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A Comparative Study on the Performance of Eight Pomegranate Cultivars (*Punica granatum* L.) Cultivated in Egypt

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Abstract: This investigation was conducted during 2013 and 2014 seasons on 5-years-old trees of pomegranate (*Punica granatum* L.) cultivars i.e. eight pomegranate cultivars [seven imported cultivars namely: Eversweet, Sweet, Wonderful, Black, Herskovitz (P.G116 and P.G118), Acco and Manfalouty (local cultivar)]. Trees were planted in a private orchard located at 65-km from Cairo-Alex. Desert Road, Egypt to evaluate differences in their morphological criteria, yield, fruit physical and chemical properties and the rooting ability of these cultivars for selecting the most suitable cultivars for planting under similar conditions. The obtained results indicated wide variations in the most important characteristics of the studied cultivars as follow: P.G 116. cleared the longest shoots, highest No. of perfect flowers/tree, fruit set, fruit aril %, juice %, anthocyanin % and the fruit colour skin pink- red, juice colour is white-pink, seeds are hard and sour and is considered early in ripening. Moreover, Wonderful cv. produced the highest No. of fruits/tree, yield, TSS%, total sugars, total vitamin C and fruit skin colour is deep red, red juice colour, seeds are hard and juice sweet taste and is late in ripening. Similarly, Acco cv. gave the highest No. leaves/shoot, fruit shape, anthocyanin%, marketable fruits % and lowest sunburn % and the skin and juice colour are deep red, seeds are softness and very sweet and is considered early in ripening. In addition, Manfaloty cv. have the highest fruit aril%, juice% and skin colour is pink- red, juice colour is deep red purple, seeds are medium to hard and sweet taste. As for the other cultivars, Eversweet and Sweet cvs. fruit skin colour is pink-red, juice colour is white- pink, seeds are softness and juice sweet taste. Moreover, fruit skin colour of P.G118 is pinky, juice colour is red, seeds are hard and juice sweet taste. Meantime, Black cv. showed the highest vitamin C content, lowest tannins % and fruit skin colour is dark purple, juice colour is red, seeds are softness and juice sweet taste and is late in ripening. As for the evaluation of rooting performance of cultivars under study, the comparison among tested cultivars showed variations in the morphological parameters were principally due to differences in cultivars. The highest rooting percentage, roots number and fresh roots weight were obtained by Manfalouty and Wonderful cultivars followed by Black cv. which achieved the highest roots length and number and roots dry/ fresh ratio and Acco cv. share with Wonderful, Manfaloty, P.G 116 and Black cvs. in fresh roots weight.

Key words: Pomegranate · Evaluation · Morphological criteria · Physical and chemical fruit characterizes · Vegetative propagation

INTRODUCTION

Pomegranate (*Punica granatum* L.) belongs to the *Punica* genus of Punicaceae family, derives from the Latin words *pomus* and *granum*, meaning a seeded or a granular apple. Pomegranate is one of the oldest known fruit species and its cultural history dates back to around 3000 BC. [1]. Egypt is one of the early recipients of pomegranate in ancient world; the trees were formed in the tomb of king tut. It is native to Iran, but now is cultivated in semi-arid, mild temperate to subtropical climates and naturally becomes adapted to regions with hot summers and cool winters [2]. The acceptability of the fruits for fresh consumption and depends on a

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combination of several quality attributes relating to their physio-chemical and mechanical properties such as peel colour, free from physical defects, sugar content, acidity and flavor. The edible part of a pomegranate fruit (arils) is mainly consumed directly as a salad or table fruit or used in different industry products such as juices and canned beverages, including alcoholic beverages, jellies and jams and it is also used for the flavoring, coloring of drinks and its medicinal effects lead to its gaining popularity in the world markets [3]. Pomegranate is considered the most important commercial fruit crop that is extensively cultivated in parts of Asia, North Africa, the Mediterranean and Middle East countries, where its trees are particularly adopted to saline, poor soils and resistant to drought conditions [4, 5]. Recent scientific studies demonstrated that, the fruit is a rich source of minerals, vitamins, antioxidants and tannins, while its juice is an excellent source of vitamins (B and C), sugars, minerals (K and Fe), antioxidant and polyphenols (ellagic acid and punicalagin) which lowers blood pressure and prevent both heart attacks and strokes [6]. Propagation by cuttings is one of the most utmost desirable methods of pomegranate which is considered the most convenient and cheap method of obtaining a fully developed stronger tree in considerably less time [7]. However, high genetic variation in root ability among varieties were existing with high interactive effect between varieties, IBA concentration and cutting age. Therefore, selection genotypes with high rooting capacity with vigorous roots are of prime importance for pomegranate commercial seedling production [8]. Although the environmental conditions of Egypt is suitable for pomegranate production, yet exportation considered to be limited compared with other countries, due to low fruit quality that resulting from corruption physiological fruits such as cracked fruit, sun burns, lake of internal coloring and some fungal and pest infestation that effects of the production. Recently, some new cultivars of pomegranate has been imported, which might contribute in the expansion of pomegranate cultivation and increasing the pomegranate production [9].

Hence, the main goal of this investigation is to assess the vegetative growth, flowering, fruiting, yield variability, physical and chemical fruit characteristics as well as the rooting ability of seven imported pomegranate cultivars compared with Manfalouty as the local and most distributed pomegranate cultivar to find out the best cultivars with desirable traits to be cultivated under the conditions of this region.

MATERIALS AND METHODS

This study was under taken during 2013 and 2014 seasons on 5-years-old trees of eight pomegranate (*Punica granatum* L.) cultivars [seven imported cultivars namely: Eversweet, Sweet and Wonderful from USA, Black, Herskovitz, (P.G116 & P.G118) and Acco from Israel compared with Manfalouty cv. from Egypt]. The trees were cultivated in a loamy sand soil under drip irrigation system at a distance of 3 x 4 meters-apart in a private orchard located at Cairo- Alexandria Desert Road (about 68 kilometers distance from Cairo). All cultivars were grown under the same geographical conditions and received the same agricultural practices to compare the different qualitative and quantitative traits of the above named cultivars(I) and studying their rooting ability (II) for selecting the most superior ones suitable for planting in this region. The physical properties of the experimental soil and chemical properties of the irrigation water were determined by Soil, Water and Environmental Research Institute, Agricultural Research Center, according to the methods as described by Jackson [10] and listed in Tables (1) and (2), respectively. The average temperature and humidity during the two studied seasons was recorded as shown in Fig. 1 and 2.

A completely randomized design was accomplished in the two seasons involved the eight cultivars mentioned before, as each cultivar replicated three with three trees for each replicate [11]. The selected trees devoted for this study were vigorous, almost uniform and healthy. Twenty shoots were labeled on each tree under study in different directions to study the following parameters:

Vegetative Growth Parameters: Length of the newly formed shoots (cm) and length & width of the leaf (cm) were measured and the number of the leaves per shoot was counted.

Flowering and fruit set percentage:

- Date of flowering was recorded at the beginning of flowering.
- Total number of flowers per tree was counted at balloon stage and percentage of perfect flowers per tree were calculated.
- The number of perfect flowers which succeeded to set fruits was also counted and labeled and fruit set (%) was calculated according to the following equation:

Fruit set (%) = No. set fruits/total No. flowers x 100.

Table 1: Physical properties of the experimental soil

Parameters	Sand (%)	Silt (%)	Clay (%)	Texture class	Bulk density (gm^{-3})	Real density (gm^{-3})	Total porosity (%)	Field capacity (FC)	Wilting point (WP)	Available water (AW)	Water Holding capacity (WHC)
Soil depth (0-30cm)	84.5	8.50	7.00	Loamy Sand	1.49	2.51	40.6	20.90	9.55	11.4	29.4

Table 2: Chemical properties of the irrigation water

						Soluble cations, ($meq.L^{-1}$)				Soluble anions, ($meq.L^{-1}$)			
Parameters	OM (%)	pH (1:2.5)	ECe, (dSm^{-1})	SAR	ESP (%)	Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	So_4^{-}
Soil depth (0-30cm)	0.98	7.63	3.10	4.42	4.99	9.00	8.00	12.9	1.10	0.00	10.5	18.00	2.50

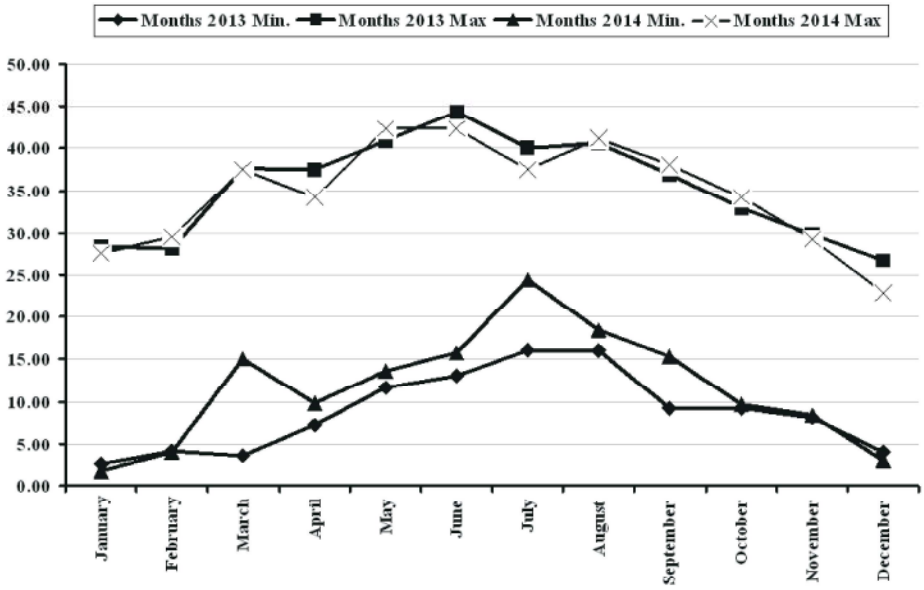

Fig. 1: Maximum and minimum temperature (°C): during 2013 and 2014 seasons

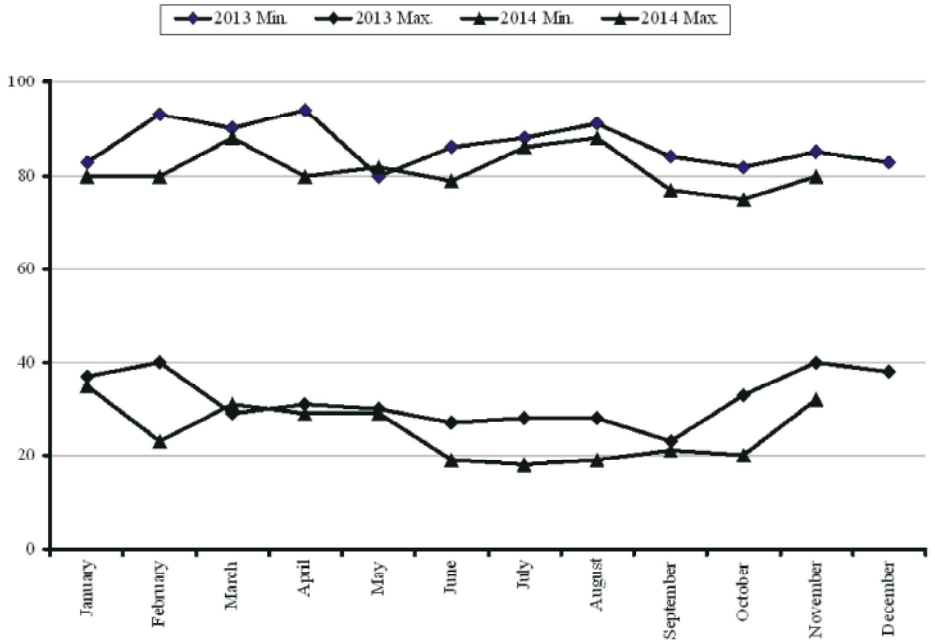

Fig. 2: Maximum and minimum relative humidity during 2013 and 2014 seasons

Fruiting and Yield: Fruit ripening date of each cultivar, total fruit number /tree and average fruit weight (g) were recorded and average total yield/tree were calculated as kg/tree. No. of cracked & sunburned fruits/tree and their percentages of No. of total fruits/tree were calculated. Marketable fruits/tree (%) was also calculated.

Fruit Quality Characteristics: Sample of fruits (n=15) of each treatment was randomly selected for determining the following physical and chemical properties:

Fruit Physical Properties: Fruit length and diameter (cm) were measured, the fruit shape index was estimated by dividing the length by the diameter (L/D) and fruit weight was recorded. Then, selected fruits were peeled by hand, then their rind and capillary membranes (non-edible part) separated and weighted, the aril (edible part) weight/fruit was calculated by the difference between total fruit weight and non-edible part weight . Afterwards, edible & non- edible parts weight/fruit (%) was calculated. Peel thickness (cm) at the equatorial area was measured by a digital caliper with 0.01 mm accuracy.

The peel and juice colour was measured using a CIELAB coordinates (L*, a* and b*) were measured along the equatorial axis of each fruit using a Minolta colorimeter (Model CR-400, Minolta, Japan) after calibration against a white tile background. Five readings of each colour index were taken per fruit colour intensity or saturation. $C^* = (a^*2+b^*2)^{0.5}$ and Hue angle (H or tan b*/a*) were calculated. In this coordinate system, the L* value is a measure of lightness, a* and b*measured colours, (h*) the hue angle and(C*) the colour intensity.

Bio Chemical Composition of Fruit Juice: Total soluble solids percentage (T.S.S. %) was determined by using hand refractometer.

Total titratable acidity (TTA%) was determined according to A.O.A.C. [12].

TSS/acidity ratio: was calculated by dividing of TSS (%) by acidity (%), Total sugars (%) were determined according to the methods described by Dubois *et al*. [13].

Vitamin (C) as (mg) Ascorbic acid/100 ml. was determined according to A.O.A.C. [12].

Total Anthocyanin (mg/100ml) content was determined according to Hsia *et al*. [14].

Total Tannins (%) were assessed in fruit juice by the method explained by Makker *et al.* [15].

Sensory Texture Evaluations: The sensory quality of separated arils was evaluated by acceptance and descriptive tests. The separated arils were extracted from at least five different fruits of each evaluated cultivar and placed in plastic cups, then evaluated by twelve researchers (6 women and 6 men) from Horticulture Research Institute. Each sample was evaluated in triplicate. The panel used two main texture attributes: the sensory hardness and taste according to Murray *et al.* [16].

Vegetative Propagation by Hardwood Cuttings: The second part of investigation aimed to study rooting ability of the evaluated pomegranate cultivars. The details of material used and techniques employed in the present experiment were described as follows:

Experimental Site: The experiment was conducted in the nursery of Horticulture Research Institute, Giza.

Source and Type of Cutting: The hard wood stem cuttings were obtained from mature branches about 0.75-1.00 cm thickness from the evaluated pomegranate trees for preparation of cuttings.

Preparation and Planting of Cuttings: During the dormancy period (February), the hard wood cuttings of uniform size (15-20 cm long) having 3-6 functional buds were prepared from pruning wood. A straight cut was made at the basal end just below the bud and a slanting cut was made at the apical end just above the bud. The cuttings were dipped in the solution of IBA at 2500 ppm for 2 minutes, then planted in polyethylene bags filled with incorporating of sand and peatmos (2:1) under plastic tunnel in greenhouse during rooting [17]. After four months of planting, the cuttings were carefully excavated out of media and rooting percentage, number of roots developed per cutting and the length of longest root/ cutting, root fresh weight (gm), root dry to fresh weight ratio for each cultivar were measured.

Statistical Analysis: Data were then tabulated and subjected to analysis of variance (ANOVA) using the program of SAS [18], which was followed by Duncan's New Multiple Range Test [19] to verify the significance level among the means at 5 % levels.

RESULTS AND DISCUSSION

Vegetative Growth Characters: Data in Table (3) exhibit a marked variation in most measurements of vegetative growth among the different cultivars used in this study. The longest shoots were scored by Manfalouty cv. and P.G116 in both seasons in partnership with Acco cv. in

Table 3: Vegetative growth characters of eight pomegranate cultivars during 2013 and 2014 seasons

	Shoot length (cm)		Leaf length (cm)		Leaf width (cm)		No. of leaves/shoot	
Cultivars	2013	2014	2013	2014	2013	2014	2013	2014
Eversweet	13.97c	17.19fg	4.68b	5.27cd	1.93ab	1.93a	13.37e	16.09d
P.G118	14.86c	18.40ef	5.00b	4.95d	1.72ab	1.80a	15.08de	18.96c
Sweet	14.38c	16.27g	6.64a	6.71a	2.27a	2.18a	10.67f	12.70e
Black	17.33b	20.43cd	4.91b	4. 59d	1.91ab	1.98a	16.00d	18.68c
P.G116	21.00a	23.67ab	5.07b	4.73d	1.58ab	1.58a	18.73c	21.11b
Acco	20.50a	21.95bc	5.24b	5.14cd	1.75ab	1.73a	24.83a	25.85a
Wonderful	15.11c	19.40de	6.63a	6.53ab	1.49b	1.67a	15.65d	19.06c
Manfalouty	21.71a	24.80a	5.34b	5.86bc	1.64ab	1.62a	22.67b	26.00a

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

Table 4: Flowering characters and fruit set of eight pomegranate cultivars during 2013 and 2014 seasons

	No. of total flowers/tree		Perfect flowers (%)		Fruit set (%)	
Cultivars	2013	2014	2013	2014	2013	2014
Eversweet	65.59 e	79.66f	30.24d	31.39c	29.74d	31. 02c
P.G118	51.83 f	58.46g	37.64bc	41.49b	37.23bc	41.00b
Sweet	96.30 c	132.66c	34.94cd	32.67c	34.27cd	32.16c
Black	116.57 b	143.83b	42.47ab	40. 39b	41.63ab	39.77b
P.G116	88.36 d	99.50 e	44.82a	46.90a	43.83a	46.23a
Acco	118.51 b	127.00d	41.18ab	41.28b	40.56ab	40.42b
Wonderful	153.12 a	167.00 a	35.08cd	37.95b	34.44cd	37.13b
Manfalouty	83.40d	95.50e	39.41bc	42.35ab	38.65bc	41.54ab

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

the first season. Meantime, there were a variation was noticed in the No. of leaves/shoot, which was maximum in Acco cv. in the two seasons in partnership with Manfalouty cv. in the second season and minimum by Sweet cv. On the other hand, the variance in the means of leaf length and width (cm) parameters between the tested cvs. was very narrow with non-significant differences in most cases of the two seasons, but the longest leaves were attained in both seasons by Sweet and Wonderful cvs.

The previous variations may be attributed to the variance of genetically characteristics of the cultivars and the interaction of these genetically structures with the agro climatic conditions (altitude, soil fertility, cultural practices and environment), which differ from site to other [6].

Flowering and Fruit Set (%): As showed in the presented data in Table (4) that the eight examined cultivars shown a vast variability in the flowering habits. No. of total flowers/tree ranged from (51.83 and 58.46) in P.G118 cv. to be equal 3 times (153.12 and 167.00) in Wonderful cv., in both seasons. However, the highest perfect flowers and fruit set (%) were shown in P.G. 116 cv. in both seasons. Although the statically appears convergent between Eversweet and other cultivars but it considered the minimal one in the percentage of perfect flowers and fruit set. The appearance of bisexual and functionally male flowers on an individual plant can provide ecological and evolutionary advantages. The ratio of bisexual and male flowers can change with season, plant age, position within the plant and environment [9]. The percentage of flowers that are male in pomegranate can be significant and more than 60% to 70% depending on variety and season [20]. This may be due to the efficiency of adaption with the Egyptian environmental conditions and the diversity of genetically composition of these cultivars [21].

Fruiting, Yield and Fruit Physical Characters: Data in Table (5) demonstrated that, the maximum records of the number of fruits/tree were fulfilled by the Wonderful and Black in two studied seasons in partnership with Acco cv. in the first season. On the other hand, number of fruit /tree reached the minimal values in both seasons by Eversweet and P.G118. Otherwise, the heaviest fruits (g) were attained by Manfaloty cv. (360.92 & 400.47 g) over all the other cultivars. However, Black cv. showed the lights fruits (168.29 & 197.33g) in both seasons. Similarly, the statically analysis observed that Wonderful cv. gave the highest yield/ tree (17.87 & 22.84 kg) in both of the studied seasons respectively. While, Eversweet and

Table 5: Fruit number/tree, fruit weight (gm) and yield (kg) of eight pomegranate cultivars during 2013 and 2014 seasons.

	Fruit number/tree		Fruit weight (gm)		Yield (kg/tree)	
Cultivars	2013	2014	2013	2014	2013	2014
Eversweet	19.51d	24.71e	323.65cd	340.51d	6.31e	8.41d
P.G118	19.29d	23.97e	353.46ab	380.84b	6.82e	9.13d
Sweet	33.00c	42.67cd	337.24b-d	358.63c	11.13c	15.30b
Black	48.53 a	57.58 a	168.29f	197.33f	8.17d	11.36c
P.G116	38.73 b	46.00 bc	320.84d	355.51cd	12.43c	16.35b
Acco	48.07a	51.33b	295.33 e	315.60 e	14.19 b	16.19 b
Wonderful	52.74a	62.00a	338.76bc	368.38bc	17.87a	22.84a
Manfalouty	32.23c	39.67d	360.92a	400.47a	11.63c	15.89b

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

Table 6: Fruit cracking (%), sunburn (%) and marketable fruits (%) of eight pomegranate cultivars during 2013 and 2014 seasons.

	Sunburn (%)		Cracking (%)		Marketable (%)	
Cultivars	2013	2014	2013	2014	2013	2014
Eversweet	9.77 a	9.69 a	--	--	90.13 de	90.21 cd
P.G118	4.31 c	4.17 cd	--	--	95.59 a-c	95.73 ab
Sweet	5.74 b	5.42 bc	--	--	94.16 a-d	94.48a-c
Black	3.68 cd	3.41 de	3.51 a	3.57 a	92.81 b-d	93.02 bc
P.G116	10.15 a	10.07 a	2.75 b	2.53 b	87.13 e	87.4 d
Acco	2.28 e	2.10 e	--	--	97.62 a	97.8 a
Wonderfull	6.42 b	6.86 b	1.83 c	1.62 c	91.75 cd	91.52b-d
Manfalouty	2.73 de	3.15 de	1.03 d	1.17 c	96.24 ab	95.68 ab

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

P.G 118 gave the lowest yield in both seasons, almost these two cultivars have a convergence trend in yielding. The yield factor was attributed to number of fruits/plant and weight of the fruit which various due to genetic makeup of the cultivar. Apart of genetic makeup, environmental factors and age of trees affects the number and weight of the fruits which in turn is responsible for overall yield efficiency [2, 6, 21]. reported that the mean fruit weight of Wonderful and Acco cultivars are 474.2 (g) and 273.6 (g) respectively, in Greece while the fruit weight of Acco in present study is significantly higher and Wonderful was lower. On the other hand, Bartual *et al.* [22] reported that the average fruit of Wonderful cultivar was 324.86 (g) in Spain, which close to the results of present study. As regard to the yield each of Wonderful, Acco and Herskovitz 116 that grown under Syprus region (Turkey) recorded higher yield (31.6, 31.4 and 39.8), respectively than those cultivated under Egyptian condition [21].

As regard to sunburn, cracking and marketable fruits % in (Table, 6), the differences among treatments which were significantly in both studied seasons. Acco and Manfalouty cvs. attained the minimal percentages of sunburn and maximal marketable fruits (%) in both seasons. Whereas, the maximal sunburned fruits (%) and minimal marketable fruits (%) were recorded by Eversweet and P.G 116 cvs. in both seasons. Moreover, the least fruit cracking (%) was attained in both seasons by Eversweet, P.G 118, Sweet and Acco cultivars, whereas, the highest one was scored by cv. Black in the two studied seasons. In relation to fruit cracking in pomegranate, as a serious problem in pomegranate production, many opinions have been propounded. The wide variation of sunburn and cracking may be due to the different genetic make-up, weather conditions during fruit development and the different biological behavior of the cultivars and its inherent capacity to tolerate these two phenomenon's, which at the end affect the percentage of marketable fruits [23]. This may occur due to orchard soil management, in-appropriate levels of water at maturity stage, light, temperature and micro-nutrient deficiency. It may also be caused as a result of hormonal effect. Cracked fruit skin and seed had lower level of auxin. The gibberellins, cytokines and abscisic acid (ABA) levels were higher in skin, seed and aril of cracked fruit [24].

Data presented in Table (7) evident that differences between the means of fruit length (cm) and fruit diameter (cm) traits were narrow among the cultivars employed in the trial, as the most cultivars gave means closely near together with non-significant differences among themselves. However, Black cv. achieved the shortest length and diameter in the two seasons thus; it gave in

Table 7: Fruit length (cm), diameter (cm) and shape (L/D) of eight pomegranate cultivars during 2013 and 2014 seasons

	Fruit length (cm)		Fruit diameter (cm)		Fruit shape (L/D)	
Cultivars	2013	2014	2013	2014	2013	2014
Eversweet	8.44a	8.70a	9.53a	10.17a	0.886bc	0.855b
P.G118	8.32a	8.63a	9.66a	9.98a	0.861c-e	0.865b
Sweet	8.54a	8.40a	9.66a	10.33a	0.884b-d	0.813c
Black	6.17b	6.53b	7.22b	7.67c	0.855de	0.851b
P.G116	8.01a	8.67a	9.64a	10.13a	0.831e	0.856b
Acco	8.39a	8.59a	8.69a	8.80bc	0.965a	0.976a
Wonderful	8.50a	8.47a	9.32a	9.72ab	0.912b	0.871b
Manfalouty	8 58a	8.83a	9.64a	10.15a	0.890bc	0.870b

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

Table 8: Non-edible part (%), edible part (%), juice (%) and peel thickness (cm) of eight pomegranate cultivars during 2013 and 2014 seasons.

	Non-edible part (%)		Edible part (%)		Juice (%)		Peel thickness (cm)	
Cultivars	2013	2014	2013	2014	2013	2014	2013	2014
Eversweet	45.65cd	42.29c	54.35bc	57.71d	33.64cd	33.03cd	0.47ab	0.51a
P.G118	54.32a	51.42a	45.68e	48.58f	30.88e	31.54d	0.70a	0.58a
Sweet	47.25bc	43.07c	52.75cd	56.93d	33.84cd	35.49bc	0.68a	0.59a
Black	49.69b	47.95b	50.31d	52.05e	33.26de	34.40bc	0.47ab	0.55a
P.G116	44.09d	36.58ef	55.91b	63.42ab	38.74b	40.31a	0.58ab	0.53a
Acco	44.23d	39.44d	55.77b	60.56c	36.05c	36.97b	0.42b	0.55a
Wonderful	45.25cd	38.68de	54.75bc	61.32bc	41.59a	42.08a	0.40b	0.53a
Manfalouty	40.05e	35.23f	59.95a	64.77a	40.06ab	41.68a	0.520ab	0.480a

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

general the smallest fruits. The ratio between fruit length and fruit diameter was calculated to determine the differences among the tested cultivars in shape. Acco cv. acquired the highest (L/D) ratio (both seasons). P.G 116 in the first season and sweet in the second season achieved the lowest (L/D). This gain is in line with that of Serhat *et al.* [21] and Zaouay *et al*. [24]. Good fruit quality includes fruit size and shape. There is large variability among cultivars for these traits that may be greatly influenced by agro-environment and harvesting date. Our results were previously confirmed by other researchers [25].

Continuation of the physical properties of the evaluated cultivars during 2013 and 2014 that cleared in Table (8), the least fruit peel (%) was acquired by Manfalouty cv. in both seasons, but the highest one was attained by P.G 118 in both seasons. The opposite was the right regarding fruit arils (%) which was the highest by Manfalouty cv., but decreased to the minimum in P.G 118, this was true in the 1st and 2nd seasons. Moreover, Wonderful and Manfalouty cvs. produced the utmost high records of juice (%) in two studied seasons in partnership with P.G 116 in the second season. Conversely, no differences were observed in the peel thickness (cm) within the evaluated cultivars during the first season and slightly differences in the second season. Similar observations detected by other workers may support the present findings, such as those of Ismail *et al.* [26]; Gawish *et al.* [9] and Chater [27] they reported that, the percentage of edible part in Wonderful, Acco and Herskovitz 116 cultivated in Greece are similar with that cultivated in Egypt, while, that cultivated in Spain was the least one [28]. Moreover, the same cultivars that cultivated under Syprus region gave the highest aril percentage [21].

Colour Dimensional of Peel and Juice: Dimensional of peel and juice colour directly affects the consumer acceptability of pomegranate fruit. The colour values including (L, a, b, chroma and hue angle) were measured using a colorimeter and summarized in Table (9) and Fig. (3). As regard to peel colour, Black cv. exhibited the highest a*, b* C and lowest L*. So, its colour can be described as a dark purple. The highest lightening was observed in Eversweet cv. Moreover, both Sweet and P.G 118 cvs. had the highest huge angle. Regarding the colour juice, it largely varied among the studied cultivars. The colour each of Wonderful and Manfaloty cvs. ranged from bright vivid red to purple, that considered to be a satisfactory colour attributes. Similarly, P.G 116 shares each of Wonderful and Manfaloty cvs. in the a* and C, but had the lowest L*, so its colour can be

Table 9: Peel color dimensional of eight pomegranate cultivars during 2013 and 2014 seasons

	Peel L*		Peel a*		Peel b*		H°		C	
Cultivars	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Eversweet	46.22a	45.61a	8.97d	9.95e	15.84c	15.75bc	60.45 b	57.72 b	18.2 c	18.63 b
P.G 118	36.83bc	38.90b	5.50e	6.51f	15.18cd	14.19d	70.08 a	65.36 a	16.15cd	15.61 b
Sweet	39.84b	35.19bc	5.64e	6.61f	15.51c	14.49cd	70.01 a	65.47 a	16.5 cd	15.93 b
Black	21.88f	22.38e	28.35a	28.87a	24.72a	23.03a	41.08 d	38.58 e	37.61 a	36.93 a
P.G116	31.54de	32.55cd	19.99b	18.97b	11.63e	10.64e	39.53 d	29.29 g	23.13 b	21.75 b
Acco	33.39de	35.82bc	11.16c	12.10d	9.21f	8.22f	39.53 d	34.19 f	14.47 d	14.63 b
Wonderful	28.56e	29.55d	11.15c	10.14c	14.07d	14.06d	51.60 c	54.20 c	17.95 c	17.34 b
Manfalouty	34.60cd	32.87cd	12.37c	13.36c	17.56b	16.55b	54.84 c	51.09 d	21.48 b	21.27 b

Lightness (L*) Redness (a*) Yellowness (b*) Hue angle (H°) Chroma (C)

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

Table 10: Juice color dimensional of eight pomegranate cultivars during 2013 and 2014 seasons

	Juice L*		Juice a*		Juice b*		H°		C	
Cultivars	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
Eversweet	34.55bc	35.57bc	9.25e	10.44e	21.91a	21.04a	67.11 b	63.61 b	23.78 bc	23.49 bc
P.G118	35.91ab	34.33c-e	15.42c	16.60c	14.64b	13.79d	43.51 d	39.71 e	21.26 c	21.58 c
Sweet	32.53cd	32.07ef	5.89f	6.65f	20.67a	20.45ab	74.09 a	71.99 a	21.49 c	21.50 c
Black	30.41d	30.20f	3.57g	3.16g	7.88c	6.99e	65.63 b	65.67 b	8.65 d	7.67 d
P.G 116	30.82d	32.86de	19.94a	18.61a	15.82b	15.79cd	38.43 e	40.31 de	25.45 ab	24.41 a-c
Acco	35.39ab	37.64ab	18.14b	17.36bc	15.81b	16.75b-d	41.07 d	43.98 d	24.12bc	24.12 a-c
Wonderful	35.22ab	35.45b-d	19.66a	18.47ab	18.63ab	18.56a-c	43.46 d	45.14 d	27.08 a	26.18 a
Manfalouty	37 56a	38.77a	13.66	14.80	18.67ab	18.03a-c	53.81 c	50.62 c	23.13 bc	23.33 bc

Lightness (L*) Redness (a*) Yellowness (b*) Hue angle (H°) Chroma (C)

Values have the same letter are not significantly different at 5% level using Duncan's New Multiple Range Test

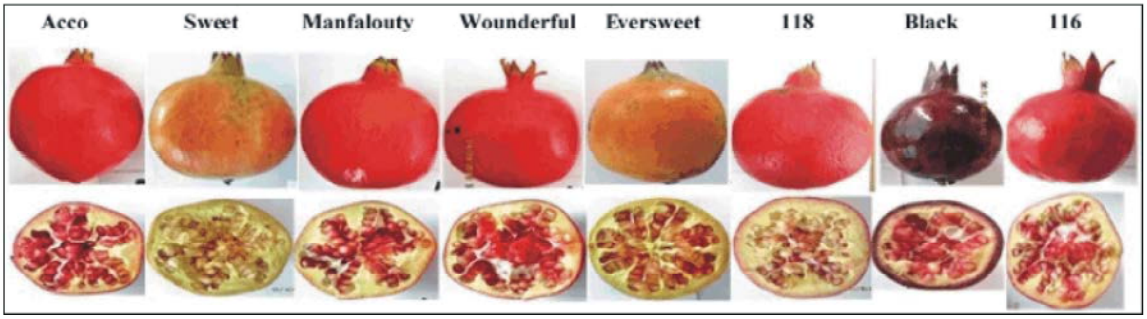

Fig. 3: Fruits of the eight pomegranate cultivars used in this study

described as deep red. Each of Eversweet and Sweet cv. had the highest b*, so its colour ranged from pink to yellowish. The aforementioned results agree with those of Zaouay *et al*. [24], they illustrated that darker juice returns to the higher levels of anthocyanin. Moreover, the findings of many studies showed that, a large diversity in pomegranate colour fruits among cultivars due to genotypes, growing region, climatic conditions, degree of maturity, storage conditions and agricultural practices [9, 22].

Fruit Chemical Properties: The chemical analysis of juice from the different investigated cultivars tabulated in Tables (11 & 12) indicated the existence of significant statistical differences among cultivars for all measured parameters, with few exceptions in both seasons.

As regards to the results in Table (11), Wonderful cv. gave the utmost high records of TSS, acidity and total sugar (%) in the two seasons. In addition, Manfalouty, P.G118 cvs. (both seasons) and P.G116 (1st season) fulfilled high means in the percentages of acidity as Wonderful cv. without significant differences among them. Conversely, the least records of TSS and acidity (%) were found in Acco (both seasons) and Black cvs. (2nd season). These observed differences in total TSS and acidity levels resulted in remarkable differences in juice

Table 11: Fruit juice content (T.S.S (%), acidity (%), total sugar (%) and TSS/ acidity of eight pomegranate cultivars during 2013 and 2014 seasons

	T.S.S (%)		Acidity (%)		TSS/ acidity ratio		Total sugar (%)	
Cultivars	2013	2014	2013	2014	2013	2014	2013	2014
Eversweet	15.47bc	15.60bc	0.52bc	0.49c	29.75b	31.84a	13.17b	12.57b
P.G118	15.70b	16.03bc	1.31a	1.27ab	11.98f	12.62c	13.61ab	13.05ab
Sweet	15.50bc	16.53b	0.46c	0.49c	33.69a	33.73a	13.33b	12.42b
Black	14.75bc	14.33d	0.63b	0.60c	23.41d	23.88b	12.90b	12.30b
P.G116	14.95bc	16.30b	1.20a	1.15b	12.46ef	14.17c	13.53b	12.91ab
Acco	14.60c	15.20cd	0.54bc	0.52c	27.04c	29.23a	13.37b	12.81b
Wonderful	18.23a	17.73a	1.27a	1.33a	14.35e	13.33c	14.59a	13.82a
Manfalouty	15.35bc	15.60bc	1.17a	1.20ab	13.12ef	13.00c	13.19b	12.44b

Values have the same letter are not significantly different at 5% level using Duncan's new Multiple Range Test

Table 12: Fruit juice content of vitamin C, tannins (%) and anthocyanin (%) of eight pomegranate cultivars during 2013 and 2014 seasons

	Vitamin C (mg ascorbic/100ml juice)		Tannins (%)		Anthocyanin (%)	
Cultivars	2013	2014	2013	2014	2013	2014
Eversweet	25.00cd	24.37cd	1.80 b-d	2.23b	24.71c	26.11d
P.G118	24.00d	22.70de	2.40ab	2.66a	31.65b	31.79c
Sweet	23.67d	22.19e	2.23a-c	2.03c	20.46d	22.07e
Black	29.60a	28.75a	1.29d	1.22d	18.08d	19.30f
P.G116	27.17b	26.54b	1.75cd	1.93c	36.30a	37.72a
Acco	20.88e	20.03 f	2.47a	2.25b	34.29ab	35.55ab
Wonderful	26.52bc	25.06bc	1.97a-c	1.85c	33.54ab	34.12bc
Manfalouty	24.33d	23.61c-e	2.13 a-c	2.34b	33.33ab	33.60bc

Values have the same letter are not significantly different at 5% level using Duncan's new Multiple Range Test

TSS/acidity ratio. Furthermore, the observed differences were primary governed by the differences in acidity levels rather than the TSS levels. TSS/acidity ratio reached maximum in juice of Sweet cv. over all the other cultivars in the 1st season and 2nd seasons in partnership with Eversweet and Acco cvs. in the 2nd season. The minimum ratios, however, acquired by P.G118, P.G 116, Wonderful and Manfalouty cvs. in both seasons. As shown in Table (12), Black cv. fruit juice was the richest in V.C. content, while the least content was found in Acco cv. Given the concentration of tannins in the juice, there was a convergence among cultivars in the first season, while P.G 118 scored the highest concentration of tannins in the second season.

Anthocyanin in fruit juice reached at the maximum in P.G 116 followed by Acco, Wonderful and Manfalouty cvs. In this concern, juice content of Acco cultivar under Egypt condition is lower than the same cultivar grown in Greece (37.9 %) and Syrups region (40.15%). While Wonderful and Herskovitz 116 that grown under Egypt condition superior to the same cultivars under Syrups region (35.59 & 29.40 %), respectively [22, 28, 29]. Furthermore, TSS of the same cultivars under Egypt condition less than in Greece, Spain and Turkey [27, 30].

Vegetative Propagation of the Evaluated Pomegranate Cultivars by Hardwood Cuttings: According to Table (13) the perusal of data showed significant differences among the produced transplants by hardwood cuttings of the evaluated cultivars. Cuttings of Manfaloty cv. achieved the highest rooting percent, roots number and fresh weight. Moreover, cuttings of Black cv. showed the highest roots length and number, fresh roots weight and root dry to fresh ratio. Additionally, cuttings of Wonderful cvs. produced the highest roots number and fresh roots weight. Similarly, Acco cv. share with Wonderful, Manfaloty, P.G 116 and Black cvs. in fresh roots weight. On the other hand, Black cv. achieved the lowest rooting percent, Manfaloty and Wonderful cvs. recorded the lowest root length. While, the lowest root number was obtained by P.G. 118 cv., whereas Sweet and P.G118 cv. achieved the least dry to fresh ratio. The factors causing one pomegranate cultivar to be more successful at rooting than another have not been confirmed. Some conducted to the type of cutting and method of planting and others suggested that, Auxins were effective in root formation and root elongation by increasing the volume associated with callus and adventitious root [7, 17, 31, 32]. Moreover, high genetic variation in rooting ability may be relatively to high carbohydrate content which associated with easy rooting of cutting and considered as an important factor that determines the variability in rooting capacity among genotypes [8, 33, 34].

Table 13: Comparison between cuttings characteristics of the evaluated pomegranate cultivars

Cultivars	Rooting (%)	Roots length (cm)	Roots numbers	Fresh roots weight (gm)	Roots dry to fresh weight ratio
Eversweet	51.41 g	7.36c	4.64 cd	3.11bc	80.67 d
P.G 118	59.22 f	6.54c	3.75 d	2.48c	75.16 e
Sweet	71. 05 e	10.38 b	5.23 c	2.77 c	72.00f
Black	31.76 h	12.83a	8.27 ab	3.78a-c	90.15a
P.G 116	75.00 d	9.23 b	7.39 b	4.57ab	84.45 b
Acco	78.28 c	10.19b	7.52 b	4.55ab	82.23 cd
Wonderful	80.30 b	3.52d	8.56 ab	5.00 a	75.96 e
Manfaloty	84.33 a	4.69 d	9.57 a	5.12a	83.70bc

Values have the same letter are not significantly different at 5% level using Duncan's new Multiple Range Test

Fig. 4: Transplants of Pomegranate from hard stem cuttings after one year of propagation

Table 14: Some important characteristics of the eight pomegranate cultivars evaluated in the present study under Egypt conditions

	Fruit characteristics							
Cultivars	Skin colour	Juice colour	Flavor	Seed taste	Seed hardness	Flowering date	Ripening date	Rooting ability
Eversweet	Pink- red	White-pink	Sweet	Sweet	Soft	Mid-April	Mid-October	Medium
P.C118	Pinky	Red	Sour sweet	Sweet	Hard	Mid-April	Mid-October	Medium
Sweet	Yellowish	White-pink	Sweet	Sweet	Soft	Mid-April	Mid-September	Easy
Black	Dark purple	Red	Sweet	Sweet	Soft	Mid-April	Late-October	Difficult
P.G 116	Pink-red	Deep red	Sour sweet	Sour	Hard	Early-April	Mid-August	Easy
Acco	Deep-red	Deep red	Sweet	Very sweet	Soft	Mid-March	Early-August	Easy
Wonderful	Deep-red	Red	Sour sweet	Sweet	Hard	Early-April	late-October	Easy
Manfalouty	Pink-red	Deep Red - purple	Sour sweet	Sweet	Medium to hard	late-March	late-September	Easy

A number of characteristics of pomegranate cultivars are the key to identification, consumer preference and preferred uses in marketing.

By studying the flowering and ripening dates (early and late), sensory evaluation taste (sweet, sour and bitter) and seed hardness (hard, medium and soft), flavor preference according to each of acidity and TSS acidity (sweet, sour sweet and sour), coloring parameters of fruit skin and juice and rooting ability of these cultivars that presented in (Table 14), we can conclude some important traits, which distinguish each cultivate and consider the categories can be characterize these cultivars.

CONCLUSION

Results of the present study showed considerable variation in the morphological and chemical characteristics of eight pomegranate cultivars grown under Egypt conditions. Although P.G 116 showed a good performance, but not having good local marketing potential because of the sour taste, thus the Wonderful cultivar, with its sweet-tart taste and high yield, seems to be the best cultivar for fresh consumption. Acco cv. follows Wonderful cv. which is characterized by, skin and aril deep red colour and juice sweet taste. The other cultivars performances is poor with low pomological characteristics, but have some good traits which can be uses in breeding programs to improve the characteristics of fruits and increase the yield. It is also worthy to mention that, Acco and P.G 116. are considered the earliest cvs., whilst Black and Wonderful are the latest cvs.

Manfalouty is the most important pomegranate local cultivar, which has good appearance and taste for fresh fruit marketing and can be considered as a strong competitor to the Wonderful pomegranate cv.

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