

Performance of Some Pomegranate Cultivars under Different Irrigation levels in North Sinai

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Received: 25 Oct. 2020 / Accepted 20 Dec. 2020 / Publication date: 30 Dec. 2020

ABSTRACT

Drought is one of the main serious problems for agriculture production which its intensity is increasing in many parts of the world. Hence, this experiment was carried out during 2015 and 2016 to study responses of four pomegranate cultivars Manfalouty, Nab-Elgamal, Wonderful and Wardi grown in sandy soil, in North Sinai Research Station, under different irrigation levels 100%, 75% and 50% of the recommended water level (11, 8.25 and 5.5m³/tree/year) on growth, flowering, yield and fruit quality. The results obtained that the highest irrigation level 100% (11 m³ /tree /year) enhanced vegetative growth, fruit set (%), number of fruits/tree, yield/kg/tree and fruit quality (fruit weight, diameter, length,) followed by descending moderate irrigation level 75% (8.25 m³ /tree /year) while, 50% (5.5 m³/tree/year) gave the lowest values during both seasons. On the other hand, the data showed that the percentage of total sugars, acidity and proline significantly increased by decreasing amount of water. Manfalouty cultivar gave the highest values of growth parameters, total flowers/tree, fruit set (%), no of fruits, yield, fruit weight aspects and sugar content, and the lowest fruit drop (%), fruit peel (%), peel thickness (cm) followed by descending order of Nab-Elgamal cultivar. While, Wonderful and Wardi cultivars exhibited the lowest significant values in both seasons respectively. Moreover, data indicated generally that the best treatment combination was gained from using irrigation level at 100% (11 m³ /tree /year) with Manfalouty and Nab-Elgamal which exhibited the highest values for all vegetative growth parameters, fruit set (%), fruit weight aspects, fruit arils and the least sugar content. Whereas, the maximum flower/tree, number of fruits/tree, fruit retention (%) and yield was observed with Manfalouty under the same irrigation level. On the other hand, Wardi cultivar under least irrigation treatment at 50% (5.5 m³/tree/years) recorded the highest significant values of fruit drop (%), fruit peel (%), fruit thickness (cm), proline (%) and acidity (%). Generally, data clarified that Manfalouty and Nab-Elgamal pomegranate cultivars are considered as a highly tolerant and significant to drought stress under North Sinai conditions compared to Wonderful and Wardi cultivars.

Keywords: Pomegranate, irrigation, drought, cultivars, productivity, fruit quality

Introduction

Pomegranate (*Punica granatum* L.) belongs to family Punicaceae and is one of the oldest known edible fruits. Pomegranate is an important commercial fruit crop of the tropical and subtropical regions of the world. It plays an important role in health development as it is packed with powerful antioxidants and vitamins (Parvizi and Sepaskhah, 2015). Pomegranate is a drought resistant tree because it tolerates heat and can grow well in arid, semi-arid and even under desert conditions (Aseri *et al.*, 2008). Regular irrigation throughout the dry season helps to reach optimal growth and yield and fruit quality for commercial production (Holland *et al.*, 2009). Water stress is one of the most significant environmental factors restricting growth, performance, and distribution of plant species worldwide (Liu *et al.*, 2011).

Plants species can tolerate water stress by synthesis and accumulation of low molecular mass organic solutes such as soluble sugars, proline or other amino acids to regulate the osmotic potential of cells Zhang *et al.*, (2010), Ebtadaie and Shekafandeh, (2016) and Pourghayoumi *et al.*, (2017). Some researchers have investigated pomegranate tree performance under different irrigation levels such as Khattab *et al.*, (2011a) who studied growth and productivity of pomegranate trees under five different irrigation levels, they observed that the highest irrigation level (15m³/tree/year) simulated vegetative growth and number of fruits per tree, fruit set (%), fruit retention (%) and total yield, whereas the lowest irrigation level (7 m³/tree/year) decreased these parameters. Shahzad *et al.*, (2016) showed that drought stress is a severe problem which effects on vegetative growth, yield, reproduction, and development of crops

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Pomegranate trees applied several mechanisms for drought resistance such as increasing cell turgid by accumulation of soluble sugars and proline, increasing water potential for more water absorption from soil, chlorophyll and carotenoid pigments preserved by control of leaf relative water content (RWC), reducing leaf area (Rad *et al.*, 2015).

In recent years, water stress has become a huge problem in pomegranate orchards caused reductions in quality, such as fruit cracking, and quantity of fruits. Therefore, identifying and introducing the most tolerant pomegranate cultivar to water deficit is very essential. The majority of studies on pomegranate trees under water stress have primarily investigated physiological responses such as transpiration, stomatal conductance, photosynthesis, intrinsic water use efficiency, stem and leaf water potential, RWC, and leaf osmotic potential (Galindo *et al.*, 2013, Intrigliolo *et al.*, 2011 and Mellisho *et al.*, 2012).

Therefore, the main aim of this study was to investigate and compare the effect of different three irrigation levels (100%, 75% and 50%) on the growth and productivity of four pomegranate cultivars (Manfalouty, Nab-Elgamal, Wonderful and Wardi) under North Sinai conditions.

2. Materials and Methods

This experiment was conducted during two successive seasons of 2015 and 2016 on different four pomegranate (*Punica granatum* L.) cultivars Manfalouty, Nab-Elgamal, Wonderful and Wardi grown at North Sinai Research Station, El-Sheikh Zuwayid, North Sinai Governorate, Egypt. All trees under investigation were seven years old, grown in sandy soil under drip irrigation system. The trees were planted at 5 × 5 m apart and all trees are almost uniform in shape and received regularly the annual horticultural practices.

The soil and irrigation water analysis was done and listed in Table (1):

Table 1: Some physical and chemical properties of the experimental soil and irrigation water.

Characteristics	Soil	Water
Particle size distribution %		
Sand	93.3	
Silt	4.9	
Clay	2.1	
Texture	Sandy soil	
SP	19.5	6.6
EC (dsm ⁻¹)	4.29	2.13
pH	8.00	8.0
Soluble cations meq/l		
Ca ⁺²	20.0	6
Mg ⁺²	7.8	1.3
Na ⁺	14.1	13.6
K ⁺	1.0	0.4
Soluble anions meq/l		
CO ₃ ⁻²	---	--
HCO ₃ ⁻	3.1	1.6
Cl ⁻	25.6	16.3
SO ₄ ⁻²	14.2	3.4
Available micronutrients in soil (ppm)		
Fe	2.8	1.5
Zn	3.6	1.5
Cu	0.7	0.2
Mn	5.4	0.1

In this experiment, three different irrigation levels 100% (control), 75% and 50% of the recommended rate of irrigations, were applied on different pomegranate cultivars

Table 2: Distribution of irrigation water (L. Month/tree) and (m³/ Month/feddan) during 2015 and 2016 seasons.

Irrigation levels	100% irrigation (control)		75% irrigation		50% irrigation	
	L. mo./tree	m ³ / mo. /Fed.	L. mo. /tree	m ³ / mo. / Fed.	L. mo. /tree	m ³ / mo. /Fed.
March	240	40.32	180	30.24	120	20.16
April	630	105.84	472.5	79.38	315	52.92
May	1500	252.00	1125	189.00	750	126.00
June	2100	352.80	1575	264.60	1050	176.40
July	2100	352.80	1575	264.60	1050	176.40
August	2100	352.80	1575	264.60	1050	176.40
September	1500	252.00	1125	189.00	750	126.00
October	660	110.88	495	83.16	330	55.44
November	180	30.24	135	22.68	90	15.12
Total m ³ /year	11.0	1849.68	8.25	1387.26	5.50	924.84

2.1. Measurements

2.1.1. Vegetative growth parameters:

- A- Average shoots length (cm): At the end of each season in September, the average shoot length was recorded by measuring the length of labeled shoots per tree and then the average shoot length (cm) was calculated.
- B- Number of leaves per shoot: Leaves developed on the new shoots were counted at the end of growing season in September.
- C- Leaf Area (cm²): Was determined by using the Laser leaf area meter CL203.

2.1.2. Flowering and fruiting parameters:

- A. Number of fruits per tree: Fruits were picked at October in both seasons and number of fruits per the tree was counted.
- B. Fruit set percentage: Was calculated according to the formula:

$$\text{Fruit set (\%)} = (\text{number of set fruits} / \text{total number of flowers}) \times 100.$$
- C. Fruit drop percentage: Was calculated by the following equation:

$$\text{Fruit drop (\%)} = \frac{\text{Total number of fruit set} - \text{Total number of fruits at harvest}}{\text{Total number of fruit set}} \times 100.$$
- D. Fruit retention percentage:
$$\text{Fruit retention (\%)} = \frac{\text{Total number of fruits at harvest}}{\text{Total number of fruit set}} \times 100.$$
- E- Yield per tree (kg): At harvest time, fruits per tree for each treatment were weighted and then average yield/tree as kg was estimated.
- F- Fruit physical properties: Ten fruits were taken randomly at harvest time from each treated tree for determination of fruit weight (g), fruit length (cm), fruit diameter (cm), fruit arils (%), fruit peel (%), peel thickness (cm).

2.1.3. Fruit chemical properties:

Sample of 10 mature fruits of each tree was taken at the harvest time to determining total acidity % in juice as citric acid by titrating 5 ml juice with 0.1 sodium hydroxide against using the phenolphalein as an indicator. The total sugars % was determined according to A.O.A.C. (1985).

Proline Percentage: Mature fresh leaf samples (0.5 g) were homogenized in 10 ml 3%-5% sulphosalicylic acid then filtered through Whitman No.1 filter paper. The filtrate (2 ml) was added to 2 ml ninhydrin reagent and 2 ml glacial acetic acid and then the mixture boiled on water both for one hour. The boiled mixture was put in ice both, then 4 ml were added to each sample with severely inverting, then calorimetrically estimated at 520 nm according to (Bates *et al.*, 1973). The proline concentration was determined from standard curve and calculated on fresh weight basis.

The obtained data were subjected to proper statistical analysis of variance for a split plot design (two factors) using MSTATC computer program with three replicates contents two trees. Duncan's multiple range tests was used for comparison between means. Different alphabetical letters in the column are significantly differed at (0.05) level of significance (Duncan, 1955). The same trees were used throughout both experimental seasons.

3. Results and Discussion

3.1. Vegetative growth characters:

Data in Table (3) clearly showed a significant difference among the three irrigation levels (100%, 75% and 50%) in terms of average shoot length (cm), number of leaves per shoots and leaf area (cm²) in both seasons. Irrigation under level 100% (11.0 m³/tree/year) recorded the highest values of shoot length (27.03 and 26.53cm), number of leaves per shoots (25.35 and 25.21) and leaf area (3.90 and 3.84 cm²) followed by irrigation level 75% (8.25m³/tree/year) during both seasons, respectively. On the other hand, least irrigation level at 50% (5.5m³/tree /year) induced the lowest values of shoot length (16.70 and 12.65cm), number of leaves per shoots (14.86 and 11.03) and leaf area (3.03 and 2.77 cm²) during two studied seasons, respectively.

Table 3: Effect of irrigation levels on vegetative growth of four pomegranate cultivars in 2015 and 2016 seasons.

Cultivars	Season 2015				Season 2016			
	Irrigation levels				Irrigation levels			
	100%	75%	50%	Mean	100%	75%	50%	Mean
Average shoot length (cm)								
Manfalouty	27.63a	26.03bc	19.48ef	24.38a	29.72a	24.39bc	16.42f	23.51a
Nab-Elgamal	28.27a	24.96cd	18.27f	23.84a	27.91a	21.79d	13.74g	21.15b
Wonderful	27.04a-c	23.18d	15.89g	22.04b	25.94b	19.78e	11.03h	18.92c
Wardi	25.18b-d	20.75e	13.14h	19.69c	22.54cd	15.23fg	9.42h	15.73d
Mean	27.03a	23.73b	16.70c		26.53a	20.30b	12.65c	
Number of leaves per shoots								
Manfalouty	27.69a	25.54b	18.21gh	23.82a	28.24a	23.89b	15.17e	22.43a
Nab-Elgamal	26.15ab	22.46de	16.87h	21.83b	27.19ab	20.90c	12.92f	20.34b
Wonderful	24.63bc	20.79ef	13.73i	19.72c	24.68b	17.71d	9.48g	17.29c
Wardi	22.93cd	19.85fg	10.63j	17.80d	20.76c	13.54ef	6.56h	13.62d
Mean	25.35a	22.16b	14.86c		25.21a	19.01b	11.03c	
Leaf area (cm²)								
Manfalouty	3.98a	3.78bc	3.27e	3.68a	4.15a	3.57cd	3.04f	3.59a
Nab-Elgamal	3.91ab	3.62d	3.16e	3.56b	4.01ab	3.43de	2.84fg	3.42b
Wonderful	3.93ab	3.53d	3.02f	3.49b	3.75bc	3.21ef	2.69g	3.22c
Wardi	3.76dc	3.25e	2.67g	3.23c	3.44de	2.97f	2.51g	2.97d
Mean	3.90a	3.54b	3.03c		3.84a	3.29b	2.77c	

Means followed by the same letter(s) within each column are not significantly different at the 0.05 level, according to Duncan's multiple range tests.

Results indicated that water stress is a vital factor limiting pomegranate cultivation in Mediterranean basin; also it can impair performance pomegranate growth and yield. The reduction in shoot growth and leaf enlargement and expansion may be due to the changes in hormone balance Webster *et al.*, (2000) and Liu *et al.*, (2005).

Similar findings are in harmony with Abd El-Samad and Ibrahim, (2007) , Khattab *et al.*, (2011a), Abd-Ella, (2011), Hamdy *et al.*, (2016), Bugueno *et al.*, (2016), Parvizi *et al.*, (2016) and Martínez-Nicolás *et al.*, (2019)

The growth parameters increased in the all cultivars under study as a result of increasing amount of water. However, Manfalouty cultivar exhibited the highest significant average of shoot length (24.38 and 23.51cm), number of leaves per shoots (23.82 and 22.43) and leaf area (3.68 and 3.59cm²) followed by descending order Nab-Elgamal then Wardi cultivars. Meanwhile, Wardi cultivar gave the lowest significant average shoot length (19.69 and 15.73cm), number of leaves per shoots (17.80 and 13.62) and leaf area (3.23 and 2.97cm²) in both seasons, respectively

For the interaction among the three levels of irrigation (100%, 75% and 50) and four pomegranate cultivars (Manfalouty, Nab-Elgamal, Wonderful and Wardi), the best results of shoot length, number of leaves per shoots and leaf area were observed with Manfalouty and Nab-Elgamal cultivars under irrigation level 100% (11.0m³/tree /year). On the other hand, the least values were observed with Wardi pomegranate cultivar under irrigation level at 50% (5.5m³/tree /year) for shoot length (13.14 and 9.42cm), number of leaves per shoots (10.63 and 6.56) and leaf area (2.67 and 2.51cm²) in both successive seasons, respectively. The other interaction came in between.

3.2. Flowering and fruiting parameters

Data presented in Table (4) indicated that a significant effect on total flowers/tree, fruit set and fruit drop percentages in response to different irrigation levels in the first and second seasons. Hence, the highest total flowers/tree (207.51 and 219.21) and fruit set percentage (28.53 and 28.02%) were noticed under irrigation level at 100% (11.0m³/tree /year). However, severe water stress at 50% (5.5m³/tree /year) recorded the lowest values of total flower/tree (133.31 and 100.63) and fruit set percentage (21.32 and 16.43) during seasons 2015 and 2016 respectively. On the other side, the highest fruit drop percentage was noticed under irrigation level at 50% (5.5m³/tree/year) which reached (19.31 and 22.66%). Meanwhile, applying irrigation at 100% (11.5m³/tree /year) gave the least fruit drop percentage (12.43 and 13.59%) in both successive seasons, respectively. These results are in harmony with Abd-Ella, (2011) who indicated that the highest mean value of number of flowers /shoot, fruit set percentage were associated with highest rate of irrigation level at 11m³/tree/year compared to irrigation level at (8.25 and 5.5 m³/tree /year).

Table 4: Effect of irrigation levels on total flowers/tree, fruit set (%) and fruit drop (%) of four pomegranate cultivars in 2015 and 2016 seasons.

Cultivars	Season 2015				Season 2016			
	Irrigation levels				Irrigation levels			
	100%	75%	50%	Mean	100%	75%	50%	Mean
Total flowers/tree								
Manfalouty	221.73a	198.82b	160.70e	193.75a	257.31a	182.88c	142.51e	194.23a
Nab-Elgamal	201.84b	178.49cd	142.31f	174.21b	229.48b	157.17d	112.72f	166.46b
Wonderful	217.97a	171.66d	124.68g	171.44b	226.83b	139.72e	91.97g	152.84c
Wardi	188.48c	157.41e	105.54h	150.48c	163.20d	107.65f	55.33h	108.73d
Mean	207.51a	176.60b	133.31c		219.21a	146.86b	100.63c	
Fruit set (%)								
Manfalouty	29.13a	27.42ab	23.57d	26.71a	30.06a	26.73c	19.80fg	25.53a
Nab-Elgamal	28.74a	26.49a-c	22.72de	25.98ab	29.58ab	25.15cd	17.70g	24.14a
Wonderful	28.59a	25.21b-d	20.14ef	24.65b	27.13bc	23.17de	14.48h	21.59b
Wardi	27.68ab	24.10cd	18.84f	23.54c	25.32cd	21.50ef	13.75h	20.19b
Mean	28.53a	25.80b	21.32c		28.02a	24.14b	16.43c	
Fruit drop (%)								
Manfalouty	11.86f	14.10 d-f	17.60bc	14.52b	12.11i	16.61fg	19.59c-e	16.11c
Nab-Elgamal	12.07f	14.49de	18.65b	15.07b	12.60i	17.60e-g	21.05c	17.08c
Wonderful	12.55ef	15.31cd	19.13b	15.66b	13.88hi	18.78d-f	23.47b	18.71b
Wardi	13.24d-f	16.88bc	21.87a	17.33a	15.76gh	20.58cd	26.54a	20.96a
Mean	12.43c	15.20b	19.31a		13.59c	18.39b	22.66a	

Means followed by the same letter(s) within each column are not significantly different at the 0.05 level, according to Duncan's multiple range tests.

Data in Table (5) showed that fruit retention%, number of fruits /tree and yield (kg/tree) were significantly affected by three different irrigation levels. However, under irrigation treatment at 100% (11.0m³/tree /year) gave the highest percentage of fruit retention (85.43 in the 1st and 83.19% in the 2nd season), no. of fruits/tree (20.18 in the 1st and 22.32 in the 2nd season) and yield (kg/tree) (4.21 in the 1st and 4.88kg in the 2nd season), followed by the moderate irrigation at 75% (8.25m³/tree /year).

Meanwhile, deficit irrigation at 50% (5.5m³/tree /year) produced the lowest fruit retention (72.52 in the 1st and 65.62% in the 2nd season), no. of fruits/tree (11.21 in the 1st and 7.68 in the 2nd season) and yield (1.70 in the 1st and 1.19kg in the 2nd season). The obtained results are in agreement with Abd El-Samad and Ibrahim (2007) , Rad *et al.*, (2015), Tavousi *et al.* (2015) , Cano-Lamadrid *et al.*, (2018), (Parvizi *et al.*, 2014) and Zhang *et al.*, (2017).

Table 5: Effect of irrigation levels on fruit retention (%), number of fruits /tree and yield of four pomegranate cultivars in 2015 and 2016 seasons.

Cultivars	Season 2015				Season 2016			
	Irrigation levels				Irrigation levels			
	100%	75%	50%	Mean	100%	75%	50%	Mean
Fruit retention (%)								
Manfalouty	87.12a	83.55bc	76.61ef	82.43a	85.58a	80.51bc	71.86ef	79.32a
Nab-Elgamal	86.13ab	80.95cd	74.48fg	80.52ab	83.68ab	76.22cd	69.38f	76.43b
Wonderful	84.48a-c	79.79de	71.75g	78.67b	82.35ab	73.86de	63.82g	73.34c
Wardi	83.99a-c	77.11ef	67.23h	76.11c	81.16b	68.83f	57.41h	69.13d
Mean	85.43a	80.35b	72.52c		83.19a	74.85b	65.62c	
No. of fruits/tree								
Manfalouty	22.17a	19.93a-c	16.43de	19.51a	29.67a	16.31d	11.21f	19.06a
Nab-Elgamal	19.41bc	15.12ef	11.71gh	15.41b	23.65b	13.78e	8.71g	15.38b
Wonderful	21.02ab	15.04ef	9.53hi	15.20b	20.46c	11.41f	6.74g	12.87c
Wardi	18.12cd	13.76fg	7.18i	13.02c	15.50de	8.44g	4.06h	9.33d
Mean	20.18a	15.96b	11.21c		22.32a	12.48b	7.68c	
Yield (kg/tree)								
Manfalouty	5.06a	4.04bc	2.52e-g	3.87a	6.89a	3.47d	1.89f	4.08a
Nab-Elgamal	4.39ab	3.14de	1.85gh	3.13b	5.39b	2.67e	1.46fg	3.17b
Wonderful	4.01bc	2.64ef	1.41hi	2.69c	4.30c	1.85f	0.91gh	2.35c
Wardi	3.38cd	2.21fg	1.03i	2.21d	2.95de	1.29fg	0.52h	1.58d
Mean	4.21a	3.01b	1.70c		4.88a	2.32b	1.19c	

Means followed by the same letter(s) within each column are not significantly different at the 0.05 level, according to Duncan's multiple range tests.

The results revealed that percentage of fruit retention; numbers of fruit/tree and yield (kg/tree) were significantly varied among the four pomegranate cultivars. However, Manfalouty cultivar produced the highest significant fruit retention (82.43 & 79.32%), number of fruit /tree (19.51 & 19.06) and yield (kg/tree) (3.87 & 4.08) followed by descending order Nab-Elgamal and Wonderful cultivars. Meanwhile, Wardi cultivar gave the lowest values in percentage of fruit retention (76.11 & 69.13%), number of fruit /tree (13.02 & 9.33) fruit /tree and (2.21 & 1.58) yield (kg/tree) during the first and second experimental seasons respectively. As for the interaction effect between different irrigation levels and four pomegranate cultivars, it is clear that the maximum fruit retention percentage (87.12 & 85.58%), number of fruit/tree (22.17 & 29.67) and yield (kg/tree) (5.06 & 6.89kg/tree) was observed with Manfalouty cultivar under level irrigation at 100% (11.0m³/tree /year). On the contrary, Wardi cultivar under severe water stress at 50% (5.5m³/tree /year) recorded the lowest values of fruit retention percentage (67.23 & 57.41%), number of fruit/tree (7.18 & 4.06) and yield (kg/tree) (1.03 & 0.52kg/tree) in the 1st and 2nd season respectively. The other interactions were in between values. The obtained results are in harmony with Abo-Taleb *et al.*, (1998) found that Manfalouty and Nab-El-gamal cultivars exhibited the greatest values of growth parameters, followed in decreasing order by Araby and Wardi under severe water stress. EL-Agamy *et al.*, (2010) observed that Manfalouty pomegranate was the most tolerant cultivar to drought and salinity in comparison to Nab-Elgamal under in vitro conditions.

Results presented in Table (6) reveal a significant effect on fruit weight, fruit length and fruit diameter in response to different irrigation levels. Hence, the highest values and significant in fruit

weight (188.47 & 200.70g), fruit length (7.09 & 7.15cm) and fruit diameter (6.62 & 6.73cm) was observed under irrigation level at 100% (11.0m³/tree /year) followed by moderate irrigation level at 75% (8.25m³/tree /year). On the other side, applied irrigation level at 50% (5.5 m³/tree /year) recorded the least average of fruit weight (123.21 & 105.67g), fruit length (5.80 & 5.42cm) and fruit diameter (6.21 & 5.75cm) in the first and second season respectively. These results are in line with Khattab *et al.*, (2011b), Mellisho *et al.*, (2012) and Parvizi *et al.*, (2014) who concluded that fruit physical properties (average fruit weight, fruit length and fruit diameter) were improved under the highest irrigation rate.

Fruit physical properties were significantly varied among the four pomegranate cultivars which grown under different irrigation levels. However, in the first season, Manfalouty and Nab-Elgamal produced the highest fruit weight (169.23 & 166.83g), fruit length (6.41 & 6.33cm) and fruit diameter (6.87 & 6.85cm). Meanwhile, in the second season, Manfalouty cultivar gave the best fruit weight (174.79 g), fruit length (6.44cm) and fruit diameter (6.21 & 5.75cm). On the other hand, Wardi cultivar exhibited the lowest average in fruit weight (139.09 & 118.39g), fruit length (5.85 & 5.65cm) and fruit diameter (6.34 & 5.84cm) during the first and second experimental seasons, respectively.

Table 6: Effect of irrigation levels on fruit weight (g), fruit length (cm) and fruit diameter (cm) of four pomegranate cultivars in 2015 and 2016 seasons.

Cultivars	Season 2015				Season 2016			
	Irrigation levels				Irrigation levels			
	100%	75%	50%	Mean	100%	75%	50%	Mean
Fruit weight (g)								
Manfalouty	191.11b	174.86cd	141.72f	169.23a	224.40a	167.20c	132.79de	174.79a
Nab-Elgamal	201.21a	169.19d	130.09g	166.83a	211.60ab	144.55d	117.90fg	158.01b
Wonderful	184.45bc	154.52e	124.75g	154.57b	197.80b	129.08ef	97.29h	141.38c
Wardi	177.10cd	143.89f	96.27h	139.09c	169.20c	111.25g	74.70i	118.39d
Mean	188.47a	160.61b	123.21c		200.70a	138.02b	105.67c	
Fruit length (cm)								
Manfalouty	6.59ab	6.51ab	6.13cd	6.41a	7.03a	6.42c	5.86d	6.44a
Nab-Elgamal	6.72a	6.35bc	5.92de	6.33a	6.83ab	6.19c	5.73d	6.25a
Wonderful	6.64ab	6.17cd	5.76e	6.19a	6.67b	5.76d	5.16e	5.86b
Wardi	6.41a-c	5.75e	5.39f	5.85b	6.38c	5.64d	4.91e	5.65c
Mean	6.59a	6.19b	5.80c		6.73a	6.00b	5.42c	
Fruit diameter (cm)								
Manfalouty	7.15ab	7.07a-c	6.41ef	6.87a	7.41a	6.72d	6.39e	6.84a
Nab-Elgamal	7.21a	6.82b-d	6.53de	6.85a	7.33ab	6.53de	6.06fg	6.63b
Wonderful	7.08ab	6.74c-e	6.24f	6.69b	7.03bc	6.32ef	5.80g	6.39c
Wardi	6.91a-c	6.43ef	5.67h	6.34c	6.83cd	5.94g	4.76h	5.84d
Mean	7.09a	6.77a	6.21b		7.15a	6.38b	5.75c	

Means followed by the same letter(s) within each column are not significantly different at the 0.05 level, according to Duncan's multiple range tests.

With regard to the combination among three levels of irrigation and four pomegranate cultivars, data indicated that, in the first season, the bigger fruit weight (201.21g), the highest fruit length (6.72cm) and fruit diameter (7.21cm) were found with Nab-Elgamal cultivar under full irrigation at 100% (11.0m³/tree /year). Meanwhile, in the second season, Manfalouty cultivar gave the best fruit weight (224.40g), fruit length (7.41cm) and fruit diameter (7.21cm) under irrigation at 100% (11.0m³/tree /year). On the other hand, Wardi cultivar recorded the lowest fruit weight (96.27 & 74.70g), fruit length (5.39 & 4.91cm) and fruit diameter (5.67 & 4.76cm) under least irrigation level at 50% (5.5m³/tree /year), in the first and second seasons, respectively. The other interactions were in between values.

Concerning the results in Table (7) it is shown that fruit arils (%), fruit peel (%) and peel thickness (mm) was significantly affected by different three irrigation levels in both seasons. However, the highest

percentage and significant in fruit arils (%) was obtained under full irrigation treatment (11.0m³/tree/year) which average (59.00 & 60.33%) followed by irrigation under level at 75% (8.25 m³/tree/year) which produced (54.27 & 51.31%). Whereas, applied irrigation at 50% (5.5 m³/tree/year) obtained the lowest percentage in fruit arils (48.05 & 43.85%) in both seasons, respectively. On the other side, the highest values and significant in fruit peel (59.00 & 60.33%) and peel thickness (59.00 & 60.33 mm) was observed under level irrigation at 50% (5.5m³/tree/year). While, irrigation at 100% (11.0m³/tree/year) resulted in the lowest significant percentage in fruit peel (59.00 & 60.33%) and peel thickness (59.00 & 60.33 mm) in both seasons, respectively.

Table 7: Effect of irrigation levels on fruit arils (%), fruit peel (%) and peel thickness (mm) of four pomegranate cultivars in 2015 and 2016 seasons.

Cultivars	Season 2015				Season 2016			
	Irrigation levels				Irrigation levels			
	100%	75%	50%	Mean	100%	75%	50%	Mean
Fruit arils (%)								
Manfalouty	59.69ab	56.87a-c	51.62d-f	56.06a	63.17a	54.85bc	48.44de	55.49a
Nab-Elgamal	60.67a	55.62b-d	49.12fg	55.14ab	62.05a	52.55cd	45.93ef	53.51ab
Wonderful	58.30ab	53.09c-e	47.74fg	53.04b	59.48ab	52.23cd	42.14fg	51.28b
Wardi	57.33ab	51.52d-f	43.73g	50.86c	56.61bc	45.58ef	38.90g	47.03c
Mean	59.00a	54.27b	48.05c		60.33a	51.31b	43.85c	
Fruit peel (%)								
Manfalouty	40.34g	43.13fg	48.38cd	43.95c	37.16g	45.15cd	51.56b	44.62d
Nab-Elgamal	40.68g	44.81ef	50.88bc	45.46bc	39.08fg	47.45c	54.67b	47.07c
Wonderful	41.70fg	46.58de	52.26ab	46.85b	40.52ef	47.77c	58.98a	49.09b
Wardi	42.99fg	48.48cd	54.87a	48.78a	43.39df	54.42b	61.10a	52.97a
Mean	41.43c	45.75b	51.60a		40.04c	48.69b	56.58a	
Peel thickness (mm)								
Manfalouty	0.31f	0.35f	0.46de	0.37c	0.35h	0.51f	0.55ef	0.47c
Nab-Elgamal	0.41e	0.49d	0.56bc	0.48b	0.43g	0.58df	0.67bc	0.56b
Wonderful	0.35f	0.46de	0.60ab	0.47b	0.42g	0.62cd	0.72b	0.59b
Wardi	0.48d	0.55c	0.64a	0.56a	0.56ef	0.65c	0.79a	0.67a
Mean	0.38c	0.46b	0.57a		0.44c	0.59b	0.68a	

Means followed by the same letter(s) within each column are not significantly different at the 0.05 level, according to Duncan's multiple range tests.

Manfalouty (56.06 & 55.49 %) and Nab-Elgamal (55.14 & 53.51 %) cultivars gave the highest percentage of fruit arils (%) followed by Wonderful cultivar (53.04 & 51.28 %). Whereas, the lowest percentage of fruit arils was observed with Wardi cultivar (50.86 & 47.03 %) in both seasons, respectively. On the other hand, Manfalouty cultivar gave the least percentage and significant of fruit peel (48.78 & 52.97 %) and peel thickness (00.37 & 00.47 mm). Meanwhile, Wardi cultivar produced the highest percentage of fruit peel (48.78 & 52.97 %) and peel thickness (mm) (00.56 & 00.67 mm). Nab-Elgamal and Wonderful cultivars recorded the intermediate values in this respect during the first and second seasons respectively.

The obtained data from the interaction among the three different irrigation levels and four pomegranate cultivars indicated that the highest percentage of fruit arils was observed with Nab-Elgamal (60.67 & 62.05 %) and Manfalouty (59.69 & 63.97 %) under irrigation 100% (11.0m³/tree/year). While, the least value of fruit arils was obtained with Wardi cultivar (43.73 & 38.90 %) under deficit irrigation at 50%. On the other side, Wardi cultivar under least irrigation level produced the highest and significant average of fruit peel (54.87 & 61.10 %) and peel thickness (00.64 & 00.79 mm) compared to Manfalouty under irrigation treatment at 100% (11.0m³/tree/year) which gave the lowest percentage of fruit peel (40.34 & 37.16 %) and peel thickness (00.31 & 00.35 mm) in both seasons, respectively. The other interaction came in between.

3.3. Fruit chemical properties

Data presented in Table (8) indicated that total sugar (%), acidity (%) and proline (%) were significantly affected by different irrigation treatments in both seasons. However, the highest level and significant of total sugar (13.36 & 13.39%), acidity (2.09 & 2.31.15%) and proline (1.34 & 1.49%) was noticed under water stress at 50% (5.5 m³/tree /year). While, the lowest level of total sugar (12.90 & 13.16%), acidity (1.44 & 1.64%) and proline (0.55 & 0.67%) were recorded under full irrigation at 100% (11.0m³/tree /year). On the other hand, moderate irrigation level at 75% (8.25m³/tree /year) exhibited an intermediate value during the first and second season, respectively. These results are in harmony with Abd-Ella, (2011), Khattab *et al.*, (2011 c), Rad *et al.*, (2015), Dinc *et al.*, (2018) and Nasrabadia *et al.*, (2019) on different pomegranates cultivars; observed that the lowest level leaf proline and fruit acidity was observed with the highest irrigation level, soluble carbohydrate content increased with reducing the irrigation level. Also, Cano-Lamadrid *et al.*, (2018) found that the highest contents of glucose and fructose were recorded under water stress in wonderful pomegranate cultivar.

Table 8: Effect of irrigation levels on total sugar, acidity and proline (%) of four pomegranate cultivars in 2015 and 2016 seasons.

Cultivars	Season 2015				Season 2016			
	Irrigation levels				Irrigation levels			
	100%	75%	50%	Mean	100%	75%	50%	Mean
Total sugars (%)								
Manfalouty	13.26e	13.46c	13.62a	13.44a	13.47c	13.61ab	13.67a	13.58a
Nab-Elgamal	13.08f	13.31e	13.59ab	13.32b	13.29d	13.54bc	13.69a	13.51b
Wonderful	12.97g	13.36d	13.55b	13.29b	13.17e	13.48c	13.51c	13.39c
Wardi	12.31j	12.53i	12.67h	12.51c	12.73fg	12.79f	12.69g	12.74d
Mean	12.90c	13.17b	13.36a		13.16c	13.35b	13.39a	
Acidity (%)								
Manfalouty	1.50fg	1.73d	2.08bc	1.77a	1.76e	1.98d	2.28ab	2.01a
Nab-Elgamal	1.42gh	1.59ef	2.01c	1.68b	1.53e	1.96d	2.21bc	1.90b
Wonderful	1.47gh	1.68de	2.11ab	1.75a	1.60e	2.05d	2.33ab	1.99a
Wardi	1.38h	1.76d	2.18a	1.77a	1.65e	2.11cd	2.39a	2.05a
Mean	1.44c	1.69b	2.09a		1.64c	2.03b	2.31a	
Proline (%)								
Manfalouty	0.49j	0.78g	1.17d	0.81d	0.56j	0.92g	1.33d	0.93d
Nab-Elgamal	0.51ij	0.83g	1.28c	0.87c	0.63i	1.08f	1.41c	1.04c
Wonderful	0.57hi	0.94f	1.39b	0.97b	0.72h	1.21e	1.56b	1.16b
Wardi	0.61h	1.03e	1.53a	1.05a	0.76h	1.29d	1.64a	1.23a
Mean	0.55c	0.89b	1.34a		0.67c	1.12b	1.49a	

Means followed by the same letter(s) within each column are not significantly different at the 0.05 level, according to Duncan's multiple range tests.

The highest percentage and significant of total sugars (13.44 in the 1st and 13.58% in the 2nd season) and the lowest level of proline percentage (0.81 in the 1st and 0.93% in the 2nd season) were recorded with Manfalouty cultivar compared to Wardi cultivar which gave the least content of sugar (12.51 in the 1st and 12.74% in the 2nd season) and the highest percentage of proline (1.05 in the 1st and 1.23% in the 2nd season). On the other side, the lowest percentage of total acidity was observed with Nab-Elgamal cultivar (1.68 in the 1st and 1.90 in the 2nd season). These results are in the same line with Hamdy *et al.*, (2016)

Also, the total sugars (%), acidity (%) and proline (%) were significantly affected by the interaction among the three levels irrigation and four pomegranate cultivars. Hence, Manfalouty and Nab-Elgamal cultivars under deficit irrigation level at 50% (5.5m³/tree/year) produced the highest values of total sugar. While, the lowest value of sugar percentage was observed with Wardi cultivar under full irrigation at 100% (12.31 in the 1st season) and 50% (12.69% in the 2nd season). On the other

hand, the highest average of acidity and proline percentage was observed with Wardi pomegranate cultivar under water stress at 50% (5.5 m³/tree /year). Whereas, Nab- Elgamal under full irrigation 100% gave the lowest average of acidity percentage (1.42 and 1.53) and Manfalouty gave the lowest average of proline (0.49% and 56%) during both seasons, respectively. The other interaction came in between.

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