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

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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 5.5 m³/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. One 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), Ebtedaie 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 x 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):

| 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 | | |
| Ca²⁺           | 20.0 | 6     |
| Mg²⁺           | 7.8  | 1.3   |
| Na⁺            | 14.1 | 13.6  |
| K⁺             | 1.0  | 0.4   |
| Soluble anions meq/l | | |
| CO₃²⁻          | ---  | --    |
| HCO₃⁻          | 3.1  | 1.6   |
| Cl⁻            | 25.6 | 16.3  |
| SO₄²⁻          | 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 (m$^3$/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 (cm$^2$): 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:

\[
\text{Fruit set} \% = \frac{\text{number of set fruits}}{\text{total number of flowers}} \times 100.
\]

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: Fruit retention (%) = Total number of fruits at harvest / Total number of fruit set X 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% sulphosalisylic 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 (cm$^2$) in both seasons. Irrigation under level 100% (11.0 m$^3$/tree/year) recorded the highest values of shoot length (27.03 and 26.53 cm), number of leaves per shoots (25.35 and 25.21) and leaf area (3.90 and 3.84 cm$^2$) followed by irrigation level 75% (8.25 m$^3$/tree/year) during both seasons, respectively. On the other hand, least irrigation level at 50% (5.5 m$^3$/tree/year) induced the lowest values of shoot length (16.70 and 12.65 cm), number of leaves per shoots (14.86 and 11.03) and leaf area (3.03 and 2.77 cm$^2$) 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 | 24.38a | 16.42f | 23.51a |
| Nab-Elgamal   | 28.27a | 24.96cd | 18.27f | 23.84a | 27.91a | 23.84a | 17.91d | 21.15b |
| Wonderful     | 27.04a-c | 23.18d | 15.89g | 22.04b | 25.94b | 22.04b | 19.78e | 18.92c |
| Wardi         | 25.18b-d | 20.75e | 13.14h | 19.69c | 25.21a | 25.21a | 15.23f | 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 | 23.82a | 15.17c | 22.43a |
| Nab-Elgamal   | 26.15ab | 22.46de | 16.87h | 21.83b | 27.19ab | 21.83b | 12.92f | 20.34b |
| Wonderful     | 24.63bc | 20.79ef | 13.73i | 19.72c | 24.68b | 24.68b | 17.71d | 17.29c |
| Wardi         | 22.93cd | 19.85fg | 10.63j | 17.80d | 20.76c | 20.76c | 13.54ef | 13.62d |
| **Mean**      | 25.35a | 22.16b | 14.86e | 25.21a | 19.01b | 11.03c |
| **Leaf area (cm$^2$)** | | | | | | | | | |
| Manfalouty    | 3.98a | 3.78bc | 3.27c | 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 | 3.23e | 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 23.51 cm), number of leaves per shoots (23.82 and 22.43) and leaf area (3.68 and 3.59 cm$^2$) followed by descending order Nab-Elgamal then Wardi cultivars. Meanwhile, Wardi cultivar gave the lowest significant average shoot length (19.69 and 15.73 cm), number of leaves per shoots (17.80 and 13.62) and leaf area (3.23 and 2.97 cm$^2$) 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, sever 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 5.5m³/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 | 160.70c | 193.75a | 257.31a | 182.88c | 142.51c | 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  | 19.80f  | 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 | 21.05e  | 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                | 12.43e  | 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  | Irrigation  |
|                 | levels      | levels      |
|                 | 100%        | 75%         |
|                 | 50%         | Mean        |
|                 | 50%         | Mean        |
|                 | 100%        | 75%         |
| 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     | 67.23b      | 76.11c  | 81.16b  | 68.83f  | 57.41h  | 69.13d |
| Mean            | 85.43a      | 80.35b      | 72.52c      | 83.19a  | 74.85b  | 65.62c  |         |        |
| Number of fruits|             |             |
| (%) per 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) |             |             |
| (%) per 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   | 2.67c   | 1.46f   | 3.17b  |
| Wonderful      | 4.01bc      | 2.64ef      | 1.41hi      | 2.69c   | 4.30c   | 1.85f   | 0.91g   | 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 Arabby 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-El-gamal 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% (11.0m\(^3\)/tree /year) followed by moderate irrigation level at 75% (8.25m\(^3\)/tree /year). On the other side, applied irrigation level at 50% (5.5 m\(^3\)/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 Parviz 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-Elgamaral 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-Elgamaral | 201.21a | 169.19d | 130.09g | 166.83a | 211.60ab | 145.55d | 117.90fg | 158.01b |
| Wonderful   | 184.45bc | 154.52e | 124.75f | 154.57b | 197.80b | 129.08ef | 97.29gh | 141.38c |
| Wardi       | 177.10cd | 143.89f | 96.27h | 139.09e | 169.20c | 111.25g | 74.70i | 118.39j |
| 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-Elgamaral | 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  | 5.86d  |
| Wardi       | 6.41ac  | 5.75c  | 5.39f  | 5.85b  | 6.38c  | 5.64d  | 4.91c  | 5.65c  |
| Mean        | 6.59a   | 6.19b  | 5.80c  | 6.73a  | 6.00b  | 5.42c  |       |       |
| Fruit diameter (cm) |       |       |       |       |       |       |       |       |
| Manfalouty  | 7.15ab  | 7.07ac | 6.41ef | 6.87a  | 7.41a  | 6.72d  | 6.39e  | 6.84a  |
| Nab-Elgamaral | 7.21a | 6.82bd | 6.53de | 6.85a  | 7.33ab | 6.53de | 6.06eg | 6.63b  |
| Wonderful   | 7.08ab  | 6.74ce | 6.24f  | 6.69b  | 7.03bc | 6.32ef | 5.80g  | 6.39c  |
| Wardi       | 6.91ac  | 6.43df | 5.67e  | 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-Elgamaral cultivar under full irrigation at 100% (11.0m\(^3\)/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% (11.0m\(^3\)/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% (5.5m\(^3\)/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 | Irrigation levels |
|            | 100% | 75% | 50% | Mean | 100% | 75% | 50% | Mean |
| Fruit arils (%) | | | | | | | | |
| Manfalouty | 59.69ab | 56.87a-c | 51.62d-f | 56.06a | 54.17a | 54.85b | 48.44e | 55.49a |
| Nab-Elgamal | 60.67a | 55.62b-d | 49.12g | 55.14ab | 62.05a | 52.55cd | 45.93ef | 53.51ab |
| Wonderful | 58.30ab | 53.09c-e | 47.74f | 53.04b | 59.48ab | 52.23cd | 42.14fg | 51.28b |
| Wardi | 57.33ab | 51.52d-f | 43.73g | 50.86c | 56.61bc | 45.58ef | 38.90gh | 47.03c |
| Mean | 59.00a | 54.27g | 48.05c | 60.33a | 51.31b | 43.85c | | |
| Fruit peel (%) | | | | | | | | |
| Manfalouty | 40.34g | 43.13f | 48.38cd | 43.95e | 37.16g | 45.15cd | 51.56b | 44.62d |
| Nab-Elgamal | 40.68g | 44.81ef | 50.88bc | 45.46bc | 39.08fg | 47.45cd | 54.67bc | 47.07c |
| Wonderful | 41.70g | 46.58de | 52.26ab | 46.85b | 40.52ef | 47.77c | 58.98a | 49.09b |
| Wardi | 42.99f | 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 mm) 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 (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%) 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% (11.0 m³/tree/year). On the other hand, moderate irrigation level at 75% (8.25 m³/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 pomegranate cultivars; observed that the lowest level of 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 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 |
| Manfalouty | 13.26 | 13.46 | 13.62 | 13.44a | 13.47c | 13.61ab | 13.67a | 13.58a |
| Nab-Elgamal | 13.08 | 13.31 | 13.59 | 13.32b | 13.29d | 13.54bc | 13.69a | 13.51b |
| Wonderful | 12.97 | 13.36d | 13.55 | 13.29b | 13.17c | 13.48c | 13.51c | 13.39c |
| Wadi | 12.31 | 12.53 | 12.67 | 12.51c | 12.73 | 12.79f | 12.69 | 12.74d |
| Mean | 12.90 | 13.17b | 13.36d | 13.16c | 13.35b | 13.39a |

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 (00.81 in the 1st and 00.93% in the 2nd season) were recorded with Manfalouty cultivar compared to Wadi 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% (5.5 m³/tree/year) produced the highest values of total sugar. While, the lowest value of sugar percentage was observed with Wadi cultivar under full irrigation at100% (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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