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Effect of Irrigation on Cracking of Pomegranate Fruits (French Variety)

[1#]Dr. Rida DRAIE, [2]Ali ABORAS

[1]Faculty of Agricultural Engineering, University of Idleb, Syria

[2]Postgraduate Student, MA, Faculty of Agricultural Engineering, University of Idleb, Syria

[#]Corresponding Author: ridadraie@hotmail.com

***Abstract* - Fruit cracking is one of the most important problems faced by pomegranates, which cause great damage to the crop, amounting to more than 60%. The French pomegranate variety is one of the varieties cultivated in northern Syria, which is highly vulnerable to this problem. The research was carried out in the 2018-2019 agricultural season in a field planted with pomegranate trees at the age of 10 years and dimensions 4x4 m, to study the effect of irrigation in reducing fruit cracking. The experiment was conducted according to a complete randomized block design. The experiment included three irrigation treatments: irrigation once after the beginning of flowering, irrigation twice after the beginning of flowering and after the completion of the fruit contract, and irrigation for three times after the beginning of flowering, after the completion of the fruit contract and after the beginning of the fruit discoloration, in addition to the treatment of the control without irrigation. The results showed high sensitivity of the French pomegranate variety to the fruit cracking (73.96%). All irrigation treatments outperformed the control treatment in most of the studied characteristics (early flowering and ripening time, enhancing the percentage of fruit-set, improving the quality of fruits, increasing the productivity). The rise in the number of irrigation times reduced the percentage of fruit cracking compared to the control, while the percentage of cracking of fruits reached 34.06%, 27.37%, 20.24%, in the treatment of irrigation once, twice, and three times, respectively.**

Keywords: Fruit Cracking, Pomegranate, French Variety, Irrigation, Productivity.

I. INTRODUCTION

Pomegranate (*Punica Granatum* L.) belongs to the family Punicaceae. It is believed to have been planted more than 4000 BC (Kahramanoglu, 2019). The region extending from Iraq and Iran to the Himalayas in northern India is the original home of the pomegranate, from where it moved to the countries of the world (Chandler, 1957; Levin, 1994). Because the tree is highly adaptive to a wide range of climates and soil conditions, it is grown in many different geographical areas including the Mediterranean Basin, Asia, California, and India (Bankar and Prasad, 1992; Holland *et al.*, 2009).

Pomegranate juice contains citric acid and sodium citrate and is used in the treatment of indigestion. The bark of the stem, roots, and peel of the fruits contain tannin and several alkaloids. Its extracts are used as drugs to stop diarrhea, dysentery, tapeworm, and bleeding. Dried flower buds can be used as a way to treat bronchitis. The leaves, seeds, roots, and bark have shown antihypertensive activity. Pomegranateis useful in controlling blood sugar level and in protecting against cancer (Morton, 1987; Bhowmik *et al.*, 2015; Chaudhari *et al.*, 2015)

Cracking is one of the most important physiological diseases affecting fruits in general and pomegranate in particular (Malhotra *et al.*, 1983). As many fruits can crack upon reaching maturity, so these fruits become undesirable to the consumer, and the high percentage of this phenomenon in some varieties of pomegranate and some years leads to a reluctance to reap the fruits. Panwar *et al.* (1994) and Singh (1995) showed that when the fruit cracks, they are susceptible to infection with bacteria and fungi, and thus they will lose their marketing value and may become unfit for human consumption, which causes a very large economic loss to pomegranate farmers and marketers alike as a result of their low prices compared to the prices of healthy fruits (Finkel and Holbrook, 2000; Schrader *et al.*, 2002). Singh *et al.* (2006) and Bankar and Prasad (1992) confirmed that about 25-40% of the fruit crack at the time of ripeness, and these fruits lose their quality and become unfit for marketing and thus cause a great loss in production. The crack rate varies between 10-70% depending on climatic conditions, which reduces production to 50%, and this is harmful to the farmer (Anonymous, 1983).

According to many studies, fruit cracking is mainly due to genetic factors. It has been emphasized that the characteristic of cracking is a constant state for each variety and is primarily due to the genetic condition in addition to being affected by environmental factors, various agricultural treatments, and the stages of fruit growth (Saad *et al.*, 1988; Prasad *et al.*, 2003;

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Chandra *et al*., 2011; Khadivi-Khub, 2014). Abd and Rahman (2010) have indicated that the cracking is associated with high temperature, high transpiration rate, low humidity, water imbalance, and sharp fluctuations in daytime and night temperatures during fruit growth and development. It was also affirmed that the cracking of pomegranate fruits is linked to irregular irrigation and long periods of drought followed by heavy rains or irrigation and a lack of nutrients, especially boron, calcium, zinc, and potassium (Gharesheikhbayat, 2006; Khalil and Aly, 2013; Saei *et al*., 2014; Galindo *et al*., 2014). The cracking is clearer when the fruits are at ripening (Hoda and Hoda, 2013; Shulman *et al*., 1984; Yazici and Kaynak, 2006).

Several agricultural practices have been recommended to manage pomegranate fruit cracking, such as regular drip irrigation, mulching, spraying with micro and macro-elements, and with growth promoters and anti-transpiration (Waskar, 2006). Irrigation once a week before flowering until rain fell (early autumn) led to a decrease in the percentage of fruit cracking to 16% for the two cultivars (Kanddhari and Beedana) compared to 84% in control (Singh *et al*., 1990). Josan *et al*. (1979) confirmed that the percentage of fruit cracked before maturity varies according to the irrigation rates. Prasad and Mail (2002) showed that irrigation of pomegranate trees with a drip irrigation system (8 L/h) for three hours a day during flowering and fruiting periods under dry conditions led to a reduction in the percentage of cracked fruits to 20.8%, while the percentage of cracked fruits was 50.8% in the control. El-Kassas (1983) found that irrigation at a humidity level of 70% of the field capacity (irrigation approximately every week) improved the physical and chemical properties of the Manfalouty pomegranate cultivar, reduced its cracking percentage, and increased production. Du-Bois and Williamson (2004) stated that the pomegranate tree needs irrigation in the absence of rain, and moderate soil moisture should be maintained, especially in late summer and early autumn, to reduce fruit cracking.

II. RESEARCH OBJECTIVES

The fruit cracking of pomegranate is one of the most important problems encountered in the cultivation of the pomegranate tree in many countries, especially in dry and semi-arid regions. Among the countries in which the fruit cracking of pomegranate spread, is Syria, where most of the varieties and in various production areas are affected by this phenomenon. It leads to a large loss of yield and causes great economic damage in production and yield.

Accordingly, this research has been carried out to study the cracking in the fruits of the French pomegranate variety spread in northern Syria and to study the effect of drip irrigation and the effect of the number of irrigation times on the possibility of limiting or mitigating this disorder.

III. MATERIALS AND METHODS

3.1 Research Location

The research was carried out in 2018-2019 agricultural season in a private orchard at the city of Sarmada in Idlib governorate, which is about 40 km to the north of the city of Idlib and on the administrative borders of the Idlib governorate with Turkey, where the city of Sarmada lies at latitude 36° north and longitude 36° east, and it rises about 383 meters. During the research season, the average precipitation was more than double the general average, with the cumulative amount of precipitation reaching 693 mm, and the concentration of precipitation in the winter months with some light precipitation in the autumn and spring. The average minimum temperatures for the coldest month were 2° C (January), the average maximum temperature for the warmest month was 35° C (July and August), the highest average maximum wind speed was 28km/h (July), and the lowest average minimum wind speed was 3 km/h (November), and the relative humidity ranged between the highest value of 90% (January) and the lowest value of 25% (May).

3.2 Plant Material

The experiment was conducted on a French pomegranate variety of 10-year-old trees planted at a distance of 4 x 4 m. As this variety is characterized by large fruits that are spherical to flat, the peel is red, the color of the fruits is bloody red, the neck of the fruit is long, the leaf is elongated, the branches have thorns, and its fruits are subject to cracking.

3.3 Experimental Treatments

The experiment included four treatments with five replicates in each treatment, and each repeat represented one pomegranate tree (French variety), and the treatments are:

- The first treatment: irrigation once after the beginning of flowering (15/5/2019).
- The second treatment: irrigation twice after the beginning of flowering (5/15/2019), and after the completion of the fruit-set (15/6/2019).
- The third treatment: irrigation three times, after the beginning of flowering (5/15/2019), after the completion of the fruit contract (15/6/2019), and when the fruits start to color (15/7/2019).
- Fourth treatment: Witness without irrigation.

The drip irrigation method was used to irrigate the trees of irrigated treatments, in which the amount of water in single irrigation was determined at a rate of 200 liters/tree for each

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tree in each planned irrigation, and the drip irrigation network was activated in the field starting from the first month in which irrigation was carried out, which is the middle of May. The drip hose was extended in a circular motion below the crown of the tree, corresponding to the root spread area.

Four drippers were installed on the hose, each dripper was discharging 5 liters/hour, and with this, the quantity of water specified in one irrigation was 200 liters/tree during a period of 10 hours (4 drippers x 5 liters x 10 hours = 200 liters). As for the source of irrigation water, it was supplied from a private well located in the experimental field, where irrigation was started early in the morning after sunrise to reduce evaporation.

3.4 Experimental Design

The research was carried out in the 2018-2019 agricultural season in a field planted with pomegranate trees at the age of 10 years and dimensions 4 x 4 m. The complete randomized block design was used. Four irrigation treatments (0, 1, 2, 3 irrigation times) were applied. Five replicates per treatment, with one tree (French pomegranate variety) per replicate, were adopted. Consequently, the number of pomegranate trees used in the experiment = 4 treatments x 5 replicates x 1 tree = 20 trees.

3.5 Measured Parameters

The following measurements were taken:

1. Flowering traits

- Number of days until the start, peak, and end of flowering.
- Number of total, male and hermaphrodite flowers.
- Percentage of hermaphroditic and male flowers.

2. Fruits-set and Yield characteristics

- Percentage of fruit-set.
- Number of days until the date of ripening of the fruits.
- Productivity kg/tree.

3. Physical properties of fruits

- Number and percentage of cracked fruits per tree.
- Diameter of fruit (cm).
- Weight of fruit peels (g).
- Internal tissue weight (g).
- Weight of seeds (g).
- Weight of juice (g).
- Weight of fruits (kg).

4. Fruit quality characteristics

- Ratio of juice (%).
- Total Soluble Solids (T.S.S.%).
- Acidity of juice (pH).

3.6 Statistical analysis

The results were analyzed by the statistical program (GenStat-12). The averages were compared by calculating the LSD at the level of significance (5%).

IV. RESULTS AND DISCUSSION

4.1 Study of the fruit cracking in the French variety

4.1.1 Fruit cracking percentage

The percentage of fruit cracked in the French pomegranate variety reached a very high value, 73.96%, while the percentage of healthy fruits reached 26.04%. This value indicates the degree of high sensibility of the French variety to this cracking, and therefore most of the production is not suitable for marketing due to the problem of cracking of fruits. The observed fruit crack ratio is higher than what Singh *et al*. (2017) stated, that the crack rate ranges between 18-62%, and what was mentioned Pant (1976) that this percentage generally varies according to the varieties, so it is about 34% in the early varieties and reaches 63% in late varieties.

4.1.2 Productivity per tree

The cracking had a very large significant effect on the production, as the average production per tree of the French pomegranate variety was 13.01 kg, of which only 3.38 kg were healthy fruits and 9.63 cracked fruits (equivalent to 74.02% of cracked fruits), and this corresponds to the rate of high cracking percentage (73.96%). The high weight of cracked fruits indicates the great degree of damage that results from the fruit cracking and negatively affects the characteristics of the fruits and the economic and marketing value of these fruits. According to previous studies, the economic loss resulting from the fruit cracking ranges between 10-40% and may sometimes reach 70% (Pal *et al*., 2017). The phenomenon of cracking reaches more than 50%. It was also mentioned that the percentage of marketing damage due to fruit cracking reaches more than 50% (El-Sayed *et al*., 2014).

4.1.3 Observed types of cracking

Regarding the types of cracking that were observed in the experiment, the longitudinal cracking, which is characterized by a slit along the longitudinal axis of the fruit (Fig. 1), and the transversal cracking, which is in the form of a horizontal

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slit in one of the sides of the fruit, slightly deep inside it and is perpendicular to the longitudinal axis of the fruit (Fig. 2), and the cracking due to sun blight that occurs on the side of the fruit directly exposed to sunlight, causes this area to be dark brown with increased looseness and then damage (Fig. 3).

Figure 1: Types of fruit cracking observed on the French pomegranate variety

4.2 Effect of cracking on the fruit properties

Table 1: Effect of cracking on the characteristics of the fruit (French pomegranate variety)

Trait	Healthy fruits	Cracked fruits	LSD (5%)	C.V.
Weight of fruit peel (g)	63.39	61.03	0.07814	2.0
Internal tissues weight (g)	62.45	55.79	0.2252	3.2
Weight of seeds (g)	145.25	126.76	0.3223	1.8
Weight of juice (g)	74.92	65.04	0.4888	1.9
Diameter of fruit (cm)	8.71	7.94	0.02251	2.3
Weight of fruits (g)	271.09	243.58	0.06342	1.3
Ratio of juice (%)				
Total Soluble Solids (T.S.S.%)	15.38	16.12	0.05219	2.9
Acidity of juice (pH)	2.64	2.53	0.00934	1.4

Table (1) shows the clear negative effect of the cracking on the whole properties fruit. While the weight of the peel decreased from 63.39 g in the healthy fruits to 61.03 g in the cracked fruits. The internal tissue weight decreased from 62.45 g in the healthy fruits to 55.79 g in the cracked fruits. In addition, there was a big difference between the weight of the fruits in the healthy fruits (145.25g) and the cracked fruits (126.76g). The total weight of the juice decreased from 74.92g in the healthy fruits to 65.04 g in cracked fruits. The decrease in the mentioned traits attributed to the increase in water loss and evaporation in the cracked fruits compared to the healthy ones. Which was reflected in all the physiological processes in the fruit and thus led to a decrease in the weight and thickness of the outer peel and a decrease in the weight of the internal tissues, fruits, seeds, and juice (Hepaksoy *et al*., 2001; Galindo) *et al*., 2014; Singh *et al*., 2020).

As for the size and weight of the fruit, it was also clearly affected (Table1). The diameter of the fruit decreased from 8.71 cm in healthy fruits to 7.94 cm in cracked fruits. The weight of the fruit decreased from 271.09 g in healthy fruits to 243.58 g in cracked fruits. The decrease in the diameter and weight of the fruit is explained by the fact that they are also affected by the water condition of the fruit on the one hand, and are directly related to the characteristics of the weight and thickness of the outer peel and the weight of the internal tissues, fruits, seeds and juice on the other hand (Saei *et al*., 2014).

Otherwise, it is evident from Table (1) that the percentage of total soluble solids and the acidity increased due to the effect of cracking. The T.S.S. percentage increased from 15.38% in healthy fruits to 16.12% in cracked fruits, and the pH increased from 2.64 in healthy fruits to 2.53 in cracked fruits (lower pH value). The increase in acidity is explained by the lower moisture content in the cracked fruits that due to evaporation and dehydration compared to the healthy fruits, which retain their moisture more due to the closure and impermeability of its outer peel (Yılmaz and Ozguven, 2009; Hoda and Hoda 2013).

4.3 Effect of irrigation on the studied parameters

4.3.1 Phenological traits

Table 2: Effect of irrigation times on the Phenological traits

Trait	0	1	2	3	LSD (5%)	C.V.
Flowering peak	52.00	51.00	49.40	49.00	0.066	0.5
End of flowering	70.00	68.50	66.25	66.00	0.0779	0.4

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Ripening beginning	151.00	147.00	145.00	144.60	0.0751	0.2
Full maturity	191.00	188.00	183.62	182.45	0.0751	0.1

a) Thepeak and end of flowering (day)

Table (2) shows the superiority of all irrigation treatments over the control in the number of days required to reach peak flowering (as the value in control was 52.00 days). The increase in the number of irrigation times had a positive effect on this characteristic, as the treatment of irrigation three times (by 49.00 days) outperformed the treatment of irrigation twice (by 49.40 days), which outperformed the treatment of irrigation once (by 51.00 days).

As for the number of days until the end of flowering, all treatments followed the same behavior in the characteristic of the flowering peak. Where all the treatments outperformed the control, which needed 70.00 days to reach the end of flowering. While the treatment of irrigation three times reached the end of flowering after 66.00 days, followed by the treatment of irrigation twice with 66.25 days, whereas the treatment of irrigation once came in third place with 68.50 days, and the differences were significant between the three treatments (Table 2).

b) The beginning and complete ripening (day)

Table (2) displays the significant effect of irrigation in reaching the beginning of the maturity of the fruits, where all the treatments were significantly superior to the control treatment, which required 151 days. Moreover, the increase in the number of irrigation times led to significant differences between the treatments. The treatment of irrigation three times exceeded (by 144.60 days) the treatment of irrigation twice (145.00 days), which outperformed the treatment of irrigation once (147.00 days).

All irrigation treatments outperformed the control in reaching full ripeness of the fruit, as the control needed 191.00 days. The increase in the number of irrigation times also had a significant effect in reaching the full ripeness of the fruits, as the treatment of irrigation three times (by 182.45 days)exceeded the treatment of irrigation twice (by 183.62 days) which surpassed the treatment of irrigation once (by 188.00 days), (Table2).

4.3.2 Flowering traits

Table 3: Effect of irrigation times on the flowering traits

Trait	0	1	2	3	LSD $_{(5\%)}$	C.V.
Number of total flowers	287.33	328.25	373.38	413.76	0.994	0.8
Number of male flowers	213.33	221.00	238.06	258.09	0.898	1.2
Percentage of male flowers	74.25	67.33	63.76	62.38	0.3071	1.8
Number of hermaphroditic flowers	74.00	107.25	135.32	155.67	1.303	2.9
Percentage of hermaphrodite flowers	25.75	32.67	36.24	37.62	0.2481	2.3
Number of fruit-set	16.00	30.31	44.48	52.94	0.612	3.3
Percentage of fruit-set	21.62	28.26	32.87	34.01	0.513	4.8

a) Number of total flowers

Table (3) shows the significant effect of irrigation and the increase in the number of irrigation times in the number of total flowers on the studied French variety, as the number of total flowers in the control reached 287.33 flowers. The treatment of irrigation once achieved a significant difference above the control and the total number of flowers reached 328.25 flowers. The treatments of irrigation twice and three times had a significant difference for irrigation once, the total number of flowers was 373.38 and 413.76, respectively, with a significant difference between these two treatments.

b) Number and percentage of hermaphroditic flowers

Through the results that were reached and shown in Table (3), we note the significant effect of irrigation and the increase in the number of irrigation times on the number and percentage of hermaphroditic flowers, as the number of hermaphroditic flowers in the control reached 74.00 and the percentage was 25.75%. as irrigation once made a significant difference above the control, with the number of hermaphrodite flowers 107,25 and the percentage of 32.67%. The treatment of irrigation twice achieved a significant difference over irrigation once, and the number of flowers reached 135.32 flowers and a percentage of 36.24%. However, the treatment of irrigation three times surpassed all treatments, with a number of flowers reached 155.67 and its rate was 37.62%.

c) Number and percentage of fruit-set

Table (3) present the significant effect of irrigation and the increase in the number of irrigation times on the number and percentage of flower-set, as the number of flowers in the control reached 16.00 and their percentage of total flowers is 21.62%. The number of fruit-set in the treatment of irrigation three times reached 52.49, and their percentage of the total

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flowers was 34.01%, and it was superior to the treatment of irrigation twice, as the number of fruit-set reached 44.48 and the percentage of the total flowers was 32.87%, which surpassed the treatment of irrigation once in which the number of fruit-set reached 30.31 and the percentage of total flowers was 28.26%. All irrigation treatments outperformed the treatment of the control, with clear significant differences.

4.3.3 Fruit traits

Table 4: Effect of irrigation times on the fruit traits

Trait	0	1	2	3	LSD (5%)	C.V.
Weight of fruit peel (g)	60.99	61.05	61.95	63.62	0.3275	2
Internal tissues weight (g)	59.12	58.89	60.10	62.63	0.37	3.2
Weight of seeds (g)	136.01	182.85	202.30	218.59	0.672	1.5
Weight of fruits (g)	256.12	302.79	324.35	344.84	0.95	1.3
Diameter of fruit (cm)	8.32	9.59	10.42	10.97	0.0527	2.3
Weight of juice (g)	69.98	108.89	118.51	130.86	0.535	1.9
Ratio of juice (%)	27.32	35.96	36.54	37.95	0.117	1.5
Acidity of juice (pH)	2.98	3.17	3.34	3.61	0.00953	1.4
Total Soluble Solids (T.S.S.%)	15.22	15.39	15.55	15.64	0.0929	2.9

a) Weight of peel and internal tissues (g)

The results of the statistical analysis according to Table (4) show the significant effect of increasing the number of irrigation times on the weight of the peel and the internal tissues of the fruit, as their weight in control reached 60.99 g and 59.12 g, respectively. While irrigation once did not achieve a significant difference from the control, the weight of the peel was 61.05 g, and the weight of the internal tissues 58.89 g. The treatments of irrigation twice and three times achieved a significant difference over irrigation once, so the weight of the peel was 61.95 g, the weight of the internal tissues was 60.10 g in the treatment of irrigation twice, the weight of the peel was 63.62 g, and the weight of the internal tissues 62.63 g in the treatment of irrigation three times, with significant differences between the treatments of irrigation twice and three times.

b) Weight of seeds (g)

Table (4) demonstrates the significant effect of irrigation and the increase in the number of irrigation times on increasing the weight of seeds, compared to the control in which the weight of seeds reached 136.01 g. All irrigated treatments achieved a significant increase in the mentioned characteristic, as the treatment of irrigation once surpassed the control and the weight of the seeds was 182.85 g. The treatment of irrigation twice also achieved a significant increase over the treatment of irrigation once and the weight of the seeds was 202.30 g. Also, the treatment of irrigation three times achieved a significant increase over the treatment of irrigation twice, and it outperformed all treatments with the weight of seeds of 218.59 g.

c) Weight (g) and diameter (cm) of fruit

Table (4) indicates the significant effect of irrigation and the increase in the number of irrigation times on the weight and diameter of the fruit, as the weight of the fruit in the control reached 256.12 g and the diameter was 8.32 cm. The treatment of irrigation once achieved a significant difference from the control and the weight of the fruit in it reached 302.79 g and the diameter of the fruit was 9.59 cm. The treatment of irrigation twice achieved a significant difference above the treatment of irrigation once, and the weight of the fruit in it was 324.35 g and the diameter of the fruit was 10.42 cm. The treatment of irrigation three times achieved a significant difference above the treatment of irrigation twice and the weight of the fruit was 344.84 g and the diameter of the fruit was 10.97 cm.

d) Weight (g) and ratio (%) of juice

Through Table (4) we note the significant effect of irrigation and the increase in the number of irrigation times on the weight and ratio of juice, where the weight of juice reached 69.98 g in the control and the juice ratio was 27.32%. All irrigation treatments outperformed the treatment of the control with clear significant differences. The weight of the juice in the treatment of irrigation three times reached 130,86 g, and its ratio was 37.95% and surpassed the treatment of two-irrigation, in which the weight of juice reached 118.51 g and 36.54%. The treatment of irrigation twice surpassed the treatment of irrigation once in which the weight of juice reached 108.89 g and the ratio was 35.96%.

e) Acidity of juice (pH)

The results of Table (4) show the significant effect of irrigation and the increase in the number of irrigation times on the acidity of the juice, as the pH of the juice in the control reached 2.98, while the treatment of irrigation once achieved a significant difference from the control and the pH of the juice reached 3.17. The treatments of irrigation twice and three times also achieved significant differences over the treatment of irrigation once, and the pH of the juice was 3.34 and 3.61, respectively, with a significant difference between these two treatments.

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f) Total soluble solids (T.S.S. %)

Table (4) displays the significant effect of irrigation and the increase in the number of times of irrigation on the percentage of total soluble solids, as its value in the control reached 15.22%. All the irrigated treatments outperformed the treatment of the control, as the total soluble solids percentage in the treatment of irrigation three times reached 15.64%, and surpassed the treatment of irrigation twice, which had 15.55% of soluble solids. The treatment of irrigation twice surpassed the treatment of irrigation once that the percentage of total soluble solids in it was 15.39%.

The results obtained in our study are consistent with the results of previous studies regarding the effect of irrigation on improving the characteristics of pomegranate fruits. El-Kassas (1983) found that irrigation at a humidity level of 70% of the field capacity (irrigation weekly) improved the physical and chemical properties of the Manfalouty pomegranate variety. Haneef *et al.* (2014) stated that drip irrigation improved vegetative growth and improved the quality characteristics of pomegranate fruits. Levin (2006) and Holland *et al.* (2009) showed that in order to improve the characteristic of fruits, pomegranates should be irrigated regularly during the growing season.

4.4 Effect of irrigation on the productivity (kg/tree)

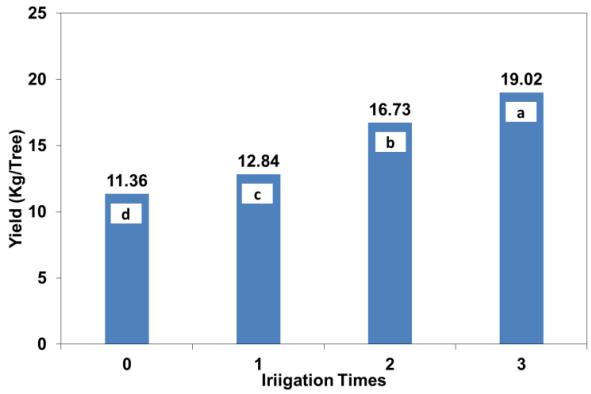

Figure 2: Effect of irrigation on the productivity of French pomegranate variety ($LSD_{(5\%)}$=0,2706)

Fig. (2) Indicates the significant effect of irrigation and the increase in the number of irrigation times on productivity, as the productivity of the control reached 11.36 kg/tree, while the treatment of irrigation once achieved a significant increase over the control and the productivity reached 12.84 kg/tree. The treatment of irrigation twice achieved a significant increase over the treatment of irrigation once with productivity of 16.73 kg/tree. Also, the treatment of irrigation three times significantly increased over the treatment of two-irrigation, and the productivity reached 19.02 kg/tree. All irrigated treatments outperformed the control, so the productivity increases were 113.03%, 147.27%, and 167.43% in the treatments of irrigation once, two-irrigation, and three-irrigation, respectively, in comparison with the control.

Our results are consistent with many studies on the effect of irrigation on improving pomegranate productivity. El-Kassas (1983) found that irrigation at a humidity level of 70% of the field capacity (irrigation weekly) increased production. Also, Prasad *et al*. (2003) stated that irrigation of pomegranate is a basic determining factor for pomegranate growth and giving economic productivity in arid and semi-arid regions. Pampattiwar *et al.* (1993) cited that the drip irrigation technology could reduce water consumption by 30-50% in pomegranate fields while maintaining productivity. Haneef *et al*. (2014) mentioned that drip irrigation improved vegetative growth and leaf content of NPK elements and increased the productivity of pomegranate trees. Levin (2006) and Holland *et al.* (2009) indicated that for optimum growth and productivity, pomegranates should be irrigated regularly during the growing season.

4.5 Effect of irrigation on the fruit cracking (%)

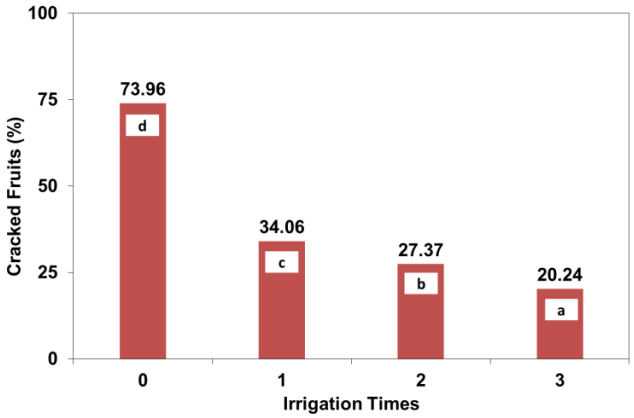

Figure 3: Effect of irrigation on the fruit cracking of French pomegranate variety ($LSD_{(5\%)}$=0,001581)

It is noticed through Fig. (3) the significant effect of irrigation and the increase in the number of irrigation times on the percentage of cracked fruits at the French pomegranate variety, as the percentage of cracked fruits in the control reached 73.96%. All irrigation treatments reduced the percentage of cracking compared to the control. The treatment of irrigation once achieved a significant decrease over the control and the percentage of cracked fruits in it reached 34.06%. Also, the treatment of irrigation twice achieved a significant decrease in the cracking rate, which amounted to 27.37%, and surpassed the treatment of irrigation once. The largest decrease was in the percentage of cracked fruits in the treatment of irrigation three times, as the percentage of cracked fruits in this transaction reached 20.24%, which was significantly higher than all the treatments.

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Our results are consistent with many studies that have shown the importance of drip irrigation in reducing the percentage of cracking of pomegranates and their negative effects. Plamenac (1971) and Pant (1976) confirmed that the drip irrigation method is most appropriate in pomegranate orchards. Prasad and Mail (2002) showed that the irrigation of pomegranate trees with drip irrigation system at a rate of 8 liters per hour for three hours a day during flowering and fruiting periods under dry conditions led to a reduction in the percentage of cracked fruits to 20.8%, while the percentage of cracked fruits was in the control 50.8%.Singh *et al*. (1990) indicated that irrigation once a week before flowering until the beginning of the rainy season in the autumn led to a decrease in the percentage of cracked fruits to 16% compared to 84% in the control. Josan *et al*. (1979) stated that the percentage of fruits cracked before maturity varies according to the irrigation rate. El-Kassas (1983) found that irrigation at a humidity level of 70% of the field capacity (irrigation roughly every week) led to a decrease in the percentage of fruit cracking. Du-Bois and Williamson (2004) stated that the pomegranate tree needs irrigation in the absence of rain, and moderate soil moisture should be maintained, especially in late summer and early autumn, to reduce fruit cracking. Galindo *et al*. (2014) and Rodríguez *et al*. (2018) indicated that to reduce the percentage of cracking in pomegranate fruits, the pomegranate should be irrigated regularly during the growing season.

V. CONCLUSION

1. The percentage of cracking of pomegranate fruits in the French variety reached 73.96%, and the types of longitudinal, horizontal, and cracking resulting from sun blight were observed on the studied cultivar, and this disorder had a significant negative impact on the overall characteristics of the fruit.
2. All irrigation treatments outperformed the control treatment in most of the studied traits (early flowering and ripening time, increasing the percentage of fruit-set, improving the quality of fruits).
3. The irrigated treatments achieved a significant increase in productivity compared to the control, which amounted to 113.03%, 147.27%, and 167.43% in the treatments of irrigation once, twice, and three times, respectively.
4. All irrigation treatments reduced the percentage of fruit cracking compared to the control. The percentage of fruit cracking was 34.06%, 27.37%, 20.24%, in the treatment of irrigation once, twice, and three times, respectively.
5. Increasing the number of irrigation times had a significant positive effect in improving all studied traits.

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