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Morphological characterization of Korean and Turkish watermelon germplasm

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Abstract : A total of 67 watermelon accessions which include 37 accessions from Korean and 27 accessions from Turkish germplasm and 3 accessions of other related species from USA were investigated for morphological characteristics. The UPOV descriptor list for 56 characters (6 seedlings, 4 plants, 11 leaves, 5 flowers, 23 fruits and 7 seeds) was used in characterization. In addition, eight quantitative characters, hypocotyl length, cotyledon width, cotyledon length, fruit weight, fruit length, fruit width, thickness of outer layer of pericarp and soluble solid content were also measured. The 56 qualitatively scored characters were analyzed by principle coordinate analysis (PCoA) while the eight quantitative ones were subjected to principle component analysis (PCA). Morphological characterization result demonstrated that the accessions displayed high morphological diversity(how much percent?). A high level of phenotypic diversity was observed from the results of morphological characterization. However, plant growth habit and leaf blade flecking showed constant characters for all of the accessions. The Korean and Turkish watermelon genotypes are diverse groups and can be separated by both multivariate analysis of morphological characters although the grouping was more apparent in PCoS results.

Key words **:** Genetic resources, multivariate analysis, *Citrullus lanatus*, *C. lanatus* var. *citroides*, *C. colocynthis*, *Praecitrullus fistulosus*

I. Introduction

Watermelon [*Citrullus lanatus* (Thumb.) Matsum & Nakai] originated in Africa and has a long history of cultivation in Africa and the Middle East. It has been an important vegetable in Egypt for at least 4000 years (Robinson and Decker-Walters, 1997).

Watermelon is one of the most widely cultivated crops in the world. The production in 2012 exceeded 105 million tons (FAO, 2012). China (66%), Turkey (3.8%) and Iran (3.6%) were major countries in the world for the watermelon production. Korea ranked 14th in the world and production was about 6.4 hundred thousand tons in 2012. Watermelons produced in Korea are mostly consumed in domestic market.

Watermelon is a very important crop in Korea. It is presumed that watermelon was introduced from Mongolia to Korea in the 13th century (Lee et al., 2007). There are official records of King Yeon San, which mentions a painting, 'Chochungdo' having a picture of watermelon (Lee et al., 2007).

In 2005, watermelon occupied 9.9% of total vegetable production value in Korea, which ranks after pepper and strawberry. Protected and open field culture are two major types for the cultivation (Lee et al., 2007). New varieties have been developed by crossing parental lines having one or more useful traits. Breeding of new varieties started in the 1950s and the first hybrid ‘Suwon’ was developed in 1967. Development of hybrids began in the early 1970s. Most varieties have medium or large size fruits and usually have round or broad elliptic shape, green fruit skin with stripes and red flesh (Cho, 2002).

Watermelon is one of the most important fruit

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vegetable in Turkey and production is 4.0 million tons from 165,000 ha (FAO, 2012). It has been cultivated for 100 years in almost all parts of the country. Even though Turkey is not the center of origin of watermelon, new variation has arisen over time. Despite the extent of distribution and cultivation, watermelon germplasm in Turkey is poorly described (Sari et al., 2007).

The objective of this study was to examine the morphological diversity of Korea and Turkey when tested in the same environment.

II. Material and Methods

The experiment was conducted at the Department of Horticulture, Faculty of Agriculture, University of Cukurova in Turkey. A total of 67 accessions were evaluated for morphological characteristics such as seedling, plant, leaf, fruit and seed characters. The Korean group consisted of 37 accessions and the Turkish watermelon genetic resources were represented by 27 accessions. *Citrullus colocynthis* (L.) Schrad., *Citrullus lanatus* var. *citroides* (Bailey) Mansf. and *Praecitrullus fistulosus* (Stocks) Pang. were also represented by one genotype of each species obtained from USDA (USA). Origins of the accessions evaluated in this study were presented in Table 1.

Seeds were sown in peat and perlite mixture (2:1) into plug trays on April 17, 2007. Ten plants of each genotype were transplanted to open field at spacing of (3 m x 0.5 m) between rows and within plants on May 8, 2007. First harvest was on July 17, 2007 and the last harvest was on August 8, 2007.

The characterization was carried out at two stages. First, eight horticultural traits [hypocotyl length (mm), cotyledon width (mm), cotyledon length (mm), fruit weight (g), fruit length (mm), fruit width (mm), thickness of outer layer of pericarp (mm) and soluble solids content (% brix)] were measured to generate a quantitative data file. Second, the accessions were categorized for 56 morphological variables of seedling, plant, leaf, fruit and seed characteristics according to UPOV (International Union for the Protection of New Varieties of Plants). Therefore, the second data file was qualitative in nature.

The data were analyzed using two multi variable analysis methods, PCoA and PCA, using SAS procedures (SAS Inst 1990) and NTSYS-PC Program (Rohlf, 1997). First, a table having descriptive statistics (mean, standard deviation and coefficient of variations (CV, %) was generated using TABULATE procedure. PRINCOMP procedure was used to perform a PCA analysis for eight quantitative traits. The 56 qualitative traits were subjected to the PCoA using NTSYS-PC. In this procedure, first a similarity matrix was determined, then was used to calculate Eigen values and scores for the accessions. The accessions were plotted on two dimensions using PCoA and PCA where the abbreviations of K, T and PI indicate Korean, Turkish and Plant Introductions.

III. Results and Discussion

Means, standard deviations and coefficient of variation (CV) of eight quantitative traits for Korean and Turkish watermelon accessions were presented in Table 2. CV values ranged from 14.0 to 24.6% for the quantitative traits among all accessions. The Korean group had higher soluble solids and fruit length while the Turkish group had greater mean values for fruit weight, cotyledon width and hypocotyl and cotyledon length. Higher soluble solid means in Korean group may be derived from elite inbred lines and F_1 hybrids among the group having higher quality, while Turkish genetic resources consisted mostly of local landraces. Comparisons of CV values indicated that the accessions in Turkish group were more diverse in hypocotyl and cotyledon length, cotyledon width and fruit weight, while the accessions in Korean group had larger CVs for the rest of the quantitative traits.

Thirty seven accessions from Korea, 27 accessions

Table 1. Origin of the watermelon accessions characterized under a common environment in Adana, Turkey.

Korean Genetic Resources			Turkish Genetic Resources		
Acc.	Name	Origin	Acc.	Name	Origin
K2	1con1	Korea	T 23	Tat Karpuzu	Sanliurfa
K3	2con7	Korea	T 38	Halep Karasi	Adana
K5	Boksubak	Korea	T 147	Medine Karpuzu	Sanliurfa
K14	Eullyeo	Japan	T 149	Beyaz Kışlık Karpuz	Diyarbakir
K22	GW1	Korea	T 150	Amerikan Karpuzu	Sanliurfa
K24	HD	Korea	T 151	Yaylak Karpuzu	Sanliurfa
K28	GW2	Korea	T 153	Sürme Hırsızı	Diyarbakir
K62	NH1	Korea	T 163	Gelin Karpuzu	Siirt
K63	NH2	Korea	T 174	-	Manisa
K66	OLA	Korea	T 175	-	Manisa
K67	OLB	Korea	T 178	Komando Karpuzu	Manisa
K81	S1	Korea	T 192	-	Tekirdag
K82	S7	Korea	T 197	-	İstanbul
K83	S8	Korea	T 200	-	Uşak
K84	S11	Korea	T 205	-	Ankara
K85	Sindaehwa	Japan	T 208	-	Konya
K86	Sindaehwa No. 2	Japan	T 215	Akkarpuz	Canakkale
K87	Sindaehwa No. 3	Japan	T 216	Kore Karpuzu	Canakkale
K88	Sindeungtaehwa	Japan	T 217	Söbü Karpuz	Canakkale
K93	Ukdaehwa	Japan	T 218	Kara karpuz	Canakkale
K95	Unknown10	Korea	T 253	-	Nigde
K96	Unknown11	Korea	T 254	Adibudu	Nigde
K97	Unknown2	Korea	T 257	-	Nigde
K99	Unknown4	Korea	T 269	-	Nevşehir
K101	Unknown6	Korea	T 277	-	Nevşehir
K102	Unknown7	Korea	T 285	-	Adıyaman
K103	Unknown8	Korea	T 286	-	Kadirli
K104	Unknown9	Korea	T 305	-	Ankara
K112	920533	Korea			
K141	Arirangggul*	Korea	Other species		
K142	Chodangggul*	Korea	PI 542616	*C. colocynthis*	Algeria
K143	Josaengsamboggul*	Korea	PI 270563	*citroides*	South Africa
K144	Samboggul*	Korea	PI 540911	*P. fistulosus*	Unknown
K145	Superkeumcheon*	Korea			
K146	Speedplusggul*	Korea			
K147	Orangequeen*	Korea			

from Turkey and 3 accessions of different species obtained from USDA were investigated for qualitative traits for seedling, plant, leaf, fruit and seed characteristics. Wide ranges of diversity were present in seedling, plant, leaf, flower, fruit and seed. However, variations in plant growth habit and leaf blade flecking were low for all the accessions, which is in accordance with the results of Krasteva(2000) study on the local watermelon populations in Bulgaria. The results of PCoA conducted for 56 qualitative traits

Table 2. Means, standard deviations (SD) and coefficient of variance (CV) of eight quantitative characters for Korean and Turkish watermelon accessions tested under a common environment in Adana, Turkey.

	Korean			Turkish			Overall		
Variable	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Hypocotyl length	34.3	7.5	21.8	37.1	14.2	38.3	35.5	10.9	30.8
Cotyledon width	22.2	2.8	12.5	28.5	7.7	26.9	25.0	6.3	25.2
Cotyledon length	33.7	5.1	15.2	41.7	6.6	15.7	37.2	7.0	18.8
Fruit weight	3480	1105	31.8	3826	1426	37.3	3631	1257	34.6
Fruit length	210.3	42.7	20.3	203.2	40.3	19.8	207.2	41.5	20.0
Fruit width	175.7	25.7	14.6	185.8	23.8	12.8	180.1	25.2	14.0
Pericarp[z]	12.8	3.1	23.9	13.7	2.5	18.1	13.2	2.8	21.5
Soluble solids	10.1	1.4	13.6	7.7	1.5	19.7	9.1	1.8	20.4

[z]Thickness of the outer layer of the pericarp.

Table 3. The first three principle components (PC) of eight quantitative characters for Korean and Turkish watermelon accessions tested under a common environment in Adana, Turkey.

Variable	PC1	PC2	PC3
Hypocotyl length	-0.18	0.36	0.60
Cotyledon width	0.06	0.50	-0.49
Cotyledon length	-0.06	0.54	0.02
Fruit weight	0.57	0.09	-0.08
Fruit length	0.44	-0.05	-0.26
Fruit width	0.50	0.17	0.09
Thickness of the outer pericarp	0.37	0.19	0.53
Soluble solids	0.23	-0.51	0.20
Eigen value	2.77	2.06	0.96
Proportion	0.35	0.26	0.12
Cumulative	0.35	0.60	0.72

with 67 accessions were presented in Fig. 1. The analysis indicated that the two groups, Korean and Turkish accessions, could be easily separated. Furthermore, it was possible to divide the Korean accessions into two subgroups, subgroup I composed of the accessions K2, K3, K5, K22, K67, K97, K101, K142, K143 and K145 and subgroup II composed of the rest of the accessions. The accessions of Turkish group tended to continuously vary in morphology and did not show any discrete subgrouping pattern within the group. The results of PCoA also indicated that some of the accessions were phenotypically highly similar (e.g., T175, T192, T200, T205, T216, T218). The accessions (PI 542626, PI 270563 and PI 540911) for other species were grouped together with the Turkish accessions, indicating that they are more closely related to the Turkish accessions than the Korean accessions.

The results of PCA conducted by eight quantitative traits for watermelon accessions were presented in Figure 2. The first three PCs explained 35%, 26% and 12% of the variation, respectively for the quantitative variables, respectively (Table 3). Fruit weight, length and width were relatively more important than other variables in constructing PC1. Overall, the Turkish accessions were located on the upper part of the PCA graph (Fig. 2), while the Korean accessions were on the lower part. This separation was mostly caused by the differences in cotyledon width and length and soluble solid among the Korean and Turkish groups.

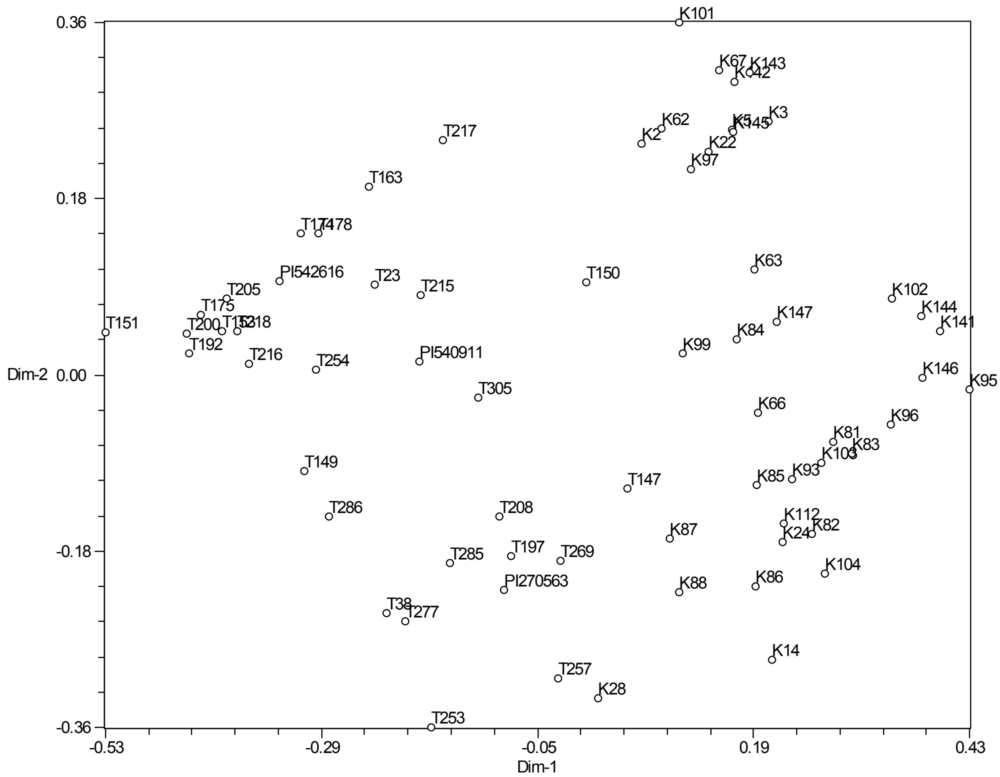

Fig. 1. The results of principal coordinate analysis (PCoA) conducted by 56 qualitative traits for Korean and Turkish watermelon accessions tested under a common environment in Adana, Turkey.

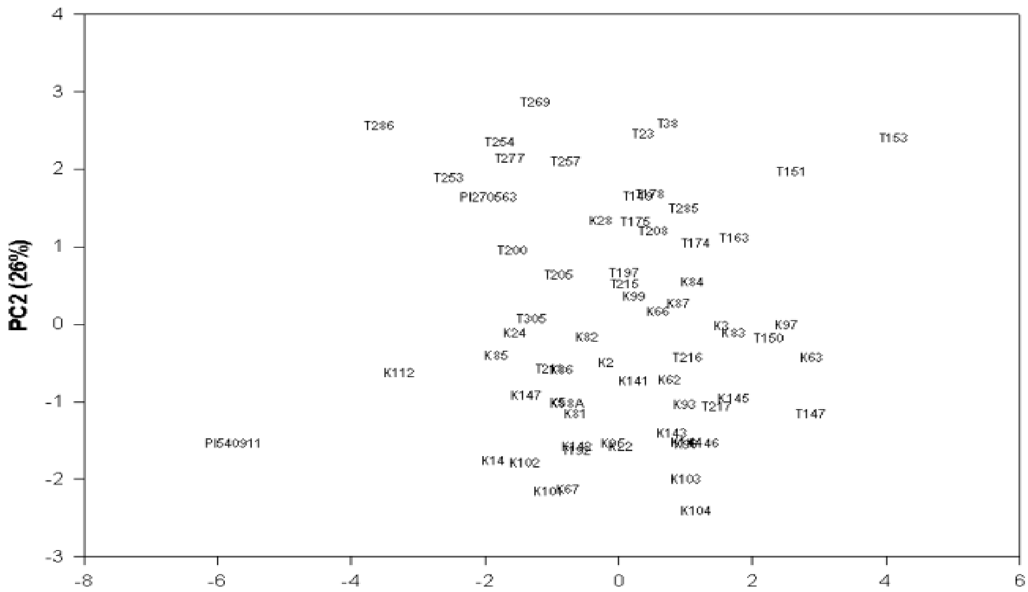

Fig. 2. The results of principal component analysis (PCA) conducted by eight quantitative characters for Korean and Turkish watermelon accessions tested under a common environment in Adana Turkey.

The separation, however, was not accurate as some of the Korean accessions were grouped into the Turkish accessions (e.g., K28 and K99) and some of the Turkish accessions into the Korean ones (e.g., T147 and T217). PI 270563 was also classified the Turkish genotypes after PCA analysis. However, PI

540911, a USDA accession of *P. fistulosus* with unknown origin was related distantly with Turkish group in this study and also reported to be distant genetically from *Citrullus* species (Levi et al. 2005).

IV. Conclusion

This study is the first report comparing the Korean and Turkish watermelon genetic resources. Although both countries are not the centers of origin for watermelon, our study demonstrated that high diversity exists for morphological traits in both germplasm sources. Selection and evaluation of useful germplasm among these collections will be beneficial for the future breeding programs.

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