Journal of Horticultural Science & Ornamental Plants 3 (2): 194-198, 2011
ISSN 2079-2158

Growth and Productivity of Pomegranate Trees under Different Irrigation Levels I: Vegetative Growth and Fruiting

[1]*Magda M. Khattab,* [1]*Ayman E. Shaban,* [2]*Arafa H. El-Shrief and* [2]*Ahmed S. El-Deen Mohamed*

[1]Pomology Department, Faculty of Agriculture, Cairo University, Giza, Egypt
[2]Horticulture Research Institute, Agriculture Research center, Giza, Egypt

Abstract: This investigation was carried out through two successive seasons of 2007 and 2008 on 20 years old pomegranate trees of Manfalouty cultivar for studying the effect of different irrigation levels on vegetative growth and fruiting. Trees under investigation were grown in a sandy soil at El-Kassasien Research Station, Ismailia Governorate. The trees received the following five irrigation levels: 7 or 9 or 11 (control) or 13 and $15m^3$/tree/year. The results indicated that, the highest irrigation level of $15m^3$/tree/year induced vegetative growth by increasing shoot length, number of leaves per shoot and leaf area. Also it increased number of flowers per shoot, fruit set, fruit retention, yield and fruit cracking. Using irrigation level of $13m^3$/tree/year recorded the highest water use efficiency (WUE) and gave the lowest fruit cracking. Meanwhile, using the lowest irrigation level of $7m^3$/tree/year decreased shoot length, number of leaves per shoot, leaf area and yield with increasing fruit cracking.

Key words: Pomegranate · Irrigation levels · Vegetative growth · Flowering · Fruiting

INTRODUCTION

The pomegranate (*Punica granatum* L.) is a popular fruit of tropical and subtropical regions, belonging to the family punicaceae. Manfalouty is considered one of the most important pomegranate cultivars grown successfully in Egypt. Drip irrigation saved up to 50 -66% of water and increased yield by 30- 40% compared to flooding irrigation [1, 2]. Also, pomegranates are fairly drought resistant but require normal watering to produce good fruit crops; over watering results in soft, poorly-colored fruit. Pomegranate trees are amenable to irrigation with saline water and the level of salinity in water range between 1600- 2500 ppm [3]. The amount and quality of available irrigation water of the arid and semi- arid regions of the world such as Egypt, are the main limiting factors for extension agriculture [4]. Therefore plant growth and development retarded when water supply was restricted [5]. As knows, in Egypt the pomegranate is irrigated by flood irrigation system. Regardless pomegranate trees can be developed under drought stress, the saving water uses became very national emergency and it must be convert the type of irrigation system from flood irrigation system to drip irrigation.

However, very little is known about pomegranate orchard water management. Water use for this crop is for instance not listed in FAO water use book by Allen *et al*. [6]. However, it can be speculated that, crop water requirements can be high based on information provided in horticultural pomegranate review by Holland *et al*. [7]. There were a little information about water use of pomegranate trees in relation to growth and productivity. Therefore, this experiment was designed to determine relatively the actual water need for irrigation pomegranate orchards under drip irrigation system that gave satisfactory growth and yield.

MATERIALS AND METHODS

This experiment was conducted during two successive seasons of 2007 and 2008 on 20 year old mature pomegranate trees (*Punica granatum* L.) of Manfalouty cultivar. Trees under investigation were grown in a sandy soil at El- Kassasien Research Station, Ismailia Governorate. Trees distances were of 5 meters between trees and between lines. Trees received the recommended horticulture management of the Horticultural Research Institute (H.R.I.).

Correspoding Athor: Magda M. Khattab, Department of Pomology Faculty of Agriculture, Cairo University, Giza, Egypt.

Uniform fifteen trees were selected randomly where the experiment included five irrigation levels: 7 or 9 or 11 (control) or 13 and 15m^3/tree/year. Each treatment was replicated three times with one tree for each replicate and the randomized complete blocks design was used. The daily amount of irrigation water as liters per tree for each treatment in 2007 and 2008 seasons are shown in Table (1).

The Following Parameters Were Determined

Length of the New Developed Shoots (cm): Ten shoots of one year old in the four directions points (East- West- North and South) were tagged for measuring new developed shoots length at the end of growing season in September.

Number of Leaves per Shoot: Leaves developed on the new shoots were also counted at the end of growing season in September.

Leaf Area (cm^2): Was determined by using the leaf area meter CL203.

Number of Flowers per Shoot: Was counted at balloon stage.

Fruit Set (%): Pomegranate has two types of flowers (perfect and male flower). Male flower dropped after opening immediately. At balloon stage the total number of flowers was counted then the number of set fruits was counted two weeks after full bloom. Fruit set % was calculated according to the formula: Fruit set % = number of set fruits / total number of flowers (balloon stage) X 100

Fruit Drop (%): Was calculated by the following equation:

$$\text{Fruit drop \%} = \frac{\text{Total number of fruit set - Total number of fruits at harvest time}}{\text{Total number of fruit set}} \times 100$$

Fruit Retention (%): Was determined by counting the number of fruits at harvest time / initial number of fruit set X 100.

Yield per Tree: Fruits were picked at September 15th in both seasons according to El-Kassas [8] and Abou El-Wafa [9]. Therefore, at harvest time, fruits per tree for each treatment were picked, counted and weighted and then average yield/tree as kg was estimated.

Table 1: Distribution of the irrigation water (L/day/tree) through the two seasons of study (2007 and 2008)

	Month (2007 and 2008)								
Treatments	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep.	Oct.	Nov.
7m^3/tree/season	4	10	28	50	50	50	28	10	4
9m^3/tree/season	6	15	40	60	60	60	40	15	6
11m^3/tree/season	8	21	50	70	70	70	50	22	8
13m^3/tree/season	12	26	60	80	80	80	60	26	10
15m^3/tree/season	14	30	65	95	95	95	65	30	12

Water Use Efficiency (kg/m^3 Water): It was calculated as water quantity in each treatment divided on the obtained yield as described by Hussein [10].

The obtained data were tabulated and statistically analyzed according to Snedecor and Cochran [11]. Differences between means were compared by Duncan's multiple range test at 5% level of probability according to Duncan [12].

RESULTS AND DISCUSSION

Vegetative Growth: Shoot length, number of leaves per shoot and leaf area were affected by irrigation treatments as shown in Table (2).

Concerning shoot length the farm control (11m^3/tree/season) displayed significantly an intermediate values in comparison to the other treatments throughout the measurement period of the two seasons. Differences between the other four treatments were significant. Shoots increased in length as irrigation water applications increased. The higher water irrigation levels than the control (13m^3 and 15m^3) indicating an induction in shoot length and exhibited significantly higher shoot in length.

Table 2: Effect of irrigation levels on some vegetative growth parameters of pomegranate cv. Manfalouty in 2007 and 2008 seasons

Irrigation levels (m^3/tree/season)	Shoot length (cm)	Leaf number/ shoot	Leaf area (cm^2)
2007 season			
7m^3	20.77 e	20.00 e	4.91 e
9m^3	22.70 d	21.03 d	5.36 d
11m^3 (control)	25.07 c	22.80 c	5.77 c
13m^3	28.83 b	24.47 b	6.68 b
15m^3	30.23 a	25.83 a	7.13 a
2008 season			
7m^3	18.92 e	18.61 e	4.45 d
9m^3	20.89 d	20.09 d	5.38 c
11m^3 (control)	23.96 c	22.09 c	5.60 c
13m^3	27.12 b	23.59 b	6.37 b
15m^3	29.76 a	25.31 a	6.91 a

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

Number of leaves increased as irrigation water applied increased and declined with decreasing amounts of irrigation water applied. With the lowest irrigation water applications among all treatments ($7m^3$/tree/season) number of leaves decline became most pronounced (20.00, 18.61) in the two seasons respectively. In contrast, the farm control ($11m^3$/tree/season) recorded a higher average number of leaves (22.80, 22.09) in both seasons. There was a great effect of irrigation water supply on number of leaves per tree in the $15m^3$ treatment during both seasons (25.83, 25, 31) indicating that, water was limiting. The number of leaves was reduced due to little vegetative growth that resulted from reducing irrigation practices. The significantly highest number of leaves per shoot was recorded in the longest shoots in contrast to the other treatments, while the relative number of leaves per terminal shoot tended to be lower in shoots shorter in length with reducing irrigation practices.

Regarding leaf area results indicated that low level irrigation water application considerably reduced leaf area in both seasons. Leaf area decreased significantly by 7.10 and 14.9% in the first season with irrigation levels 7 and $9m^3$/tree/season. In contrast, during the second season the control and treatment $9m^3$ were not significantly different from each other. In the irrigation level $7m^3$ leaf area was reduced significantly by 20.52% comparing to the control $11m^3$. The highest leaf area increased by 23.57- 23.39% with irrigation level at $15m^3$ followed by $13m^3$ (15.77 and 13.75%) across both seasons. With the $15m^3$ irrigation level leaf area increased by 45.21 and 55.28% comparing to $7m^3$ with increasing amount of water by $8m^3$.

Generally, increasing irrigation levels from 7 to $15m^3$/tree/ season induced vegetative growth of pomegranate by increasing shoot length, number of leaves per shoot and leaf area. These could be explained that, water stress decrease in the cytokinin transport from root to shoots and increase in amount of leaf abscisic acid. These changes in hormone balance cause reduction in shoot growth and enlargement and leaf expansion [13]. Also, reduction in tree growth under water stress condition could be attributed to lower photosynthetic rate and stomatal conductance [14]. Our results are in harmony with the conclusion given by Abo-Taleb *et al*. [15] and Abou El-Wafa [16] who noticed that, stem length, number of leaves and leaf area was the greatest when pomegranate transplants were growing under lower water stress. Also, with Ibrahim and Abd El-Samad [17] who revealed that shoot length of pomegranate significantly affected by irrigation regimes.

Fruiting: Number of flowers per shoot was reduced significantly with declining applications of irrigation water. The treatment $7m^3$ exhibited the highest reductions among all treatments, the data in Table 3 indicating that, with this irrigation treatment, declining yields can be expected, although the most water was saved in this treatment. Increasing irrigation level to $15m^3$/tree/season recorded the highest significant number of flowers (4.10- 3.63) this number decreased to 3.70 and 3.44 by decreasing irrigation level to $13m^3$. Irrigation levels $11m^3$ exhibited the moderate number of flowers (3.33- 3.17). While, reducing irrigation treatment to $9m^3$, the number of flowers (3.20- 2.97) decreased in both seasons.

The increasing in fruit set (%) was associated with increasing rate of irrigation during two seasons. Reducing application of irrigation levels than the used farm control $11m^3$ which displayed moderate values (28.98 and 27.36%), fruit set was decreased significantly to 26.96, 25.94 and 23.27, 21.81% with both irrigation treatments 9 and $7m^3$/tree/season (Table, 3). By raising irrigation levels than farm control ($11m^3$) to 13 and $15m^3$/tree/season, fruit set increased significantly to 31.52, 30.13 and 33.40, 32.10% in both seasons respectively. The application of irrigation level at $15m^3$ increased average fruit set in both seasons from 22.54% to 32.75% compared to the lowest irrigation level $7m^3$ when increasing water quantity by $8m^3$.

As for fruit retention (%) the irrigation level at 15 m^3/tree/season recorded the highest fruit retention percentage (91.25 and 90.91%) and decreased it to 88.26 and 88.31% by $13m^3$ treatment while, with reducing irrigation levels from $11m^3$ to 9 then $7m^3$, fruit retention percentage reduced from 86.31- 85.48% with control ($11m^3$) to 85.23, 84.18 and 82.85, 82.12% with both irrigation treatments 9 and $7m^3$ respectively across both seasons (Table, 3).

The highest significant fruit drop percentage (17.15 and 17.88%) took place with the lowest irrigation rate ($7m^3$/tree/ season) followed by $9m^3$ (14.77 and 15.82%). While, the lowest significant fruit drop (8.75 and 9.09%) was resulted from trees which irrigated with $15m^3$/tree/season then $13m^3$ (11.74 and 11.69%) compared with the control $11m^3$ which recorded 13.69 and 14.52% (Table, 3). Comparing between the highest and lowest irrigation levels, $15m^3$ gave the lowest fruit drop percentage (8.75 and 9.09%) while $7m^3$ exhibited the highest fruit drop percentage (17.15 and 17.88%) in both seasons respectively.

Table 3: Effect of irrigation levels on flowering and fruiting attributes of pomegranate cv. Manfalouty in 2007 and 2008 seasons

Irrigation levels (m^3/tree/season)	Number of flowers/ shoot	Fruit set (%)	Fruit retention (%)	Fruit drop (%)
2007 season				
$7m^3$	2.70 d	23.27 e	82.85 d	17.15 a
$9m^3$	3.20 c	26.96 d	85.23 c	14.77 b
$11m^3$ (control)	3.33 c	28.98 c	86.31 c	13.69 b
$13m^3$	3.70 b	31.52 b	88.26 b	11.74 c
$15m^3$	4.10 a	33.40 a	91.25 a	8.75 d
2008 season				
$7m^3$	2.76 e	21.81 e	82.12 e	17.88 a
$9m^3$	2.97 d	25.94 d	84.18 d	15.82 b
$11m^3$ (control)	3.17 c	27.36 c	85.48 c	14.52 c
$13m^3$	3.44 b	30.13 b	88.31 b	11.69 d
$15m^3$	3.63 a	32.10 a	90.91 a	9.09 e

Means designated with the same letter in the same column are not significantly different at 0.05 level of probability

Table 4: Effect of irrigation levels on number of fruits /tree, yield, fruit cracking and water use efficiency of pomegranate cv. Manfalouty in 2007 and 2008 seasons

Irrigation levels (m^3/tree/season)	Number of fruits /tree	Yield (kg/tree)	Fruit cracking (%)	WUE (kg/m^3 water)
2007 season				
$7m^3$	88.67 e	20.47 e	8.58 a	2.92 c
$9m^3$	102.0 d	25.61 d	7.27 c	2.85 c
$11m^3$ (control)	113.3 c	33.87 c	6.85 d	3.08 b
$13m^3$	130.0 b	41.83 b	6.02 e	3.22 a
$15m^3$	135.3 a	44.81 a	7.93 b	2.98 bc
2008 season				
$7m^3$	81.00 e	17.41 e	8.99 a	2.49 d
$9m^3$	93.00 d	22.86 d	8.22 c	2.54 cd
$11m^3$ (control)	101.7 c	29.20 c	6.72 d	2.65 bc
$13m^3$	123.3 b	37.84 b	6.09 e	2.91 a
$15m^3$	126.7 a	40.09 a	8.65 b	2.67 b

Means designated with the same letter(s) in the same column are not significantly different at 0.05 level of probability

Number of fruits per tree increased significantly with increasing irrigation levels as it increased by 14.70, 21.23 and 19.42, 24.58% when irrigation amount increased from $11m^3$ to 13 and $15m^3$ in both seasons respectively (Table, 4). Farm control ($11m^3$) displayed significantly an intermediate number of fruits in comparison to the other treatments throughout the two seasons. On the other hand, by reducing irrigation rates to 9 then 7 m^3/tree/season, the number of fruits decreased by 9.97-8.55 and 21.74- 20.35% in both seasons respectively.

Yield (kg/tree) was significantly affected by different irrigation treatments (Table, 4). The farm control ($11m^3$) displayed significantly an intermediate yield (33.87 and 29.20 kg) in comparison to the other treatments in both seasons. Yield of 9 and $7m^3$ treatments declined from 24.39 to 21.71 and from 40.37 to 39.56 % respectively during two seasons. Increasing irrigation levels from $11m^3$ to 13 and $15m^3$ increased the yield from 23.50 to 29.59 and 32.29 to 37.29 % respectively. By increasing irrigation levels from 7 to $15m^3$ the average yield in both seasons increased from 18.94 to 42.45kg. Doubling the yield needed an increase the amount of irrigation levels by about $8m^3$.

According to fruit cracking, the lowest significant fruit cracking percentage (6.02 and 6.09%) resulted from trees received irrigation at $13m^3$ sequenced by $11m^3$ (control farm) (6.85 and 6.72 %) and $9m^3$ (7.27 and 8.22%) then $15m^3$ (7.93 and 8.65%). Finally, the highest significant fruit cracking percentage was appeared with irrigation treatment $7m^3$ (8.58 and 8.99%) during 2007 and 2008 seasons respectively.

These results are in line with those reported by Abd El-Rhman [18] who found that, by increasing soil moisture level, fruit cracking of Manfalouty pomegranate decreased. It can be illustrated that, increasing fruit cracking with declining irrigation water application may be due to these fruits was taken from trees which grow under water stress. Also he noticed that, the highest yield was resulted with the highest moisture availability meanwhile, the lowest number of fruits was observed by least irrigation level**.** Moreover, El-Khoreiby and Salem [19] on guava indicated that, sufficient soil moisture gave the highest percentage of fruit set and fruit retention while reduction of soil moisture had resulted in marked decrease in fruit retention percentage.

Water Use Efficiency (kg/m^3 Water): Water use efficiency (WUE) is defined by the ratio between the crop and the amount of water consumed by crop. The WUE indicator defined by that ratio is useful to identify the best irrigation scheduling [20]. As a general trend Table 4 indicated that, the highest significant WUE (3.22 and 2.91 kg/ m^3 water) in both seasons was found in trees grown under irrigation level at $13m^3$/tree/season. The values decreased with either decreasing or increasing water quantity than $13m^3$/tree/season. Whereas, both the least irrigation levels $7m^3$ and $9m^3$ had the lowest significant WUE while, $11m^3$ and $15m^3$ exhibited middle significant affect in both seasons. Our results represented that, $13m^3$/tree/season gave the maximum benefit for using irrigation water. The same results referred that receiving more frequent irrigation had greater water use than trees receiving less frequent irrigation under similar climatic conditions [21-23].

REFERENCES

1. Behnia, A., 1999. Comparison of different irrigation methods for pomegranate orchards in Iran. Irrigation under conditions of water scarcity. Vol 1C. 17th ICID International Congress on Irrigation and Drainage, Granada, Spain, pp: 207-217.
2. Chopade, S.O., S.D. Gorantiwar., P.S. Pampattiwar and V.S. Supe, 2001. Response of pomegranate to drip, bubbler and surface irrigation methods. Advances in Horticulture and Forestry. Scientific Publishers India Jodhpur, 8: 53-59.
3. Maas, E.V., 1990. Crop salt tolerance. In: Agricultural Salinity Assessment and Management, (Ed. K.K. Tanji), Amer. Soc. Civil Engineering, New York, pp: 262- 304.
4. Beaumont, P., 1993. Dryland Environmental Management and Development. Routledge, London and New York, pp: 536.
5. Wright, J.L. and J.C. Stark, 1990. Irrigation of agricultural crops. Amer. Soc. Agron., 30: 112-117.
6. Allen, R.G., L.S. Pereira, D. Raes and M. Smith, 1998. Crop evapotranspiration. In: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper 56, Rome, Italy, pp: 15-27.
7. Holland, D., K. Hatib and I. Bar-Yaakov, 2009. Pomegranate: botany, horticulture and breeding. Hort. Rev., 35: 127-191.
8. El- Kassas, S.E., 1983. Effect of irrigation at certain soil moisture levels and nitrogen application on the yield and quality of Manfalouty pomegranate cultivar. Assiut J. Agric. Sci., 14: 167-179.
9. Abou El-Wafa, M., 2006. Effect of Some Treatments on Improving Pomegranate Fruit Quality. Ph.D. Thesis, Fac. Agric. Hort. Dept. Cairo Univ. Egypt, pp: 170.
10. Hussein, S.M.M., 2004. Effect of Different Irrigation Levels on the Le-Cont Pear Trees. Ph.D. Thesis, Fac. Agric. Hort. Dept., Cairo Univ. Egypt, pp: 175.
11. Snedecor, G.W. and W.G. Cochran, 1980. Statistical methods. Oxford and J. B. H. Bub com. 7^{th} Edition.
12. Duncan, D.B., 1955. Multiple range and multiple F test. Biometrics, 11: 1-24.
13. Atkinson, C.J., A.D. Webster, S.P. Vaughan, L. Toylor and G. Kingswell, 2000. Interaction between root restriction, irrigation and rootstock treatments on Queen Cox apple trees: Effect of soil and plant water relation. J. Hort. Sci. Biotech., 75: 376-382.
14. Mpelasoka, B.S., M.H. Behboudian and T.M. Mills, 2001. Water relation, photosynthesis, growth, yield and fruit size of Braeburn apple: Responses to deficit irrigation and to crop load. J. Hort. Sci. Biotech., 70: 150-156.
15. Abo- Taleb, A.S., F.V. Noaman and S. Sari El-Deen, 1998. Growth of pomegranate transplants as affected by different water regimes., Ann. Agric. Sci. Moshtohor, 36: 1073- 1091.
16. Abou El-Wafa, M., 2002. Effect of Some Treatments on Drought Resistance of Transplants of Some Pomegranate Cultivars. M.Sc. Thesis, Hort. Dept. Fac. Agric., Cairo Univ. Egypt, pp: 132.
17. Ibrahim, A.M. and G.A. Abd El-Samad, 2009. Effect of different irrigation regimes and partial substitution of N-mineral by organic manures on water use, growth and productivity of pomegranate trees. Euro. J. Sci. Res., 38: 199-218.
18. Abd El-Rahman, I.E., 2010. Physiological studies on cracking phenomena of pomegranate. J. Appl. Sci. Res., 6: 696-703.
19. El- Khoreiby, A.M.K. and A.T. Salem, 1989. Effect of different irrigation regimes on growth, fruiting and fruit quality of seedy guava trees. Ann. Agric. Sci., Fac. Agric. Ain Shams Univ., 34: 313- 321.
20. Zhang, H. and T. Oweis, 1999. Water-yield relation and optimal irrigation scheduling of wheat in the Mediterranean region. Agric. Water Manage., 38: 195-211.
21. Smitle, D.A., W. Dickens and J.R. Stansell, 1994. irrigation regimes affect yield and water use by Bell pepper. J. Amer. Soc. Hort. Sci., 119: 936.
22. Abd El-Samad, G.A., 2001. Water use and productivity of Navel and Acidless orange trees as affected by deficit irrigation. Fayoum J. Agric. Res. & Dev., 15: 150-159.
23. Abd El-Samad, G.A., 2005. Water use, growth and productivity of some new guava strain as affected by different irrigation regimes. Egypt. J. Hort., 32: 41-56.