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Variation for Fruit Morphological, Chemical and Seed Physical Traits in Three *Cucurbita pepo* L. Genotypes

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ABSTRACT

A collection of three genotypes belong to *Cucurbita pepo* L. (Family: Cucurbitaceae) representing both fruit-shape morphotypes; zucchini and pumpkin was observed and screened in field and laboratory trials during 2014 at Ismailia, Egypt. The goal of the present investigation was to characterize morphological and chemical variation among and within genotypes. Also, seeds of the three genotypes were evaluated for their dimensional and physical characteristics. A wide range of variability among genotypes was recorded for fruit morphological and chemical characteristics as well as seed dimensional and physical characteristics. Positive significant correlation coefficient values have been detected between most fruit morphological and chemical traits. Fruit length has shown the only negative correlation relation with soluble solid content (S.S.C.) and fruit firmness. Also, highly significant correlation coefficient values were obtained for seed dimensional and physical characteristics with exception for seed thickness and seed weight which showed non- significant or negative correlation relations. Analysis of variance results and F test showed highly significant results for all fruit morphological and chemical traits and for most seed dimensional and physical characteristics except for seed thickness and sphericity which showed non-significant F test. Current results support the development of breeding programs in *C. pepo* since high genetic variability in its germplasm has been found.

Keywords: Summer squash - Pumpkin- Genotypes characterization - Fruit firmness- S.S.C.- Ascorbic acid- Seed traits.

INTRODUCTION

Characterization and assessment of genetic variability in the germplasm accessions are extremely important in plant breeding studies. Knowledge of the genetic diversity of a crop is necessary for the parental selection that maximizes the genetic improvement. More accurate and complete descriptions of the genotypes and patterns of the genetic diversity could help determine future breeding strategies and facilitate the introgression of diverse germplasm into the current commercial genetic base. Genetic variation is the bases of any genetic improvement program. Before starting any program plant breeders search for genetic variation for the crop they interested in and if they were not able to find it, they start to create it. Characterization is also useful in germplasm organization and identification of promising genotypes for future breeding actions (Mohammadi and Prasanna, 2003).

Study of genetic diversity is the process by which variation among individuals or groups of individuals or populations is analysed by a specific method or a combination of methods. The data often involve numerical measurements and in many cases, combinations of different types of variables. Diverse data sets have been used to analyse genetic diversity in crop plants; such as pedigree data (Bernardo, 1993), morphological data (Bar-Hen *et al.*, 1995), biochemical data (Smith *et al.,* 1987; Hamrick and Godt, 1997; Soliman and Rizk, 2004) and recently, DNA-based marker data that allow more reliable differentiation of genotypes. To increase germplasm usefulness for breeders, its morphological and chemical characterization is needed. Morphological markers were useful in distinguishing between ecotypes and identified a high degree of phenotypic variability between populations of several genotypes.

Cucurbita is a New World genus of about 20 species; they have been and remain important in diets of world populations ranging from the tropics to warm, temperate regions (Decker, 1988). Three *Cucurbita* species, *C. pepo*, *C. moschata*, *C. maxima* comprise the principal cultivated squash and/or pumpkin crops. Both mature and immature fruit are the most important edible plant parts, although for some species; seeds, flowers, roots and even leaves are consumed. *C. pepo* L. is believed to be the oldest of the domesticated species. In addition, *C. pepo* L. is the most diverse *Cucurbita* species, has slightly more cold temperature tolerance than other related species **(**Rubatzky and Yamaguchi, 1997).

The germplasm pool of the genus *Cucurbita* is characterized by abundant diversity (Diez *et al.*, 2002). The enormous morphological diversity of the cultivated races of *Cucurbita* has resulted from variable climate and geographical exposure in which its wild ancestors evolved, coupled with selection pressure (Lira Saade, and Montes Hernandez, 1994). Many sources of exotic and unique germplasm have been discovered and utilized over the years for *Cucurbita* improvement (Paris and Brown, 2005). Traits such as yield, disease resistance, fruit quality have been found and incorporated into current germplasm and have resulted in large improvements in the crop.

Eight different groups existed in *Cucurbita* spp.; Acorn, Crookneck, Scallop, Straightneck, Cocozelle, Pumpkin, Vegetable Marrow, and Zucchini Groups (Paris 1986, 1996, 2000; Jeffrey 2000; Teppner 2000). Fruits that are round or nearly so, known as pumpkins, as well as fruits with a length-to-width ratio approximating 1:1, such as acorn squash, are usually consumed when mature whilst the others, having a length-to-width ratio of the fruit deviating strongly from 1:1, are usually consumed when immature and are

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known generally as summer squash (Paris and Nerson, 2003).

Fruit quality may include; color, size, firmness, S.S.C., and nutritional value which involve the content of various phytochemicals and vitamins. Fruit firmness is one of the most important characteristics that contribute to postharvest quality of fresh commodities. Fruit firmness is related to shelf-life and to fruit texture, and thus has been frequently measured in genetic studies. Fruit firmness tends to be influenced greatly by many pre-harvest and post-harvest factors. Among the pre-harvest factors, the genotype effect is of great importance. Genotypes vary significantly in their fruit firmness extent which facilitates the identification of superior genotypes to be utilized in breeding programs with elite varieties. For instance, the first step in QTL mapping analysis is selecting parents that considerably differ for the trait to generate recombinant inbred lines or F_2-derived population.

The level of soluble solid content (SSC) in a fruit or vegetable is one of the main components of internal quality and influences how sweet it may taste and it relates to a subjective criterion that consumers use to assess vegetable quality (flavour or sweetness). Typically, SSC are strongly correlated with total sugars and perceived sweetness (Maness and Perkins-Veazie, 2003). Evaluation of SSC can aid in variety selection, harvest scheduling and post-harvest management (Kleinhenz and Bumgarner, 2012). The high SSC of certain genotype suggests that the genetic and physiological potential exists for developing plants with enhanced SSC.

Ascorbic acid has well-known functions in oxidative stress defence, associated with its antioxidant properties and its abilities to detoxify reactive oxygen species which explain its role in the resistance to a wide range of biotic and abiotic stresses (Davey *et al.,* 2000).

It also has important roles in the regulation of plant cell growth and expansion, photosynthesis, as well as hormone functions (Smirnoff, 2000). Increased antioxidant contents and in particular higher Ascorbic acid levels may be associated with improved fruit postharvest properties (Hodges *et al.,* 2004; Hancock and Viola, 2005). It is generally recognized that dietary Ascorbic acid also has important health benefits for human, and an increased intake of Ascorbic acid has been associated with a decreased incidence of several important human diseases and disorders (Demmig-Adams and Adams, 2002; Hancock and Viola, 2005).

Vegetables and fruits are usually the major source of vitamin C (Ascorbic acid) to human diet. More than 90% of the vitamin C in human diets is supplied by fruits and vegetables (Lee and Kader, 2000). The content of vitamin C in fruits and vegetables can be influenced by various factors such as genotypic differences.

The accessibility of genetic resources is enabling the identification of vitamin superior genotypes or the identification of vitamin-improved alleles and their introduction into elite varieties for many crop species (Giovannoni, 2006; Tester and Langridge, 2010). Strategies to utilize natural genetic variability of a given trait are now well established in plants and have been applied in a variety of species. Increasing the vitamin C content by breeding is well advanced (Davey *et al.,* 2006).

Basic physical properties of biological materials have major role in designing processing machines as wells as deciding final product characteristics. Advanced research activities provided improved techniques for handling and processing of bio-materials, but use of these techniques lacking scientific information about basic physical properties of biological materials. The information related to properties of biological materials is essential not only to the engineers but also to the food scientists, processors, and plant breeders (Mohsenin, 1986).

Knowledge on the extent of variability of physical properties of seeds is necessary during the processes of obtaining seeds, their cleaning, sorting, transporting, processing and sowing. It allows planning and controlling the above processes and gives a possibility of selecting parameters to functioning of devices and machines (Jayan and Kumar, 2004; Abuajah and Alonge, 2013).

The physical properties of cucurbit seeds are essential. However, such data appear to be lacking and unfortunately only few studies concerning the physical properties of cucurbit seeds have been performed up to now (Milani *et al.,* 2007) which special emphases on watermelon (Suthar and Das, 1996; Razavi and Milani, 2006; Koocheki *et al.*, 2007; Altuntas, 2008; Sihui *et al.,* 2012), and pumpkin (Joshi *et al.,* 1993; Altuntas, 2008; Seymen *et al.*, 2013; Kaliniewicz *et al.*, 2014). There is considerable interest in squash seeds because of their high nutritional quality, mainly in terms of protein and oil content and few attempts have been done in this area (Paksoy and Aydin, 2004).

Seed size, shape, and color vary greatly among *C. pepo* L. germplasm (Nerson, 2007). Genotypes may differ considerably in size and other seed traits; on the other hand, this considerable variation is not adequately characterized.

Paris and Nerson (2003) observed that differences in seed dimensions can occur among different commercial stocks of the same cultivar. However, they also observed that relative dimensions, that is length-to-width ratio, length-to-thickness ratio, and width-to-thickness ratio, were constant among different stocks of the same cultivar and therefore should be quite reliable for comparative purposes (Paris and Nerson, 2003).

The objectives of current investigation were the characterization and analysis of genetic diversity for selected morphological and chemical traits among three *C. pepo* L. genotypes. Besides, the determination of the scope of variability of selected physical properties of seeds of the three genotypes in order to achieve a complete profile of these attributes.

MATERIALS AND METHODS

Plant material

A collection of three genotypes of *C. pepo* L. representing fruit-shape morphotypes (cultivar-groups) zucchini and pumpkin was observed and analyzed in this study. Names, source, origin and type of all genotypes are presented in Table (1).

Fruit morphological and chemical evaluation

The three genotypes of *C. pepo* L were planted in field at the Experimental Research Farm, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt. The experiment was carried out in summer of 2014. The soil of the experimental field was sandy soil (83.12% sand, 12.6% silt and 4.28% clay) with pH 8.11 and EC 0.51 dsm^{-1}. Before planting, the experimental location was prepared three months before transplanting. During preparation, a rate of 50 m^3 of cattle manure plus 300 kg calcium superphosphate (15.5 % P_2O_5) per feddan were supplemented, then the soil of the site was cleared, ploughed, harrowed and divided into plots. Seeds of squash genotypes were directly sown in soil. Recommended practices for irrigation, fertilization and disease and insect control were followed.

Leaf area of different genotypes was recorded using a portable leaf area meter and expressed as (cm^2). Fruit weight and fruit length at commercial fresh market maturity of different squash genotypes were manually recorded and expressed as (gm) and (cm), respectively. Fruit firmness was measured using a hand Magness Taylor pressure tester and expressed as (Ib/in^2) (Mitcham *et al.,* 1996). Soluble Solid Content (S.S.C.) was measured using hand refractometer at 20° and expressed as percent (%) (Mitcham *et al.,* 1996). The extraction and determination of ascorbic acid was performed using the protocol of Pearson (1970) by titration method using 2, 6 dichlorophenolindophenol in the presence of oxalic acid and expressed as mg/100 fresh weight (A.O.A.C., 1990).

Seed physical Characterization

The 100 seed weight was determined by the mean of a digital electronic balance having an accuracy of 0.001 g. Seed color, brightness, size, shape were visually determined following Balkaya *et al.,* (2009). Linear dimensions (the three principal axial dimensions), i.e. length (L), width (W) and thickness (T) were measured in randomly selected seeds using a digital micrometer with an accuracy of 0.01 mm. The arithmetic mean diameter (D_a), the geometric mean diameter (D_g) and equivalent diameter (D_p) in mm were then calculated by the following relationships, respectively (Mohsenin, 1986):

$$D_a = (L + W + T)/3$$
$$D_g = (LWT)^{1/3}$$
$$D_p = [L\,(W+T)^2/4]^{1/3}$$

Seed volume (V) in mm^3 was calculated using equations suggested by Jain and Ball (1997):

$$V = 0.25[(\pi/6)\,L\,(W+T)^2]$$

The aspect ratio (R_a %) was obtained using following relationship as recommended by Maduako and Faborode (1990):

$$R_a\,\% = W/L * 100$$

The criterion used to describe the shape of the seed was sphericity. Thus, the sphericity (Φ) of samples was found according to the relationship given by Mohsenin (1986):

$$\Phi = (LWT)^{1/3}/L$$

The Surface area (S) in mm^2 of seeds is defined as the total area over the outside of the seed and was theoretically calculated using the following equation suggested by McCabe *et al.,* (1986):

$$S = \pi(D_g)^2$$

Statistical analysis

The experiment was laid-out in a Complete Randomized Design (CRD) with three replications. Data were statistically analyzed using SPSS Statistics release 17.0 (SPSS, 2008) with mean values compared using Duncanś multiple range with a significance level of at least $p \leq 0.05$.

Table 1: Names, source, origin and type of *Cucurbita pepo* L. genotypes used in the study.

Genotype	Source	Origin	Idtype	Type
PI 506441	NPGS, USA	Moldova (Farmer's market, Kishinev)	Local type	Summer Squash
PI 601144	NPGS, USA	USA,W. Atlee Burpee Company	Cultivar	Pumpkin
Black Beauty	Fredonia Seeds®	USA	Cultivar	Summer Zucchini

RESULTS

Fruit morphological and chemical characteristics

Considerable amount of variation has been found among the three *C. pepo* genotypes for all fruit morphological and chemical traits (Table 2). Genotype 'PI 601144' showed the highest leaf area, fruit weight, SSC, and ascorbic acid content and fruit firmness, while genotype 'PI 506441' showed the lowest leaf area, fruit length and SSC. Genotype 'Black Beauty' ranked first for fruit length only. Wide range of values was obtained for all fruit morphological and chemical traits (Table 2). Moderate to high standard deviation (SD) values as well as percentages of coefficient of variation (CV %) were detected in all fruit morphological and chemical traits. Positive significant correlation coefficient values have been detected between most fruit morphological and chemical traits in *C. pepo* genotypes (Table 3).

Table 2: Mean, range, standard deviation, and coefficient of variation for fruit morphological and chemical traits in three *Cucurbita pepo* L. genotypes.

Genotypes	Mean	Range	S.D.*	C.V.%#
		Leaf Area (cm^2)		
PI 506441	277.3c$	213-320	31.6	11.40
PI 601144	429.1a	339-471	37.78	8.80
Black Beauty	330.8b	300-360	19.74	5.97
		Fruit Weight (gm)		
PI 506441	96.0b	63-122	20.54	21.4
PI 601144	203.3a	132-242	34.70	17.07
Black Beauty	92.8b	77-113.5	13.07	14.08
		Fruit Length (cm)		
PI 506441	8.2b	7-9.5	0.83	10.12
PI 601144	14.2a	12.18	2.59	18.24
Black Beauty	14.7a	13.5-16	1.03	7.00
		Fruit Firmness (Ib/in^2)		
PI 506441	3.3a	3-3.8	0.27	8.18
PI 601144	3.6a	3-4	0.36	10.0
Black Beauty	2.8b	2.4-3.6	0.47	16.79
		S.S.C (%)		
PI 506441	5.3a	4.2-6.2	0.77	14.53
PI 601144	5.8a	5-6.5	0.46	7.93
Black Beauty	3.6b	3-4.2	0.45	12.5
		Ascorbic Acid (mg/100 g FW)		
PI 506441	3.3b	2.7-3.8	0.46	13.94
PI 601144	4.4a	3.2-6.2	1.08	24.55
Black Beauty	2.8b	2.2-3.6	0.46	16.43

* S.D. = Standard Deviation, # C.V. = Coefficient of Variation, $for each trait, means followed by the same letter are not significantly different at ($p \leq 5\%$).

Table 3: Phenotypic correlation (*r*) and significance level between fruit morphological and chemical traits in three *Cucurbita pepo* L. genotypes.

Traits	Leaf Area	Fruit Weight	Fruit Length	S.S.C	Fruit Firmness
Fruit Weight	0.692**				
	0.000				
Fruit Length	0.550**	0.418*			
	0.003	0.030			
S.S.C	0.329	0.495**	-0.264		
	ns	0.009	ns		
Fruit Firmness	0.301	0.604**	-0.088	0.549**	
	ns	0.001	ns	0.003	
Ascorbic Acid	0.550**	0.534**	0.162	0.636**	0.414*
	0.003	0.004	ns	0.000	0.032

* = Correlation is significant at the 0.05 level, ** = Correlation is significant at the 0.01 level, ns= Non-significantly different.

Leaf area was highly correlated with fruit weight (*r*= 0.69), fruit length (*r*=0.55), ascorbic acid (*r*=0.55). Leaf area was non-significantly correlated but with high (*r*) value with fruit firmness and SSC (Table 3). Fruit weight was also positively correlated with fruit length (*r*=0.42), SSC (*r*=0.5), fruit firmness (*r*=0.6) and ascorbic acid content (*r*=0.53). SSC was correlated with fruit firmness (*r*=0.55) and ascorbic acid content (*r*=0.64). Fruit length has shown the only negative correlation relation with SSC (*r*=-0.26) and fruit firmness (*r*=-0.09). Analysis of variance was used to separate the total variability found within our data set into systematic (between genotypes) and random (within genotypes) (Table 4). ANOVA results and F test showed highly significant *p* value for all morphological and chemical traits. In addition, R^2 (between genotypes sum-of-squares / total sum-of-squares) have been calculated for all traits. A large value means that a large fraction of the variation is due to the genotypes. High R^2 values were detected and they were 0.83, 0.83, 0.78, 0.75, 0.41, 0.51 for leaf area, fruit weight, fruit length, fruit firmness, S.S.C, ascorbic acid, respectively.

Table 4: Analysis of variance for different fruit morphological and chemical traits in three *Cucurbita pepo* L. genotypes.

Source of Variation	Sum of Squares	d.f	Mean Squares	F	Sign.
		Leaf Area (cm^2)			
Between Genotypes	106686.741	2	53343.370	56.848	0.000
Within Genotypes	22520.444	24	938.352		
Total	129207.185	26			
		Fruit Weight (gm)			
Between Genotypes	71222.167	2	35611.083	59.457	0.000
Within Genotypes	14374.5	24	598.938		
Total	85596.667	26			
		Fruit Length (cm)			
Between Genotypes	239.685	2	119.843	42.541	0.000
Within Genotypes	67.611	24	2.817		
Total	307.296	26			
		Fruit Firmness (Ib/in^2)			
Between Genotypes	24.810	2	12.405	36.574	0.000
Within Genotypes	8.140	24	0.339		
Total	32.950	26			
		S.S.C (%)			
Between Genotypes	2.992	2	1.496	10.450	0.001
Within Genotypes	3.436	24	0.143		
Total	6.427	26			
		Ascorbic Acid (mg/100 g FW)			
Between Genotypes	12.836	2	6.418	12.220	0.000
Within Genotypes	12.604	24	0.525		
Total	25.440	26			

Seed dimensional and physical characteristics

Table (5) and Figure (1) representing the descriptive seed dimensional characteristics of the three *C. pepo* genotypes. Variation can be observed among the three genotypes in colour, brightness, shape and size. Genotype 'Black Beauty' characterized by large size wide elliptic seeds while the other two genotypes characterized by medium size narrow elliptic seeds.

Similar to fruit morphological and chemical traits, seed dimensional characteristics exhibited a high amount of variation between genotypes. Genotype 'Black Beauty' showed high length (L), width (W), and all derived relations (LW, WT, and LWT) (Table 6). Seed Thickness (T) showed non-significant difference between genotypes as well as (LT). As expected, a wide range of values and high percentages of CV was obtained for the three *C. pepo* genotypes (Table 6).

Highly significant correlation coefficient values (*r*) were obtained for seed dimensional characteristics (Table 7). The only exception was the correlation between seed thickness and each of (L), (W), and (LW). Correlation between simple dimensions such as L and W (r=0.53) was lower than the correlation between derived dimensions such as WT and LWT (r=0.98) (Table 7).

ANOVA outcomes confirmed the results concerning the non-significant difference between genotypes in regard to seed thickness as both T and LT showed non-significant values in F test (Table 8). In addition, when compared to fruit characteristics, lower R^2 values were obtained for seed dimensional traits. The values were 0.26, 0.6, 0.13, 0.57, 0.08, 0.27, and 0.32 for seed L, W, T, LW, LT, WT, and LWT, respectively.

Furthermore, seed physical properties exhibited broad range of variation among the three *C. pepo* genotypes. Only seed sphericity showed non-significant difference between genotypes, while the rest of seed physical traits differed significantly among genotypes (Table 9). Genotypes changed their rank when compared at each specific trait. 'Black Beauty' has the highest mean for almost all physical traits except the seed weight.

Table 5: Seed morphological traits of the three *Cucurbita pepo* L. genotypes evaluated in this study.

Genotype	Seed Color	Seed Brightness	Seed Size	Seed Shape
PI 506441	Tawny	Bright	Medium	Narrow Elliptic
PI 601144	Gray-green	Matte (Dull luster)	Medium	Elliptic
Black Beauty	Light Cream	Intermediate	Large	Wide Elliptic

Figure 1: Morphology of seeds of the three *Cucurbita pepo* L. genotypes evaluated in this study.

Table 6: Mean, range, standard deviation, and coefficient of variation for seed dimensional traits in the three *Cucurbita pepo* L. genotypes evaluated in this study.

Genotypes	Mean	Range	S.D.*	C.V.%#
		Seed Length (L) (mm)		
PI 506441	13.66ab$	13.51-14.17	0.53	3.88
PI 601144	13.23b	12.68-14.13	0.59	4.46
Black Beauty	13.95a	13.34-14.67	0.44	3.15
		Seed Width (W) (mm)		
PI 506441	7.58b	7.05-8.51	0.44	5.81
PI 601144	7.23b	6.66-7.99	0.45	6.22
Black Beauty	8.61a	7.36-9.37	0.61	7.09
		Seed Thickness (T) (mm)		
PI 506441	2.45a	2.03-2.96	0.25	10.20
PI 601144	2.39a	1.7-2.91	0.30	12.55
Black Beauty	2.45a	2.26-3.0	0.24	9.80
		L*W (mm)		
PI 506441	103.60b	93.95-116.84	8.08	8.82
PI 601144	95.81b	84.78-110.92	9.14	10.77
Black Beauty	120.13a	100.98-137.90	10.32	8.59
		L*T (mm)		
PI 506441	33.47a	25.44-40.64	4.05	6.60
PI 601144	31.66a	22.93-39.26	2.21	12.50
Black Beauty	34.33a	30.15-41.88	3.96	11.54
		W*T (mm)		
PI 506441	18.60b	15.25-25.19	2.64	14.62
PI 601144	17.33b	12.38-23.25	2.72	17.48
Black Beauty	21.20a	17.59-28.11	3.03	14.29
		L*W*T (mm)		
PI 506441	254.46b	190.72-345.95	40.30	15.68
PI 601144	229.61b	166.95-313.66	39.90	20.69
Black Beauty	296.31a	241.34-392.42	47.50	16.03

*S.D. = Standard Deviation, # C.V. = Coefficient of Variation, $For each trait, means followed by the same letter are not significantly different at ($p \leq 5\%$).

Table 7: Phenotypic correlation (*r*) and significance level between seed dimensional traits in three *Cucurbita pepo* L. genotypes.

Traits	L	W	T	L*W	L*T	W*T
W	0.573**					
	0.001					
T	0.251	0.266				
	ns	ns				
L*W	0.771**	0.963**	0.291			
	0.000	0.000	ns			
L*T	0.561**	0.430*	0.942**	0.519**		
	0.001	0.018	0.000	0.003		
W*T	0.502**	0.776**	0.811**	0.768**	0.871**	
	0.005	0.000	0.000	0.000	0.000	
L*W*T	0.653**	0.804**	0.760**	0.840**	0.879**	0.982**
	0.000	0.000	0.000	0.000	0.000	0.000

Table 8: Analysis of variance for different seed dimensional traits in three *Cucurbita pepo* L. genotypes.

Source of Variation	Sum of Squares	d.f	Mean Squares	F	Sign.
		Seed Length (L)			
Between Genotypes	2.576	2	1.288	4.681	.018
Within Genotypes	7.430	27	.275		
Total	10.006	29			
		Seed Width (W)			
Between Genotypes	10.243	2	5.121	20.222	.000
Within Genotypes	6.838	27	.253		
Total	17.080	29			
		Seed Thickness (T)			
Between Genotypes	.024	2	.012	.175	.840
Within Genotypes	1.886	27	.070		
Total	1.910	29			
		L*W			
Between Genotypes	3083.822	2	1541.911	18.120	.000
Within Genotypes	2297.544	27	85.094		
Total	5381.366	29			
		L*T			
Between Genotypes	37.039	2	18.519	1.115	.342
Within Genotypes	448.255	27	16.602		
Total	485.294	29			
		W*T			
Between Genotypes	78.070	2	39.035	4.970	.015
Within Genotypes	212.076	27	7.855		
Total	290.146	29			
		L*W*T			
Between Genotypes	22728.804	2	11364.402	6.231	.006
Within Genotypes	49247.415	27	1823.978		
Total	71976.219	29			

Very high correlation coefficient (*r*) values were found between seed physical traits. However, seed weight showed negative non-significant differences with the rest of seed physical traits (Table 10). ANOVA results pointed out that the substantial amount of variation exhibited for seed physical traits is attributed to variation between genotypes except for sphericity which showed non-significant F test (Table 11).

Relatively higher R^2 values have been recorded for seed physical traits when compared with seed dimensional traits. The values were 0.48, 0.33, 0.51, 0.5, 0.47, 0.07, 0.32, and 0.21 for arithmetic mean diameter, geometric mean diameter, equivalent diameter, volume, aspect ratio, sphericity, surface area, and 100 seed weight, respectively.

Table 9: Mean, range, standard deviation, and coefficient of variation for seed physical traits of the three *Cucurbita pepo* L. genotypes evaluated in this study.

Genotypes	Mean	Range	S.D.*	C.V.%#
Arithmetic Mean Diameter (D_a) (mm)				
PI 506441	7.90**b**$	7.35-8.4	0.31	3.92
PI 601144	7.62**b**	7.24-8.09	0.33	4.33
Black Beauty	8.33**a**	7.82-8.87	0.33	3.96
Geometric Mean Diameter (D_g) (mm)				
PI 506441	6.32**b**	5.76-7.02	0.33	5.22
PI 601144	6.11**b**	5.51-6.79	0.35	5.73
Black Beauty	6.65**a**	6.23-7.32	0.34	5.11
Equivalent Diameter (D_p) (mm)				
PI 506441	7.00**b**	6.58-7.67	0.31	4.43
PI 601144	6.74**b**	6.36-7.37	0.33	4.90
Black Beauty	7.53**a**	6.88-8.11	0.37	4.91
Volume (V) (mm^3)				
PI 506441	180.57**b**	148.96-236.33	24.85	13.76
PI 601144	161.19**b**	134.61-209.69	24.38	15.13
Black Beauty	224.65**a**	170.64-279.48	33.17	14.77
Aspect Ratio (R_a %)				
PI 506441	55.58**b**	50.96-61.98	3.37	6.06
PI 601144	54.64**b**	51.45-59.76	2.80	5.13
Black Beauty	61.72**a**	53.64-67.12	4.18	6.78
Sphericity (Φ)				
PI 506441	0.46**a**	0.45-0.51	0.02	4.35
PI 601144	0.46**a**	0.41-0.50	0.03	6.52
Black Beauty	0.48**a**	0.45-0.52	0.02	4.17
Surface Area (S) (mm^2)				
PI 506441	125.78**b**	104.04-154.7	13.13	10.44
PI 601144	117.39**b**	95.21-144.95	13.51	11.51
Black Beauty	139.22**a**	121.72-168.30	14.64	10.52
100 Seed Weight				
PI 506441	10.11**a**	8.85-13.0	1.24	12.27
PI 601144	10.27**a**	7.9-14.3	1.69	16.46
Black Beauty	8.87**b**	7.89-9.76	0.79	8.91

* S.D. = Standard Deviation, # C.V. = Coefficient of Variation, $for each trait, means followed by the same letter are not significantly different at ($p \leq 5\%$).

Table 10: Phenotypic correlation (*r*) and significance level between seed physical traits in three *Cucurbita pepo* L. genotypes.

Traits	(D_a)	(D_g)	(D_p)	(V)	(R_a)	(Φ)	(S)
(D_g)	0.922**						
	0.000						
(D_p)	0.981**	0.941**					
	0.000	0.000					
(V)	0.973**	0.939**	0.997**				
	0.000	0.000	0.000				
(R_a)	0.641**	0.604**	0.762**	0.772**			
	0.000	0.000	0.000	0.000			
(Φ)	0.462*	0.725**	0.601**	0.616**	0.658**		
	0.010	0.000	0.000	0.000	0.000		
(S)	0.921**	0.999**	0.942**	0.943**	0.613**	0.730**	
	0.000	0.000	0.000	0.000	0.000	0.000	
Weight	-0.122	-0.053	-0.098	-0.104	-0.039	0.086	-0.0520
	ns	ns	ns	ns	ns	ns	ns

* = Correlation is significant at the 0.05 level, ** = Correlation is significant at the 0.01 level, ns= Non-significantly different.

Table 11: Analysis of variance for different seed physical traits in three *Cucurbita pepo* L. genotypes.

Source of Variation	Sum of Squares	d.f	Mean Squares	F	Sign.
Arithmetic Mean Diameter (D_a) (mm)					
Between Genotypes	2.631	2	1.315	12.511	.000
Within Genotypes	2.839	27	.105		
Total	5.469	29			
Geometric Mean Diameter (D_g) (mm)					
Between Genotypes	1.507	2	.754	6.511	.005
Within Genotypes	3.125	27	.116		
Total	4.633	29			
Equivalent Diameter (D_p) (mm)					
Between Genotypes	3.224	2	1.612	14.056	.000
Within Genotypes	3.096	27	.115		
Total	6.320	29			
Volume (V) (mm^3)					
Between Genotypes	21147.679	2	10573.840	13.721	.000
Within Genotypes	20807.354	27	770.643		
Total	41955.033	29			
Aspect Ratio (R_a) (%)					
Between Genotypes	295.845	2	147.923	12.123	.000
Within Genotypes	329.451	27	12.202		
Total	625.296	29			
Sphericity (Φ)					
Between Genotypes	.001	2	.001	1.540	.233
Within Genotypes	.012	27	.000		
Total	.014	29			
Surface Area (S) (mm^2)					
Between Genotypes	2424.396	2	1212.198	6.389	.005
Within Genotypes	5123.150	27	189.746		
Total	7547.547	29			
100 Seed Weight (gm)					
Between Genotypes	11.814	2	5.907	3.544	.043
Within Genotypes	44.999	27	1.667		
Total	56.813	29			

DISCUSSION

Germplasm characterization is an important link between the conservation and utilization of plant genetic resources. Knowledge of the genetic diversity of a crop is essential for the parental selection in order to maximize genetic improvement. More accurate and complete descriptions of the genotypes and patterns of the genetic diversity could help determine future breeding strategies and facilitate the introgression of diverse germplasm into the current commercial summer squash genetic base. Genetic variation in traditional landraces is the crucial genetic pool for plant breeding. Evaluation of the landraces in terms of phenotypic behavior and genetic variability needs to be performed before they are used in breeding programs to develop new cultivars that are more productive and of greater nutritional value. The identification and use of landraces of diverse genetic background is a critical issue for successful breeding programs through the selection of suitable parents (Hoisington *et al.,* 1999).

For a successful breeding program, genetic diversity and variability play a vital role. Genetic diversity is a prerequisite for an effective plant breeding program. It is a useful and essential tool for parents' choice in hybridization to develop high yield potential cultivars and to meet the goals of plant breeding. Genetic diversity is also used to study the taxonomic relationship among genotypes and to choose varieties with superior behavior and incorporate them into breeding programmes (Escribano *et al.,* 1991; Cartea *et al.,* 2002). The knowledge of genetic diversity and characterization of genotypes provides an informative tool for better classification and use in breeding. Morphological characterization is the first step in description and classification of genetic resources (Smith and Smith, 1989).

The significant variation for fruit morphological and chemical traits in the three *C. pepo* genotypes that was observed in this study was much expected given that the *Cucurbita* genus is one of the most variable genera within the Cucurbitaceae family (Paris, 1986, 1996, 1998, 2000). The variability was high enough to alter the genotypes rank when compared for nearly all traits. Moreover, the moderate to high standard deviation indicates that the data points are spread out over a wide range of values. Also, the high coefficient of variation means that the extent of variability in relation to the mean is high. In general, genetic diversity in *C. pepo* L. is well documented (Decker and Wilson 1986; Paris and Nerson 1998, 2003; Paksoy and Aydin 2004; Nerson, 2007) and current results as well presented high genetic variation between and within genotypes which offer plant breeders the opportunity for selection in this collection of *C. pepo* germplasm for enhanced fruit traits. Fruit firmness, SSC, and ascorbic acid (vitamin C) content are among the most important quality factors in many vegetable crops. These traits can be influenced by various factors such as genotypic differences. Genotype 'Black Beauty' has the lowest ascorbic acid content (2.8 mg/100 g FW), lowest fruit firmness (2.8 Ib/in^2), and lowest SSC (3.6%) among the three genotypes. On the other hand, 'Black Beauty' is a commercial cultivar and characterized also by the highest fruit length due to selection and breeding for this preferred trait. Current results detected a negative non-significant correlation coefficient between fruit length and both fruit firmness and SSC and non-significant correlation with ascorbic acid content which may explain the low rank of 'Black Beauty' for fruit firmness, SSC and ascorbic acid content among the three genotypes. Negative correlation has been detected in pumpkin between fruit length and both fruit firmness and SSC (Du *et al.,* 2011) which in much agreement with current results. ANOVA results and F test showed highly significant *p* value for all fruit morphological and chemical traits and high R^2 values were detected which means that a large fraction of the variation is due to the genotypes. Similar results have been reported for fruit length in pumpkin (Du *et al.,* 2011), in cucumber (Golabadi *et al.,* 2012) and in watermelon (El-Madidi and Hakimi, 2015), for fruit weight in pumpkin (Du *et al.,* 2011) and in melon (Zalapa *et al.,* 2008), for ascorbic acid in pumpkin (Pandey et al., 2003; Zinash et al., 2013), for fruit firmness in tomato (Shokat *et al.,* 2013) and in cucumber (Cook *et al.,* 1994) and for SSC in watermelon (El-Madidi and Hakimi, 2015) and pumpkin (Du *et al.,* 2011; Zinash *et al.,* 2013). Screening germplasm for different yield and quality traits and locating a wide range of variation that ascribed to genotypes will provide the basic requirements for breeding to obtain elite genotypes with enhanced traits. In present study, considerable variability was displayed in seed characteristics indicating a high degree of morphological polymorphism which is in agreement with previous studies in such area (Decker and Wilson 1986; Joshi *et al.,* 1993; Paris and Nerson, 2003; Paksoy and Aydin, 2004; Milani *et al.,* 2007; Altuntas, 2008; Kaliniewicz *et al.,* 2014). The moderate standard deviation and coefficient of variation for different seed traits indicates that the data points are spread out over a wide range of values relative to mean. These differences are mainly due to differences in the individual properties of genotypes but also could be as a result of environmental and growth condition variation.

Sphericity was the only seed characteristic that show non-significant ANOVA results and F test among the rest of physical traits. The three genotypes did not differed in their sphericity values and they did not change their rank. Sphericity and aspect ratio (relates width to length) were found to be 47% and 57.3% averaged over the three genotypes, respectively. These medium values is indication of the tendency of the seed shape away from being a sphere which mean that seeds will undergo sliding action on their flat surface rather than rolling. Other investigators argue that seed may be considered as sphere when sphericity value is more than 70-80% (Dutta *et al.,* 1988; Deshpande *et al.,* 1993). Movement of non-spherical seeds is usually slower in machine parts. *C. pepo* seed shape is elliptical with near flat nature which force the seed to roll, however their flatness help seed to slide.

This investigation revealed that seed length and width was significantly correlated (*r*=0.573) which was confirmed by the results of Kaliniewicz *et al.,* (2014) (*r*= 0.745). However, current results found that seed thickness is not significantly correlated with seed length and width which was not established in Kaliniewicz *et al.,* (2014) study. The results indicated that seed weight is non-significantly correlated with the physical properties of the seed and the negative relation was dominant. These unexpected results was partially reported by Asoegwu *et al.,* (2006) in African oil bean seed as they reported non-significant correlation between seed weight and sphericity.

Lower seed length and weight were detected in current study compared with results of Paksoy and Aydin (2004) and Aydin and Paksoy (2006) with edible summer squash seeds. The reduction was 30% and 14% for length and width, respectively. However, comparable results were recorded concerning seed thickness and sphericity. Also, in zucchini, similar result about sphericity was reported by Gholami *et al.,* (2012). In pumpkin, lower arithmetic and geometric mean diameters and surface area were reported by Milani *et al.,* (2007) compared to current study corresponding measurements while sphericity was similar. Also, lower measurements were detected in this study compared to results of Joshi *et al.,* (1993) and Altuntas, (2008) in pumpkin.

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التنوع في الصفات المورفولوجية والكيميائية للثمار والصفات الطبيعية للبذور في ثلاثة تراكيب وراثية تابعة للنوع *Cucurbita pepo* L.

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الملخص العربي

مجموعة من ثلاثة تراكيب وراثية تنتمي الى النوع *Cucurbita pepo* L. يمثلون نوعى ثمار هذا النوع (الكوسة والقرع العسلى) قد تم ملاحظتهم ومسحهم في تجربة حقلية ومعملية خلال عام ٢٠١٤. وكان الهدف من التجربة توصيف التباين بين الثلاث تراكيب وراثية بالنسبة لكل من الصفات المورفولوجية والكيميائية للثمار. بالإضافة إلى ذلك، تم تقييم بذور الثلاث تراكيب وراثية من حيث خصائصها المورفولوجية والفيزيائية. وقد تم تسجيل مدى واسع من التباين بين الثلاث تراكيب وراثية للخصائص المورفولوجية والكيميائية للثمار وكذلك الخصائص المورفولوجية والفيزيائية للبذور. وأظهرت النتائج وجود قيم معامل ارتباط إيجابية بدرجة معنوية بين معظم الصفات المورفولوجية والكيميائية للثمار. وقد ظهر أن طول الثمرة هى الصفة الوحيدة التى أظهرت علاقة إرتباط سلبية مع المحتوى من المواد الصلبة الذائبة وصلابة الثمار. أيضا، تم الحصول على قيم معامل ارتباط معنوية لخصائص البذور المورفولوجية والفيزيائية مع استثناء صفتى سمك ووزن البذور التي أظهرت معامل ارتباط اما سلبي أو غيرمعنوي. نتائج تحليل التباين واختبار F أظهر معنوية نتائج كل الخصائص المورفولوجية والكيميائية للثمار وكذلك الخصائص المورفولوجية والفيزيائية للبذور باستثناء سمك واستدارة (كروية) البذور والتى اظهرت اختبار F غيرمعنوى. النتائج الحالية تدعم تبنى برامج تربية في النوع *C. pepo* L. بعد التاكد من وجود تباين وراثي عالي داخل هذا النوع.