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Performance of Manfalouty and Wonderful Pomegranate Cultivars under Four Egyptian Climate Regions

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Abstract: In the last decade, the area of pomegranate planted in Egypt has expanded. Difference in the average and daily temperature during maturity and harvest period had significant effects on productivity and quality of pomegranate. So it was necessary to investigate the effect of climate regions on productivity and fruit quality of different pomegranate cultivars. This experiment was carried out during two seasons of 2017/2018 and 2018/2019 at four different geographical locations in Egypt: Ismailia governorate; Giza governorate; Al-Minya governorate and Sohag governorate on 8 years old pomegranate trees. Climate data in different geographical locations under study, fruiting, yield (kg/tree) and fruit quality properties were assessed. The results showed that, physical fruit properties was affected by the different pomegranate cultivars and geographical locations, Wonderful pomegranate cultivar cultivated in Ismailia achieves the highest values of average fruits weight, volume and fruits edible part % in most cases. While the chemical properties of the fruits were different, the pomegranate cultivated at Giza gives the highest values of (total sugar (%), non-reducing sugar, vitamin (C) mg/100g and TSS (%). The pomegranate cultivated at Ismailia gives the highest values of (reducing sugar (%), acidity (%) and TSS/acidity ratio). Finally, it is advisable to plant Wonderful pomegranate cv. in Ismailia region for better physical properties and to obtain higher productivity with the appropriateness of the fruits obtained for fresh consumption. While, the southern regions were more suitable for cultivating different cultivars of pomegranate

Key words: Pomegranate · Manfalouty · Wonderful · Geographic and climate regions · Productivity and Quality

INTRODUCTION

Pomegranate (*Punica granatum* L.) is one of the family Punicaceae plants and is mainly belongs to semi-arid mild-temperate to subtropical climates, which consist of only one genus and two species. It is an important economic fruit and one of the oldest edible fruit tree species. It has a wide geographic distribution additionally high ability to adaptation in diverse environmental situation [1]. Pomegranate orchards are now grown in many regions of the world, particularly in the Mediterranean Basin, where high quality fruits are obtained [2, 3]. Pomegranate is considered one of the important deciduous and favorable fruit crops in Egypt, Manfalouty (native cv.) and Wonderful (imported cv.) are considered the most important pomegranate cultivars grown successfully in Egypt [4]. It has been cultivated for its economic, ornamental and medicinal properties. Globally, pomegranate fruits are rather eaten fresh or used as syrup [5].

The quality of pomegranate fruits is strongly depends on the cultivar, growing region, climate, various maturity levels and cultural practice are the main factors determining chemical composition of pomegranate fruits and effects on colour and anthocyanin accumulation [6-9]. The pomegranate juice colour is a significant index for juice quality; it is originally related to anthocyanin concentration.

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Anthocyanin accumulation in plants is sensitive to environmental conditions and changed inversely to the season's temperatures, the findings can benefit breeding and agricultural efforts to enhance pomegranate quality, especially in the face of "global warming" [10, 11]. Low temperatures enhance anthocyanin accumulation, whereas at high temperatures the pigment concentration is reduced [12, 13].

The abundance of total flavonoid concentration, tannin, reducing sugar and anthocyanin pigments of pomegranate juice compounds and their activities are related to cultivar definite, climate and growing region [14-16]. They were also correlated with latitude, altitude and longitude of growing regions. Additionally, difference in the average temperature and daily temperature during maturity and harvest period had significant effects on the total polyphenols, flavonoids and anthocyanin concentration of pomegranate [17, 18]. Accumulation of nutrients, such as sugar and acid, polyphenol, anthocyanin and vitamin C influenced by different varieties and environmental conditions [19-21].

Meanwhile, different growth regions, cultivar and cultivation approaches are also considered the important factors that affect the accumulation of these metabolites in plant [22, 19].

Therefore, the present study aimed to investigate the effect of different growing region on most important pomegranate cultivars (Manfalouty and Wonderful cvs.) in Egypt.

MATERIALS AND METHODS

This experiment was carried out during two successive seasons of 2018 and 2019 at four different geographical locations in Egypt (private farms): 1) Ismailia governorate; (30°32'03.0"N 31°57'37.8"E), 2) Giza governorate; (30°16'05.6"N 30°48'23.5"E), 3) Al-Minya governorate; (28°10'11.5"N 30°30'53.1"E) and 4) Sohag governorate; (26°38'01.8"N 31°39'09.1"E).

Plant Materials: The pomegranate trees (Manfalouty and Wonderful cvs.) 8 years old, distributed in different climatic regions in Egypt. The experimental trees were planted at 5x4 meters apart (210 trees/fed) in sandy soil under drip irrigation system. Four pomegranate trees for each cultivar/region were selected and devoted for this work during the two studied seasons. These trees were nearly similar in their growth vigor, size, shape and diseases-free. The same regular agricultural managements were applied to all experimental trees as recommended by the Ministry of Agriculture as possible.

Climatic Conditions: The climate is a major factor in this study, the following data were recorded for both seasons (2018 and 2019) and analyzed by Central Laboratory of Agricultural Climate CLAC - Agriculture Research Center, Giza, Egypt. Table 1 showed: Average air temperatures, maximum and minimum temperatures, relative humidity and precipitation amount (mm), of four agro meteorological stations (Ismailia, Giza, Al-Minya and Sohag).

Plant Measurements

Fruiting and Yield: Full bloom date, fruit set date and harvesting date of Pomegranate cultivars were recorded under different geographical locations. At harvest, the fruits of all treated trees were picked on the second half of September (Manfalouty) and first week of October (Wonderful) in the two seasons. Fruits per tree were counted and weighted to estimate the total number of fruits and yield/tree (kg) was calculated [3]. Marketable fruits (%): Number of healthy fruits without any cracked and sunburned or even diseases injury were counted and their percentages of No. of total fruits per tree were calculated

Fruit physical properties: Sample of fruits per tree (n=10) replication were collected randomly and directly transported to the laboratory for determining the physical properties (fruit length and diameter "cm", fruit shape index by dividing length by diameter (L/D), fruit weight "g" and fruit volume "cm^3") were recorded. In order to determine peel and aril weight percentage, fruits were manually peeled then, separately, their rind and capillary membranes (non-edible part) and weighted, thus calculated the aril (edible part) weight/fruit by the difference between total fruit and non-edible part weights. Then edible and non-edible parts weight /fruit weight percentage were calculated.

Bio Chemical Composition of Fruit Juice:

- Total sugars (%): It was determined in juice according to the method of Lane and Eynon as described in the A.O.A.C. [23].
- Reducing sugar (%) in Juice: was estimated, according to A.O.A.C. [23].
- Non-reducing sugar was obtained by subtracting reducing sugars from the total sugars.
- Total anthocyanin content of aril and peel (%): It was estimated according to the methods described by Geza *et al.* [24].
- Total Tannins content (%): It was determined by using the method of A.O.A.C. [23].

Table 1: The climate data* in different geographical locations under study

	2018					2019				
					Ismailia					
	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Humidity (%)	Precipitation amount (mm)	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Humidity (%)	Precipitation amount (mm)
March	20.3	27.0	13.6	40.0	0.51	16.6	22.0	11.3	50.3	7.11
April	22.3	28.80	15.9	42.1	10.1	19.9	26.1	13.8	44.0	0.00
May	27.2	33.50	20.9	38.2	0.00	26.1	33.4	18.9	33.1	0.00
June	28.3	34.7	22.0	41.0	0.00	28.5	34.9	22.1	44.6	0.00
July	29.7	35.8	23.7	46.9	11.0	29.5	35.8	23.3	48.1	0.00
August	29.4	35.1	23.8	51.9	0.00	29.8	35.8	23.8	50.4	0.00
September	28.2	33.9	22.6	52.3	0.00	27.7	33.1	22.3	50.5	0.00
October	24.3	30.3	18.4	51.4	0.00	25.1	31.0	19.3	53.4	0.00
Giza										
March	22.0	28.2	15.8	41.9	3.05	17.8	22.7	12.9	52.5	6.10
April	23.4	29.1	17.8	45.4	7.12	21.1	26.8	15.4	45.2	0.76
May	28.2	34.2	22.3	43.3	0.00	27.6	34.7	20.6	34.9	0.00
June	29.9	35.6	24.3	45.4	0.00	29.9	35.6	24.2	47.1	0.00
July	30.7	36.0	25.4	52.9	0.00	30.6	36.0	25.2	50.3	0.00
August	30.5	35.6	25.4	56.0	0.00	30.8	36.1	25.6	51.4	0.00
September	29.4	34.2	24.6	54.7	0.00	28.5	33.3	23.7	56.2	0.00
October	25.8	30.4	21.2	52.6	0.51	26.2	30.9	21.6	57.2	0.25
Al-Minya										
March	20.9	28.9	13.0	44.0	0.00	17.0	24.1	10.0	48.2	0.00
April	24.3	32.1	16.6	35.6	0.00	21.4	28.7	14.1	40.5	0.00
May	29.6	37.2	22.0	32.7	0.00	28.3	37.0	19.7	29.2	0.00
June	30.0	37.2	22.8	36.6	0.00	30.8	37.9	23.8	35.9	0.00
July	30.4	37.2	23.7	43.7	0.00	30.4	37.0	23.9	39.5	0.00
August	30.8	37.0	24.6	44.5	0.00	30.8	37.3	24.3	40.6	0.00
September	29.1	34.9	23.3	46.4	0.00	28.5	34.5	22.6	47.0	0.00
October	24.7	30.8	18.6	51.6	0.00	25.6	32.3	19.0	50.9	2.03
Sohag										
March	25.1	34.0	16.2	29.0	0.00	19.8	27.5	12.1	36.7	0.00
April	27.0	35.2	18.8	29.6	19.8	24.9	32.9	17.0	29.7	0.00
May	32.6	40.2	25.0	27.3	4.06	32.1	40.9	23.3	23.4	0.00
June	33.9	41.5	26.4	27.6	0.00	34.4	42.0	26.9	28.5	0.00
July	33.8	40.9	26.7	30.3	0.00	34.2	41.8	26.7	28.7	0.00
August	34.0	41.1	27.0	34.5	0.00	33.8	41.2	26.4	30.5	1.02
September	32.7	39.8	25.6	37.6	0.00	31.7	39.0	24.5	38.6	0.00
October	28.30	35.60	21.00	39.10	4.06	28.80	35.70	21.80	39.30	1.02

*According to Central Laboratory of Agricultural Climate

- Vitamin C: (as "mg" ascorbic acid/100 ml juice) it was determined by titration in presence of 2.6 dichlorobhenol-indophenol blue dye as indicator against 2% oxalic acid solution as substrate according to A.O.A.C. [23].
- Total Soluble Solids: (TSS %) of fruit juice was determined using an Atago N-20 refractometer at 20°C.
- Total Acidity (%): was determined using titration by NaOH 0.1 N and Phenolphthalein as an indicator then, expressed as citric acid, according to A.O.A.C. [23] and then, TSS/Acidity ratio was calculated.
- Total Flavonoids: It was determined as described by Abu Bakar *et al.* [25].
- Total Phenolic contents: It was conducted according to the modified Folin– Ciocalteu colorimetric method according to Zhou and Yu [26] and Kubola and Siriamornpun, [27]. Results were expressed as g gallic acid /100 g FW.
- Total antioxidant activities (%DPPHsc): The antioxidant activity was evaluated by 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging method according to the procedure of Chen *et al.* [28].

Statistical Analysis Procedures: Experimental plots were arranged in a split-plot design with three replicates. The main plots represent for the cultivars (Manfalouty and Wonderful). The sub-plots were geographical locations (Giza, Ismailia, Al-Minya and Sohag governorates). There were eight treatments each treatment was represented by three replicates (one tree/each) as a total of twenty-four trees. The statistical analysis was conducted according to Sendecor and Cochran [29], by using M Stat C program, [30]. Significant differences among the means of various treatments were compared by new L.S.D. at 5% probability.

RESULTS AND DISCUSSION

Fruiting and Yield: Results in Table (2) disclose that, Manfalouty pomegranate cultivar had significantly the highest number of fruits/tree (122.67 and 111.67) in both seasons and highest fruit yield (55.42 kg) in the first season compared to Wonderful cultivar. Similar results were also reported by Khattab *et al.* [31] showed that, the number of Manfalouty pomegranate fruits/tree differ among different treatments between (88.67-135.30) fruits/tree and (81.00-126.7) in two seasons of study. The variation in fruit production was because of genetic behaviour of varieties.

On the other hand, number of fruits/tree and fruit yield of pomegranate differed among the climatic regions. The highest number of fruits (125.33 and 128.33) and fruit yield (52.23 and 42.69 kg) were obtained from Giza region in both seasons.

Regarding to the interaction effect of cultivars and geographical locations, pomegranate cv. Manfalouty cultivated in Sohag induced statistically highest number of fruits/tree (129.67) and fruit yield (55.42 kg) in 1st season. Moreover, in the second season, pomegranate cv. Wonderful cultivated in Giza revealed significant higher number of fruits/tree (141.67) and fruit yield (45.11 kg). The range of number of fruits/tree of pomegranate is near to those obtained by Abd El-all and Fouad [32] for Manfalouty cultivar grown in Sohag (120.67 and 177.67 fruits/tree).

Marketable and Non-Marketable Fruits (%): According to the presented data in Table (3), geographic locations caused significant differences in marketable fruits % of pomegranate trees. In this respect, the highest values have been displayed when the trees were cultivated in Ismailia (90.00 and 86.00%) in both seasons, respectively. On the other hand, the lowest values were recorded in Giza and Sohag governorate. The reverse was noticed for non-marketable %, when Ismailia produced the least value of non-marketable fruits (10.00, 14.00 %), while the highest values (13.50 and 13.67%) and (17.50 and 17.67%) were produced in in Giza and Sohag governorate.

The tested varieties showed a significant differences regarding marketable and non-marketable fruits % of pomegranate in both seasons, the Wonderful cv. achieved the highest marketable fruit (87.92 and 83.92 %) and least non-marketable fruits % (12.08 and 16.08 %) in both seasons.

Regarding the interaction effect Manfalouty cv. planted in Giza and Wonderful planted in Sohag showed the least % of marketable fruits and highest % of non-marketable fruits of pomegranate in both seasons. Meanwhile, Wonderful cv. cultivated in Ismailia achieved the highest % of marketable fruits (95.00 and 91.00 %) and least % of non-marketable fruits (5.00 and 9.00 %), in both seasons.

Pomegranate fruits are sensitive to sunburn because they are carried at the end of the branches. Pomegranate trees are distinguished by their small size of leaves. This results in the fruits being exposed to the sun for long periods, causing sunburn. In addition, Fruit cracking is influenced by many factors which include fluctuation in soil moisture regimes, climate, tree nutrition and cultivars has also reported by Hegazi *et al.* [33].

Physical Properties

Fruit Dimensions: Table (4) revealed significant differences between Wonderful and Manfalouty regarding fruit length. Wonderful fruits gave the highest values in both seasons. The tested cultivars failed to show any significant differences between them regarding fruit diameter and fruit shape index (1st season), but in the second season Manfalouty fruits displayed higher values in fruit diameter. Wonderful fruits give highest value in fruit shape index. Faten *et al.* [34] showed that, Wonderful fruits had the highest length and diameter compared to other pomegranate cultivars grown in Egypt.

As for, the effect of different locations were statistically significant in the two seasons. The least fruit length (9.52 and 8.80 cm) and fruit diameter (8.71 and 8.15 cm) resulted from Ismailia in the first and second season, respectively. Al-Minya and Sohag produced the highest values of fruit length (10.32 and 9.99 cm) and (10.42 and 10.18 cm), fruit diameter (9.60 and 9.48 cm) and (9.65 and 9.75 cm) in the first and second seasons, respectively. Meanwhile, the pomegranate trees cultivated in Ismailia achieved the highest values (1.09 and 1.15) of fruit shape index, in both seasons.

Table 2: Effect of pomegranate cultivars and geographic locations on number of fruits/tree and fruit yield (kg/tree) during 2018 and 2019 seasons

	Number fruits/tree			Fruit yield (kg/tree)		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
			2018			
Ismailia	123.00^{c}	108.33^{e}	115.67^{B}	42.85^{e}	53.85^{b}	48.35^{B}
Giza	124.00^{bc}	126.67^{ab}	125.33^{A}	54.17^{b}	50.29^{d}	52.23^{A}
Al-Minya	114.00^{d}	115.00^{d}	114.50^{B}	42.32^{e}	52.17^{c}	47.24^{C}
Sohag	129.67^{a}	95.00^{f}	112.33^{C}	55.42^{a}	35.39^{f}	45.40^{D}
Mean	122.67^{A}	111.25^{B}		48.69^{A}	47.92^{B}	
			2019			
Ismailia	97.67^{e}	70.67^{g}	84.17^{D}	32.21^{e}	43.87^{b}	38.04^{C}
Giza	115.0^{d}	141.67^{a}	128.33^{A}	40.27^{c}	45.11^{a}	42.69^{A}
Al-Minya	113.33^{d}	86.33^{f}	99.83^{C}	40.05^{c}	39.92^{c}	39.98^{B}
Sohag	120.67^{c}	128.33^{b}	124.50^{B}	38.27^{d}	32.70^{e}	35.49^{D}
Mean	111.67^{A}	106.75^{B}		37.70^{B}	40.40^{A}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

Table 3: Effect of pomegranate cultivars and geographic locations on marketable and non-marketable fruits during 2018 and 2019 seasons:

	Marketable fruits			Non Marketable fruits		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
			2018			
Ismailia	85.00^{d}	95.00^{a}	90.00^{A}	15.00^{b}	5.00^{e}	10.00^{C}
Giza	81.33^{e}	91.67^{b}	86.50^{C}	18.67^{a}	8.33^{d}	13.50^{A}
Al-Minya	90.33^{c}	84.33^{d}	87.33^{B}	9.67^{c}	15.67^{b}	12.67^{B}
Sohag	92.00^{b}	80.67^{e}	86.33^{C}	8.00^{d}	19.33^{a}	13.67^{A}
Mean	87.17^{B}	87.92^{A}		12.84^{A}	12.08^{B}	
			2019			
Ismailia	81.00^{d}	91.00^{a}	86.00^{A}	19.00^{b}	9.00^{e}	14.00^{C}
Giza	77.33^{e}	87.67^{b}	82.50^{C}	22.67^{a}	12.33^{d}	17.50^{A}
Al-Minya	86.33^{c}	80.33^{d}	83.33^{B}	13.67^{c}	19.67^{b}	16.67^{B}
Sohag	88.00^{b}	76.67^{e}	82.33^{C}	12.00^{d}	23.33^{a}	17.67^{A}
Mean	83.17^{B}	83.92^{A}		16.84^{A}	16.08^{B}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

The interaction between pomegranate cultivars and geographic locations was significant. It could be noticed the most consistent trend for fruit length recorded by Wonderful cultivated in Al-Minya (10.77 and 11.63 cm) and for fruit diameter achieved by Manfalouty in Sohag (9.83 and 10.00 cm). Finally, the pomegranate Manfalouty cv. trees cultivated in Ismailia and Wonderful cv. cultivated in Al-Minya gives the highest fruit shape index in both seasons. Shulman *et al.* [35] showed that these differences between the fruits of different pomegranate cultivars can be attributed to the effect of differences of cultivars and environmental conditions. Kahramanoglu *et al.* [36] indicated that, number of the pomegranate fruits/tree effect on the average fruit sizes. This is due to fruits competing with each other for carbohydrates and thus reducing the size of the fruits. Climate date showed that the different between 1st and 2nd season in temperature that in Giza in average temp. (March and April), (4.5 and 2.2), respectively and also increase the difference between night and day temperature from (7.7 to 8.7).

Fruit Weight and Volume: Data in Table (5) showed that, Wonderful trees produced the maximum fruit weight (431.0 and 414.0 g) and fruit volume (441.0 and 420.4 cm^{3}) in the two tested seasons. Abou El-Wafa [37] mentioned that, the average weight of Wonderful fruits varies between (400.1 and 450 g).

Concerning the effect of geographic locations, fruit weight values ranged from 399 and 288g (Sohag) to reach 423 and 473g (Ismailia). As for fruit volume the records increased (429.2 and 473.3 cm^{3}) with Ismailia while it decreased to (406.7 and 290.8 cm^{3}) with Sohag, This was true in both studied seasons, respectively.

Table 4: Effect of pomegranate cultivars and geographic locations on fruit length, diameter (cm) and fruit shape index during 2018 and 2019 seasons:

	Fruit length (cm)			Fruit diameter (cm)			Fruit shape index (L/D)		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
					2018				
Ismailia	8.70^{c}	10.33^{ab}	9.52^{B}	8.09^{d}	9.33^{bc}	8.71^{C}	1.07^{ab}	1.11^{a}	1.09^{A}
Giza	10.67^{a}	9.83^{b}	10.25^{A}	9.60^{ab}	9.00^{c}	9.30^{B}	1.11^{a}	1.09^{a}	1.10^{A}
Al-Minya	9.87^{b}	10.77^{a}	10.32^{A}	9.57^{ab}	9.73^{ab}	9.65^{A}	1.03^{bc}	1.11^{a}	1.07^{A}
Sohag	9.98^{b}	10.00^{b}	9.99^{A}	9.83^{a}	9.67^{ab}	9.75^{A}	1.01^{c}	1.03^{bc}	1.02^{B}
Mean	9.80^{B}	10.23^{A}		9.27^{A}	9.43^{A}		1.06^{A}	1.08^{A}	
					2019				
Ismailia	8.70^{f}	8.90^{ef}	8.80^{C}	7.80^{e}	8.50^{d}	8.15^{C}	1.13^{a}	1.17^{a}	1.15^{A}
Giza	9.83^{c}	9.57^{cd}	9.70^{B}	9.40^{b}	8.27^{d}	8.83^{B}	1.08^{b}	1.00^{b}	1.01^{C}
Al-Minya	9.20^{de}	11.63^{a}	10.42^{A}	9.53^{b}	9.67^{b}	9.60^{A}	1.02^{b}	1.16^{a}	1.09^{B}
Sohag	9.33^{de}	11.03^{b}	10.18^{A}	10.00^{a}	8.97^{c}	9.48^{A}	1.02^{b}	1.14^{a}	1.08^{B}
Mean	9.27^{B}	10.28^{A}		9.18^{A}	8.85^{B}		1.05^{B}	1.12^{A}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

Table 5: Effect of pomegranate cultivars and geographic locations on fruit weight (g) and volume (cm^3) during 2018 and 2019 seasons:

	Fruit weight (g)			Fruit volume (cm^3)		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
			2018			
Ismailia	348.1^{g}	498.0^{a}	423.1^{A}	351.7^{g}	506.7^{a}	429.2^{A}
Giza	436.7^{c}	397.0^{e}	416.8^{B}	425.0^{d}	417.3^{e}	421.2^{B}
Al-Minya	371.0^{f}	456.7^{b}	413.8^{B}	348.3^{g}	470.0^{b}	409.2^{C}
Sohag	427.0^{d}	372.3^{f}	399.7^{C}	443.3^{c}	370.0^{f}	406.7^{C}
Mean	395.7^{B}	431.0^{A}		392.1^{B}	441.0^{A}	
			2019			
Ismailia	330.0^{d}	616.7^{a}	473.3^{A}	330.0^{e}	616.7^{a}	473.3^{A}
Giza	350.0^{c}	318.3^{e}	334.2^{C}	355.0^{d}	321.7^{f}	338.3^{C}
Al-Minya	353.3^{c}	461.7^{b}	407.5^{B}	365.0^{c}	476.7^{b}	420.8^{B}
Sohag	317.1^{e}	259.2^{f}	288.2^{D}	315.0^{g}	266.7^{h}	290.8^{D}
Mean	337.6^{B}	414.0^{A}		341.3^{B}	420.4^{A}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

This difference between different locations may be due to the humidity levels during fruit growing season which play a main role in the transpiration process.

As for the combined effect of pomegranate cultivars and geographic locations, the highest values of fruit weight and fruit volume were recorded in Wonderful cultivated in Ismailia location.

Fruit Aril, Peel Weight and Aril /Fruit Weight: Data presented in Table (6) revealed that, aril (edible part) and peel & capillary membranes (non-edible part) weight and aril/peel fruit weight were significantly affected by pomegranate cultivars and geographic location in both seasons. As such, Wonderful cv. resulted in the highest records of fruit aril (242.3 and 251.8 g), peel weight (188.2 and 162.2 g) and aril/fruit weight (56.41 and 59.31 %). It was demonstrated that the edible part of the Wonderful pomegranate fruit varied between 46 and 56% of the fruit [37]. Faten *et al.* [34] found that, the percentage of aril in Manfalouty pomegranate fruits was 51.78% and in Wonderful pomegranate fruits was 51.91%.

Regarding the effects of geographic locations, the data reveal that, Ismailia location exceed other locations for fruit aril weight (231.7 and 308.3 g). Meanwhile, Al-Minya was the best for peel weight (192.3 and 187.1 g) in both seasons of the study. The highest values of aril/fruit (%) were obtained under Giza conditions in the first season and Ismailia in the second season.

On the other hand, cultivated trees in Sohag location produced fruits with the minimum fruit aril weight (147.4 g) and aril/fruit weight (51.16 %) this were true two seasons of study.

Table 6: Effect of pomegranate cultivars and geographic locations on aril and peel weight (g) and aril/fruit weight (%) during 2018 and 2019 seasons:

	Aril weight (g)			Peel weight (g)			Aril /fruit weight (%)		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
					2018				
Ismailia	190.0^{d}	273.3^{a}	231.7^{A}	161.7^{e}	224.7^{a}	193.2^{A}	54.58^{b}	54.89^{b}	54.73^{AB}
Giza	246.7^{b}	219.3^{c}	233.0^{A}	190.0^{c}	177.7^{d}	183.8^{B}	56.49^{b}	55.25^{b}	55.87^{A}
Al-Minya	192.3^{d}	250.7^{b}	221.5^{B}	178.7^{d}	206.0^{b}	192.3^{A}	51.84^{c}	54.89^{b}	53.37^{B}
Sohag	220.0^{c}	225.7^{c}	223.8^{B}	205.0^{b}	145.0^{f}	175.0^{C}	51.99^{c}	60.61^{a}	56.30^{A}
Mean	212.8^{B}	242.3^{A}		183.8^{B}	188.3^{A}		53.73^{B}	56.41^{A}	
					2019				
Ismailia	186.7d	430.0a	308.3A	143.3d	186.7b	165.0B	56.57d	69.73a	63.15^{A}
Giza	206.7c	205.0c	205.8C	143.3d	113.3f	128.3D	59.05c	64.40b	61.72^{B}
Al-Minya	201.7c	239.1b	220.4B	151.7c	222.6a	187.1A	57.08d	51.78e	54.43^{C}
Sohag	161.7e	133.1f	147.4D	155.5c	126.1e	140.8C	50.98e	51.34e	51.16^{D}
Mean	189.2^{B}	251.8^{A}		148.5^{B}	162.2^{A}		55.92^{B}	59.31^{A}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

Table 7: Effect of pomegranate cultivars and geographic locations on total, reducing and non-reducing sugar (%) during 2018 and 2019 seasons

	Total sugar (%)			Reducing sugar (%)			Non-reducing sugar		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
					2018				
Ismailia	11.85^{cd}	12.62^{b}	12.23^{C}	10.15^{a}	10.07^{a}	10.11^{A}	1.70^{f}	2.55^{d}	2.13^{D}
Giza	14.70^{a}	14.00^{a}	14.35^{A}	9.17^{c}	9.77^{b}	9.47^{C}	5.53^{a}	4.23^{b}	4.88^{A}
Al-Minya	11.71^{cd}	14.13^{a}	12.92^{B}	9.67^{b}	9.77^{b}	9.72^{B}	2.04^{e}	4.36^{b}	3.20^{B}
Sohag	11.44^{d}	12.34^{bc}	11.89^{C}	8.75^{d}	9.27^{c}	9.01^{D}	2.69^{d}	3.07^{c}	2.88^{C}
Mean	12.42^{B}	13.27^{A}		9.44^{B}	9.72^{A}		2.99^{B}	3.56^{A}	
					2019				
Ismailia	14.62^{b}	12.54^{d}	13.58^{B}	10.41^{a}	10.14^{a}	10.28^{A}	4.20^{d}	2.40^{g}	3.30^{C}
Giza	15.21^{a}	14.41^{b}	14.81^{A}	9.19^{c}	9.47^{bc}	9.33^{B}	6.02^{a}	4.95^{b}	5.49^{A}
Al-Minya	12.54^{d}	14.12^{c}	13.33^{C}	8.86^{d}	9.71^{b}	9.29^{B}	3.68^{e}	4.41^{c}	4.05^{B}
Sohag	11.46^{f}	12.10^{e}	11.78^{D}	8.73^{d}	9.30^{c}	9.02^{C}	2.72^{f}	2.80^{f}	2.76^{D}
Mean	13.46^{A}	13.29^{A}		9.30^{B}	9.66^{A}		4.16^{A}	3.64^{B}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

According to the results in Table (6) the highest values of aril and peel weight and aril/fruit weight were recorded for Wonderful cultivated in Ismailia (except for aril/fruit weight in 1`st season). Schwartz *et al*. [8] illustrated that, environmental conditions play a mean role in forming arils and making them juicier. According to Table 1, Ismailia region has lower levels of temperature and humidity stress.

Bio Chemical Composition of Fruit Juice:

Total, Reducing and Non-reducing Sugar: The perusal of data in Table (7) indicate generally that, sugar % (Total, reducing sugar and non-reducing sugar) were significantly affected by the tested factors in both seasons. As such, the highest values of sugar % (Total, reducing sugar and non-reducing sugar) were obtained by Wonderful cultivar in almost cases. Moreover, results reveal that, the highest total sugar % (14.35 and 14.81%) and non-reducing sugar % (4.88 and 5.49 %) were found in fruits of trees located in Giza, while the highest reducing sugar % (10.11 and 10.28 %) came from fruits of trees located in Ismailia. The values of total sugar in Wonderful pomegranate fruit juice are near to thus were obtained by Abou El-Wafa [37] and El- Khawaga *et al.* [38].

As for the combined effect of cultivars and geographic locations, the richest fruits in values of sugar % (Total, reducing sugar and non-reducing sugar) were recorded in pomegranate cv. Manfalouty cultivated in Giza. However, the maximum values of reducing sugar were shown in both pomegranate cultivars located in Ismailia.

Table 8: Effect of pomegranate cultivars and geographic locations on total anthocyanin in peel and aril (g/100 g) during 2018 and 2019 seasons

	Total anthocyanin/peel (g/100g)			Total anthocyanin/aril (g/100g)		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
			2018			
Ismailia	0.037^{d}	0.059^{bc}	0.048^{B}	0.068^{ab}	0.034^{de}	0.051^{A}
Giza	0.018^{e}	0.069^{b}	0.043^{B}	0.019^{e}	0.052^{b-d}	0.035^{B}
Al-Minya	0.048^{cd}	0.092^{a}	0.070^{A}	0.035^{de}	0.073^{a}	0.054^{A}
Sohag	0.071^{b}	0.067^{b}	0.069^{A}	0.044^{cd}	0.061^{a-c}	0.052^{A}
Mean	0.043^{B}	0.072^{A}		0.042^{B}	0.055^{A}	
			2019			
Ismailia	0.082^{b}	0.056^{c}	0.069^{B}	0.036^{ab}	0.038^{ab}	0.037^{A}
Giza	0.018^{d}	0.072^{bc}	0.045^{C}	0.012^{c}	0.050^{a}	0.031^{A}
Al-Minya	0.065^{bc}	0.144^{a}	0.105^{A}	0.039^{ab}	0.29^{b}	0.034^{A}
Sohag	0.074^{bc}	0.057^{c}	0.066^{B}	0.035^{ab}	0.039^{ab}	0.037^{A}
Mean	0.060^{B}	0.082^{A}		0.030^{A}	0.039^{A}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

Richardson *et al.* [39] suggested that, Kiwi fruit heated during fruit maturation have delayed mobilization of sugars from starch. In different locations under study, the temperature rise during maturation stage in southern regions.

Total Anthocyanin Content: As shown in Table (8), it is worthy to mention that, wonderful cultivar achieved the richest fruits in total anthocyanin (0.072 and 0.082 g/100g) in peel and (0.055 and 0.039 g/100g) in aril in both seasons.

Tabulated data also reveals that, tested locations significantly affected total anthocyanin/peel in pomegranate fruits were significantly increased when the fruits came of trees located in Al-Minya in both seasons (0.070 and 0.105 g/100g). While, the tested locations failed to show any significant differences regarding the total anthocyanin/aril (g/100g) in pomegranate fruits in most cases.

The interaction between cultivars and locations pointed that; all parameters of total anthocyanin/peel (g/100g) and total anthocyanin/aril (g/100g) were significantly affected. As such, the Wonderful cultivar in Al-Minya gave the highest total anthocyanin/peel (0.092 and 0.144 g/100g) in both season, respectively. In addition, the data clarify that Manfalouty located in Ismailia and Wonderful located in Al-Minya and Sohag gave the highest total anthocyanin/aril in the first season. While, the interaction between cultivar and location failed to show significant differences regarding the total anthocyanin/aril during second season.

Borochov-Neori *et al.* [40] revealed that the color of pomegranate fruits was inversely related to heat units accumulated during fruit development and ripening season. Jamali and Bonyanpour [41] mentioned that, anthocyanin content varies between pomegranate verities, affected by genetic, climatic reasons and agronomic operations. The reduction of anthocyanin may be due to the high oxidative stress that can induce peroxidase activities [8]. Also, Castro *et al.* [42] illustrated that, crop load affect apple skin color as a result of the reduced amount of photo-assimilates available to individual fruits, this may explain the reduction of total anthocyanin in Giza.

Tannins and Vitamin C: The results in Table (9) demonstrated that, aril extract of Manfalouty and Wonderful pomegranate cvs showed that, the specific and interaction effect of geographic location and pomegranate cvs. was obtained fruits from Wonderful cv. planted in Sohag governorate expressed the highest aril content of tannins (0.099 and 0.098 %) in both seasons, respectively. On the other hand, Manfalouty cv. planted in Giza governorate took the other way around (0.028 and 0.014 %) in 2018 and 2019 seasons, respectively. This could be attributed to the higher temperatures and radiation conditions faces pomegranate trees grown in Sohag and Al-Minya.

Regarding Vitamin C %, data tabulated showed that, Wonderful cv. recorded higher significant value (23.53 %) in the first season only, but in the second season Manfalouty cv. was the superior (23.89 %). Regarding the specific effect of locations, Giza governorate gave the greatest percentage of vitamin C (23.10 and 26.64 %) in both seasons, respectively. Contrariwise, fruits of Manfalouty cv. planted in Al-Minya governorate were the poorest in vitamin C. Regards the interaction, Wonderful cv. planted in Giza gave the maximum records

Table 9: Effect of pomegranate cultivars and geographic locations on tannins (%) and vitamin C (mg/100g) during 2018 and 2019 seasons

	Tannins (%)			Vitamin (C) mg/100g		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
			2018			
Ismailia	0.025^{d}	0.055^{c}	0.040^{C}	19.48^{de}	21.55^{c}	20.52^{C}
Giza	0.028^{d}	0.038^{cd}	0.033^{C}	19.08^{e}	27.11^{a}	23.10^{A}
Al-Minya	0.048^{c}	0.081^{b}	0.064^{B}	19.80^{d}	21.1^{c}	20.81^{C}
Sohag	0.081^{b}	0.099^{a}	0.090^{A}	19.88^{d}	23.65^{b}	21.77^{B}
Mean	0.045^{B}	0.068^{A}		19.56^{b}	23.53^{A}	
			2019			
Ismailia	0.063^{c}	0.051^{c}	0.057^{B}	30.07^{a}	20.91^{f}	25.49^{B}
Giza	0.014^{e}	0.032^{d}	0.023^{C}	25.81^{c}	27.46^{b}	26.64^{A}
Al-Minya	0.083^{ab}	0.086^{ab}	0.084^{A}	19.89^{g}	21.78^{e}	20.84^{D}
Sohag	0.080^{b}	0.098^{a}	0.089^{A}	19.80^{g}	23.56^{d}	21.68^{C}
Mean	0.060^{A}	0.067^{A}		23.89^{A}	23.43^{B}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

Table 10: Effect of pomegranate cultivars and geographic locations on TSS (%), acidity (%) and TSS/acidity ratio during 2018 and 2019 seasons

	TSS (%)			Acidity (%)			TSS/acidity ratio		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
					2018				
Ismailia	15.53^{f}	17.33^{c}	16.43^{C}	2.70^{a}	1.53^{bc}	2.11^{A}	5.75^{h}	11.35^{e}	8.553^{D}
Giza	17.20^{cd}	18.30^{b}	17.75^{A}	1.10^{c}	1.74^{b}	1.42^{B}	15.63^{a}	10.51^{f}	13.08^{B}
Al-Minya	17.97^{b}	16.57^{e}	17.27^{B}	1.87^{b}	1.36^{bc}	1.61^{B}	9.62^{g}	12.21^{d}	10.92^{C}
Sohag	18.80^{a}	16.83^{de}	17.82^{A}	1.33^{bc}	1.11^{c}	1.22^{B}	14.10^{c}	15.16^{b}	14.63^{A}
Mean	17.38^{A}	17.26^{A}		1.75^{A}	1.43^{A}		11.27^{B}	12.31^{A}	
					2019				
Ismailia	16.33^{e}	17.87^{c}	17.10^{B}	1.12^{a}	0.52^{c}	0.82^{B}	14.54^{f}	33.92^{a}	24.23^{A}
Giza	17.93^{c}	18.53^{b}	18.23^{A}	0.80^{b}	0.74^{bc}	0.76^{B}	22.70^{c}	25.04^{b}	23.87^{B}
Al-Minya	19.27^{a}	17.10^{d}	18.18^{A}	1.25^{a}	1.35^{a}	1.30^{A}	15.40^{e}	12.58^{g}	13.99^{D}
Sohag	19.36^{a}	17.07^{d}	18.21^{A}	1.20^{a}	1.11^{a}	1.15^{A}	15.96^{d}	15.45^{e}	15.71^{C}
Mean	18.22^{A}	17.64^{B}		1.23^{A}	1.1^{B}		17.15^{B}	21.75^{A}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %.

Table 11: Effect of pomegranate cultivars and geographic locations on total flavonoids, phenolic compounds (g gallic acid /100 g FW) and antioxidant activity (DPPH) (%) during 2018 and 2019 seasons

	Total flavonoids			Phenolic compounds g/100g			Antioxidant activity %		
Location	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean	Manfalouty	Wonderful	Mean
	2018								
Ismailia	0.027^{a-c}	0.016^{c}	0.022^{B}	0.045^{a}	0.043^{a}	0.044^{A}	90.08^{b}	84.45^{c}	87.27^{A}
Giza	0.035^{a-c}	0.019^{bc}	0.027^{AB}	0.037^{ab}	0.047^{a}	0.042^{A}	71.27^{d}	91.43^{a}	81.35^{B}
Al-Minya	0.036^{ab}	0.028^{a-c}	0.032^{AB}	0.036^{ab}	0.049^{a}	0.043^{A}	83.81^{c}	90.57^{ab}	87.19^{A}
Sohag	0.039^{a}	0.032^{a-c}	0.036^{A}	0.028^{a-c}	0.041^{a}	0.034^{A}	83.30^{c}	89.86^{b}	86.58^{A}
Mean	0.034^{A}	0.024^{A}		0.037A	0.045^{A}		82.12^{B}	89.08^{A}	
	2019								
Ismailia	0.027^{ab}	0.018^{b}	0.023^{B}	0.047^{a}	0.043^{a}	0.045^{A}	91.08^{b}	85.13^{d}	88.11^{A}
Giza	0.037^{ab}	0.031^{ab}	0.034^{AB}	0.039^{ab}	0.047^{a}	0.043^{A}	70.27^{f}	92.42^{a}	81.35^{D}
Al-Minya	0.034^{ab}	0.028^{ab}	0.031^{AB}	0.034^{ab}	0.050^{a}	0.042^{A}	84.14^{de}	89.56^{c}	86.85^{B}
Sohag	0.035^{ab}	0.038^{a}	0.036^{A}	0.025^{a-c}	0.042^{a}	0.033^{A}	83.27^{e}	88.86^{c}	86.07^{C}
Mean	0.033^{A}	0.029^{A}		0.036^{A}	0.045^{A}		82.19^{B}	89.00^{A}	

Means of specific and interaction effects followed by the same capital and small letter/s, respectively did not significantly different according to New LSD at 5 %

of vitamin C (27.11 %) in first season, moreover in the second one Manfalouty cv. planted in Ismailia proved to be the best (30.07 %). Schwartz *et al.,* [8] declared that, an increased temperature in the final weeks prior to harvesting decreased citrate production. In addition, Tharayil *et al.* [43] improved that, tannins in Acer rubrum increased under warm and drought stress. As shown in Table 1 Sohag had the highest temperature.

Total Soluble Solids (TSS), Acidity and TSS/ Acidity Ratio: The statistical analysis of the data showed that TSS was significantly affected by cultivars and geographic locations. Manfalouty cv. was superior in TSS value (17.38 and 18.22 %) in both seasons, respectively (Table 10).

Moreover, Sohag governorate is more suitable than the other locations under study as it produced fruits with the highest values of TSS %. Concerning the interaction effect, maximum TSS (18.80 and 19.36 %) was recorded with Manfalouty cv. planted in Sohag governorate in 2018 and 2019 seasons, respectively. On contrary the minimum TSS values (15.35 and 16.33 %) was registered when Manfalouty cv. planted in Ismailia governorate.

Determination of TSS is important for establishing organoleptic quality of the juice, acidity can play an important role in the perception of fruit quality, it affects the fruit's sour taste but also its sweetness by masking the taste of the sugars [44].

Also, Data in Table 10 reveal that the highest values of pomegranate juice acidity were obtained by Manfalouty cv. (1.75 and 1.23%) in both tested seasons. While, the least values were recorded for Wonderful cv. As for the effect of cultivar, data clarify that pomegranate trees located in Ismailia induced the highest juice acidity 2.11 % in the first season, while in second one it was achieved by pomegranates located in Al-mania and Sohag (1.30 -1.15 %).

As for the combined effect of pomegranate cultivars and geographic locations, the highest suitable values of juice acidity were recorded by Manfalouty cv. cultivated in Ismailia (2.70 and 1.12%).

Thus the acidity is apparently the main contributor to taste, is determined by ratio between TSS and acidity. This ratio ranged significantly from 5.75 to 33.92.

The specific effect of geographic locations and cultivars on juice acidity showed that Wonderful cv. the highest as a higher value in both seasons.

Absar *et al.* [45] reported that TSS was increased with maturity of mango fruit. But, they found highest TSS in the Langra. These might be possible due to genetic differences between cultivars. The TSS/Acid ratio is a key characteristic determining the taste, texture and feel of fruit segments. Lokesha *et al.* [46] said that, TSS and acidity increased in all tomatoes genotypes under high temperature stress. This can explain the reason of achieving the highest TSS and acidity values in Sohag in most cases.

Total Flavonoids, Phenolic Compounds and Total Antioxidant: The values obtained for fruit juice total flavonoids, total phenolic and antioxidant activity during the test are presented in Table (11). There is no significant effect between cultivars. On the other hand, Sohag governorate scored the highest significant values of total flavonoids (0.036 and 0.036) in both seasons.

Regarding the interaction effect, total flavonoids ranged between (0.016 to 0.039) and the highest values was obtained with Manfalouty cv. planted in Sohag (0.039) in 1st season and Wonderful cv. planted in Sohag (0.038) in 2nd one.

The results of phenolic compounds confirmed that, the results didn't reach the level of significance effect for geographic locations and pomegranate cv. in both seasons. Regarding the interaction effect Manfalouty cv. planted in Ismailia showed the superior values (0.045 and 0.047) in both seasons, respectively. And there are no significant values between all geographic locations planted with Wonderful cv. in both seasons. Regarding the statistical analysis of total antioxidant, the specific effect of geographic locations and pomegranate cv. showed that, Wonderful cv. suppressed Manfalouty cv. in total antioxidant (89.08 and 89.00 %) in both seasons, respectively. The interaction effect showed that, Wonderful cv. planted in Giza governorate (91.43 and 92.42%) transcend Manfalouty cv. planted in all other locations in both seasons, respectively, regarding to climatic data in different locations, we can noticed that pomegranate cultivated in Giza exposed to a high % of air humidity. Air humidity percentage play an important role in physiological activities of plants and fruit quality [47].

CONCLUSION

In summary, the results of this study indicate that pomegranate yield and quality affected by the prevailing climate in cultivated region. The results indicate that northern region Ismailia governorate could be the best area to grow cultivar Wonderful for better physical properties and to obtain higher productivity with the appropriateness of the fruits obtained for fresh

consumption. While, the southern regions were more suitable for cultivating different cultivars of pomegranate. Therefore, it is possible that this study will be the nucleus for making a map to determine suitable places for cultivating different pomegranate cultivars in Egypt.

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