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Physicochemical Properties Changes During Pomegranate Fruit Development Stages under Different Environmental Conditions

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Abstract: The experiment was existed at two private orchards throughout two successive seasons of 2016 and 2017, first orchard located at 64 km at Cairo- Alexandria desert road- Giza governorate and the second orchard located at 170 km at Cairo- west Assuit road-Minia governorate. The aim of the present study was to focus on the effect of environmental condition in two different locations (Giza and Minia) on fruit development stages and the variation in physical and chemical fruit properties of four pomegranate cultivars (Manfalouty, Wonderful, Acco and 116). Generally, fruits of four cultivars in Giza orchard showed the highest yield (Kg/tree), fruit marketable (%) and fruit physical and chemical properties than Minia orchard. The behavior of the four cultivars was as follow: Manfalouty, cv. recorded the highest values of fruit weight, fruit dimension, yield and fruit cracking and sunburn (%), additionally Wonderful cv. registered the maximum fruit aril and juice percentage. While, the Acco cv. had the lowest values of fruit weight, dimension, yield, fruit cracking and sunburn (%), also fruit juice acidity percentage but gave high fruit juice percentage, juice anthocyanin content and maturity index (TSS/ acid). The highest acidity, TSS and peel anthocyanin content was obtained by 116 cv. In addition, Acco was harvested earlier compared with Manfalouty, Wonderful and 116, which considered as cultivars late harvesting. Under Giza orchard conditions, the four cultivars (Manfalouty, Wonderful, Acco and 116) can be cultivated, in this concern, Acco or 116 produced the best colorful fruits (peel and aril). While, under Minia orchard conditions, Manfalouty and Wonderful produced poor coloring of peel and aril, therefore, it could be recommend by Acco or 116 cvs.

Key words: Pomegranate · Manfalouty · Wonderful · Acco · 116 · Yield · Fruit quality

INTRODUCTION

Pomegranate (*Punica granatum* L.) is a highly valued crop and is widely cultivated in Mediterranean countries. It is an ideal crop for the sustainability of small holdings, as pomegranate is well suited to the topography and agro-climate of arid and semi-arid regions [1]. Pomegranate fruits are important for human health because of their high antioxidant capacity and a high polyphenols and anthocyanins content [2].

During the growth and development, the fruit passes through various stages of ripening, which result in a variety of physiological, biochemical and structural processes [3]. The chemical changes that occur during fruit ripening will affect the nutritional and beneficial health properties of pomegranate. So it is important to harvest the fruits in a good ripening stage because early harvesting may inhibit the development of the quality characteristics (e.g., color, ?avor and aroma), while late harvesting may result in fruits with reduce in shelf life and increase sensitivity to disease [4, 5]. In addition, the fruit quality is also strongly dependent on farming region, climate and cultural practices [6]. Fruit maturity status is commonly assessed based on external (skin) colour, aril and juice colour and acidity of juice [7]. Consumers and manufacturers have accepted fruits depend on the combination of several quality attributes that are related to the physico-chemical properties including size, skin color, sugar content, acidity and flavour [8].

Colour is an important factor affecting marketability and consumer preference of pomegranate fruits [9, 10]. However, there is no correlation between the outer skin (peel) colour and the colour of arils inside fruit [9, 11]. Anthocyanins are the major pigments responsible for

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pomegranate fruit color. Six major anthocyanin compounds have been identified in pomegranate fruit, including mono- and diglucosides of cyanidin (red), pelargonidin (orange) and delphinidin (purple) [12, 13]. The color variability in various tissues and among different pomegranate accessions stems from different contents of anthocyanin and different relative amounts of their derivatives [12].

Pomegranate antioxidant activity and content of total phenolics, total anthocyanins, total soluble solids, glucose, fructose and acidity are affected by environmental conditions [14-16]. Temperature is the primary factor affecting fruit quality. Higher temperatures can increase the capacity of air to absorb water vapor and, consequently, generate a higher demand for water. Higher evapotranspiration indices could lower or deplete the water reservoir in soils, creating water stress in plants during the dry seasons [17]. It is well documented that water stress not only reduces crop productivity but also tends to accelerate fruit ripening [18]. Exposure to elevated temperatures cause morphological, anatomical, physiological and, ultimately, biochemical changes in plant tissues and, as a consequence, affect the growth and development of different plant organs. Temperature is one of the most important factors affecting nutrient uptake by strawberry [19]. Temperature is of paramount importance in the establishment of a harvest index. High temperatures have the most impact on the final harvestable crop [20]. On the other hand, high temperatures are known to reduce fruit size and fruit weight. Likewise, high-temperature stress negatively affects the reproductive process and plant response to high temperature stress [21]. Higher than normal temperatures affect the photosynthetic process through the modulation of enzyme activity as well as the electron transport, chain [22]. Temperature has a major effect on anthocyanin synthesis in plants. As a result of recent global warming, there are increasing concerns that global warming may be detrimental to fruit reddening [23].

Recently, the cultivated pomegranate area are increased in Egypt due to the cultivation expansion in the newly reclaimed lands which took more attention not only in one province but on the whole country. Egyptian farmers have accepted to grow pomegranate after it became one of the most important exporting crops. Unfortunately, although pomegranate orchards has increased significantly in Egypt, the cultivation in different microclimatic zones having diverse growth conditions. Pomegranate cultivation faced poor coloring problem in interior and exterior parts of fruits. Also, awareness about environmental conditions effect on the pomegranate fruit's nutritional value, quality and health properties has not yet been established. For that, the aim of the present study was to focus on the effect of two Egyptian different environmental conditions on variation among pomegranate fruits of four cultivars from the perspective of physical and chemical properties.

MATERIALS AND METHODS

The experiment was existed at two private orchards, first orchard located at 64 km at Cairo- Alexandria desert road- Giza Governorate-within Greater Cairo Regional Unit [24] and the second orchard located at 170 km at Cairo- west Assuit road- Minia Governorate -within North Upper Egypt Regional Unit [25] throughout two successive seasons of 2016 and 2017. The experiment included four pomegranate cultivars namely Manfalouty (local cv.), Wonderful, Acco and 116 (exported cvs.). The pomegranate trees were 8 years old and planted at 3 x 4 m apart in a sandy soil. Trees were irrigated with deep well water using a drip irrigation system. Horticultural management (irrigation, fertilization, pest and diseases control, pruning, thinning and weed control) was based on recommended practices by the Ministry of Agriculture. Some physical and chemical characteristics of the studied soil and irrigation water of both locations are shown in Tables (1 and 2).

The maximum and minimum values of temperature (°C) and relative humidity (%) in Giza and Minia orchards for the 2016 and 2017 seasons are presented in Figures (1, 2, 3 and 4).

Collected Data: Three trees were chosen from each studied cultivar and each tree was represented as a replicate. Eighty days after full bloom (DAFB) for each cultivar, sixty fruits approximately at the same size were labeled, whereas five fruits of them were randomly picked and repeated during fruit growth development every twenty days intervals (80, 100, 120, 140). The fruit samples were picked and transferred to the laboratory to determine:

Fruit Physical Characteristics: Average fruit weight (g) was recorded and average fruit diameter and length (cm.) by using a Vernier caliper. Fruit aril (%) and fruit juice content (%) of total fruit weight were calculated.

Fruit Chemical Contents: Juice total soluble solids (Brix°) were determined by using hand Carl Zeis refractometer and titratible acidity was determined as percentage of anhydrous citric acid by direct titrating of 0.1 N sodium

Table 1: Some physical and chemical characteristics of the experimental soil at Giza and Minia orchards.

Giza orchard				Minia orchard			
Sand (%)	85.2	EC dS/m (1:2.5)	3.03	Sand (%)	59.9	EC dS/m (1:2.5)	0.76
Silt (%)	8.63	pH (1:2:5)	7.71	Silt (%)	19.4	pH (1:2:5)	0.8
Clay (%)	6.17	Texture	Loamy sand	Clay (%)	20.7	Texture	Sandy
Soluble cations and anions (meq /L)				Soluble cations and anions (meq /L)			
Ca^{++}	9.00	CO_3^{--}	0.00	Ca^{++}	2.70	CO_3^{--}	0.00
Mg^{++}	8.00	HCO_3^{--}	10.5	Mg^{++}	2.20	HCO_3^{--}	1.90
Na^{+}	12.9	Cl^{-}	18.0	Na^{+}	1.67	Cl^{-}	2.95
K^{+}	1.10	SO_4^{--}	2.50	K^{+}	0.25	SO_4^{--}	1.97

Table 2: Chemical composition of the irrigation water used for irrigation at Giza and Minia orchards.

Giza orchard										
			Cations (meq/L)				Anions (meq/L)			
E.C.w mmhos	TSS ppm	pH	Mg^{++}	Ca^{++}	K^{+}	Na^{+}	SO_4^{-}	Cl^{-}	HCO_3^{-}	CO_3^{-}
6.44	4121.6	6.5	8.95	20.4	2.01	33	4.59	39.3	20.5	--
Minia orchard										
			Cations (meq/L)				Anions (meq/L)			
E.C.w mmhos	TSS ppm	pH	Mg^{++}	Ca^{++}	K^{+}	Na^{+}	SO_4^{-}	Cl^{-}	HCO_3^{-}	CO_3^{-}
1.22	780	7.5	3.63	3.38	0.13	5.65	5.41	5.59	1.79	--

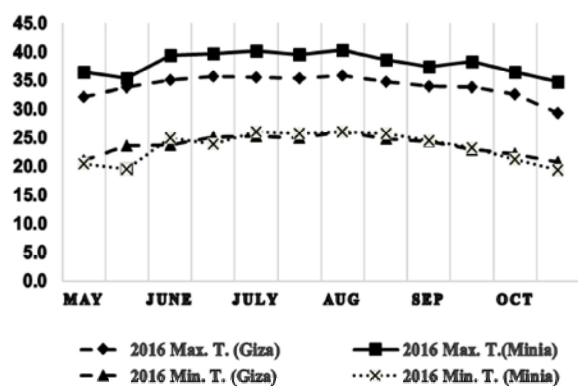

Fig. 1: The maximum and minimum temperature (°C) in Giza and Minia during 2016 season

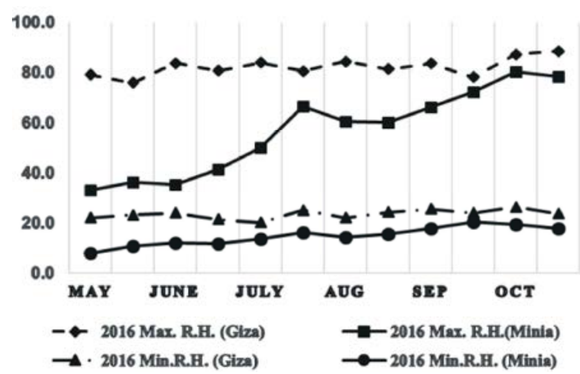

Fig. 3: The maximum and minimum relative humidity (%) in Giza and Minia during 2016 season

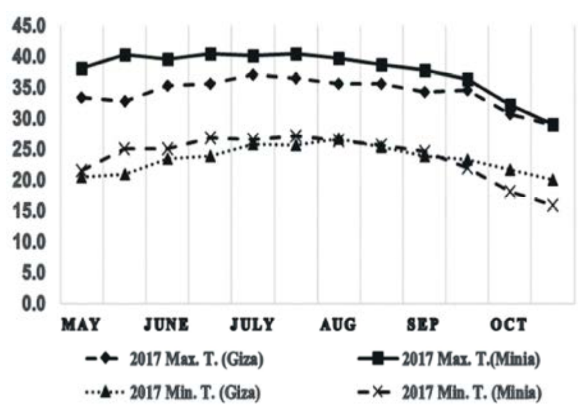

Fig. 2: The maximum and minimum temperature (°C) in Giza and Minia during 2017 season

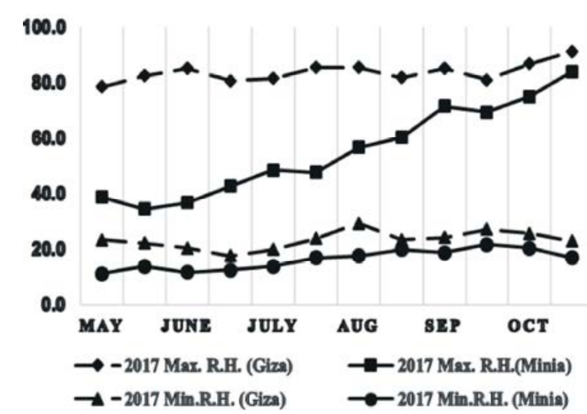

Fig. 4: The maximum and minimum relative humidity (%) in Giza and Minia during 2017 season

hydroxide using phenolphthalein 1% as an indicator [26]. Then maturity index (TSS/ acid) was calculated by dividing of TSS by acidity. Total sugars were determined colorimetrically (phenol 80%) in fresh weight according to Dubois *et al*. [27]. Total anthocyanin of arils (mg/L) and peel (mg/Kg peel) were determined by spectrophotometer as described by Hsia *et al*. [28]. Juice total phenolic contents expressed as mg of gallic acid equivalents (GAE) / liter were determined according to the method described by Singleton and Rossi [29].

Yield Characteristics: At 140 DAFB (days after full bloom) of each cultivar, total fruit number/ tree and average fruit weight (g) were recorded and average total yield/tree was calculated as kg/tree. No. of cracked & sunburned fruits/tree and their percentages of total number of fruits/tree were calculated. Marketable fruits/tree (%) was also calculated.

Statistical Analysis: Test of normality distribution was carried out according to method of Shapiro and Wilk, [30], by using SPSS v. 17.0 [31] software package. Also, data were tested for violation of assumptions underlying the combined analysis of variance by separately analyzing of each location and then combined analysis across the two locations was performed if homogeneity (Bartlet test) was insignificant. Estimates of LSD were calculated to test the significance of differences among means according to Snedecor and Cochran [32] by using MSTAT-C software package.

RESULTS AND DISCUSSION

Analysis of Variance: The combined analysis of variance of the studied cultivars and for all characters under four dates across the two locations was presented in Tables (3 and 4). Mean squares due to locations were significant ($P \leq 0.05$ or $P \leq 0.01$) for all studied characters that affected by climatic conditions. However, mean squares due to the four dates were significant ($P \leq 0.05$ or $P \leq 0.01$) for all characters, suggesting that the dates had a significant effect on most studied traits.

Mean squares due to the cultivars were significant ($P \leq 0.05$ or $P \leq 0.01$) for all characters. While, mean squares due to locations x dates x cultivars were non-significant ($P \leq 0.05$ or $P \leq 0.01$) for all studied characters except total phenols, maturity index, peel anthocyanin content in both seasons and juice anthocyanin content and TSS in the second season.

Fruit Physical Characteristics: Fruit physical characteristics of pomegranate as affected by cultivar, trees growing region and picking dates after full blooming and their interactions are presented in Tables (5-9).

Fruit Weight: Results in Table (5) prove that, Giza orchard recorded heavier significant pomegranate fruit weight in both seasons. Fruit weight was increased progressively whereas fourth date (140 DAFB) goaled the highest values that reached about the triple when compared with the 1st date (80 DAFB). Wonderful and

Table 3: Mean squares from combined analysis of variance of factorial design for the four cultivars evaluated under four dates across the two locations (Giza and Minia) during 2016 season.

S.V	df	Fruit weight	Fruit dimension	Fruit length	Fruit aril	Fruit juice	Juice anthocyanin
Location (L)	1	14999.3**	7.35**	4.31**	165.9**	504.6**	34621**
R(L)	4	45251.4**	8.15**	7.14**	4539.6**	308**	191.3**
Dates (D)	3	262473.9**	29.43**	24.29**	688.6**	1411**	15117**
L x D	3	541.6	0.111	0.08	0.47	2.35**	3127**
Cultivars (C)	3	13909.5**	2.81**	3.12**	139.1**	82.58**	18629**
L x C	3	77.6	0.014	0.06	92.9**	22.7**	555**
D x C	9	1653.6**	0.40**	0.10**	1.41	4.92**	172.4**
L x D x C	9	300.4	0.044	0.06	1.43	1.9	122.6
Error	60	403.5	0.062	0.04	13.94	1.1	1.18
S.V	df	Total sugar	TSS	Acidity	Total phenol	Maturity index	Peel anthocyanin
Location (L)	1	35.10**	63.13**	1.36**	283040**	12.72**	416593.5**
R(L)	4	77.23**	21.65**	3.65**	163735**	11.25**	60.15**
Dates (D)	3	57.66**	43.29**	5.87**	1401420**	889.4**	128602.2**
L x D	3	1.30	1.82**	0.02	3270**	1.88**	42079.8**
Cultivars (C)	3	2.73*	7.92**	3.21**	54364**	810.1**	49909.7**
L x C	3	0.48	1.84**	0.14**	96025**	7.54**	17043.6**
D x C	9	0.35	0.06	0.028	3510**	76.3**	2425.8**
L x D x C	9	0.11	0.04	0.015	5703**	0.39**	1052**
Error	60	0.67	0.11	0.03	67.03	0.14	0.39

Table 4: Mean squares from combined analysis of variance of factorial design for the four cultivars evaluated under four dates across the two locations (Giza and Minia) during 2017 season.

S.V	df	Fruit weight	Fruit dimension	Fruit length	Fruit aril	Fruit juice	Juice anthocyanin
Location	1	21433**	2.17**	3.34**	153.4**	367.38**	19211**
R(L)	4	46540**	6.03**	6.72**	3906**	287.89**	132**
Dates (D)	3	233882**	29.18**	24.85**	695**	1268.9**	11882**
L x D	3	822.5	0.12**	0.01	15.1	5.08**	1990**
Cultivars (C)	3	11989**	5.48**	2.86**	98.5**	53.74**	20817**
L x C	3	504.7	1.61**	0.36**	24	12.89**	214**
D x C	9	1789*	0.31**	0.24**	2.27	9.94**	312**
L x D x C	9	251.4	0.02	0.04	2.21	2.46	71.1**
Error	60	434.4	0.03	0.02	11.80	1.16	1.1
S.V	df	Total sugar	TSS	Acidity	Total phenol	Maturity index	Peel anthocyanin
Location	1	38.25**	70.33**	0.78**	374271**	4.18**	395727.5**
R(L)	4	90.24**	18.52**	4.86**	166944**	17.74**	49.53**
Dates (D)	3	48.23**	46.77**	6.25**	1553293**	868.0**	101771**
L x D	3	2.83*	1.66**	0.00	8621**	0.53*	36552.9**
Cultivars (C)	3	6.61**	5.93**	3.51**	42407**	722.7**	41995.8**
L x C	3	0.21	1.54**	0.11	55353**	4.48**	16751.9**
D x C	9	0.08	0.12	0.06	2590**	55.9**	2716.6**
L x D x C	9	0.39	0.26**	0.02	4494**	0.51**	1163.14**
Error	60	0.77	0.09	0.05	169	0.17	0.49

Table 5: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for fruit weight combined over locations (Giza and Minia) during 2016 and 2017 seasons.

		Fruit weight (g)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	140.75	135.40	128.07	138.31	136.50	133.42	124.60	129.68
	100	254.21	240.67	200.50	230.35	252.70	234.71	217.56	230.60
	120	361.85	355.25	290.21	338.56	364.57	330.20	275.00	320.58
	140	400.13	415.60	318.71	380.10	417.34	382.14	300.45	371.25
Minia	80	126.50	125.50	108.87	121.43	124.76	128.50	100.85	112.65
	100	212.47	232.40	205.39	200.67	216.75	190.33	200.75	215.30
	120	320.60	328.10	252.15	314.25	303.45	300.35	249.85	294.22
	140	380.54	368.28	286.73	344.80	353.39	347.62	275.50	328.70
Mean (C)		274.63	275.15	223.83	258.56	271.18	255.91	218.07	250.37
Mean (D)		128.10	222.08	320.12	361.86	123.87	219.84	304.78	347.05
Mean (L)		270.54		245.54		263.83		233.94	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	11.59	11.59	Sig.	32.79
Season 2017	12.03	12.03	Sig.	34.02

Table 6: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for fruit diameter combined over locations (Giza and Minia) during 2016 and 2017 seasons.

		Fruit diameter (cm)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	5.97	6.13	5.84	6.28	6.37	5.80	5.62	5.67
	100	7.66	7.54	6.88	6.91	7.84	7.18	6.37	6.45
	120	8.30	8.55	7.69	8.15	9.00	8.14	7.28	7.70
	140	9.16	9.13	8.10	8.55	9.46	8.83	7.65	8.00
Minia	80	5.54	5.69	5.50	5.80	5.50	5.97	5.60	5.71
	100	7.15	6.85	6.53	6.63	6.83	7.48	6.31	6.46
	120	7.91	8.00	6.85	7.42	7.86	8.23	7.20	7.29
	140	8.53	8.57	7.21	7.80	8.25	8.74	7.50	7.61
Mean (C)		7.53	7.56	6.83	7.19	7.64	7.55	6.69	6.86
Mean (D)		5.84	7.02	7.86	8.38	5.78	6.87	7.84	8.26
Mean (L)		7.55		7.00		7.34		7.03	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.1414	0.1414	Sig.	0.4067
Season 2017	0.0949	0.0949	Sig.	0.2684

Table 7: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for fruit length combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Fruit length (cm)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Location (L)	Date (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	5.87	6.21	5.39	5.78	5.86	5.60	5.51	5.47
	100	7.06	7.50	6.59	6.66	7.31	6.57	6.45	6.53
	120	7.80	7.84	7.26	7.49	8.10	7.76	6.74	7.38
	140	8.30	8.34	7.54	7.90	8.56	8.23	7.20	7.70
Minia	80	5.24	5.37	4.90	5.41	5.30	5.53	5.11	5.10
	100	6.64	7.05	6.20	6.58	6.33	6.45	6.00	6.34
	120	7.31	7.64	6.67	7.09	7.46	7.50	6.61	6.98
	140	8.00	8.25	6.84	7.56	7.85	8.07	7.10	7.26
Mean ©		7.03	7.28	6.42	6.81	7.10	6.96	6.34	6.60
Mean (D)		5.52	6.79	7.39	7.84	5.44	6.50	7.32	7.75
Mean (L)		7.10		6.67		6.94		6.56	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.111	0.111	Sig.	0.3142
Season 2017	0.0817	0.0817	Sig.	0.2310

Table 8: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for fruit aril percentage combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Fruit Aril (%)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	44.54	46.75	41.80	41.90	39.66	43.40	37.57	41.86
	100	50.20	53.46	47.50	45.94	47.58	51.02	42.23	45.88
	120	54.73	56.44	51.85	51.54	52.62	54.38	48.15	50.44
	140	57.00	59.14	54.59	54.21	56.37	56.95	51.46	54.42
Minia	80	40.32	43.26	37.36	44.30	39.50	41.05	37.00	41.48
	100	43.51	50.53	42.61	51.06	44.59	45.66	43.27	46.96
	120	48.60	53.57	46.94	53.73	48.74	48.32	45.19	49.63
	140	51.46	55.62	49.78	56.81	50.39	50.70	48.92	52.14
Mean (C)		48.80	52.35	46.55	49.94	47.43	48.94	44.22	47.85
Mean (D)		42.53	48.10	52.18	54.83	40.19	45.90	49.68	52.67
Mean (L)		50.72		48.09		48.37		45.85	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	2.153	2.153	Sig.	6.089
Season 2017	1.983	1.983	Sig.	5.608

Table 9: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for fruit juice percentage combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Fruit Juice content (%)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Location (L)	Date (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	23.73	30.80	26.61	25.59	24.58	26.41	22.89	23.19
	100	35.62	40.14	36.50	33.56	32.81	36.09	31.72	32.00
	120	38.91	44.50	41.43	40.62	34.33	40.74	39.84	40.24
	140	42.86	47.85	43.10	43.91	38.24	44.53	40.63	42.21
Minia	80	22.00	23.25	25.50	20.23	20.00	22.83	23.29	20.58
	100	29.41	33.48	33.52	28.00	27.60	29.08	29.76	26.70
	120	35.51	36.73	37.60	36.39	31.56	34.00	35.87	35.92
	140	39.20	41.29	40.74	39.52	35.16	38.65	37.21	38.64
Mean (C)		33.41	37.26	35.63	33.48	30.54	34.04	32.65	32.44
Mean (D)		24.71	33.78	38.96	42.31	22.97	30.72	36.56	39.41
Mean (L)		37.23		32.65		34.40		30.43	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.5945	0.5945	Sig.	1.682
Season 2017	0.6219	0.6219	Sig.	1.759

Manfalouty cvs. produced the highest significant fruit weight (275.15-274.63 g), respectively in the 1st season, while only Manfalouty cv. in the 2nd season. However, Acco cv. gave the least values of fruit weight (223.83-218.07 g) in both seasons respectively.

Concerning the interaction among locations, cultivars and dates, results show that in Giza orchard at 140 DAFB Wonderful and Manfalouty cvs. (1st season) and Manfalouty (2nd season) possessed the heaviest significant fruit weight (415.60, 400.13 and 417.34 g), respectively. Acco in Minia orchard at 80 DAFB noted the least fruit weight in both seasons.

Fruit Diameter: As shown in Table (6) results reveal that, Giza orchard registered longer fruit diameter compared with Minia orchard in both seasons. Fruit diameter was increased with the development of the fruit and reached the maximum values at the fourth date (140 DAFB). In addition, Wonderful and Manfalouty gave the highest significant fruit diameter in both seasons. Acco goaled the least values of fruit diameter in both seasons.

The interaction among locations, cultivars and dates, clear that at 140 DAFB, Manfalouty at Giza orchard owned the highest significant fruit diameter in the two studied seasons in partnership with Wonderful at Giza in the first season.

Fruit Length: The perusal of results (Table, 7) indicates that, Giza orchard marked longer fruit in both seasons. Fruit length was increased about one and a half times as the DAFB increased from 80 to 140 days as they scored 5.52, 5.44 and 7.84, 7.75 cm, respectively in both seasons. In addition, Wonderful and Manfalouty showed the highest significant fruit length in the 1st and 2nd seasons, respectively. The lowest fruit length was occurred with Acco in both seasons.

Regarding the interaction among locations, cultivars and dates, show that at 140 DAFB, both Manfalouty and Wonderful earned the highest significant fruit length in the first season and Manfalouty only in the second season at Giza orchard.

The obtained results are in accordance with those of Shwartz *et al*. [4] who reported that, the changes in physical characteristics of pomegranate fruit indicate that the fruit continues to grow even after the optimum harvesting stage, presumably due to cell expansion from uptake of water and other nutrients. The increment in fruit weight and fruit dimension in Giza orchard may be due to lower temperature than Minia orchard. In this line, Mditshwa *et al*. [33] recorded that pomegranate cultivated in Wellington (highest temperature) had the least fruit weight and diameter. Moreover, Ledesma *et al*. [21], Sun *et al*. [34], Palencia *et al*. [35] and Balasooriya *et al*. [36] observed that the high temperatures reduced strawberry fruit size, weight and irregular shaped fruit. The reduction in fruit dimension and weight under high temperatures may be due to lower dry matter accumulation as a result of higher fruit transpiration rate and decreasing photosynthetic rates at higher temperatures [37].

Fruit Aril Percentage: Results in Table (8) show the higher significant fruit aril percentage was obtained by Giza orchard than Minia. Fruit aril was increased during different growth stages and reached the maximum value at 140 DAFB. Wonderful cv. gave the highest significant aril percentage (52.35%) in the 1st season. While, in the second season no significant differences were appeared among Wonderful, 116 and Manfalouty cvs. as they appeared to have higher records of fruit aril percentage. Reversely, Acco realized the lowest fruit aril percentage (46.55-44.22 %) in both seasons.

The interaction between locations, dates and cultivars showed that, at 140 DAFB the variance between the means of fruit aril percentage among the tested cvs. was very narrow with non-significant differences in most cases of the two seasons, whereas the highest fruit aril (%) was noted by Wonderful (59.14%) in the 1st season and both Manfalouty and Wonderful (56.37 and 56.95%) at Giza orchard in the 2nd season. On the other side, the lowest fruit aril percentage in both seasons was appeared by Acco cv. (37.36 and 37.00%) in Minia orchard at 80 DAFB.

Fruit Juice Percentage: Fruit juice percentage appeared to be higher in Giza orchard (Table, 9). The highest value of fruit juice content (%) was achieved at 140 DAFB. Besides, Wonderful cv. gave the highest significant fruit juice content (%) in both seasons. While, 116 and Manfalouty recorded the lowest percentages in first season and Manfalouty in the second one. The interaction between locations, date and cultivars showed that, during the two seasons, fruit juice (%) for four cultivars were low at (80) DAFB and it reached the maximum at 140 DAFB in Giza and Minia. The highest fruit juice percentage in both seasons was recorded by Wonderful in Giza orchard (47.85 and 44.53 %). Otherwise, the minimum rates (39.20 and 35.16 %) in both seasons respectively were scored by Manfalouty cultivar that was planted in Minia orchard and picked at 140 DAFB.

In pomegranate, many researchers reported that, fruit juice continued to increase until harvest time constituting 35-45% of the total fruit weight [38]. In addition, juice content ranged between 57 - 67% of the total fruit weight [11]. Furthermore, Schwartz *et al*. [14] demonstrated that, volume of pomegranate aril juices was higher in Mediterranean temperate climate (lower temperature) than desert climate (higher temperature). Moreover, decline in pomegranate aril number and juice content under higher temperature condition due to climate, mainly attributed to the temperature and humidity which vary significantly during fruit development [39].

Fruit Chemical Characteristics

Juice Total Soluble Solids Content (TSS): Displayed results in Table (10) reveal that, planting location had a significant effect on fruit juice TSS content since Giza orchard recorded higher values (15.44 and 15.61 Brix°) compared to Minia orchard (13.82 and 13.90 Brix°) in both seasons. TSS had a positive correlation with number of days after full blooming as it reached the maximum values at 140 DAFB. 116 cv. produced fruits with the highest significant TSS content. On the contrary, the lowest TSS content in both seasons was recorded by Manfalouty cv.

Regards the interaction between locations, cultivars and dates, results viewed that, 116 cv. in Giza orchard at 140 DAFB registered the highest significant fruit juice TSS (18.35 and 18.67 Brix°) in both seasons. Contrariwise, the minimum rates at 140 DAFB were detected with Manfalouty (14.33 and 14.5 Brix°) in Minia`s orchard during 1st and 2nd seasons, respectively.

Juice Total Sugars Content: The results presented in Table (11) indicate that the richer of fruits juice in total sugars content in both seasons was registered by Giza orchard. Total sugars were increased progressively and reached the maximum values at 140 DAFB. Wonderful and Acco cvs gave the highest total sugars content in both seasons. The opposite was inherent with 116 cv. In connection with interaction between cultivars, dates and locations, results presented that, at 140 DAFB, in Giza orchard there is no clear significant differences between cultivars in both seasons. But Wonderful and Acco created high values of total sugars content in first and second seasons, respectively.

The present findings are in agreement with those of Al-Maiman and Ahmad, [40] and Shwartz *et al*. [4] who recognized that sugar and TSS concentrations were increased significantly during fruit maturation of Wonderful pomegranate and juice from fully mature pomegranate fruit has 12 - 16% sugar content, consisting mainly of glucose and fructose. An increase in TSS content with advancing fruit maturity was explained by a mechanism related to synthesis and hydrolysis of starch into simple sugars as fruit advances in maturation

Table 10: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for juice TSS content combined over locations (Giza and Minia) during 2016 and 2017 seasons

		TSS (Brix°)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	12.38	13.50	13.53	14.50	13.00	13.50	13.46	14.42
	100	13.97	14.87	14.81	16.00	14.50	14.45	15.00	16.13
	120	15.42	16.20	16.00	17.20	16.00	16.41	15.84	17.54
	140	16.35	17.20	16.83	18.35	16.80	17.50	16.56	18.67
Minia	80	11.80	12.80	12.33	12.61	12.40	12.30	12.42	12.80
	100	13.30	13.78	13.66	13.90	13.27	13.86	13.37	13.75
	120	13.82	14.61	14.23	14.72	14.00	14.50	14.50	14.88
	140	14.33	15.40	14.75	15.12	14.50	15.23	15.14	15.47
Mean (C)		13.92	14.80	14.52	15.30	14.31	14.72	14.54	15.46
Mean (D)		12.93	14.29	15.27	16.04	13.04	14.29	15.46	16.23
Mean (L)		15.44		13.82		15.61		13.90	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.1915	0.1915	Sig.	0.5417
Season 2017	0.1732	0.1732	Sig.	0.49

Table 11: Mean performance of cultivars, dates and cultivars x dates interaction for juice total sugars content combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Total Sugars (%)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	10.29	10.92	10.38	9.83	10.42	10.50	10.35	9.42
	100	13.12	12.75	12.82	12.86	11.52	12.88	12.50	11.44
	120	13.57	13.86	13.81	13.28	12.48	13.76	13.71	12.85
	140	14.15	14.78	14.60	13.70	13.69	14.80	14.83	13.90
Minia	80	9.80	10.15	10.23	9.00	9.16	10.30	10.26	9.32
	100	11.00	11.34	11.60	10.98	10.80	11.23	11.38	10.24
	120	11.71	12.54	12.98	12.32	11.62	11.89	12.15	11.13
	140	12.40	13.48	13.35	12.50	12.05	12.64	12.58	11.70
Mean (C)		12.01	12.48	12.47	11.81	11.47	12.25	12.22	11.25
Mean (D)		10.08	12.06	13.01	13.62	9.97	11.50	12.45	13.27
Mean (L)		12.80		11.59		12.42		11.15	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.4727	0.4727	Sig.	1.337
Season 2017	0.5067	0.5067	Sig.	1.433

[41]. A comparable effect of climate on sugar and TSS content was observed by Schwartz *et al*. [14] who found that pomegranate fruits obtained from the relatively temperate climate most likely promoted an increase in glucose and fructose compared to those from desert climate. Furthermore, Mphahlele *et al*. [42] worked on pomegranate and showed that cooler temperatures promoted the increase in glucose and fructose, whereas relatively higher temperatures decreased sugar content. Decreasing sugar content, presumably owing to respiration at higher temperatures [43]. Also, Wang and Camp [44] worked on strawberry and proved that under higher temperature condition sweetness significant decline in fruits. Pereira *et al*. [45] worked on grape berries and noted that higher temperatures exceeding 40°C (as prevailed in Minya orchard in the present study) can decrease sugar content.

Table 12: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for juice acidity content combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Total acidity (%)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	2.29	2.40	1.44	2.28	2.25	2.37	1.52	2.35
	100	1.83	1.95	0.89	1.83	1.70	2.03	0.90	1.93
	120	1.48	1.43	0.56	1.39	1.31	1.45	0.58	1.45
	140	1.12	1.12	0.48	1.14	1.06	1.17	0.52	1.11
Minia	80	2.18	1.84	1.37	2.23	2.25	1.89	1.28	2.38
	100	1.44	1.41	0.81	1.55	1.65	1.53	0.79	1.81
	120	1.13	1.03	0.49	1.18	1.12	1.16	0.53	1.20
	140	0.90	0.88	0.44	0.93	0.90	0.90	0.45	0.96
Mean (C)		1.55	1.51	0.81	1.57	1.53	1.56	0.82	1.65
Mean (D)		2.00	1.46	1.09	0.88	2.04	1.54	1.10	0.88
Mean (L)		1.48		1.24		1.48		1.30	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.1	0.1	Sig.	0.2829
Season 2017	0.1291	0.1291	Sig.	0.3652

Juice Acidity Content: Recorded results in Table (12) illustrate that, the Minia orchard had the lowest acidity in both seasons. During 1st and 2nd seasons, juice acidity was high in the first date (80 DAFB) and then gradually decreased upon reached the lowest values at fourth date (140 DAFB). Pomegranate cultivar 116 gave the highest acidity and Acco recorded the lowest values of these traits in both seasons. Around the interaction between locations, dates and cultivars, results reveal that, the lowest significant acidity content was noted by Acco in both Giza and Minya orchards at 140 DAFB during the two seasons compared with the rest cultivars.

In this respect, the present results are in line with the findings by Shwartz *et al*. [4] who recorded that, titratable acidity (TA) is an important quality attribute of pomegranate juice. Generally, acidity in pomegranate juice decreases with advancing fruit maturation but the rate of decline differs among cultivars and growing region [12, 40, 46]. Generally, the observed decrease in acidity with ripening could be attributed to an array of factors, such as increasing respiration, reducing translocation of acids from leaves, transformation of acids to the other compounds, dilution due to increasing volume of fruit and reducing the ability of fruit to synthesise acids with maturity [47, 48]. Acidity levels in pomegranate grown in coastal plain region were higher than those grown in the warmer valley region [38, 49, 4]. This is also in accordance with the results that obtained for tomatoes, in which TA levels were decreased to 25% when the temperature increased from 21 to 26°C [43].

Juice Maturity Index: TSS of fruit juice as well as total acidity mainly affects fruit quality. Therefore, TSS/ acid ratio can truly express the fruit quality indices. It is apparent from the results presented in the Table (13) that the Minia orchard marked higher significant maturity index (13.94-13.52) in first and second seasons, respectively. Maturity index was increased with advancing fruit maturation and the highest significant value of maturity index was appeared at 140 DAFB. Acco cv. produced the highest significant maturity index. While, the lowest significant value was generated by Manfalouty in the 1st season and Manfalouty, Wonderful and 116 cvs in the 2nd season.

The interaction between dates, cultivars and locations show that, at 140 DAFB, the highest significant maturity index (35.06 and 33.64) was realized by Acco cv. at Giza in the first season and at Minia in the second one, respectively. While, the minimum values at 140 DAFB (14.60 and 14.96) booked by Manfalouty and Wonderful cv. during 1st and 2nd seasons, respectively at Giza orchard.

Table 13: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for maturity index combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Maturity index (TSS/Acidity)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Location (L)	Date (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	5.41	5.63	9.40	6.36	5.78	5.70	8.86	6.14
	100	7.63	7.63	16.64	8.74	8.53	7.12	16.67	8.36
	120	10.42	11.33	28.57	12.37	12.21	11.32	27.31	12.10
	140	14.60	15.36	35.06	16.10	15.85	14.96	31.85	16.82
Minia	80	5.41	6.96	9.00	5.65	5.51	6.51	9.70	5.38
	100	9.24	9.77	16.86	8.97	8.04	9.06	16.92	7.60
	120	12.23	14.18	29.04	12.47	12.50	12.50	27.36	12.40
	140	15.92	17.50	33.52	16.26	16.11	16.92	33.64	16.11
Mean (C)		10.11	11.04	22.26	10.86	10.57	10.51	21.54	10.61
Mean (D)		6.73	10.69	16.33	20.54	6.70	10.29	15.96	20.28
Mean (L)		13.20		13.94		13.10		13.52	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.2161	0.2161	Sig.	0.6111
Season 2017	0.2381	0.2381	Sig.	0.6734

Generally, our presented results in Table (13) illustrated that, the highest significant maturity index observed by Acco cv. in both seasons and proved that it can be considered an early harvesting cultivar and can be harvested at least one month earlier than the rest cultivars under study. In addition, it can be classified the pomegranate cultivars depending on maturity index (MI) = 5-7 for sour, MI = 17-24 for sour-sweet and MI = 31-98 for sweet cultivars [50]. Taking into consideration of this simple rule, the following classification of cultivars can be concluded: Acco as sweet variety and Manfalouty, wonderful and 116 tends to be sour-sweet. This finding corroborates with the results reported by Kulkarni and Aradhya, [41] who found an increase in TSS content during fruit development with concomitant decrease in TA levels is an inherent process during growth and development of pomegranate, which imparts the characteristic juice flavor. In addition, Zarei *et al*. [51] highlighted the importance of TSS: TA value as a good indicator for fruit maturity because it increases significantly during fruit ripening. Reduction in maturity index in the first location (Giza) may be due to the decline in temperature during fruit growth period than the second location (Minia) which leading to delay fruit maturity. In this sphere, Ledesma *et al*. [21] on strawberry and Greer and Weedon [52] on grape reported that, at high temperature, the number of days to fruit ripening was significantly lower than the low temperature.

Juice Anthocyanin Content: The results depicted in Table (14) clear that, Giza orchard submitted higher significant juice anthocyanin content (90.61-82.17 mg/L) in both seasons. Anthocyanin pigment in pomegranate juice was increased gradually from 44.54 and 43.99 mg/L at 80 DAFB to 102.71 and 95.01mg/L in the last date under study (140 DAFB). Acco cv. took the first rank in juice anthocyanin content subsequent by 116 cv. then Wonderful and finally Manfalouty in both seasons.

The interaction effect of dates, locations with cultivars showed that, at the last date (140 DAFB) in Giza orchard, Acco cv. was superior in juice anthocyanin content (175.35 and 167.95 mg/L) during the two seasons of study, respectively. At 140 DAFB, the less juice anthocyanin content (36.57 and 34.84 mg/L) was displayed by Manfalouty cv. in Minia cross two seasons respectively.

Peel Anthocyanin Content: Results in Table (15) displayed that Giza orchard had higher significant values of peel anthocyanin content (199.66-180.39 mg/kg peel) in both seasons. The last date (140 DAFB) achieved the highest peel anthocyanin content. Pomegranate cultivar had a clear significant effect on peel anthocyanin content, whereas, the highest peel anthocyanin content (189.66 and 165.27 mg/kg peel) achieved by 116. While, the lowest one was Manfalouty (84.99 and 71.65 mg/kg peel) during 1st and 2nd seasons. Regarding to the interaction between,

Table 14: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for juice anthocyanin content combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Juice Anthocyanin content (mg/L)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	24.30	35.61	75.34	70.44	20.43	32.74	72.11	69.82
	100	42.34	56.26	105.18	91.76	31.03	48.42	97.23	89.47
	120	57.69	83.76	146.80	115.54	50.62	75.33	139.86	105.39
	140	97.15	125.83	175.35	146.37	83.08	108.71	167.95	122.60
Minia	80	18.17	24.15	58.16	50.12	17.46	27.93	62.80	48.63
	100	26.39	30.27	66.10	62.41	21.64	35.80	75.32	58.70
	120	31.87	36.92	83.71	76.74	27.90	44.21	94.38	69.57
	140	36.57	45.61	96.33	98.50	34.84	52.93	111.60	78.40
Mean (C)		41.81	54.80	100.87	88.99	35.88	53.26	102.66	80.32
Mean (D)		44.54	60.09	79.13	102.71	43.99	57.20	75.91	95.01
Mean (L)		90.61		52.63		82.17		53.88	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.6273	0.6273	Sig.	1.774
Season 2017	0.6138	0.6138	Sig.	1.736

Table 15: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for peel anthocyanin content combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Peel Anthocyanin content (mg/ kg peel)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	41.60	57.52	85.53	113.10	37.80	51.60	78.50	96.71
	100	81.00	114.90	170.30	219.10	75.22	98.20	157.33	194.80
	120	134.10	203.10	265.70	348.51	125.14	172.60	253.47	323.31
	140	218.62	306.65	366.11	468.75	189.50	260.94	338.20	432.84
Minia	80	21.90	20.50	38.80	42.00	15.55	17.28	25.47	30.11
	100	42.30	39.50	65.70	77.75	30.45	31.76	46.85	55.71
	120	61.92	63.10	85.05	112.61	42.75	46.80	78.20	80.30
	140	78.50	85.70	116.23	135.43	56.80	67.45	97.77	108.38
Mean (C)		84.99	111.37	149.18	189.66	71.65	93.33	134.47	165.27
Mean (D)		52.62	101.32	159.26	222.00	44.13	86.29	140.32	193.99
Mean (L)		199.66		67.94		180.39		51.98	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	0.3606	0.3606	Sig.	1.02
Season 2017	0.4042	0.4042	Sig.	1.143

dates, locations and cultivars, at 140 DAFB, the highest peel anthocyanin content was scored by 116 cv. under Giza conditions. Contrary, the minimum values of peel anthocyanin content were presented by Wonderful and Manfalouty in Minia at first date (80 DAFB) during 1st and 2nd seasons of the study, respectively.

When compared between both locations under study, it was evident that the fruit peel and arils which had better red coloration in Giza could be attributed to the relatively lower temperatures (about 35 °C) during fruit development and ripening compared to Minia. Whereas, low temperatures increased both anthocyanin content and genes expression, which involved in anthocyanin biosynthetic pathway [53, 54, 55]. In addition, the optimal temperature for anthocyanin accumulation (15 °C) was recorded during apple fruit ripening, whereas anthocyanin accumulation was repressed under (30 °C) [56, 57]. The anthocyanin

Table 16: Mean performance of cultivars, dates (DAFB) and cultivars x dates interaction for juice total phenol content combined over locations (Giza and Minia) during 2016 and 2017 seasons

		Total Phenol (mg GAE/L)							
		First season: 2016				Second season: 2017			
		Cultivars (C)				Cultivars (C)			
Locations (L)	Dates (D)	Manfalouty	Wonderful	Acco	116	Manfalouty	Wonderful	Acco	116
Giza	80	1109.38	1330.70	1270.49	1254.08	1248.10	1380.33	1284.22	1310.70
	100	881.67	1104.50	941.38	986.41	830.61	1117.82	918.50	1010.49
	120	694.67	870.10	810.29	825.37	696.80	860.36	786.50	840.41
	140	561.53	722.66	635.31	730.40	584.73	734.80	663.00	746.17
Minia	80	1176.65	968.33	1174.18	1108.40	1105.27	1070.91	1170.50	1150.64
	100	841.24	758.16	913.60	943.11	870.44	806.38	890.10	861.70
	120	653.33	643.47	786.73	805.20	650.81	679.54	720.30	735.16
	140	495.76	480.71	630.51	612.00	520.06	533.86	684.70	563.89
Mean (C)		801.78	859.83	895.31	908.12	813.35	898.00	889.73	902.40
Mean (D)		1174.03	921.36	761.15	608.61	1215.08	913.26	746.24	628.90
Mean (L)		920.56		811.96		938.35		813.39	

LSD value at 0.05	Dates (D)	Cultivars (C)	Locations (L)	D x C x L
Season 2016	4.727	4.727	Sig.	13.37
Season 2017	7.507	7.507	Sig.	21.23

biosynthesis pathway involves enzymes that operate at an optimum temperature between 17 and 26 °C, beyond which anthocyanin synthesis is inhibited [58]. Additional studies have shown that chemical or enzymatic degradation also plays a role in anthocyanin accumulation [59]. In red wine grape, high temperatures (maximum 35 °C) reduced total anthocyanin content less than half of that in the control berries (maximum = 25 °C) [60]. In apple, high temperatures prevent the accumulation of cyanidin and UDP-sugars [61], resulting in a rapid reduction in anthocyanins, followed by renewed synthesis with cooler temperatures, causing fluctuations in skin colour [54]. The decrease in anthocyanin accumulation at the high temperature was attributed to many factors such as enhancing anthocyanin degradation as well as the inhibition of mRNA transcription of anthocyanin biosynthesis genes. Also, due to the high oxidative stress which induced peroxidase that degraded anthocyanin in the skin of the berries [60].

Therefore, declining anthocyanin levels in peel and aril under Minia condition may be due to the prevailing temperature was extremely high during fruit development (about 40°C) which inhibited the anthocyanin biosynthesis pathway as well as anthocyanin degradation and also due to the high oxidative stress that can induce peroxidase activities.

These results are in harmony with the conclusion given by Shulman *et al*. [38], Borochov-Neori *et al*. [39], Schwartz *et al*. [14] and Mditshwa *et al*. [33] who noticed that, low heat condition is known to be an optimum factor for the biosynthesis of red anthocyanins compounds in pomegranate fruit. Pomegranate fruit grown under coastal regions (lower temperature) developed more intense colour (peel and aril) than those grown in desert region (higher temperature). Furthermore, Borochov-Neori *et al*. [39] shown that fruit ripening during July and August when the temperature was extremely high (about 40 °C), had a less intense aril color than fruits from the same trees that ripened in October when the temperature decreased to about 30 °C. Additionally, when shade nets was employed in the desert region to reduce air temperature during ripening in July and August, Borochov-Neori *et al*. [39] found a significantly darker red color of the pomegranate arils.

Juice Total Phenol Content: Recorded results in Table (16) illustrate that the Giza orchard had higher significant total phenol content in both seasons. Commonly, the total phenol content was very high in the first stage of fruit growth and continued the decreasing during fruit development. The lowest total phenol content was observed at 140 DAFB in both seasons. The highest total phenol content was generated by 116 cv. and the lowest was Manfalouty cv.

It can be observed from interaction between dates, locations and cultivars that, at 140 DAFB the maximum concentration of total phenol content (730.40 and 746.17 mg GAE /L) was detected by 116 cv in Giza orchard in

Table 17: Mean performance of pomegranate cultivars, for yield combined over locations (Giza and Minia) during 2016 and 2017 seasons

	Yield (Kg/tree)					
	First season: 2016			Second season: 2017		
	Locations (L)			Locations (L)		
Cultivars (C)	Giza	Minia	Means (C)	Giza	Minia	Means (C)
Manfalouty	22.34	20.74	21.54	26.54	23.83	25.19
Wonderful	20.49	19.40	19.95	24.76	22.07	23.42
Acco	15.98	16.64	16.31	18.73	20.16	19.45
116	19.53	17.69	18.61	22.39	21.43	21.91
Means (L)	19.59	18.65	---	23.11	21.87	---

LSD value at 0.05	Cultivars (C)	Locations (L)	C x L
Season 2016	0.4185	0.2959	0.5918
Season 2017	0.5354	0.3786	0.7572

both seasons respectively. While, the minimal values at 140 DAFB (480.71 and 520.06 mg GAE / L) were registered by Wonderful and Manfalouty cvs. in Minia`s orchard during the first and second seasons, respectively.

The loss of astringency is one of the desirable changes that occur during maturation and ripening of many pomegranate cultivars and this is primarily due to the decline in phenolic compounds [40, 41]. The significant reduction in phenolic compounds in pomegranate coincides with a sharp decline in juice antioxidant capacity during fruit development [39, 4, 46]. The reduction in total phenolic compounds had been occurred during fruit development and continued until the fruit had considered full ripe, thus may be due to the oxidation of phenolic content by polyphenol oxidase that characterizes these stages of maturity [41, 46, 51]. Furthermore, Shwartz *et al*. [4] revealed that total phenolic in pomegranate aril juice was higher in fruit grown in Mediterranean temperate climate than in desert climate. Li *et al*. [19] reported that there was negative correlations of average temperature with total phenol. Phenolic compounds are secondary metabolites widely found in fruits, mostly represented by flavonoids and phenolic acids. The growing interest in these substances is mainly because of their antioxidant potential and the association between their consumption and the prevention of some diseases [62]. The health benefits of these phytochemicals are directly linked to a regular intake and their bioavailability. In terms of human health, the higher level of phenolic compounds the higher total antioxidant activity of pomegranate fruit juice and its relative human health benefit [2, 63].

Yield Characteristics

Yield (Kg/tree): Results presented in Table (17) demonstrate that, the higher significant yield (19.59 and 23.11Kg/tree) was obtained by Giza orchard in both seasons, respectively. According to cultivars, Manfalouty cv. recorded the highest yield (21.54 and 25.19 Kg/tree), while the lowest values (16.31 and 19.45 kg/tree) were noted by Acco in both seasons, respectively. The interaction between cultivars and locations appeared that, Manfalouty at Giza orchard produced the highest yield in both seasons. While the lowest values were observed by Acco at Giza in both seasons.

Fruit Cracking (%): Location and cultivar had a significant effect on fruit cracking (%) as clear in (Table 18), the lower values (2.86 and 3.23%) were recorded under Giza conditions in both seasons. Whereas, the lowest significant values were observed by Acco. While the highest values were observed by Manfalouty in both seasons. Considering interaction effect between cultivars and locations, Manfalouty under Minia conditions in both seasons scored the highest fruit cracking percentage (5.78 and 6.34%). Contrarily, Acco under Giza conditions had the lowest (1.10 and 1.87 %) in both seasons.

Fruit Sunburn (%): Sunburn percentage was affected significantly by location and cultivar (Table 19). Minia orchard recorded higher significant values than Giza orchard. In addition, fruit sunburn (%) ranged from 3.77 and 4.17% with Acco and reached 6.26 and 7.84 % with Wonderful and Manfalouty in 1st and 2nd seasons respectively. Interaction among cultivars and locations illustrated that, Acco recorded the lowest values in both seasons under Giza conditions. On the other side, Manfalouty under Minia conditions possessed the highest significant percentage of sunburnt fruit in both seasons and sharing with Wonderful in the first one.

Table 18: Mean performance of pomegranate cultivars, for fruit cracking combined over locations (Giza and Minia) during 2016 and 2017 seasons.

	Fruit cracking (%)					
	First season: 2016			Second season: 2017		
	Locations (L)			Locations (L)		
Cultivars (C)	Giza	Minia	Means (C)	Giza	Minia	Means (C)
Manfalouty	3.63	5.78	4.71	3.65	6.34	4.99
Wonderful	2.78	4.48	3.63	3.45	5.37	4.41
Acco	1.10	3.02	2.06	1.87	3.69	2.78
116	3.92	4.93	4.43	3.93	5.71	4.82
Means (L)	2.86	4.55	---	3.23	5.28	---

LSD value at 0.05	Cultivars (C)	Locations (L)	C x L
Season 2016	0.1699	0.1201	0.2403
Season 2017	0.2835	0.2005	0.4010

Table 19: Mean performance of pomegranate cultivars, for fruit sunburn combined over locations (Giza and Min\ia) during 2016 and 2017 seasons.

	Fruit Sunburn (%):					
	First season: 2016			Second season: 2017		
	Locations (L)			Locations (L)		
Cultivars (C)	Giza	Minia	Means (C)	Giza	Minia	Means (C)
Manfalouty	4.46	7.40	5.93	5.83	9.85	7.84
Wonderful	4.85	7.67	6.26	6.31	8.16	7.24
Acco	2.65	4.88	3.77	2.52	5.82	4.17
116	5.46	6.76	6.11	4.68	7.12	5.90
Means (L)	4.36	6.68	---	4.84	7.74	---

LSD value at 0.05	Cultivars (C)	Locations (L)	C x L
Season 2016	0.2613	0.1848	0.3696
Season 2017	0.2316	0.1637	0.3275

Table 20: Mean performance of pomegranate cultivars, for fruit marketable combined over locations (Giza and Minia) during 2016 and 2017 seasons.

	Fruit marketable (%)					
	First season: 2016			Second season: 2017		
	Locations (L)			Locations (L)		
Cultivars (C)	Giza	Minia	Means (C)	Giza	Minia	Means (C)
Manfalouty	91.91	86.82	89.37	90.52	83.81	87.17
Wonderful	92.37	87.85	90.11	90.24	86.47	88.36
Acco	96.25	92.10	94.18	95.61	90.49	93.05
116	90.62	88.31	89.47	91.39	87.17	89.28
Means (L)	92.79	88.77	---	91.94	86.99	---

LSD value at 0.05	Cultivars (C)	Locations (L)	C x L
Season 2016	0.6601	0.4668	0.9335
Season 2017	0.8135	0.5752	1.1505

Fruit Marketable (%): Fruit marketable percentage was significantly higher (92.79 and 91.94%) under Giza conditions (Table, 20) compared with Minia conditions (88.77 and 86.99%) cross both seasons. Acco booked the highest significant percentage of marketable fruits comparing with the rest cultivars in both seasons. Concerning the interaction between cultivars and locations, fruit marketable (%) was increased significantly (96.25 and 95.61 %) by Acco under Giza conditions. Conversely, the lowest one was Manfalouty under Minia conditions (86.82 and 83.81%) in both seasons, respectively.

Reduction in yield and increasing fruit cracking and sunburn consequently decreased fruit marketable under Minia conditions due to raising temperature (about 40 °C) and lower relative humidity compared with Giza conditions (about 35 °C) during fruit development. Kadir and Sidhu [64], Sun *et al*. [34], Balasooriya *et al*. [65] suggested that, high temperature reduced the average fruit yields. Moretti *et al*. [17] clarify that high temperatures reduce the synthesis of photo-assimilates and increase respiration. For a high yield, not only photosynthesis should be high but also the ratio photosynthesis/respiration should be much higher than one. Fruit cracking may be attributed to weather conditions during fruit development, particularly prevalence of high temperature and moisture stress conditions of soil [66]. In addition, Singh *et al*. [67] found that, fruit surface temperature was 3.85 to 5.5°C higher than air temperature and canopy temperature was lower than ambience, because evaporation cause cooling however, fruit skin did not allow loss of moisture. Therefore, water loss from plant through canopy surface to atmosphere, thus greatly influences water relations and hence lead to incidence of cracking in fruits. Sunburn of pomegranate called blacking (large black spots) occurred when the surface temperature reached up to 45-50°C [68]. Sunburn is a physiological disorder resulting from the combined action of high solar radiations, high temperatures and low humidity [69]. When air temperatures are higher than 30°C, fruit surface temperatures are higher than 40°C that causes sunburn damage occurs on the pomegranate fruits. In addition, air humidity having an effect on solar radiation leading to decrease in fruit surface temperature [70]. In this case, the appearance quality of fruits decreases due to fruit cracking and burnt fruit, which leads to losses in yield and quality [69].

CONCLUSION

It could be concluded from the present study that, growing pomegranate in Minia led to losses in yield and fruit marketable percentage and lessened color density compared to those grown in Giza. The juice of these fruits (grown in Minia) have lower total phenols, anthocyanin and sugars as well as acidity levels, this is may be due to the higher temperature in Minia, which negatively affects pomegranate fruit quality. These parameters, (color and taste) determine fruit attractiveness to the consumer, which is a vital factor for marketing considerations. However, pomegranate fruits that grown under Giza conditions, fruits have higher quality (total phenols, anthocyanin levels and sugars as well as acidity) than those grown in Minia conditions. Under the conditions of Giza orchard the studied four cultivars (Manfalouty, Wonderful, Acco and 116) can be cultivated, but Acco then 116 produce the best colorful fruits (aril and peel). While, under Minia conditions only Acco then 116 can be recommended. Besides, Acco is considered an sweet and early harvesting cultivar while Manfalouty, Wonderful and 116 are considered as late harvesting cultivars and tend to be sweet-sour.

These findings can be used as a tool to help pomegranate growers in the investigated areas to detect the right cultivar that will yield the highest production with the best quality. Besides, to shed light on further research to create a categorical map to help decision-makers.

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