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Original article

Selection and screening of fruit phenotypic characters of Greek local and foreign pomegranate germplasm

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Summary

Pomegranate is an ancient plant species and it is of great importance to capture the existing biodiversity and explore their horticultural and fruit quality attributes. The aims of the present study were to entail a prospection, characterize fruit morphological traits and study possible associations among foreign and local pomegranate germplasm; the studied planting material included 47 cultivars/accessions (10 selections of 'Ermioni'; 28 other local germplasm; 9 foreign cultivars). The largest phenotypic variability was found in titratable acidity, fruit fresh weight, peel-*a and -hue color parameters. Fruit from the local germplasm had lower weight, and less red peel and seed coloration, compared with those from foreign cultivars. The 'Ermioni' selections had the heaviest 100-seed weight and highest maturity index, compared with the rest local germplasm and foreign cultivars, while the selection 'ER2' was separated with the best peel coloration. Local cultivars with marketable or distinct phenotypic traits were separated. In conclusion, the present study provides information on the diversity of morphological traits in local pomegranate germplasm that need to be explored for their phenotypic and agronomic stability and genetic relatedness and could be used for conservation and breeding.**

Keywords
breeding, fruit quality, genetic resources, local accessions, *Punica granatum*

Significance of this study

What is already known on this subject?
- Local cultivars could provide an essential source of genes for breeding.
- Pomegranate germplasm originates and has been appreciated from ancient years in Greece.

What are the new findings?
- A prospection and characterization of fruit morphological traits in local and foreign germplasm was made.

What is the expected impact on horticulture?
- Provide an opportunity for plant breeders to develop new and improved cultivars.

Introduction

The pomegranate fruit has superior organoleptic attributes and the crop is well suited for low-input production systems and adapted in hardy and marginal areas. However, it was until recently an underutilized crop cultivated for local markets, and only in the recent decades, due to the growing demand for fruit rich in nutritional and healthy active compounds, there was a substantial worldwide expansion in its cultivation. Due to the immediate demand for propagation material, the use of foreign cultivars with worldwide use, mainly cultivar 'Wonderful' was a direct solution, while local germplasm endangered. It is of great importance that the local germplasm is explored for its fruit quality, horticultural and adaptability attributes since it may provide an opportunity for plant breeders to develop new and improved cultivars with desirable characteristics.

The pomegranate is believed to have originated in Persia (modern-day Iran), Afghanistan, Pakistan, and it was spread throughout the Middle East to Southeastern Europe around the Mediterranean, to China, North Africa, and eventually to warm regions of the New World (Stover and Mercure, 2007; Holland and Bar-Ya'akov, 2018; Van Wyk and Wink, 2004). In the Mediterranean basin, it was cultivated as early as the third millennium BC and cherished for its therapeutic properties by the Egyptians, Greeks and Romans. In Greece, local accessions of pomegranate can be found in every geographical region from the southern and warmer regions to the northern and colder regions. The most important varietal group is that denominated as 'Ermioni', with a long tradition of cultivation in an area of the same name 'Ermionida' located in Argolida, Peloponnese, and recently registered as protected designation of origin. The exceptional organoleptic quality of 'Ermioni' fruit was the reason for its spread to other regions of Greece. Considering that phenotypic variation within a cultivar can evolve related with somatic mutations due to vegetative propagation or due to hybridization, it is important to identify clones with advanced agronomic and fruit quality characters.

In situ phenotypic observations on morphological traits are useful for preliminary evaluation of germplasm and can be used as a first approach for assessing genetic diversity and cultivar improvement. As a second step, the selection and establishment of an *ex situ* collection could serve effectively to characterize germplasm under the same environmental conditions and serve for comparing local and introduced genetic material (Greece, Karapetsi et al., 2021; Drogoudi et al., 2005; Cyprus, Kyriacou et al., 2020; Italy, Cristofori et al., 2011; Ferrara et al., 2011; Spain, Bartual et al., 2011; Croatia, Radunić et al., 2015; Tunisia, Mars and Marrakchi, 1999; Turkey, Ozgen et al., 2008). Furthermore, genetic characterization in local germplasm has also served as a means to

study the genetic diversity and genetic relationships of pomegranates (Karapetsi et al., 2021; Kyriacou et al., 2020). In our previous studies, fruit quality and pomological attributes were characterized in 26 pomegranate accessions isolated from Northern Greece and foreign cultivars evaluated under uniform conditions. The difference in the frost resistance was found and fruit quality traits while there were associations found among the studied traits (Karapetsi et al., 2021; Drogoudi et al., 2005). The availability of information on the phenotypic and genetic relationships among cultivars/accessions is very important for breeding programs.

The aims of the present study were to entail a prospection of local germplasm, including selections of the local cultivar 'Ermioni', and to characterize the variability in fruit morphological traits with high commercial importance. It was hypothesized that germplasm with advanced agronomic and fruit quality characters could be separated and the prospected germplasm can further be studied for agronomic stability and genetic relatedness and be used for conservation and breeding.

Materials and methods

The studied planting material included 47 cultivars/accessions; 10 selections of the local cultivar 'Ermioni', 28 other local accessions/cultivars and 9 foreign cultivars, as shown in Table 1. Fruit was sampled *in situ* (21) and from an *ex situ* collection located at the Department of Deciduous Fruit Trees in Naoussa, Greece (26) (Karapetsi et al., 2021; Drogoudi et al., 2005). The local pomegranate germplasm studied had distinct characters and was identified from private collections, commercial groves, or nurseries across regions in northern, central and southern Greece while some are of unknown origin in Greece.

Fruit phenotypic characterization was made in six replicate fruit of uniform size and shape, harvested when commercially ripe and according to their size and color. Samples from the germplasm harvested *in situ* were carefully packed and transferred via fast courier to the laboratory where analyses were conducted directly.

Fruit fresh weight (FW) was measured and later the fruit was hand-cracked and the seeds were separated. The peel and seed weight were measured, and the percentage edible portion was calculated. The weight of 100-seeds was measured. Juice was hand-extracted from a known seed portion weight, weighted and the percentage of juice per fruit and edible portion were calculated.

Total soluble solid (SSC) and total acidity (TA) contents were determined in pomegranate juice extracted as above. SSC was measured using a digital refractometer (model PR-1, Atago, Japan), and TA by titration to pH 8.2 with 0.1 N NaOH and expressed as citric acid content (g 100 mL^{-1}). The maturity index was calculated as the ratio SSC/TA.

The fruit peel-color L^* (brightness or lightness; 0=black, 100=white), a^* (−a*=greenness, +a*=redness) and b^* (−b^*=blueness, +b^*=yellowness), a^* and b* dimensions were measured using the chromatometer Minolta (model CR-400, Minolta, Ramsey, NJ), and the Hue angle (0= red purple; 90= yellow) and Chroma (departure from gray toward pure chromatic color) parameters were calculated. Readings were taken close to the stalk of each fruit exocarp.

Seed color (1, white; 2, rose-white; 3, rose; 4, dark-rose; 5, rose-red; 6, red; 7, very red) and tegmen hardness (1, soft; 2, medium; 3, hard) were characterized by a panel of 5 people, in accordance with the "Descriptor's list for pomegranate" set up in the framework of EC Project GENRES 29 "Conservation, Evaluation, Exploitation, and Collection of Minor Fruit Tree Species".

Statistical analysis

Statistical analysis was performed using a one-way ANOVA, using as treatment a) the genotype (47 cultivars/accessions) and b) the origin of genotype (accessions of 'Ermioni', 10; other local accessions/cultivars, 28; foreign cultivars, 9). Principal component analysis (PCA) was also performed. Least significant difference (LSD) was calculated. Percentage data were arcsine transformed and ratio data were log transformed before analyses. The statistical package SPSS was used (SPSS Inc., Chicago, Illinois, U.S.A.).

Results and discussion

Comparison among the 46 studied pomegranate cultivars/accessions

There was significant variation in the measured fruit phenotypic parameters and the highest variability was found in TA (CV%=109.7), followed by FW (CV%=37.3) and peel-a^* and -hue color parameters (CV%=38.1–49.7%). TA was previously shown to show very limited yearly variation and therefore it constitutes a signature trait for pomegranate accessions (Kyriacou et al., 2020). Variation in FW and peel color parameters are mainly influenced by the genotype but pedo-climatic parameters may also play an important role in regulating the source-skin relations and fruit growth (Joshi et al., 2021; Drogoudi et al., 2021; Mphahlele et al., 2014).

The heaviest fruit was found in the local 'Katinaria' and the foreign cultivars 'Wonderful', 'Sweet' and 'Eversweet' (mean 512.8 g), whereas the lightest fruit was found in '11010', 'SIF' and 'Georgias' (mean 149.5 g) (Table 1). 'Wonderful' was reported to exhibit relatively high fruit weight (536.6 g), which was similarly reported in other studies when compared with other germplasm (Karapetsi et al., 2021; Kyriacou et al., 2020), although a large variation in mature fruit size within commercial orchards was also reported that poses a problem for fresh market growers and packers (Wetzstein et al., 2011).

The percentage of edible portion varied between 45.0–71.0% with the highest values found in 'Eversweet', two selections of 'Ermioni' ('ER6' and 'ER1') and 'Georgias' suggesting for low peel thickness (Kyriacou et al., 2020; Drogoudi et al., 2008) and lowest value in 'Kampadika'. The range in percentage edible portion reported was similar to the range reported in other studies and 'Wonderful' was similarly shown to have the lowest percentage edible portion (49.0%) (Kyriacou et al., 2020; Martinez-Nicolas et al., 2016; Radunić et al., 2015; Chater et al., 2018). Juiciness was previously shown to be associated primarily with a thin rind and a high percentage of edible portion, and secondarily with high seed gross weight (Kyriacou et al., 2020).

Percentage juice per fruit varied between 26.8% and 53.0% with the highest values in 'ER6', 'Eversweet', 'Angel red', 'Ambrosia', 'Foustani', 'ER5' and 'Katinaria', which renders them appropriate for the juice industry. Fruit from cultivar 'Wonderful' had 33.8% juice per fruit. The lowest juiciness was found in 'Kampadika' and '11006' (Table 1). The percentage juice/edible portion was highest in 'ER8' (83.1%) while values in the highest range were similarly reported only in varietal phenotypic study made for Indian germplasm (60–84%) (Agrawal and Chandra, 1991). Considerable was the variation found in the 100-seed weight (CV%=25.8), and values ranged from 21.5 g ('11025') to 66.4 g ('Katinaria') (Table 1).

Levels of SSC and TA in the pomegranate juice are important characteristics since they result in the sensations of 'sweetness' and 'sourness' attributes related mainly to the taste of pomegranate, while consumers prefer high sweetness and moderate to low acidity (Mayuoni-Kirshinbaum and Porat, 2014). SSC was lowest in 'ER7' and 'Katinaria' (14.1 °Brix) and highest in 'SE2' and '11021' (18.8 and 19.1 °Brix, respectively) (Figure 1a). TA ranged between 0.2 and 2.7 g 100 mL^{-1}. Almost all the local accessions/cultivars studied can be classified as sweet (TA < 1%) apart from three accessions that would be termed as sweet-sour (TA < 2%), whereas three of the foreign cultivars studied were sour ('Wonderful' and 'Georgias') (Pareek et al., 2015). In the present study the maturity index varied from 5.0 in '11011', 'Wonderful' and 'Georgias' to the highest value of 86.0 in 'Eversweet', while the 'Ermioni' accessions also had high maturity index (Figure 1b). For the maturity index many authors also mentioned wide ranges for this parameter (Kyriacou et al., 2020; Chater et al., 2018; Martinez-Nicolas et al., 2016), as seen in the present study, while it was previously found to be moderately affected by the yearly variation (Kyriacou et al., 2020).

The peel color is of the most required quality parameters for marketing; cultivars 'Persephone', 'Georgias' and the accessions '11015', '11010' and '11009' had the reddest colored peel (high *a** values). The poorest peel coloration was found in 'ER7', '11029', '11002' and 'Katinaria' (low *a** values) (Table 1). Highest peel-*L** (lightest color) and peel-Hue (>50) was found in 'ER7', '11011', 'ER4', '11006', '11002', '11001', '11029', 'Foustani', '11026' and 'Katinaria' suggesting for more extensive yellow ground color.

Tegmen softness or absence of tegmen is a desirable economic trait that improves the consumptive qualities of fruits. Seeds were categorized as soft, medium and hard in 18, 14 and 15 of the studied germplasm, respectively. From the local germplasm soft seeds were contained in the 'Ermioni' selections studied, '11029' (also named as 'Kallisti'), 'Persephone', 'Ploutos' and 'SE1'.

Principal component analysis

PCA1 and PC2 accounted for 25.4% and 22.7% of total variability, respectively (Figure 2). The first component was positively correlated with peel-*a** and seed-color and negatively with peel-*L**, -*b** and –Hue parameters, Three selections of 'Ermioni' ('ER1', 'ER2' and 'ER5'), 'Persephone', 'Angel Red', 'Georgias' and 'Sweet' belonged to this group with positive values, whereas '11029', 'Katinaria' and 'ER7' showed the opposite behavior.

The second component was positively correlated with

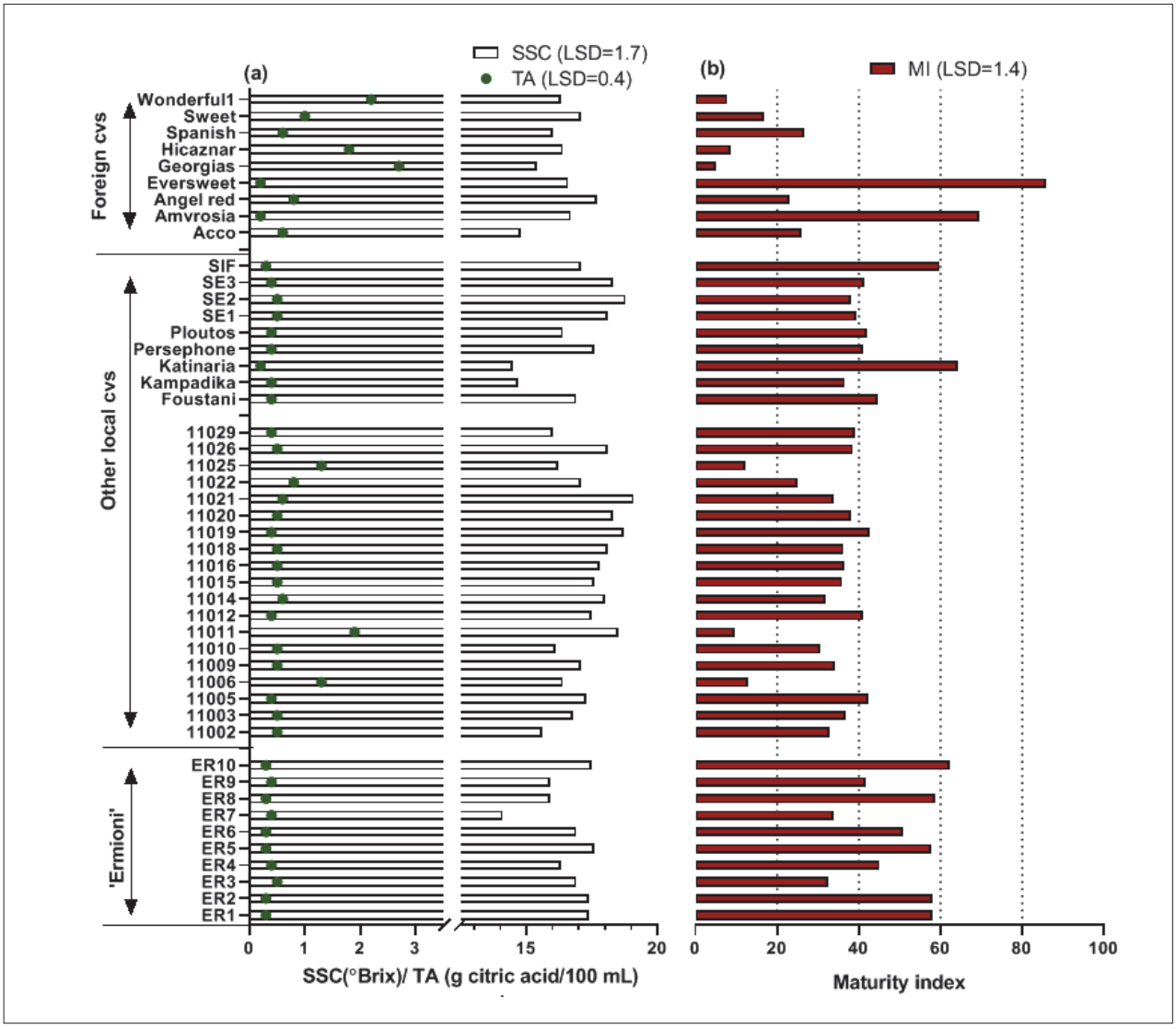


Figure 1. Means for the (a) soluble solid content, titratable acidity and (b) maturity index (SSC/TA) in the studied pomegranate germplasm. LSD, least significant difference.

Table 1. Mean, minimum and maximum values for fruit fresh weight (FW) (g), % edible portion (%EP), % juice/fruit (%J/FR), % juice/edible portion (%J/EP), 100 seed-weight (g), tegmen hardness (TH), peel color parameters *L*, *a** and *b** and seed color (SC). Location where sampled and origin of 10 'Ermioni' selections, 28 other local germplasm and 9 foreign cultivars studied. LSD = Least significant difference.

Cv/accession	Sampled	Origin	FW	% EP	% J/FR	% J/EP	100-seed	TH	*L*	*a**	*b**	SC
'Ermioni' selections												
ER1 (Afthonia)	Argolida	Argolida/GRC	290.7	65.2	41.6	63.7	41.8	1	47.3	41.6	13.1	5
ER2 (Areti)	"	"	371.5	49.0	39.0	68.7	60.7	1	45.1	44.1	11.8	5
ER3	"	"	295.0	61.0	41.5	66.5	47.7	1	53.7	35.5	21.6	5
ER4	Naoussa	"	326.3	58.2	39.9	68.7	52.9	1	67.1	27.3	21.4	3
ER5 (Enotita)	Argolida	"	369.0	63.4	43.9	69.2	47.9	1	49.9	42.7	15.9	5
ER6	Evia	"	389.3	70.2	49.8	70.0	46.1	1	58.3	29.7	34.4	5
ER7	Imathia	"	219.2	57.7	40.1	69.5	48.2	1	73.9	13.8	41.2	3
ER8	Lakonia	"	300.0	62.0	40.0	83.1	53.3	1	61.8	36.4	33.0	5
ER9	Messinia	"	325.0	60.5	41.0	68.0	60.6	1	59.1	38.2	35.4	5
ER10	Lakonia	"	300.0	63.5	42.0	70.4	49.8	1	59.2	41.4	30.7	5
Other local germplasm												
11002	Naoussa	Drama/GRC	221.0	47.0	33.5	55.8	29.6	2	66.0	19.7	37.8	4
11003	"	Messinia/GRC	240.0	55.0	37.5	61.3	22.3	3	61.5	28.4	30.3	4
11005	"	Drama/GRC	256.5	58.6	37.6	67.0	34.5	2	61.5	33.6	34.8	5
11006	"	Imathia/GRC	390.0	59.0	26.8	61.7	31.2	2	67.0	25.5	37.4	3
11009	"	"	214.7	52.0	33.7	58.5	21.8	2	51.5	45.3	26.4	3
11010	"	"	125.2	51.8	29.6	60.9	21.7	2	50.3	46.6	22.5	6
11011	"	"	289.6	54.7	32.0	66.9	38.8	3	68.3	26.1	35.2	5
11012	"	"	230.4	58.1	40.4	69.3	36.1	3	57.5	32.9	28.5	6
11014	"	"	257.0	60.6	35.8	68.0	39.1	3	60.2	33.0	30.5	5
11015	"	"	186.5	48.8	33.8	61.4	33.6	2	47.0	49.7	21.5	3
11016	"	"	326.4	61.5	38.1	68.3	34.5	3	53.5	39.1	24.2	6
11018	"	Unknown/GRC	217.0	47.8	38.2	67.8	41.6	2	65.9	25.8	35.6	5
11019	"	"	303.8	58.3	38.2	67.5	39.1	3	58.4	28.4	31.0	6
11020	"	"	241.1	60.4	34.8	58.4	32.5	2	58.8	32.9	29.0	6
11021	"	"	338.5	60.4	34.2	63.4	28.9	3	60.6	35.9	26.9	5
11022	"	"	261.3	54.5	31.8	65.1	35.3	3	59.8	38.3	26.2	3
11025	"	"	320.0	60.5	31.3	62.6	21.5	3	63.0	32.1	29.5	3

Table 1. Mean, minimum and maximum values for fruit fresh weight (FW) (g), % edible portion (%EP), % juice/fruit (%J/FR), % juice/edible portion (%J/EP), 100 seed-weight (g), tegmen hardness (TH), peel color parameters *L*, *a** and *b** and seed color (SC). Location where sampled and origin of 10 'Ermioni' selections, 28 other local germplasm and 9 foreign cultivars studied. LSD = Least significant difference.

Cv/accession	Sampled	Origin	FW	% EP	% J/FR	% J/EP	100-seed	TH	*L*	*a**	*b**	SC
11026 (Andromachi)	"	Imathia/GRC	306.8	49.8	34.7	64.8	35.0	2	63.1	27.6	33.4	6
11029 (Kallisti)	"	Imvros/Trk	340.0	57.5	32.6	56.9	31.6	1	65.4	14.8	41.6	2
Foustani	Pella	Pella/GRC	360.6	63.0	44.3	70.4	44.5	2	63.4	24.7	34.7	6
Kampadika	Pieria	Imathia/GRC	242.7	45.0	28.8	64.1	35.2	2	43.7	42.2	18.5	3
Katinaria	Rodos	Rodos/GRC	629.8	55.5	43.8	74.1	66.4	3	61.7	20.0	33.7	1
Persephone	Naoussa	Argol./GRC	373.5	60.4	40.4	66.8	46.5	1	43.4	49.9	20.7	5
Ploutos	Argolida	"	394.4	56.3	36.3	64.6	47.8	1	43.5	42.5	19.5	6
SE1	Serres	Serres/ GRC	193.3	50.7	35.9	70.8	32.3	3	57.7	39.0	24.0	7
SE2	"	"	231.6	57.6	43.0	74.6	54.4	1	58.1	36.5	26.0	6
SE3	"	"	319.9	61.6	42.7	69.2	44.1	2	46.5	35.5	26.0	6
SIF	Sifnos	Sifnos/ GRC	152.4	61.3	39.4	64.3	35.9	1	59.5	40.0	20.0	7
Foreign cultivars												
Acco	Naoussa	Israel	325.3	57.4	35.4	61.5	29.6	1	53.1	45.1	23.9	6
Amvrosia	Rodos	U.S.A.	278.2	62.1	46.7	72.9	28.5	1	59.9	38.4	34.4	5
Angel red	"	"	335.4	64.0	48.6	72.3	46.4	2	30.8	29.2	6.4	6
Eversweet	"	"	447.4	71.0	49.0	74.7	39.9	2	51.1	43.7	24.8	5
Georgias	Naoussa	Russia	170.9	64.5	43.0	66.7	34.8	3	46.4	50.2	16.4	6
Hicaznar	"	Turkey	446.4	51.1	33.8	66.6	31.0	3	55.3	31.5	27.3	6
Spanish	"	Spain	331.8	63.5	39.9	62.8	37.3	1	58.4	34.0	18.5	2
Sweet	Rodos	U.S.A.	504.5	55.4	37.9	68.5	37.0	3	38.0	43.3	19.3	7
Wonderful1	Naoussa	Israel	536.6	49.0	33.7	68.9	35.8	3	55.7	40.1	17.9	6
		Mean	309.1	57.7	38.1	66.8	39.3	1.9	56.3	35.2	26.7	4.9
		Min.	125.2	45.0	26.8	55.8	21.5	1.0	30.8	13.8	6.4	1.0
		Max.	629.8	71.0	53.0	83.1	66.4	3.0	73.9	55.0	41.6	7.0
		LSD	103.2	3.9	3.6	3.9	5.6		8.4	10.9	5.7	

[1]: also named as 'Andromachi'; [2]: also named as 'Kallisti'.

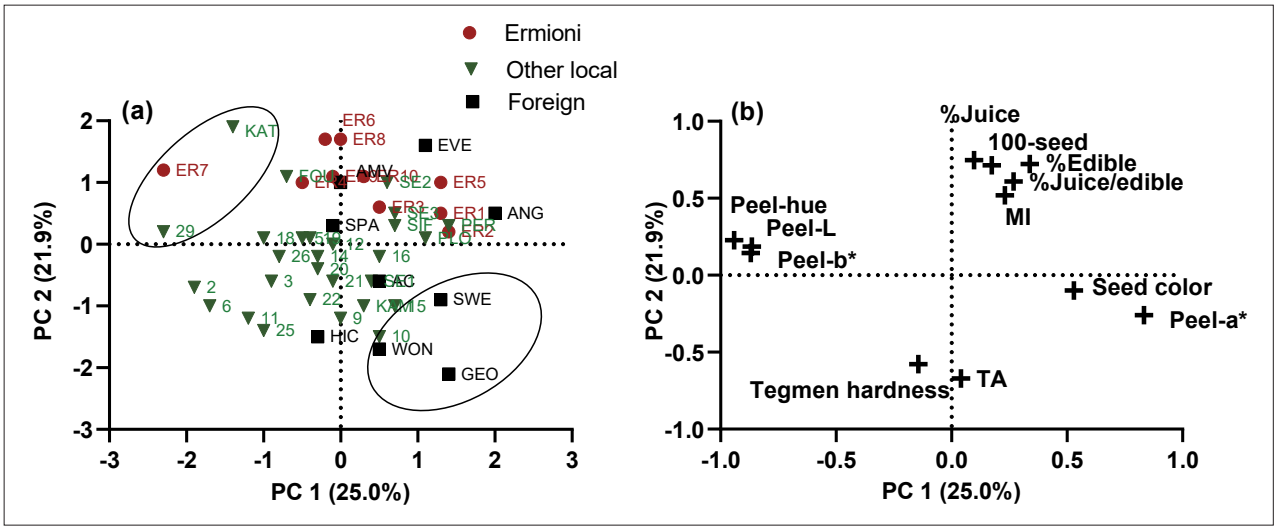


Figure 2. (a) Segregation and (b) factor loadings, of 47 pomegranate cultivars/accessions; 10 selections of 'Ermioni' (circles), 28 other local (triangles) and 9 foreign cultivars (rectangular), on the basis of fruit quality characters, determined by principal component analysis (PCA).

the percentage of juice/fruit and percentage juice per edible portion, percentage edible portion and maturity index and negatively with TA and tegmen hardness. Two selections of 'Ermioni' ('ER6' and 'ER8'), 'Katinaria' and 'Eversweet' were separated with higher values in PC1, being positively correlated; while 'Georgias', 'Hicaznar', 'Wonderful', '11009', '11010', '11011' and '11025' were separated with low values.

'Ermioni' selections

The 'Ermioni' selections were separated for having the heaviest 100-seed weight and highest maturity index, compared with the rest of Greek germplasm and foreign cultivars. Moreover, fruit from 'Ermioni' selections had high juice content, pale peel (lower *a** and higher *L**) and seed coloration and low tegmen hardness (Table 2). Poulimenos (2012) also found that 'Ermioni' had a high percentage of juice and larger seed weight, compared with 'Wonderful'. The pomegranate 'Ermioni' is highly appreciated by the Greek market and sales are far higher compared with foreign cultivars. However, it has a low storability compared with other more thick skinned cultivars such as 'Wonderful' (Pantelidis and Vasilakakis, unpublished data).

An aim of the present study was to separate 'Ermioni' clones with superior quality attributes. Results showed that the selection 'ER2' was separated with having the largest 100-seed weight and best peel coloration (high *a** and low *b** and hue values), when compared with the rest of the studied accessions. 'ER2' was identified in Argolida and comparison was made with the rest accessions identified in the same orchard or other locations in Lakonia and Messinia, southern Greece, areas with similar environmental conditions. However, the selection 'ER7', sampled in northern Greece, had in-

Table 2. Mean and covariate coefficient (CV%) for fruit fresh weight (g), % edible portion, % juice/fruit, % juice/edible portion, 100-seed weight (g), total soluble solid content (°Brix), titratable acidity (g 100 mL^{-1}), maturity index, tegmen hardness (1, soft; 2, medium; 3, hard), skin color parameters *L*, *a**, *b**, Hue and Chroma and seed color (1, white; 2, rose-white; 3, rose; 4, dark-rose; 5, rose-red; 6, red; 4, very red), in germplasm with different origin. Means with different letters indicate significant differences.

	'Ermioni' selections	Other local germplasm	Foreign cvs.	CV%
Fruit weight	329.6 b	284.4 b	375.2 a	37.3
% Edible portion	61.0 a	56.0 b	59.8 ab	7.1
% Juice/fruit	41.2 a	36.0 b	41.3 a	9.6
% Juice/edible portion	69.8 a	65.2 b	68.3 a	5.4
100-Seed weight	51.2 a	36.3 b	35.6 b	25.8
Soluble solid content	16.9 a	17.2 a	16.3 b	8.8
Titratable acidity	0.3 b	0.6 b	1.1 a	109.7
Maturity index	51.7 a	36.4 b	29.9 c	0.8
Tegmen hardness	1.0 b	2.2 a	2.1 a	
Peel-*L**	55.7 a	57.7 a	50.5 b	20.0
Peel-*a**	37.4 ab	33.8 b	38.6 a	38.1
Peel-*b**	24.1 b	28.8 a	21.1 b	33.7
Peel-Hue	33.9 b	41.7 a	29.2 b	49.7
Peel-Chroma	44.9 b	47.0 a	45.8 ab	15.0
Seed color	4.8	4.8	5.4	

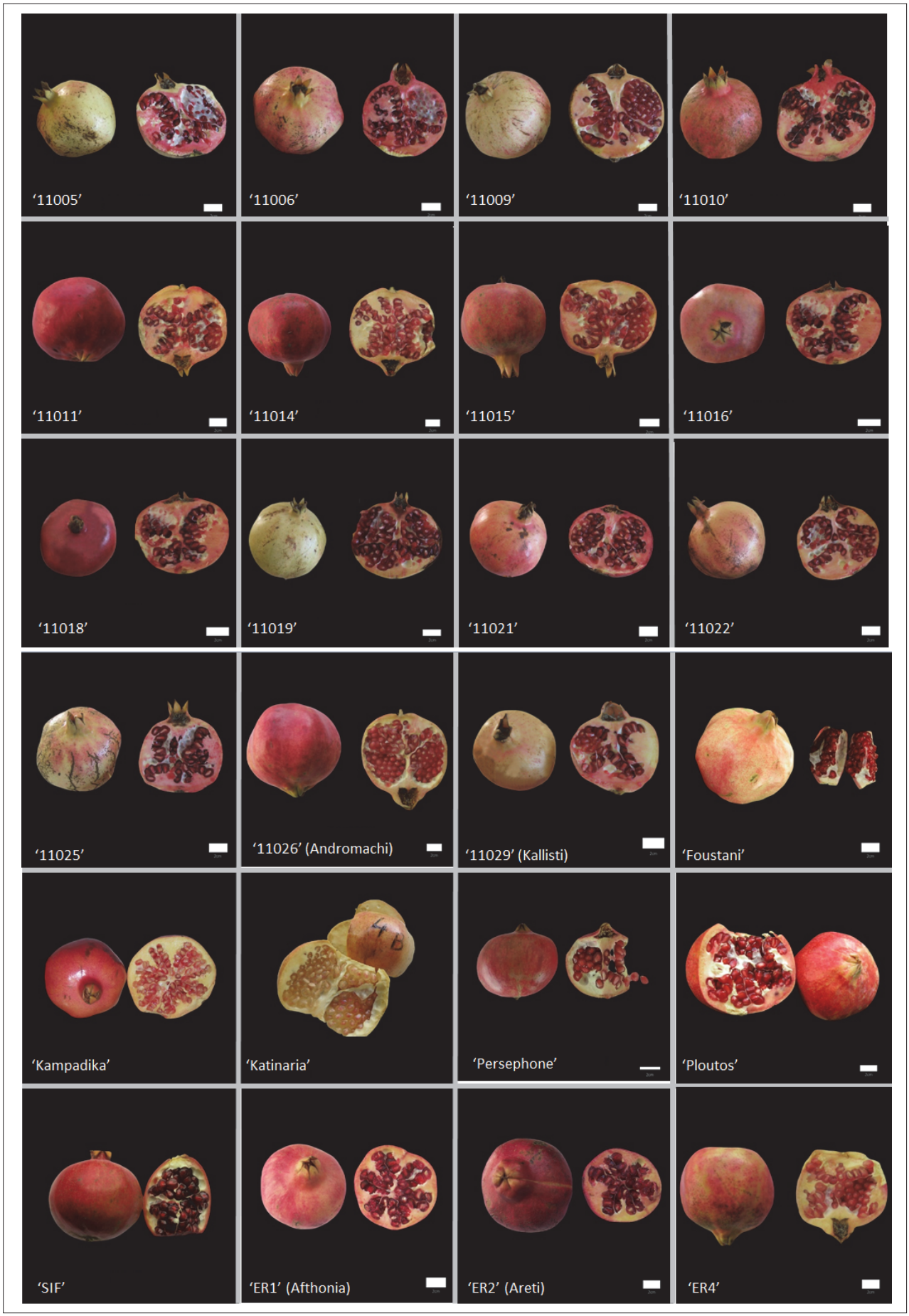


Figure 3. Representative intact and equatorial section of the studied pomegranate cultivars/accessions. The white bars represent two cm.



FIGURE 3. Continued.

ferior fruit quality attributes (lower maturity index and less red peel and seed coloration) and it was separated from the rest as shown in the segregation made based on principal component analysis (Figure 2).

Other local germplasm

There were important differences among the fruit's physical characteristics of the rest of local pomegranate germplasm compared with foreign cultivars, such as having lighter fruit weight, less red and lighter colored peel (lower a^* and high L^*), more pale seed coloration and lower percentage of edible portion, juice/fruit and juice/edible portion compared with foreign cultivars. Nevertheless, SSC and maturity index was higher in the other local germplasm compared with foreign cultivars.

The cultivar 'Foustani' was separated for having high percentage juice per fruit, intense red seed color that makes it appropriate for the juice industry and intermediate tegmen hardness. Moreover it was sweet with pleasant taste that gives an extra value for the fresh market. It is named after the village Foustani where it originates in Pella, northern Greece and has a place in local markets that consumers appreciated its quality. It offers an advantage of high juice content (53.0%) compared with 'Wonderful' having a relatively low percentage of juice/fruit (33.8%).

The cultivar 'Kampadika' was separated for having intense red peel coloration that makes it appealing to the fresh fruit market, but it had inferior internal fruit quality, since the juice had a pale coloration, the fruit had low juiciness and the peel was thick suggested by the low percentage of edible portion (Kyriacou et al., 2020; Drogoudi et al., 2005). 'Kampadika', also named as 'Kolindrou', has a long tradition in the regions of Imathia and Pieria, northern Greece, and locals refer that it originates from northern Epirus/Southern Albania.

The local cultivar 'Katinaria' has a long tradition in the island Rodos. It was separated for many phenotypic characteristics; from the heaviest FW and 100-seed weight and high percentage juice per fruit, but with hard tegment, low sweetness and almost lack of peel and juice coloration, the latter being less marketable characteristics. Finally the accession 'SIF' selected from the island Sifnos and cultivars 'Ploutos' and 'Persephone' recently selected by a grower in Argolida, warrant further investigation because their fruit had high juice content, the seeds were soft and with an appealing red peel and seed coloration, that renders them promising germplasm (Figure 3).

Conclusions

The local accessions studied were phenotypically divergent from commercial foreign pomegranate cultivars and shared phenotypic characteristics of smaller fruit weight, less peel and seed coloration, higher maturity index and softer tegmen. The 'Ermioni' selection 'ER2' (also named as 'Areti') and the local cultivars/ accessions 'Ploutos', 'Persephone', 'Foustani' and 'SIF', were separated with promising marketable phenotypic traits. The local 'Katinaria' isolated in Rodos had district phenotypic traits.

Further investigation of their agronomic and phenotypic stability is required when grown in an *ex situ* collection, since some of the studied traits (color and fruit weight) can be affected by agro-environmental conditions. Moreover, it is important to consider establishing a reference pomegranate

collection with germplasm with district traits across countries and different environmental conditions so that their phenotypic stability under adverse climatic conditions imposed by climate change can be evaluated. Furthermore, since the *ex situ* collection cannot exceed a limited number of accessions, *ex situ*/*in situ* conservation of genetic resources and the role of traditional local growers in the preservation of this primary gene pool would be valuable (Mars, 2000).

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Author contributions

All authors contributed to the study conception, design, laboratory work and data analysis. The first draft of the manuscript was written by PD and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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