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Effect of Supplementary Spring and Summer Irrigation on the Growth and Productivity of the Olive Tree (Sourani Variety) in the Region of Al-Rouj Plain

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***Abstract* - The effect of supplementary summer and spring irrigation on the productivity of the olive tree (Sourani variety) was studied. The study was conducted in the village of Kfar Rouhin, located in Sahel Al-Rouj, west of Idlib, during the years 2012-2013. In this research, we adopted the design of the complete random sectors and conducted 5 transactions, and in each treatment, we had five replicates and each repeater was an olive tree. During the experiment, supplementary irrigation was applied so that the transactions differed between them by the number of irrigations (0, 1, 2, 3, and 4 irrigations) and their dates (April; April and June; April, June, and July; April, June, July, and August). The results showed that the treatment of spring irrigation (one irrigation in April) was significantly higher than the other irrigation treatments in most studied growth and flowering indicators. This treatment achieved an increase in the vegetative growth (5.6 cm), in the foliar surface (2.59 cm^2), in a number of flowering clusters/branch (13.96), in the number of flowers/flowering clusters (8.08), in the number of flowers/branch (358.33), in the fruits-set percentage (0.72%), and in the number of fruits/branch (25.05), compared to the control. The results also showed that the summer irrigation treatment (irrigation in April, June, July, and August) achieved a significant increase in the fruiting and productivity criteria: fruit weight (2.86 g), fruit size (2.65 mL), pulp/fruit ratio (7.92%), the productivity per tree (57.98 kg), oil percentage (10.33%) as compared to the control. Finally, the results showed the superiority of the first year of the study 2012 over the second year 2013 in the indicators of the number of flowering clusters/branch, the number of flowers/flowering cluster, the number of flowers/branch, the number of fruits/branch, and the productivity per tree. While the second year of the study exceeded in the rest of the studied indicators. Thus, the phenomenon of alternate bearing, by which the olive trees are characterized, had a clear effect, but all experimental treatments reduced the difference in all studied indicators compared with the control.**

Keywords: Olive Tree, Supplementary Irrigation, Vegetative Growth, Productivity, Oil percentage.

I. INTRODUCTION

One of the most important fruit trees is the *Olea europaea* L. olive tree (from the Oleaceae family). It is a perennial tree, more than 1,000 years old. Many researchers point out that natural Syria is the origin of the olive tree, as wild olives are still spread in many areas there (Aswad et al., 1993). Europe occupies the first place 66.4% of the global area, followed by Africa and Asia 15.5% each. Spain ranks first in world olive production with an annual production of 5.5 million tons, followed by Italy 3 million tons, in third place Greece comes 2.4 million tons and Syria comes in seventh place with an estimated production of 750 thousand tons (FAO, 2019). The olive tree in Syria occupies about 62.59% of the total area of fruit trees, and olive cultivation is mainly distributed in northern and western Syria in the governorates of Idleb, Aleppo, Lattakia, Tartous (CSO, 2019).

Drought is one of the most important environmental factors that negatively affect plant growth and physiological, biological and metabolic processes. Drought is also a specific and important factor in the distribution of plants, their productivity and the quality of the fruits produced (Agnes et al., 2002). Olive trees differ in their tolerance to drought according to the genetic factors, and the rate of oil accumulation in the fruits of olives depends on the environmental conditions and the different agricultural conditions in addition to the genetic factors (Lavee 1991; Barone, 1994). Despite the environmental resilience of the olive tree to the limited water conditions in the agricultural systems of the Mediterranean countries, it responds to any water additives (Serrano, 1998). Under dry climatic conditions, the olive tree shows a significant impact, including a decrease

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in the rate of photosynthesis and consequently less growth, more fruit fall and less productivity (Bongi et al., 1994), where Hsiao (1973) mentioned that growth is the first affected by water stress. Trees resist water stress by dropping some of their fruits to maintain growth (Gomez-Rico et al., 2005). Excessive stress in olive trees weakens and stops them from functioning (Tognetti et al., 2004). Water stress also causes a decrease in the size of tree crowns (Michelakis et al., 1994), and it reduces net optical absorption in the paper (Alegre et al., 2002), and has a role in reducing the length and diameter of the branches (Girona et al., 2000). It is known that there are two periods of growth in olive dense growth wave that starts from spring and reaches summer and the second wave is less active in autumn. Mezghani et al. (2007) and Henar (2002) note that the recent growth wave subsides when growing under conditions of water stress in summer and early fall. Wahbi et al. (2006) stated that the water stress caused a decrease in the percentage of (pulp/fruit) due to the decrease in the weight of the fruits. Deidda et al. (1968) indicated a severe decrease in the hardness of the water-stressed olive fruit. Goldhamer et al. (1994) also observed that olive productivity decreased dramatically under conditions of water stress during the second period of fruit growth. Water stress also reduces the percentage of oil and when the purpose of production is to obtain pickling fruits, water stress leads to a large loss that occurs as a result of the low quality of the fruits due to their small size (Pastor et al., 1999).

Although the olive tree has a high resistance to drought, irrigation allows increased productivity in olive growing areas where water scarcity and scarce rains, as the Mediterranean countries suffer from a decrease in rainfall during the period from June to September and this period coincides with the stages of growth Fruits and the second wave of vegetative growth (Tombesi et al., 2007; Natali et al., 1991). Hadiddou (2006) and Inglese et al. (1999) stated that the response of olive trees to irrigation is particularly evident in the period of intensive growth and development that extends from flowering differentiation until harvest that is from April to October in Mediterranean conditions.

Michelakis et al. (1994) and Pastor et al. (1999) mentioned that the response of the olive tree to irrigation can achieve up to 50-60% of production when it moves from dry (rainfed) conditions to irrigation. Studies were also conducted in spring irrigation of trees by Crous et al. (2009) and Cuevas et al. (1999) where they found that early spring irrigation prevented many physiological disturbances in olive blossoms such as low flower development and miscarriage of the pistil, and spring irrigation also had a role Aid in mitigating the phenomenon of alternate bearing (Pastor et al., 1999). Moriana et al. (2003) and Manrique et al. (1999) also found that spring and summer irrigation greatly increases the growth of fruits even during the period of seed stiffness where the fruit growth is usually slow and, accordingly, irrigation allows for increased productivity.

Lavee et al. (1990) and Moriana and Orgaz (2003) note that there are clear differences between irrigated and rain-fed olives in the dry year, especially when droughts occur during the period of olive tree activity (June, August), but the differences are less important in the rainy years, and they stated that with the addition of water, olive productivity improved. Tardieu et al. (2006) explained that the increase in vegetative growth when applying supplementary irrigation is the result of an increase in the activity of the mechanical movement of water in tree cells, as well as the irrigation of olives, improves the strength of the branches growth and this leads to stronger fruiting in the following years (Tognetti et al., 2006). Girona et al. (2000) and Pérez et al. (2004) confirmed the effect of supplementary irrigation on increasing the growth of branches in rainfed olives, but this response varies according to the different timing of water supply and to the quantities provided. The results of research conducted by Sole-Riera et al. (1990) and Chartzoulakis et al. (1992) in olive groves in which supplementary irrigation was applied showed that the provision of irrigation water led to increased growth of branches and flowers and increased percentage of fruit-set as well as irrigation reduced the alternation in productivity. Also, a good supply of irrigation water leads to obtaining high-quality fruits from table olives, and this is linked to an increase in the commercial value of the product (Ozyilmaz and Ozkara, 1990; Gatto, 1989). Where the provision of supplemental irrigation during the sensitive physiological stages of fruit growth, especially during the expansion of mesocarb cells, leads to an increase in the weights of the fruits, and in the pulp and the total productivity of the fruits and oil (Dettori et al., 1993). Several studies have also shown that the productivity of olives from fruits increased with increasing levels of irrigation (Mitchell et al., 1984; Aurora et al., 2007). D'Andria et al. (2007) stated that the weight of the fruits at harvest was in direct correlation with the volume of water applied in the cultivars Frantoio and Leccino. Grattan et al. (2006) stated that the volume of fruits increased with increasing amounts of irrigation water in olive trees. Moriana et al. (2003) obtained an increase in the total tree productivity of oil by increasing the applied irrigation rate. Moriana et al. (2003) and Hartmann et al. (1949) stated that irrigation has an effect on the fruit content of oil when irrigation coincides with the period of oil accumulation which is most active during the seed hardening stage and the rapid stage of fruit growth.

Generally, most of the areas planted with olives in Syria depend mainly on rain water and the irregularity of rainfall rates from year to year leads to a significant decrease in the

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productive efficiency of the tree. Therefore, studies recommended conducting supplementary irrigation in order to improve the productivity of this tree and reduce the phenomenon of floating, but the studies did not specify the exact numbers and dates of these supplementary irrigations. Therefore, this research was conducted with the aim of studying the effect of supplementary spring and summer irrigation on the growth and production indicators in the olive tree and determining the optimum number and dates for irrigation.

II. MATERIALS AND METHODS

2.1 Experiment Location

This research was conducted during the years 2012 and 2013 in an olive orchard in the village of Kafr-Rouhin, which is about 10 km to the west of Idleb city. It follows the Mediterranean semi-arid climate and the medium-cold temperature. Whereas the general rain rate for the previous ten years 450 mm, according to the rainy bulletin issued by the Directorate of Agriculture and Agrarian Reform in Idleb Governorate, but during the two research years the average did not exceed 300 mm on average.

2.2 Plant material

The orchard is planted with olive trees of Sourani variety, at a distance of 10x10 m. It is homogeneous in size, with a height of about 5 m, and with a close lifespan of about 30 years. Sourani variety is considered one of the finest cultivars cultivated in Syria and it is characterized by its being dual purpose, its tree is medium size taking the spherical shape. Its fruits are medium-sized, elongated, light green with a red shine and become black at maturity. It has a high oil content (28-30%). It is used for green and black pickling and is desirable for marketing. It is excellent resistance to olive knot disease, leg diggers and peacock's eyespot (Al-Bakeer, 2005).

2.3 Experimental treatments

Samples from the site soil were analyzed before the beginning of the work, where the results showed that the soil is clay loamy and tends to be basic, light, saline and poor in organic matter, nitrogen, phosphorous and rich in potassium Table (1), and according to the recommendations of the Agricultural Scientific Research Center in Idleb, the following fertilizer quantities/dunum were added: 54 kg of urea fertilizer, 26 kg of superphosphate fertilizer and 3 m3 of organic fertilizer decomposed during the years of study, with the same level over the entire land area, in order to standardize the treatments in terms of the effect of the soil fertilizer applied during the research years. The service, agriculture, pruning, and pest control operations were applied uniformly to all treatments.

TABLE 1
Soil analysis results for experimental plots

Compenent	Value	Compenent	Value
pH	7.67	Organic matter (%)	1.5
EC (ds/m)	0.47	Sand %	12
K (ppm)	585	Celtic %	24
P (ppm)	6	Clay %	64
N (ppm)	3	Color	reddish brown

Supplementary irrigation was applied to trees in this orchard by drip irrigation, in which the amount of water in one irrigation was determined at the rate of 200L per tree in all treatments. The experimental treatments differed between them according to the number of irrigations and their dates, as shown in Table (2).

TABLE 2
Experimental Transactions

Treatment	Number of irrigations	date of irrigations
1	0	Control
2	1	April
3	2	April; June
4	3	April; June; July
5	4	April; June; July; August

2.4 Measured parameters

- **Annual vegetative growth rate (cm):** 10 recent branches were taken on the perimeter of each studied tree, the start of which was determined from the last old leaf of the previous year, and serial numbers were given and strips were placed on them in different colors as markers in order to calculate the annual vegetative growth rate.
- **Foliar surface (cm^2):** This trait was studied on a sample of 40 leaves taken from the middle part of 10 branches one-year-old using the following formula:

$$\text{Foliar surface } (cm^2) = [0.53 \times \text{leaf length (cm)} \times \text{leaf width (cm)}] + 1.66$$

- **Indicators of flowering and fruit-set:** The start of blooming buds was determined when 10% of the flowers blooms, 10 recent branches were taken on the perimeter of each tree studied in different directions, and bars with different colors were placed on them as a marker for each branch. The number of flowering clusters per branch, the number of flowers per flowering cluster, and the number of flowers per branch were calculated. Also, the number of formed fruits per branch was recorded four weeks after full flowering and the percentage of the fruit-set was calculated.

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- **Characteristics of the fruit:** 10 recent branches were taken on the perimeter of each tree studied and in different directions, strips of different colors were placed on them as a marker for each branch, and the number of remaining fruits was recorded on each branch. Also, the weight of the fruit (g) was calculated using a sensitive balance, and the volume of the fruit (mL) was calculated by using the listed cylinder and calculating the amount of water displaced from the position of the fruits inside the cylinder. Then, after the weight of each fruit, the seed was weighed to calculate the pulp/fruit ratio.
- **Productivity (kg/tree):** the harvest was done manually on November 5 of each year. After collecting the production of each tree and removing the leaves, branches, soil, and impurities present among the olive fruits, the fruits of each tree were weighed with a normal scale, and then the average for each treatment (5 replications) was calculated.
- **Oil percentage (%):** A sample of 40 fruits was taken from the middle part of the fruiting branch and from all sides. An amount of 2 kg of olive fruits was collected from each tree and the oil was extracted on the basis of wet weight by a special olive press in the laboratories of the Olive Research Center in Idleb.

2.5 Experimental design

A complete randomized block design was used. Five irrigation treatments (0, 1, 2, 3, 4 irrigation times) were applied. Five replicates per treatment, with one tree (Saurani olive variety) per replicate were adopted. Consequently, the number of olive trees used in the experiment = 5 treatments x 5 replicates x 1 tree = 25 trees.

2.6 Statistical analysis

The results were statistically analyzed using the GENSTAT -12 SPSS-18 software to find the significance of the differences with the ANOVA method and extract the least significant difference (LSD) at the level of 5%. The work and analysis of samples were carried out in the laboratories of the faculty of agricultural engineering at the University of Idleb.

III. RESULTS AND DISCUSION

3.1 Annual Vegetative Growth of Branches (cm)

By studying the effect of supplemental irrigation on the annual vegetative growth rate of the branches, we reached the results shown in Table (3).

TABLE 3
Effect of supplementary irrigation

Treatment	Season		Average
	2012	2013	
1	8.73	11.69	10.21^{c*}
2	12.68	18.93	15.81^{b}
3	13.67	20.38	17.03^{a}
4	13.76	20.51	17.14^{a}
5	14.22	20.76	17.49^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=1.10)

It appears from Table (3), which shows the results of the application of spring and summer irrigation on the annual vegetative growth of the branches, that all treatments had of a significant impact compared to the control, and the second treatment (one irrigation in April) had the greatest effect in increasing the rate of vegetative growth compared to the rest of the spring and summer irrigation treatments.

It achieved an increase in vegetative growth by 5.6 cm from the control. also, the third treatment (2 irrigations in April and June) achieved an increase in the vegetative growth by 6.82 cm from the control and 1.22 cm from the second treatment (one irrigation in April). While the rest of irrigation treatments (4 and 5) did not achieve any significant increase in the annual vegetative growth compared to the third treatment.

These results demonstrate the positive effect of supplementary irrigation on plant growth and the increase in the length of vegetative branches. These results are consistent with Magliulo et al. (2003) who showed that irrigation increased the vegetative growth of trees.

Whereas, Mahhou et al. (2005) stated that the increase in the growth of branches as a result of irrigation is due to the increase in transpiration, which leads to an increase in the speed of cell division, an increase in the elasticity of cell walls, and an increase in cell enlargement, which lead to increased cell growth. The results are also consistent with Attalla et al. (2011) who demonstrated that applying irrigation twice was more effective than application once.

3.2 Foliar surface (cm^2)

After studying the effect of supplementary irrigation on the area of the leaf surface (cm^2), we obtained the results shown in Table (4).

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TABLE 4

Effect of supplementary irrigation on the foliar surface (cm^2)

Treatment	Season		Average
	2012	2013	
1	4.14	4.60	4.37^{b*}
2	6.48	7.43	6.96^{a}
3	6.49	7.44	6.97^{a}
4	6.53	7.45	6.99^{a}
5	6.60	7.46	7.03^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=0.48)

These results demonstrate the positive effect of supplementary irrigation on causing a significant increase in the foliar surface. This effect can be explained by improving the nutritional status of trees and providing better water and nutrients, thus improving the movement and transmission of gases and water vapor during stomata in the leaves, which increase photosynthesis, stimulates growth, and increase in the length and width of the leaves, thereby increasing the foliar surface. These results are consistent with Bakeer (2016) who showed through his research on different varieties of olives, that the complementary irrigation treatments outweigh the rain fed treatments in the average foliar surface which amounted to 36.83 mm^2 and 29.92 mm^2, respectively.

3.3 Indicators of flowering and fruit-set

3.3.1 Number of flowering clusters/branch

Via our study, to clarify the effect of supplementary irrigation on the number of flowering clusters/branch, we reached the results presented in the Table (5).

TABLE 5

Effect of supplementary irrigation on the number of flowering clusters/branch

Treatment	Season		Average
	2012	2013	
1	16.08	6.50	11.29^{b*}
2	27.82	22.67	25.25^{a}
3	28.37	22.75	25.56^{a}
4	28.08	23.17	25.63^{a}
5	28.25	23.13	25.69^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=1.08)

It is clear from Table (5), which illustrates the effect of supplementary spring and summer irrigation on the number of flowering clusters/branch, that all the treatments had a significant effect compared to the control. The second treatment (one irrigation in April) had a major effect on the number of flowering clusters/branch, which increased to more than twice its value in the treatment of the control (2.24 times). While the rest of the spring and summer irrigation treatments (3, 4, 5) did not have any additional significant effect over the effect achieved by the second treatment.

3.3.2 Number of flowers/flowering cluster

As a consequence of our study of the effect of supplementary irrigation on the number of flowers/flowering cluster, we attained the results shown in Table (6).

TABLE 6

Effect of supplementary irrigation on the number of flower/flowering cluster

Treatment	Season		Average
	2012	2013	
1	14.75	8.42	11.59^{b*}
2	22.67	16.67	19.67^{a}
3	22.75	16.83	19.79^{a}
4	22.83	17.08	19.96^{a}
5	22.92	17.17	20.05^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=0.85)

It is noted from Table (6), which clarifies the effect of supplementary spring and summer irrigation on the number of flowers/flowering cluster, that all treatments had a significant effect compared to the control. The impact was evident in the second treatment (one irrigation in April), where the number of flowers/flowering cluster nearly doubled compared to the treatment of the control (1.7 times). While the rest of the spring and summer irrigation treatments did not have any additional significant effect on the effect achieved by the second treatment.

3.3.3 Number of flowers/branch

In accordance with our study of the effect of supplementary irrigation on the number of flowers/branch, we obtained the results shown in Table (7).

TABLE 7

Effect of supplementary irrigation on the number of flowers/branch

Treatment	Season		Average
	2012	2013	
1	237.18	54.73	145.96^{b*}
2	630.68	377.91	504.29^{a}
3	645.42	382.88	514.15^{a}
4	641.07	395.74	518.41^{a}
5	647.49	397.14	522.32^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=20.48)

It appears from Table (7), which explains the effect of supplementary spring and summer irrigation on the number of flowers/branch, that all treatments had a significant effect compared to the control. The effect was obvious in the second treatment (one irrigation in April), where the number of flowers/branch more than tripled compared to the treatment of the control (3.46 times). While the rest of the supplementary spring and summer irrigation treatments did not have any additional significant effect on the effect achieved by the second treatment.

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3.3.4 Fruit-set (%)

Based on studying the effect of supplementary irrigation on the percentage of fruit-set, we achieved the results shown in Table (8).

TABLE 8

Effect of supplementary irrigation on the percentage of fruit-set (%)

Treatment	Season		Average
	2012	2013	
1	5.95	6.21	6.08^{b*}
2	6.42	7.18	6.80^{a}
3	6.44	7.27	6.86^{a}
4	6.47	7.28	6.88^{a}
5	6.49	7.30	6.90^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=0.33)

It is noted from Table (8), which clarifies the effect of supplementary spring and summer irrigation on the percentage of fruit-set, that all treatments achieved a significant increase compared to the control. The effect of second treatment (one irrigation in April) was evident, as the percentage of the fruit-set in this treatment increased by 0.72% over the treatment of the control. While the rest of the supplementary spring and summer irrigation treatments did not have any additional significant effect on the effect achieved by second treatment.

The previous results show the positive effect of irrigation on the indicators of flowering and fruit-set (the number of flowering clusters/branch, the number of flowers/flowering cluster, the number of flowers/branch, the percentage of fruit-set). This effect is due to the improvement of the nutritional status of the trees and the provision of water requirements, which leads to increased physiological and biological activity in the treated trees. Our results of flowering and fruit-set indicators are consistent with many previous studies in this field. Whereas Grattan (2006) showed that irrigation treatments applied to olive trees significantly increased the number of flowers, the number of flowering clusters/branch, and the percentage of fruit-set compared to the treatment of control non-irrigated. Mitchell et al., (1984) attributed the increase in the number of flowers and the number of flowering clusters in irrigated olives to the increase in carbohydrate content during the flower differentiation phase as a result of irrigation treatments.

3.4 Fruit characteristics

3.4.1 Number of fruits/branch

Through our study of the effect of supplementary irrigation on the number of fruits/branch, we reached the results shown in Table (9).

TABLE 9

Effect of supplementary irrigation on the number of fruits/branch

Treatment	Season		Average
	2012	2013	
1	14.11	3.40	8.76^{b*}
2	40.49	27.13	33.81^{a}
3	41.56	27.84	34.70^{a}
4	41.48	28.81	35.14^{a}
5	42.02	28.99	35.51^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=2.67)

It appears from Table (9), which shows the results of supplementary spring and summer irrigation on the number of fruits/branch, that all treatments have achieved a significant effect compared to the control. The second treatment (one irrigation in April) almost doubled the number of fruits (3.86 times) compared to the control. While the increase in the number of irrigation times (2, 3 or 4 irrigations) did not achieve a significant addition to the effect achieved by one irrigation in April.

3.4.2 Fruit weight (g)

In our study of the effect of supplementary irrigation on the fruit weight (g), we obtained the results exposed in Table (10).

TABLE 10

Effect of supplementary irrigation on fruit weight (g)

Treatment	Season		Average
	2012	2013	
1	2.14	2.52	2.33^{d*}
2	2.83	3.94	3.39^{c}
3	2.81	4.70	3.76^{c}
4	4.03	5.36	4.70^{b}
5	4.41	5.96	5.19^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=0.45)

It appears from Table (10), which shows the results of supplementary spring and summer irrigation on the weight of the fruit (g), that all treatments significantly outperform the control. Whereas the second treatments (one irrigation in April) achieved an increase of 1.06 g over the control. While, the third treatment (two irrigation in April, and June) was not significantly superior to the second treatment, the increase in the number of irrigations to 3 times in April, June and July (fourth treatment) achieved a significant increase over the third treatment with a value of 0.94 g and 2.37 g over the control. Similarly, the increase in the number of irrigations in the fifth treatment (4 irrigations in April, June, July, and August) showed a significant increase above the fourth treatment (3 irrigations in April, June, and July) with a value of 0.49 g and 1.43 g over the third treatment (two irrigations in April, and June) and 2 .86 g on the treatment of control.

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3.4.3 Fruit size (mL)

Based on our study of the effect of supplementary irrigation on the size of the fruit (mL), we reached the results presented in Table (11).

TABLE 11
Effect of supplementary irrigation on fruit size (mL)

Treatment	Season		Average
	2012	2013	
1	1.00	1.30	1.15^{d*}
2	1.11	1.60	1.36^{d}
3	1.70	2.60	2.15^{c}
4	2.50	3.20	2.85^{b}
5	3.70	3.90	3.80^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=0.32)

It appears from Table (11), which shows the results of the application of spring and summer irrigation in the size of the fruit (mL), all treatments exceeded the control with significant differences (except for the second treatment one irrigation in April). Where the third treatment (two irrigations in April, and June) achieved an increase in the size of the fruit by 1.00 mL. The addition of third irrigation in April, June, and July (the fourth treatment) achieved a significant increase in the treatment of two irrigations (the third treatment), with a significant difference of 0.7 mL. Also, the addition of the fourth summer irrigation in April, June, July, and July (the fifth treatment) achieved a significant increase in the size of fruit amounting to 0.95 mL compared to the treatment of three irrigations (the fourth treatment).

3.4.4 Pulp/fruit ratio (%)

In accordance with our study of the effect of supplementary irrigation on the pulp/fruit ratio (%), we reached the results presented in Table (12).

TABLE 12
Effect of supplementary irrigation on pulp/fruit ratio (%)

Treatment	Season		Average
	2012	2013	
1	80.69	82.00	81.35^{d*}
2	84.84	86.14	85.49^{c}
3	85.87	87.30	86.59^{b}
4	86.86	88.05	87.46^{b}
5	87.94	90.59	89.27^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=1.07)

It appears from Table (12), which shows the results of the application of spring and summer irrigation in the pulp/fruit ratio, that all treatments achieved a significant increase compared to the control. Whereas one irrigation (second treatment) led to an increase in the pulp/fruit ratio of 4.14% compared to the control. The addition of a second irrigation (the third treatment: two irrigations in April, and June) resulted in a significant increase of 1.1% over that of one irrigation (the second treatment). While the effect of adding a third irrigation (three irrigations in April, June, and July) was not significant compared to two irrigation (third treatment). However, the addition of a fourth irrigation in April, June, July, and August (the fifth treatment) achieved a significant increase of 1.81% compared to three irrigations (the fourth treatment) and 7.92% compared to the control.

These results show the positive effect of supplementary irrigation in causing a significant increase in the characteristics of the fruit (number, weight, size, pulp/fruit ratio). Our results are consistent with many studies. D'Andria et al., (2007) concluded that the fruit weight at harvest was in direct correlation with the quantity of water applied in the cultivars Frantoio and Leccino. Lavee et al (1990) mentioned that providing supplementary irrigation during the sensitive physiological stages of fruit growth, especially during the expansion of mesocarb cells, has led to an increase in the weight of the fruits, and to an increase in the pulp/fruit ratio and the total productivity of the fruits. Our results are consistent with that shown by Faci et al (2002) and Breton et al (2009), that the weight of the fruits increases with increasing irrigation rates, and they attribute the increase in the weight of fruits to the increase in the volume of fruits resulting from the accumulation of water, oil and other accumulates in the tissue of fruits.

3.5 Productivity/tree (Kg)

Through our study of the effect of supplementary irrigation on the productivity/tree (Kg), we found the results shown in Table (13).

TABLE 13
Effect of supplementary irrigation on the productivity/tree (Kg)

Treatment	Season		Average
	2012	2013	
1	50.83	18.82	34.83^{e*}
2	77.09	51.15	64.12^{d}
3	90.17	65.41	77.79^{c}
4	97.22	72.33	84.78^{b}
5	105.31	80.30	92.81^{a}

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=6.79)

It appears from Table (13), which shows the results of the application of spring and summer irrigation on the productivity/tree, that all treatments led to a significant increase in productivity compared to the control. Whereas the second treatment (one irrigation in April) achieved an increase of 29.29 kg . Furthermore, the increase in the number of irrigations resulted in a significant increase in productivity. So the third treatment (two irrigations in April, and June) increased by 13.67 kg over the second treatment, the fourth treatment (three irrigations in April, June, and July) achieved a significant increase of 6.99 kg over the third treatment, and the

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fifth treatment (four irrigations in April, June, July, and August) increased productivity by 8.03 kg over the fourth transaction.

These results demonstrate the positive effect of supplementary spring and summer irrigation on increasing productivity. Noting the increase in the positive impact on productivity with the increase in the number of irrigations. The results are consistent with what Michelakis et al. (1994) mentioned in the importance of spring irrigation in increasing productivity and reducing altering in it. It agrees with Moriana et al. (2003), which showed that spring and summer irrigation greatly increases the growth of fruits even during the period of hardening of the seed where the growth of fruits is usually slow and, accordingly, irrigation allows increased productivity. The results are also consistent with Aurora et al. (2007), which showed that olive productivity increased with increasing irrigation times.

3.6 Percentage of oil (%)

Depending on our study of the effect of supplementary irrigation on the productivity/tree (Kg), we found the results displayed in Table (14).

TABLE 14
Effect of supplementary irrigation on the percentage of oil (%)

Treatment	Season		Average
	2012	2013	
1	12.72	14.88	13.80[d*]
2	15.18	17.44	16.31[c]
3	18.92	20.72	19.82[b]
4	19.88	21.80	20.84[b]
5	23.25	25.01	24.13[a]

* Any two treatments, they share one letter, there is no significant difference between them ($LSD_{0.05}$=1.83)

It appears from Table (14), which shows the results of the application of supplementary irrigation in the oil percentage, that all treatments achieved a significant increase compared to the control. Whereas, the percentage of oil in the second treatment increased by 2.51% compared to the control. Moreover, the increase in the number of irrigations gave an additional increase in the percentage of oil compared to one irrigation. where the third treatment (two irrigations in April, and June) gave an increase in the oil percentage of 3.51% over the second treatment (one irrigation in April), The fifth treatment (four irrigation in April, June, July, and August) gave an increase in the oil percentage of 3.29% compared to the fourth treatment (three irrigations in April, June, and July).

These results demonstrate the positive effect of supplemental irrigation on significantly increasing of the oil content. Our results are in agreement with many studies and researches conducted on olives. Whereas, Rotundo et al. (1992) and Dettori et al. (1990) mentioned that the water deficiency during the period of the fourth stage of fruit development caused a sharp decrease in the final rate of oil accumulation in the fruits. Also, Lavee et al. (1990) stated that providing supplementary irrigation during sensitive physiological stages of fruit growth, especially during the expansion of mesocarb cells, leads to increased oil production. Furthermore, Moriana et al. (2003) explained that irrigation increased the productivity of olives and thus increased the productivity of the oil.

3.7 Comparing the two research years

By comparing the averages of studied indicators between the two research years, we obtained the results shown in Table (15).

TABLE 15
Comparing the average of studied indicators between the two research years

Trait	Season		LSD (0.05)
	2012	2013	
Annual vegetative growth of branches (cm)	12.61[b]	18.45[a]	0.49
Foliar surface (cm^2)	6.05[b]	6.88[a]	0.22
Fruit-set (%)	6.35[b]	7.05[a]	0.15
Fruit weight (g)	3.24[b]	4.50[a]	0.12
Fruit size (mL)	2.00[b]	2.52[a]	0.13
Pulp/fruit ratio (%)	85.24[b]	86.82[a]	0.52
Percentage of oil (%)	17.99[b]	19.97[a]	0.47
Number of flowering clusters/branch	25.72[a]	19.64[b]	0.48
Number of flowers/flowering cluster	21.18[a]	15.23[b]	0.38
Number of flowers/branch	560.39[a]	321.68[b]	15.83
Number of fruits/branch	35.93[a]	23.23[b]	3.54
Productivity/tree (Kg)	84.12[a]	57.60[b]	3.04

Table (15) shows the difference in the average of studied indicators between the years 2012 and 2013. Where the year 2012 exceeded most of the production indicators (number of flowering clusters/branch, number of flowers/flowering cluster, number of flowers/branch, number of fruits/branch and productivity/tree). While in 2013, it outperformed most indicators of vegetative growth (annual vegetative growth of branch, floliar surface, percentage of fruit-set) and fruit characteristics (fruit weight, fruit size, pulp/fruit ratio, percentage of oil). Thus, the first year of research war a high year of production, while the second year was a low year of production (the phenomenon of alternate bearing), and on the contrary, for vegetative growth. Our results are consistent with several studies that showed the difference in the rate of production and vegetative growth between the year of high production and the year of low production (Henar, 2002).

On the other hand, all treatments resulted in reducing the difference in the average of indicators studied between the two study years, compared to the control. This was evident in the tree productivity index (which is the most important indicator of the alternate bearing phenomenon). While the productivity of the control decreased in the second year of the research by

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63% from the first year, the decrease in productivity ranged between 34% in the second treatment (one irrigation in April) and 24% in the fifth treatment (four irrigations in April, June, July, and August), Figure (1).

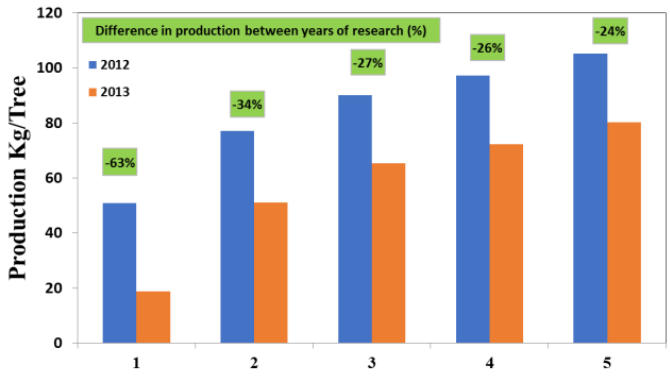

Figure 1: Difference of olive tree productivity in experimental treatments between the two study years

Based on this result, we find that the importance of irrigation is not only in increasing production in the same year of application, but also in reducing the phenomenon of alternate bearing and obtaining a balanced and stable production over the years.

IV. CONCLUSION

1) All experimental treatments achieved a significant increase in comparison with the control in all studied parameters.

2) The treatment of spring irrigation (one time in April) gave the most significant increase in comparison with the control and with summer irrigation treatments in most studied growth and flowering indicators (annual vegetative growth, foliar surface, number of flowering clusters/branch, number of flowers/flowering cluster, number of flowers/branch, fruit-set percentage, and number of fruits/branch).

3) The treatments of summer irrigation gave the best results with regard to the criteria for fruiting and productivity (weight and size of the fruit, pulp/fruit ratio, tree productivity, and oil percentage) compared to the spring irrigation treatments, and the increase in the number of summer irrigation times improved all the mentioned parameters.

4) The first year of study exceeded the second year in productivity indicators, while the second year of study exceeded the indicators of vegetative growth and fruit quality specifications. The phenomenon of alternate bearing that is characteristic of olive trees has had a clear effect, but all the applied irrigation treatments reduced the difference between the two years of the study in all indicators studied, compared to the control.

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