.0	12.4 ±1.8	17.0 ± 5.8	8.7 ± 0.7	14.5 ± 2.3
Seed number / 1g	3.2 ± 0.5	3.3 ± 0.6	2.0 ± 0.4	6.8 ± 2.2	8.0 ± 1.2	7.5 ± 0.7	13.0 ± 1.4	8.0 ± 1.6
Seed size*	2	2	4	1	1	1	1	1
Seed shape*	3	3	3	1, 2	1	1	1	3
Seed color*	1	4, 5	1	2 , 3	5	1,2	2,3	3
Seed brightness*	1	2	3	1	1	3	1	1

*This numerical coding is median values for seed size, shape, colour and brightness.

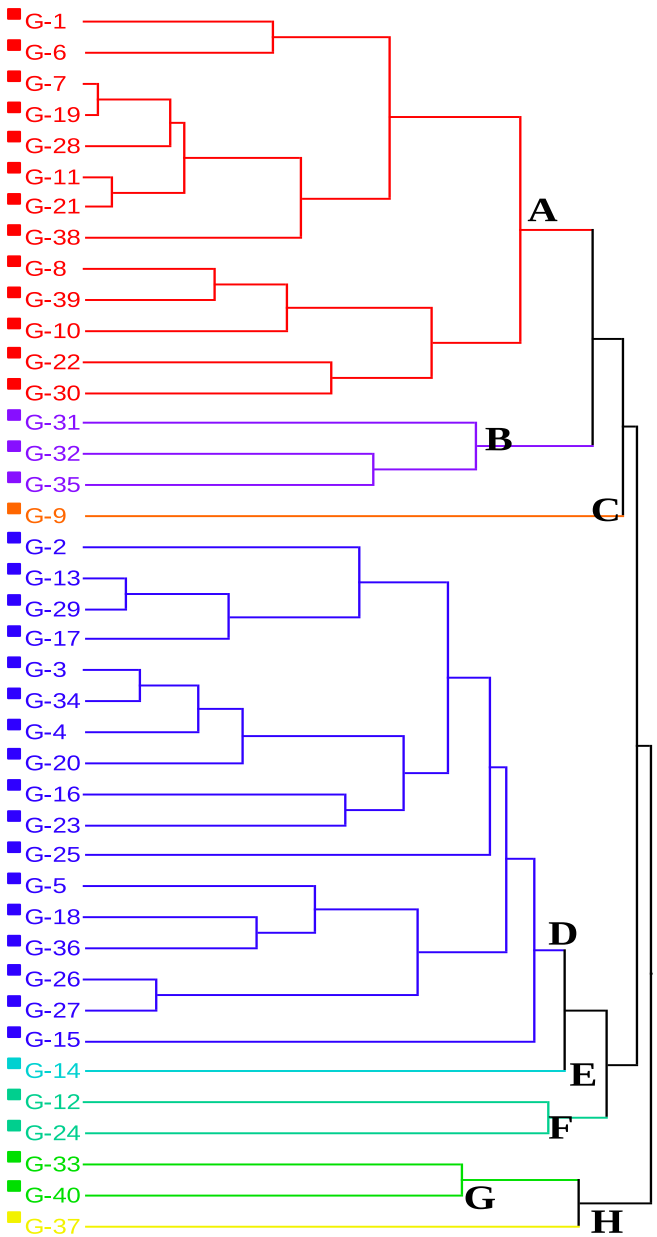

Figure 3. Genetic grouping of pumpkin (*Cucurbita moschata*) population by cluster analysis.

- Group E: It was formed by only one population (G-14) originating form Erzin, Hatay province (Table 1). The seeds were classified as very small size, narrow-elliptic shape, and having tawny color.
- Group F: This group included two populations. These populations were clustered in a subgroup, and originating from Bolu and Hatay provinces. Seed sizes of these populations were small or very small. Average seed thickness of populations was 3.0 mm, and the shape of seeds was narrow-elliptic and elliptic (Table 4).
- Group G: There was two populations in this group. Seed size was very small, with the average seed number per g higher than for all other groups. Average seed thickness of populations was the lowest in all groups. Seed color was light cream and cream tones.
- Group H: This group included one population from the University of Çukurova. Seed size of this population was very small, with wide elliptic shape, cream tones, and seed brightness was mat.

DISCUSSION

Turkey is very rich in cucurbit genetic resources due to it's diverse geography and ecology (Sari et al., 2008). Ekinci (1976) emphasized Anatolia's great genetic diversity for melons, watermelons and squash. In this study, the present collection showed an appreciable genotypic variation of seed shape, color, brightness, seed dimensions and 100 seed weight in pumpkin populations. Other researchers have found that genetic diversity within landraces and populations of squash is high including variation in shape, size and color of fruits; number and size of seeds; quality, color and thickness of fruit flesh; tolerance to pests; and precocity in fruit production, among other traits (Nerson et al., 2000; Ferriol et al., 2003; Paksoy and Aydin, 2004; Hernandez et al., 2005; Balkaya et al., 2009). In Turkey, consumers prefer large pumpkin seeds with cream tones. Detailed pumpkin seed populations were usually determined as having wide elliptic shape. With respect to the marketing of pumpkin seeds for consumption, seed taste and flavor are the most important for consumer's approval of traditional products (Acompara and Ciaffi, 2007).

In the current study, the authors determined seed color and shape of pumpkin populations for landrace classification, but did not analyze indicators of quality for consumption. However, they are planning to study seed quality parameters in the near future. The objective will be the selection of pumpkin lines to be grown for seed consumption. In this study, 100 seed weight for all populations ranged from 8.5 to 50.9 g (Table 2). Data showed that seed size of most populations (67.5 %) were very small, and small. Cultivars of watermelon and squash may differ considerably in their seed size and other seed characteristics (Joshi et al., 1993; Paris and Nerson, 1998; Paksoy and Aydin, 2004). In the present study, it seemed appropriate to look for trends in the relationships among the investigated seed traits, because the range of variation found in the collection was large (Table 2). Average seed length for all populations ranged from 13.8 mm to 24.3 mm, average seed width from 7.5-15.3 mm, and seed thickness from 1.6 - 4.7 mm. Variability of the seed dimensions of pumpkin populations was very large (Table 2). The results for relative dimensions of pumpkin seeds are presented in Table 2 and they show considerable variability. Length to width ratio ranged from 1.3 to over 2.1. With regard to seed length to thickness ratio, and seed width to thickness ratio, populations showed a range of 3.7 to 10.8, and 2.1 to 6.4, respectively. These results show the seeds of populations displaying big differences between minimum value and maximum values for the stated ratios. In the current study, results supported this contention as considerable variability was found among collected populations. Similar results were also observed in Turkish *C. maxima* populations (Balkaya et al., 2009; Kurtar, 2009).

Some differences exist between this study and the current study. For example; length: width, length: thickness, and width: thickness ratios for subgroups of *C. maxima* were 1.4 - 2.1, 3.2- 14.2, and 2.2 to 8.5, respectively (Balkaya et al., 2009). The cluster analysis reported here differentiates between populations on the basis of their similarity, thus providing a hierarchical classification (Gil and Ron, 1992; Balkaya and Ergün, 2008). The 40 pumpkin populations were classified into eight groups and the number of populations per group varied considerably (Figure 3). The clustering of Turkish pumpkin populations on the dendrogram in eight separate groups resulted from their different morphological structure and special characteristics. The present work has also identified the relationship among major pumpkin groups in the collected genetic materials.

The results are a reference for further evaluation of pumpkin populations. Populations with similar seed traits were grouped together, irrespective of collection region. No associations of clusters within the collection zone were observed (Table 1, Figure 3). This absence of association may be due to the continuous conscious and unconscious transport of seed by humans. Secondly, seed size variation is higher in open pollinated populations (Robinson and Decker-Walters, 1997). Pumpkin plants are monoceious and have high rates of cross pollination. Cross pollination events can change the genetic identity of populations. In this study, the results are similar and variation was found to be quite high among pumpkin populations.

All pumpkin populations used for this study are also maintained as stable inbred lines for variety breeding programs in another study.

The conclusions of this study are as follows. The multivariate techniques applied morphological data sets demonstrate that introducing a component of seed characters of Turkish pumpkin populations.

A morphometric analysis of seed traits showed that variation was relatively high among the pumpkin populations studied. Thus, different selective pressures seem to have been applied in several regions of Turkey. In addition, pumpkin populations were classified into eight groups and the number of populations per group varied considerably.

These populations are an important source of diversity which could be used in future breeding programs. This study may also find application in helping identify poorly described pumpkin populations collected by Turkish seed gene banks.

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