Influence of Soil Conditioner and Different Irrigation Levels on the Growth and Productivity of Two Olive Cultivars under Sandy Soil Conditions

[1]Madlen R. Sawarsan and [2]M.S.M. Ahmed

[1]Olive and Fruits of Semi-Arid Zone Department, Horticulture Research Institute, ARC, Giza, Egypt
[2]Central Laboratory for Agricultural Climate (CLAC), ARC, Giza, Egypt

Abstract: This field study was carried out during two growing seasons of 2014 & 2015 on adult and almost simillar10 years old trees of two olive cultivars namely Manzanillo (dual cv. 'Spain') and Maraki (commercial oil cv.) cultivated in a private orchard, located at 64 km on the Cairo-Alexandria desert road and cultivated at 3×6 m apart in sandy soil irrigated with underground water to assess the impact of soil amendments such as super absorbent polymer (SAP) in two doses (1/2 kg and 1 kg per tree) applied once to the soil combined with the compost around the olive tree at the beginning of the first season in January. In addition, three irrigation levels depending on reference evapotranspiration (ETo) such as 4384 m^3/feddan (100%), 3738 m^3/feddan (85%) and 3090 m^3/feddan (70%) of full irrigation requirements (IR) were applied to investigate their impact on cultivars under study. The results of both growing seasons obtained that adding SAP soil conditioner enhanced all of nutrients uptake, water holding capacity and decrease electrical conductivity of soil solution. On the other hand, using of 85 % irrigation levels with SAP treatments enhanced vegetative growth characteristics, i.e., number of leaves/shoot, leaf area as well as flowering characteristics, i.e., as number of flowers per inflorescence, number of perfect flowers per inflorescence, flowering density, fruit set, fruit characterizes, yield and oil content. Nutrient contents of N, P and K in leaves were increased by using 70% irrigation level. The total yield of olive fruits as well as water use efficiency (WUE) was increased by using 85% irrigation level combined with 1/2 Kg SAP application rate. Highest water applications (100%) gave lowest values of WUE. So, we can recommend using 85% (3738 m^3) of irrigation level for olive trees (Manzanillo and Maraki cultivars) in sandy soil which produced the highest yield and quality of olive trees. Besides, it gives the highest net income. This is due to the savings in irrigation water comparing with 100 % (4384 m^3) of irrigation level.

Key words: Olive · Manzanillo · Maraki · Irrigation · Water Stress · WUE · Economic evaluation and Soil amendments

INTRODUCTION

Olive (*Olea europaea* L.) is a medium-sized evergreen tree belongs to family Oleaceae. It considered as one of the oldest known cultivated trees in the world, with a great historic importance from thousands years ago [1, 2]. The tree grows and fruits well under the Mediterranean climate [3]. Olive tree is a drought tolerant species withstanding prolonged dry periods using physiological and morphological mechanisms of resistance to water stress [4, 5]. In Egypt, olive cultivation and production is considered among the major commercial trees, it ranks the fourth after citrus, mango and grapes [6]. Today, there are

attempts to increase olive yield and olive oil production due to rising demand for olive fruit and olive oil. Areas that may be available for this purpose are marginal soils in arid and semi-arid areas, but the environmental conditions are usually not well suited for good production [7]. The majority of olive orchards are drip irrigated and increasing the irrigated area is very difficult in the olive industry, because of water scarcity and competition with non-agricultural uses [8]. Thus, establishment of a sagacious irrigation approach is a major task in modern olive growing [9]. Super absorbent polymer (SAP) is one of the soil amendments among the natural soil conditioners, which have been used in Egypt for

Corresponding Author: Madlen R. Sawarsan, Olive and Fruits of Semi-Arid Zone Department,
Horticulture Research Institute, ARC, Giza, Egypt

reclamation of sandy and sandy calcareous soils and reduce the efficient water consumption. It is considered as an environmentally friendly material, increase soil's water holding capacity, providing plants with eventual moisture and nutrients as well as improving plant viability and ventilation and root development and reduction in irrigation costs [10, 11]. The aforementioned are of results of Super Absorbent Polymer pointed that, treating sandy soil with (SAP) enhances water-holding capacity, reduce drought stress on plants resulted in the highest growth rate, biomass and fruit yield significantly higher than the control [12, 13].

The main objective of this study was to correlate the effect of different irrigation levels combined with two different levels of soil conditioner (SAP) on the yield and quality of two olive cultivars namely (Maraki and Manzanillo) cultivated in the newly reclaimed area and to study some soil physical and chemical properties of the tested soil.

MATERIALS AND METHODS

Field Experiment: This investigation was undertaken during two growing seasons (2014 and 2015) on ten years old of two olive cultivars (Manzanillo and Maraki) grown in a private orchard located at the 64km on the Cairo-Alexandria desert road, Egypt. The trees were planted at 6 x 3 m apart in sandy soil under drip irrigation system with 8 adjustable discharge emitters/trees through 2 irrigation lines.

Soil Analysis: Soil samples were randomly collected at the beginning of the experiment from the zone of the end of root ramification of the canopy at depth 60cm. Some soil physical properties were determined as described by Klute [14]. Soil pH was measured using pH meter in 1:2.5 soil: water suspension and EC in the extract using EC meter. Chemically available N, P and K were determined according to the methods described by Page, *et al.* [15]. Organic matter content was determined by the methods described by Baruah and Barthakur [16] and the results of soil and water analyses are summarized in Tables (1 and 2).

Treatments: The experiment contained two factors with nine treatments that were applied to olive cultivars (dual cv. 'Spain') and Maraki (oil cv. commercial). Fifty four trees were selected from both cultivars each selected

and divided in two factors; First factor was irrigation levels which estimated according to dominant reference evapotranspiration (Eto) at (100%" 4384 m^3/feddan", 85% "3740 m^3/feddan" and 70% "3090 m^3/feddan) which applied through the growing season as a time of irrigation according to the common practice of the grower irrigation quantity). The second factor was soil conditioner super absorbent polymer (SAP) at 1/2 Kg / tree, 1 Kg/tree and control (without application); the treatments were represented with three replicates (two trees for each replicate) as follows:

- 4384 m^3/feddan (100%) irrigation level without SAP.
- 3738 m^3/feddan (85%) irrigation level without SAP.
- 3090 m^3/feddan (70%) irrigation level without SAP.
- 4384 m^3/feddan (100%) irrigation level with 1/2 Kg / tree SAP.
- 3738 m^3/feddan (85%) irrigation level with 1/2 Kg / tree SAP.
- 3090 m^3/feddan (70%) irrigation level with 1/2 Kg / tree SAP.
- 4384 m^3/feddan (100%) irrigation level with1 kg / tree SAP.
- 3738 m^3/feddan (85%) irrigation level with1 kg / tree SAP.
- 3090 m^3/feddan (70%) irrigation level with1kg / tree SAP.

The irrigation levels were applied by installment of a flow-meter and valve to control the applied water quantity. The irrigation interval depended on the climatic conditions during the growing season. The trees received irrigation two times weekly in November, December, January and February, three times/week in March, April, September and October, five times/week in May and June, six times/week in July and August. In addition, they received the recommended fertilization program applied to all trees on equal bases according to the Ministry of Agriculture, Egypt. Soil conditioner (SAP) samples were obtained from the Agriculture Research Center (ARC). The soil conditioner was mixed with compost then added to the soil in first of January one time only under irrigation lines at 30 cm depth in both sides surround the tree. At the end of both growing seasons soil samples were collected from different irrigation levels and soil conditioner (SAP) treatments to investigate the influence of each factor on physical and chemical characteristics of experimental soil.

Table 1: Some physical and chemical characteristics of the studied soil (0-60cm)

Particle size distribution (%)

Sand	Silt	Clay	Texture class	Bulk density (g cm^{-3})	Real density (g cm^{-3})	Total porosity (%)	Field Capacity (FC)*	Wilting Point (WP)*	Available Water (AW)*	Water Holding Capacity (WHC)*
84.5	8.50	7.00	Loamy sand	1.49	2.51	40.6	20.9	9.55	11.4	29.4

			Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})						
OM (%)	pH (1:2.5)	EC (dS m^{-1})	Ca^{++}	Mg^{++}	Na$^+$	K$^+$	CO3$^-$	HCO3$^-$	Cl$^-$	SO4$^-$	SAR	ESP (%)	CEC (cmolc kg^{-1})
0.98	7.63	3.10	9.00	8.00	12.9	1.10	0.00	10.5	18.0	2.50	4.42	4.99	15.3

* % on dry weight basis

Table 2: Chemical composition of the studied water sample used for irrigation

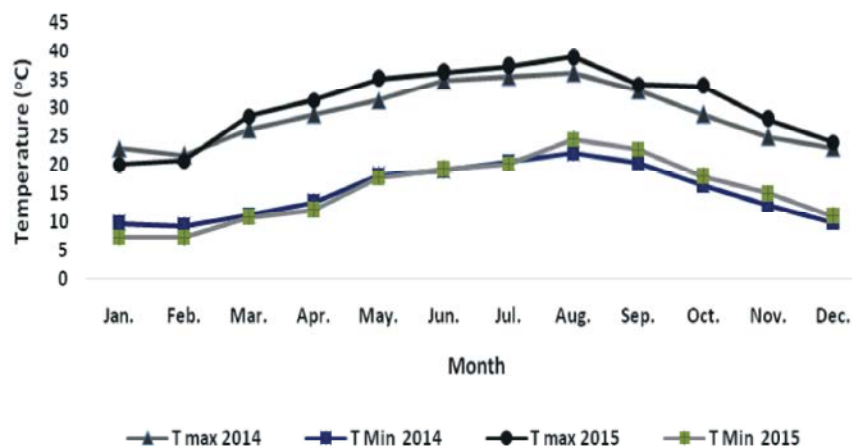|		Soluble ions (meq L^{-1})								
pH	EC dS / m^{-1} (1:5)	Ca^{++}	Mg^{++}	Na$^+$	K$^+$	CO3$^-$	HCO3$^-$	Cl$^-$	SO4$^-$	SAR
7.68	4.4	10	8	27.1	0.34	0	2.4	32.5	10.6	9.03

Fig. 1: The maximum and minimum air temperature in the experimental site during 2014 and 2015 growing seasons.
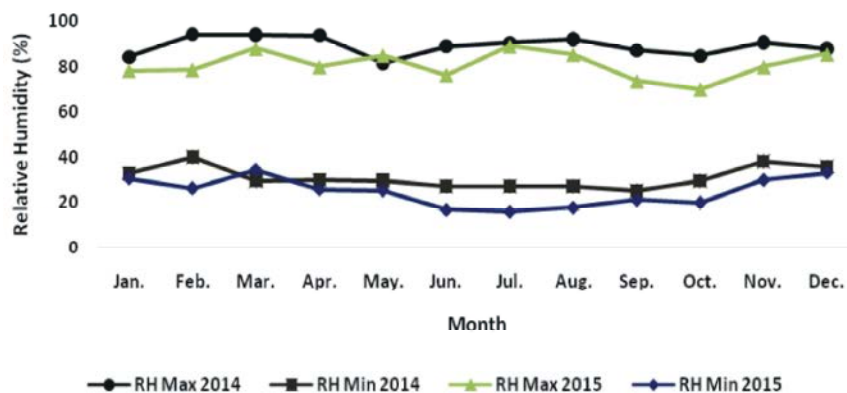

Fig. 2: The maximum and minimum relative humidity percentage in the experimental site during 2014 and 2015 growing seasons

Climate Data: The daily maximum and minimum temperature and relative humidity were recorded by Data logger Model SK-L200THIIα. Other climate factors (wind speed, precipitation and solar radiation) were collected from automated weather station to calculate reference evapotranspiration (ETo). The reference evapotranspiration (ETo) was calculated using Food and Agricultural Organization (FAO) Penman- Monteith (PM) procedure, FAO 56 method, presented by Allen, [17].

Table 3: List of major components of Super Absorbent polymers (SAP)

A	Super absorbent polymers (SAPS)		Major components
	Aqua keep		Polyacrylic acid
	Arasoubu S-107		Polyacrylic acid
	Aron T-121		Polyacrylic acid
B	Bargas 700		Polyacrylic acid
1	Sanwet H-5000D		Polyacrylic acid
	Composites		---
	B1	SAP-20%	Bentonite+SAP-20%
2	K1	A SAP-20%	Kaolinite+SAP-20%

Table 4: Some characteristics of the studied polymer

pH	7.12
Bulk density, g cm^{-3}	0.67
Real density, g cm^{-3}	1.72
Total porosity, %	61
Water Holding Capacity (WHC), cm^3 g^{-1}	60

Estimation of Irrigation Requirements for Olive Tree: The estimated crop irrigation requirement in Table (5) is calculated by multiplying the reference crop evapotranspiration, ETo, by a crop coefficient, Kc according to FAO [18], the same methodology was adopted by many studies [17, 19].

$$IR = Kc * ETo * LF * IE * R* \text{Area (Feddan)}/1000$$

where:

IR = Irrigation requirement (m³/feddan).
Kc = Crop coefficient [0.40-0.80] according to Allen *et al.* [17] and Goldhamer *et al.* [20].

The Major Components and Characteristics of Super Absorbent Polymers (SAP): SAP is a mixtures of polyacrylic of super absorption polymer and clay deposits (Bentonite) at ratio 1:5 according to Ahmed [21]. Some chemical features of these composites are shown in Tables (3 and 4).

ETo = Reference crop evapotranspiration (mm/day).
LF = Leaching fraction (assumed 20% of irrigation water).
IE = Irrigation efficiency of the irrigation system in the field, (assumed 85% of the total applied).
R = Reduction factor (35-70 % cover in this study)
Area = The irrigated area (one feddan = 4200 m²).
1000 = To convert from liter to cubic meter.

Recorded Data

Vegetative Measurements: At the end of each growing season the following parameters were recorded:

- Average shoots length (cm).
- Average number of leaves / shoot.
- Leaf area (cm²): using a planimeter according to Aly, [22].

Floral Characteristics: Inflorescence length (cm): thirty inflorescences were randomly taken from each replicate tree and the length of their axis was measured.

Flowering density: was determined according to the following equation;
Flowering density = (Number of inflorescences x 100)/ average shoot length (cm).
No. of perfect flowers per inflorescence
Perfect flowers (%): was determined according to the following equation:
Perfect flowers (%) = No. of perfect flowers / No. of total flowers x 100 [23 and 24].

Fruiting and Yield: Fruit set (%): were calculated after 60 days from full bloom according to Hegazi and Hegazi, [25] and Hegazi *et al.* [26] as a formula:

$$\text{Fruit set } \% = \frac{\text{No. of fruits}}{\text{No. of total flowers}} \text{ x } 100$$

The average yield (kg) was recorded at ripe stage (olive with superficial pigmentation on more that 50% of the skin) for each replicate tree.

Fruits Physical Characteristics: Fifty fruits at ripe stage were randomly selected in both seasons from each replicate tree to study physical and chemical characteristics of fruits in different treatments according to the following basis:
Fruit characters: length (cm), diameter (cm) and weight (g.).
Stones were extracted from the selected fruits to determine their length (cm), diameter (cm) and weight (g).
Flesh weight (g) = average fruit weight - average stone weight.
- Flesh/stone ratio was calculated according to Fouad *et al.* [27].

Fruits Oil Content (%): Fruit oil content as dry weight was determined according to A.O.A.C [28].

Leaf Minerals Content: At the first week of August in the both tested seasons fifty samples of mature leaf were taken from previously labeled non-fruited shoots on each replicate from the upper third of shoot top.

- Nitrogen was determined by the Micro-Kjeldahl method [29].
- Phosphor was estimated by the method described by Murphy and Riely [30].

Potassium was flame- photometerically determined according to Brown and Lilleland, [31].

Water Use Efficiency (WUE): Water use efficiency (WUE) was calculated by the method according to FAO, [32] as follows:

WUE = Y (Kg) / IR (m^3) which is the ratio of crop yield (Y) to the total amount of consumed irrigation water (IR) during the growing season.

Economic Evaluation: Economic evaluation was calculated according to Radinovic *et al*., [33] as follows:

Total return (EGP/feddan) = Total yield (kg) × (price/(Kg) which was (5 EGP in Manzanillo & 4 EGP in Maraki) in 2014 season and (6 EGP in Manzanillo & 5 EGP in Maraki) in 2015 season.
Water cost = Total water quantity × (water price / m^3 which was 0.5 EGP in 2014 and 0.6 in 2015).
Cost of SAP =20EGP/kg.
Operation cost (Fertilizers, Laborers, pesticides and others) = 5500 EGP
Net income = Total return − (water cost + SAP + cost operation cost)

Statistical Analysis: Data were statistically analyzed using statistical analysis system (SAS) program (SAS, [34]. The experiment treatments were arranged in a split-plot design in complete randomized block system with three replicates. The means that were significant were separated using Duncan's Multiple Range Test [35].

RESULTS AND DISCUSSION

Estimated Evapotranspiration (ETo): The reference evapotranspiration (ETo) of experimental farm was calculated during both studied seasons by using the collected climatic data from the meteorological station nearby the farm (Fig. 3). Data revealed that the values of ETo were different during the growing season. Values of ETo ranged from 2.80 mm day^{-1} to 8.45 mm day^{-1} depending on the period of the year. The lowest values of ETo were recorded during Dec. 2.83 and 2.80 mm day^{-1} in

the first and second seasons, respectively. In the contrary the highest values of ETo were recorded during Aug. 8.21 and 8.45 mm day^{-1} during the both seasons, respectively. The high values of ETo means the increasing of water consumption for olive trees to compensate the amount of consumed water. So, the increasing of air temperature led to increase the evaporation and water consumption of olive trees. These results may be due to that Evapotranspiration is normally computed from the Penman- Monteith equation using weather data. This equation is affected by principal weather parameters such as radiation, air temperature, humidity and wind speed. These results are matched with Ahmed and Aly [36].

Estimated and Applied Irrigation Water: Data in Table (5) show the monthly amount of estimated and applied irrigation water. They illustrated that the estimated amount of irrigation water (100% from ETo) was different during the growing season from January to December. As an average of both seasons, the lowest amount of estimated irrigations water occurred in Dec., (103 m^3/feddan). Whereas, the highest amount of estimated irrigation water occurred in Jul., (585 m^3/feddan) followed by Aug., (569 m^3/feddan). The total amount of estimated irrigation water of 100% irrigation level was 3908 m^3/feddan. As regard to the actual applied irrigation water, it obviously cleared that the lowest amount of applied water was recorded during Dec., 209, 178 and 147 m^3/feddan for 100%, 85% and 70% irrigation treatments, respectively Whereas, the highest amount of actual applied water were recorded during Jul. and Aug. which were 626, 534 and 441 m^3/feddan for 100%, 85% and 70% irrigation levels, respectively. The average total amount of applied water for both growing seasons were differed among different irrigation treatments which were 4384, 3738 and 3090 m^3/feddan for 100%, 85% and 70% irrigation levels, respectively. On the other hand, there was difference between estimated and applied irrigation water. For example, when the estimated amount of irrigation at 100% irrigation level was 4908 m^3/feddan, it was 4384 m3/feddan in 100% of actual applied water treatment, it means that there was much irrigation water than olive tree needs. Besides, the amount of actual applied water in 85% treatment (3738 m^3) is very close from 100% of ETo estimated amount of irrigation water. Obviously, estimating of irrigation requirements for olive trees depending on climatic conditions by Penman Monteith equation is more accurate and water
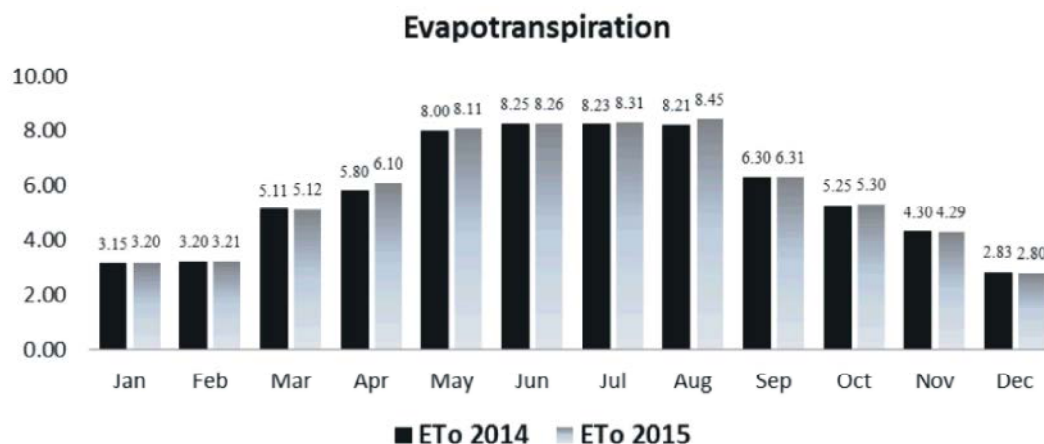
Evapotranspiration

Fig. 3: Reference Evapotranspiration (Eto) during two growing seasons 2014 and 2015 at Cairo-Alexandria desert road

Table 5: Applied and estimated water during the two growing seasons of 2014 and 2015 for Manzanillo and Maraki olive cultivars tree

	Applied water m³/ feddan in both seasons			Estimated water m³/ feddan		
Month	100% (3.5h)	85% (3.0h)	70% (2.50h)	2014 season	2015 season	Average for both seasons
Jan	209	178	147	112	113	112.5
Feb	209	178	147	105	106	105.5
Mar	313	267	221	249	251	250.0
Apr	313	267	221	351	355	353.0
May	522	445	368	505	516	510.5
Jun	522	445	368	510	511	510.5
Jul	626	534	441	572	597	584.5
Aug	626	534	441	550	587	568.5
Sep	313	267	221	414	418	416.0
Oct	313	267	221	266	269	267.5
Nov	209	178	147	126	127	126.5
Dec.	209	178	147	103	103	103.0
Total	4384	3738	3090	3863	3953	3908

saving than traditional method of on-farm irrigation method. These results may be due to the different climatic conditions especially air temperature during different months. So, the increasing of air temperature led to increasing of evaporation and water consumption by olive trees. Our results are in agreement with those of Farag *et al.* [37].

Soil Physical and Chemical Properties: Data in Table (6) represent the effect of different irrigation water levels and SAP application on some soil physical properties at the end of the field experiment. Soil bulk density is a major product of the changes in the soil and field conditions, also one of the most important parameters of soil structure. Data in Table (6) revealed that the treatment of (100%) irrigation without addition of soil conditioner had significantly higher bulk density which consistently was decreased with increase in deficit water level. The reports of Farag *et al.* [12] were in conformity with such findings. The increment of soil bulk density under high irrigation

level may be due to decrease in soil organic matter (OM), as mentioned in Table 7, which led to rearrangement of soil particles and reorientation of soil pores. Regarding the addition of soil conditioner, the soil bulk density values were significantly decreased with increasing its added amount; which enhance access to soil moisture and increase nutrient uptake resulting in higher crop yield, as observed by Ikpe and Powell [38]. Conditioners improve soil aggregation, increase water stable aggregates, activate soil water retention and finally improve the dynamic soil-water movement through infiltration, as have been reported by Ahmed [39] and Abu and Malgwi [40] who reported that soil conditioner such as sewage sludge and gypsum contributed to increase the hydraulic conductivity, total porosity and reduced soil bulk density of red mud soil. Polyacrylamide is a long-chain synthetic polymer that acts as a strengthening agent, binding soil particles together and holding soils in place, so improves their properties [41]. In addition, hydraulic conductivity is one of the most important soil characteristics which play

171

Table 6: Some physical properties of the studied soil after harvesting of Manzanillo and Maraki cultivars during 2014 and 2015 seasons

Treatment	Bulk density, g cm^{-3}	HC, ×10^{-3} cm Sec^{-1}	FC	WP	AW
			----------------------- % -----------------------		
First season; 2014					
70% irrigation level without SAP	1.62c	1.93h	12.6f	4.35a	8.25g
85% irrigation level without SAP	1.68b	2.01g	13.0e	4.09b	8.91f
100% irrigation level without SAP	1.71a	2.06fg	13.0e	4.03c	8.97e
70% irrigation level with 1/2 Kg SAP	1.60cd	2.11f	13.5d	3.97d	9.53d
85% irrigation level with 1/2 Kg SAP	1.56e	3.45c	13.9c	3.88e	10.0c
100% irrigation level with 1/2 Kg SAP	1.59d	3.26d	13.8c	3.85e	9.95c
70% irrigation level with 1 Kg SAP	1.51f	2.98e	14.1b	3.78f	10.3b
85% irrigation level with 1 Kg SAP	1.43h	4.29a	14.3a	3.71g	10.6a
100% irrigation level with 1 Kg SAP	1.47g	3.67b	14.3a	3.70g	10.6a
Second season; 2015					
70% irrigation level without polymer	1.65c	1.91h	12.3f	4.37a	7.93f
85% irrigation level without SAP	1.69b	1.96g	12.8e	4.11b	8.69e
100% irrigation level without SAP	1.73a	1.97g	12.9e	4.01c	8.89e
70% irrigation level with 1/2 Kg SAP	1.58d	2.25f	13.7d	3.95d	9.75d
85% irrigation level with 1/2 Kg SAP	1.53e	3.51c	14.1c	3.81f	10.3c
100% irrigation level with 1/2 Kg SAP	1.55e	3.22d	14.5b	3.87e	10.6b
70% irrigation level with 1 Kg SAP	1.47f	3.17e	14.4b	3.75g	10.7b
85% irrigation level with 1 Kg SAP	1.41g	4.60a	14.8a	3.70g	11.1a
100% irrigation level with 1 Kg SAP	1.45f	3.81b	14.7a	3.72g	11.0a

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

a vital role in irrigation and drainage practices along with behavior of soil water, consequently most of physical and chemical properties of the soil. In this respect, soil hydraulic conductivity depends mainly on soil structure, soil texture and management processes. Data given in Table 6 show the effect of the applied treatments on soil hydraulic conductivity values. In general, addition of 1/2 kg polymer combined with 85% irrigation water level clearly increased values of soil hydraulic conductivity in the two tested seasons; such treatment being the superior. The obtained results in Table 6 show, also, that the available water content significantly increased by application of soil conditioner. The amount of available soil moisture due to the treatment of 1/2 kg polymer combined with 85% irrigation water level was relatively higher compared to the other treatments, the effect in the second season being better than the first one.

There is a relation exists between the supply of polyacrylamide and water level due to the effect of polyacrylamide at a suitable concentration on improving the physical properties of the sandy soil, especially when the soil contains the suitable amount of water consequently the plants gave the highest growth and yield [42].

Data in Table (7) present some soil chemical properties after harvesting fruits of two olive cultivars during the two studied seasons of 2014 and 2015. Results showed that soil pH increased with increasing the amount of applied polymer, possibly due to that the applied polymer reduces EC value of the studied soil which was related oppositely with pH, as compared to the control. Also, soil pH increased with increasing irrigation water level due to the dilution effect. The electrical conductivity of the tested soil significantly decreased with increasing the amount of applied polymer and increasing irrigation water level, due to that the polymer adsorbed cations such as Ca^{2+}, Mg^{2+}, K^+, Na^+ and H^+; lets anions easy to leach with excess water and reduce EC value of the studied soil. Increasing irrigation water level, solubilize and leach more salts which reduce EC value [43].

After harvesting season, the analysis of the soil indicated that addition of the polymer increased the available amount of N, P and K in the tested soil, especially with K followed by N; this may confirm that the polymer chelate cations; preferring monovalent cations to replace water molecules [44]. The organic matter (OM) content in the studied soil showed an increase with increasing the amount of applied polymer, which is reflected on conserving available macronutrients from leachability and increasing soil fertility. C/N ratio in the studied soil went hand by hand with available N and OM content in the soil. Similar trend was observed in the second season which means that the studied polymer was effective and more stable that worked with the same efficiency without another addition in the second season.

Table 7: Some chemical properties of the studied soil after harvesting of Manzanillo and Maraki cultivars during 2014 and 2015 seasons

Treatments	pH (1:2.5)	Ece dS m/1	Chemically available macronutrients, %			OM (%)	C/N ratio
			N	P	K		
First season, 2014							
70% irrigation level without SAP	7.97h	2.71a	0.56e	0.23e	4.39g	1.07f	1.11c
85% irrigation level without SAP	8.03g	2.64b	0.51f	0.19f	4.16h	1.04g	1.18b
100% irrigation level without SAP	8.05fg	2.58c	0.49f	0.18f	4.02h	1.02h	1.21a
70% irrigation level with 500 SAP	8.08e	2.01e	0.61d	0.25e	6.65f	1.19e	1.13c
85% irrigation level with 1/2 Kg SAP	8.43d	1.99e	0.80a	0.39b	9.38b	1.27b	0.92e
100% irrigation level with 1/2 Kg SAP	8.48c	0.92f	0.69c	0.29d	7.78d	1.23d	1.03d
70% irrigation level with 1 Kg SAP	8.06e-g	2.51d	0.70c	0.31d	7.57e	1.24cd	1.03d
85% irrigation level with 1 Kg SAP	8.51b	0.89f	0.90a	0.46a	10.2a	1.29a	0.83f
100% irrigation level with 1 Kg SAP	8.54a	0.62g	0.77b	0.36c	8.54c	1.25c	0.94e
Second season, 2015							
70% irrigation level without SAP	8.02f	2.74a	0.51f	0.21f	4.21g	1.03f	1.17c
85% irrigation level without SAP	8.05e	2.67b	0.48f	0.18g	4.11g	1.00g	1.21b
100% irrigation level without SAP	8.06e	2.62b	0.44g	0.17g	4.03g	0.99h	1.31a
70% irrigation level with 1/2 Kg SAP	8.09d	1.97d	0.67e	0.26e	6.73f	1.23e	1.06d
85% irrigation level with 1/2 Kg SAP	8.45c	1.93d	0.83b	0.42b	9.44b	1.28a	0.89f
100% irrigation level with 1/2 Kg SAP	8.50b	0.90e	0.71d	0.33d	7.85d	1.26c	1.03d
70% irrigation level with 1 Kg SAP	8.11d	2.42c	0.76c	0.35cd	7.68e	1.25d	0.95e
85% irrigation level with 1 Kg SAP	8.54a	0.82f	0.92a	0.49a	10.1a	1.28a	0.81g
100% irrigation level with 1 Kg SAP	8.55a	0.61g	0.80b	0.37c	8.70c	1.27b	0.92ef

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

Treatment of 85% irrigation water level + 1kg polymer was superior in increasing N, P, K and OM contents in the studied soil. This may be due to that suitable amounts from the applied water and polymer are reflected on suitable conditions in the soil.

Vegetative Growth: Dealing with the specific effect of the two investigated factors (irrigation levels, soil conditioner) and their interaction on the average shoot length (cm), average no. of leaves per shoot and leaf area (cm^2) on each of Manzanillo and Maraki cultivars during 2014 and 2015 reflected that, the highest value of shoot length was attained by70% of irrigation level in the first season and 85% in the second season of Manzanillo cultivar , while 100% acquired the highest value in Maraki cultivar in both studied seasons. Similarly, irrigation at 85% (3738m^3/feddan) gave the highest values of no. of leaves per shoot and leaf area in both seasons of each of Manzanillo cultivar in Table (8-a) and Maraki cultivar in Table (8-b). Moreover, irrigation at 70% (3090 m^3/feddan) shared 85%in Maraki leaf area in both studied seasons. On the other hand the lowest values of shoot length , no. of leaves per shoot and leaf area was differ from first and second season in each of Manzanillo and Maraki cultivar.

As regards to effect of soil conditioner treatments, it was noticed that, SAP at 1/2 kg gave the highest values in both seasons of Manzanillo and Maraki cultivars shared with the control treatment (without polymer) in the number of leaves per shoot and leaf area in the second season of Manzanillo cultivar and the first season of Maraki cultivar. Concerning the interaction effect between the irrigation level and soil conditioner treatments, it was showed that, in each of Manzanillo and Maraki cultivars, the highest values of vegetative parameters in Table (9-a & b) were obtained by each of 85 % and 70% of irrigation level combined with polymer at 1/2 Kg followed by 1 kg in both seasons. In the contrary, the lowest values of shoot length cm, no. of leaves per shoot and leaf area (cm^2) differed from season to another in two cultivars. The varied trend in vegetative growth parameters of olive trees during both seasons may be resulted from change of irrigation level that effect of the root system and addition the soil amendments increases both saturated and residual water content, water holding capacity and available water content that tend to enhance the growth. Moreover, the difference between cultivars may be due genetic and heritability factors. These results are agreed with those of [36, 13].

Table 8-a: Effect of different irrigation water levels and SAP on vegetative growth parameters of Manzanillo cv. during 2014 and 2015 seasons.

	Shoot length (cm)				Average no .of leaves/shoot				Leaf area (cm²)			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	16.50f	28.78c	24.21de	23.16C	31.10c	25.77f	28.44e	28.44B	6.24c	6.60b	5.21f	6.02B
85% (3738 m³)	31.44b	36.39a	37.19a	35.01A	29.44e	31.10c	36.67a	32.40A	5.30a	7.72de	6.53b	6.52A
70% (3090 m³)	24.76d	31.67b	22.55e	26.33B	32.67b	23.17h	24.17g	26.67C	5.58e	5.66de	5.87d	5.70C
Mean	24.23C	32.28A	27.98B		31.07A	26.68C	29.76B		6.37A	5.99B	5.87B	
	Second season, 2015											
100% (4384m³)	21.78c	29.22a	26.21b	25.74B	20.33cd	20.74cd	21.10c	20.73C	6.56a	6.16b	4.56d	5.76B
85% (3738 m³)	30.12a	28.89a	29.22a	29.41A	22.10 b	25.67a	20.67cd	22.81A	5.61c	6.60a	6.04b	6.08A
70% (3090 m³)	22.20c	29.55a	20.50c	24.08C	25.17a	21.00c	20.10d	22.09B	5.67c	5.54c	5.86bc	6.69B
Mean	24.70B	29.22A	25.31B		22.53A	22.47A	20.62B		5.95A	6.10A	5.49B	

Table 8-b: Effect of different irrigation water levels and SAP on vegetative growth parameters of Maraki cv. during 2014 and 2015 seasons

	Shoot length (cm)				Average no .of leaves/shoot				Leaf area (cm²)			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season 2014											
100% (4384m³)	15.17e	22.00bc	16.67e	17.95C	20.00d	24.67c	21.00d	21.89B	6.02d	6.58bc	6.77bc	6.46B
85% (3738 m³)	21.67e	19.78d	23.75b	21.73A	15.56f	26.67a	25.67b	22.63A	6.50c	6.97ab	6.57bc	6.68A
70% (3090 m³)	16.22e	28.33a	15.33e	19.96B	27.00a	18.00e	21.00d	22.00B	6.62bc	6.53c	7.33a	6.83A
Mean	17.69B	23.37A	18.58B		20.85B	23.11A	22.56A		6.38B	6.69A	6.89A	
	Second season, 2015											
100% (4384m³)	13.44e	20.00b	15.33d	16.26B	17.33e	24.00b	17.11e	19.48C	5.94c	6.54b	6.68b	6.45B
85% (3738 m³)	19.75bc	17.89c	22.78a	20.14A	21.67c	21.00cd	28.44a	23.70A	6.74b	7.43a	6.83b	7.00A
70% (3090 m³)	19.78bc	20.25b	11.56f	17.20B	20.33d	29.11a	15.33f	21.59B	6.81b	7.47a	6.90b	7.04A
Mean	17.66B	19.38A	16.56C		19.78B	24.70A	20.29B		6.50C	7.14A	6.86B	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

Flowering: Influence on flowering characteristics (inflorescence length, number of inflorescence/ shoot and flowering density) of Manzanillo and Maraki cultivars presented in Table (9-a & b) showed that irrigation at 85% (3738 m³/feddan) gave the highest values in both seasons except the inflorescence length of Maraki cultivar which, 100% (full irrigation) acquired the highest value in both studied seasons. With respect to the soil addition, polymer at 1/2 kg in Manzanillo and polymer at 1 kg in Maraki cultivar acquired the highest number of inflorescences/shoot and flowering density in both seasons. Meanwhile, control treatment (untreated) of Manzanillo and Maraki cultivars recorded the highest values of inflorescence length in both seasons shared with treatments of soil addition in Manzanillo cultivar. Dealing with the interaction effect between irrigation level and amendments on the length of inflorescence, it was noticed that, there were a convergence in the inflorescence length both of Manzanillo and Maraki cultivars. In the majority, 85% irrigation requirement with 1/2 kg of polymer in the Manzanillo cultivar and by increasing the dose (1kg) in Maraki cultivar recorded the highest values in both seasons. Additionally, there was no clear trend towards the least records.

According to the tabulated data in Table (10 a & b) it has been stated that, irrigation level at 85% (3738m³/feddan) achieved the maximum number of total flowers per inflorescence in two cultivars, number of perfect flowers per inflorescence in both seasons of Manzanillo and second of Maraki and Perfect flowers (%) in both seasons of Manzanillo cultivar shared significantly with 100% (4384m³/feddan) in Maraki cultivar in (Table 10-b). As the effect of SAP soil amendment polymer at the rate of 1/2kg gave the highest values in the tested amendments of Manzanillo cultivar shared with the increase in dose of Maraki cultivar. This was true in both seasons of study. According to the interaction between irrigation level and amendments, the 85 % irrigation requirement with SAP at high dose (1 kg) recorded a significant value in the majority of tested characteristics.

These results may be attributed to the availability of water especially in 85% irrigation level with addition of SAP that enhanced the initiation of olive tree flowering because of preventing water stress effects. The difference between cultivars may be due genetic factors and heritability. These results are in line with those of Andria *et al.* [45], Caruso *et al.* [46, 11].

Table 9-a: Effect of different irrigation water levels and SAP on inflorescence length (cm), number of inflorescence/shoot and flowering density of Manzanillo cv. during 2014 and 2015 seasons

	Inflorescence length (cm)				Number of inflorescence /shoot				Flowering density			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	2.60d	2.63d	2.65cd	2.63C	6.30e	5.07g	5.48f	5.62C	38.18a	17.62i	22.64e	26.14B
85% (3738 m³)	3.10a	3.13a	2.90a-c	3.04A	6.50de	9.00a	6.77cd	7.42A	20.67g	24.73d	18.20h	21.20C
70% (3090 m³)	2.70cd	2.80b-d	2.97ab	2.82B	6.83cd	6.94c	7.50b	7.09B	27.58c	21.91f	33.26b	27.59A
Mean	2.80A	2.86A	2.84A		6.54B	7.00A	6.58B		28.81A	21.42C	24.70B	
	Second season, 2015											
100% (4384m³)	2.90ab	2.73bc	2.35d	2.66B	4.67c	5.30d	4.35d	4.77C	21.44g	18.14h	16.60i	18.73C
85% (3738 m³)	3.10a	3.04ab	2.82a-c	2.99A	7.17b	7.20b	8.83a	7.73A	23.80f	24.92e	30.22b	26.32B
70% (3090 m³)	2.87ab	2.90ab	2.53cd	2.77B	7.17b	7.60b	5.67c	6.81B	32.30a	25.72d	27.66c	28.56A
Mean	2.96A	2.89A	2.57B		6.34B	6.70A	6.28B		25.85A	22.93C	24.82B	

Table 9-b: Effect of different irrigation water levels and SAP on inflorescence length (cm), number of inflorescence/shoot and flowering density of Maraki cv. during 2014 and 2015 seasons

	Inflorescence length (cm)				Number of inflorescences /shoot				Flowering density			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	3.20a	3.23a	2.95bc	2.13A	6.13g	5.25h	10.84a	7.41C	40.41d	23.86f	65.03a	43.10B
85% (3738 m³)	3.13ab	2.80c	3.03ab	2.99B	9.00d	10.50b	7.67f	9.06A	41.53d	53.08b	32.29e	42.30C
70% (3090 m³)	3.10ab	2.53d	2.77c	2.80C	8.00e	8.86d	9.86c	8.91AB	49.32c	31.27e	64.32a	48.30A
Mean	3.14A	2.86B	2.92B		7.71C	8.20B	9.46A		43.75B	36.07C	53.88A	
	Second season, 2015											
100% (4384m³)	3.27a	3.30a	2.70c	3.09A	10.50b	9.50b	6.33f	8.78B	78.13b	47.50d	41.29e	55.64A
85% (3738 m³)	2.63c	2.69c	3.03b	2.78B	7.50e	8.83d	11.17a	9.17A	37.97f	49.36c	49.03c	45.46B
70% (3090 m³)	3.20ab	2.33d	2.67c	2.73B	5.00g	3.75h	9.83c	6.19C	25.28g	18.52	85.03a	42.94C
Mean	3.03A	2.78B	2.80B		7.67B	7.36B	9.11A		47.13B	38.46C	58.45A	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05.

Table 10-a: Effect of different irrigation water levels and SAP on the no. of total flowers/inflorescence, no. of perfect flowers/ inflorescence and perfect flowers% of Manzanillo cv. during 2014 and 2015 seasons

	No. of total flowers / inflorescence				No. of perfect flowers / inflorescence				Perfect flowers percent			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	11.33d	12.43c	12.31c	12.02B	4.72e	7.20b	4.28f	5.40B	41.66e	57.92b	34.77f	44.78B
85% (3738 m³)	11.83d	13.84a	12.56c	12.74A	6.40c	5.23d	8.01a	6.55A	54.10c	37.79e	63.77a	51.89A
70% (3090 m³)	11.77d	11.56d	11.70d	11.68B	5.24d	6.30c	3.53g	5.03C	44.52d	54.50c	30.17g	43.06C
Mean	11.64C	12.61A	12.19B		5.46B	6.25A	5.27C		46.76B	50.07A	42.90C	
	Second season, 2015											
100% (4384m³)	12.02b-d	12.33b	11.77d	12.04B	4.57d	6.68b	3.56e	4.94C	38.02f	54.18a	30.25h	40.81C
85% (3738 m³)	11.90cd	12.11b-d	13.11a	12.37A	5.79c	4.93d	7.20a	5.97A	48.66c	40.71e	54.92a	48.10A
70% (3090 m³)	12.23bc	13.00a	11.16e	12.13B	5.80c	6.53b	3.67e	5.33B	47.42d	50.23b	32.89g	43.51B
Mean	12.05B	12.48A	12.01B		5.39B	6.05A	4.81C		44.70B	48.37A	39.35C	

Table 10-b: Effect of different irrigation water levels and SAP on the no. of total flowers/inflorescence, no. of perfect flowers/ inflorescence and perfect flowers% of Maraki cv. during 2014 and 2015 seasons

Irrigation levels	No. of total flowers |inf.				No. of perfect flowers/inf.				Perfect flowers percent			
	Superabsorbent polymer (SAP)											
	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	22.23d	22.03d	24.21b	22.82B	16.21f	19.23c	19.59c	18.34B	72.92f	87.27b	80.92c	80.38A
85% (3738 m³)	23.30c	21.47e	28.26a	24.34A	17.74d	20.00b	21.42a	19.72A	76.14d	93.15a	75.80e	80.70A
70% (3090 m³)	22.30d	23.90b	21.15e	22.45C	15.70g	17.00e	15.89fg	16.20C	70.40h	71.13g	75.13e	72.22B
Mean	22.61B	22.47B	24.54A		16.55B	18.74A	18.96A		73.15C	83.86A	77.28B	
	Second season, 2015											
100% (4384m³)	23.59b	20.13e	22.00d	21.91B	19.27b	19.15b	20.87a	19.76A	81.69e	95.13a	94.86a	90.56A
85% (3738 m³)	24.99a	24.67a	22.87c	24.18A	16.77d	20.97a	19.00b	18.91A	67.11f	85.00c	83.08d	78.40Bq
70% (3090 m³)	15.65f	22.21d	22.20d	20.02C	13.97e	13.24f	18.20c	15.14C	89.27b	59.61g	81.98e	76.95C
Mean	21.41B	22.34A	22.36A		16.67C	17.79B	19.36A		79.35B	79.92B	86.64A	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

Table (11-a): Effect of different irrigation water levels and SAP on the fruit set (%) and yield (kg/tree) of Manzanillo cv. during 2014 and 2015 seasons.

Irrigation levels	Fruit set (%)				Yield (kg/tree)			
.	Superabsorbent polymer (SAP)							
	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014							
100% (4384m³)	27.01h	51.73a	36.96e	38.57B	37.67d	39.67c	42.00b	39.78B
85% (3738 m³)	32.38g	44.15b	43.23c	39.92A	36.60e	44.67a	45.00a	42.09A
70% (3090 m³)	35.34f	41.52d	22.74i	33.20C	21.33g	22.67f	19.00h	21.00C
Mean	31.58C	45.80A	34.31B		31.87B	35.67A	35.33A	
	Second season, 2015							
100% (4384m³)	27.70d	33.25a	29.57b	30.17A	15.33d	16.17c	21.00b	17.50B
85% (3738 m³)	28.49c	27.75d	26.70e	27.64B	13.00f	20.33b	25.67a	19.67A
70% (3090 m³)	17.42f	30.54b	17.92	21.96C	12.00g	15.33d	14.33e	13.89C
Mean	24.54B	30.51A	24.73B		13.44C	17.28B	20.33A	

Table (11-b): Effect of different irrigation water levels and SAP on the fruit set (%) and yield (kg/tree) of Maraki cv. during 2014 and 2015 seasons.

Irrigation levels	Fruit set (%)				Yield (kg/tree)			
	Superabsorbent polymer (SAP)							
	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014							
100% (4384m³)	15.97g	23.69c	24.08b	21.25A	15.67ef	25.00c	32.33b	24.33B
85% (3738 m³)	17.85e	25.76a	15.85g	19.82B	21.00d	25.33c	33.67a	26.67A
70% (3090 m³)	19.42d	16.74f	16.55f	17.57C	15.00f	16.33e	15.00f	15.44C
Mean	17.75C	22.06A	18.83B		17.22C	22.22B	27.00A	
	Second season, 2015							
100% (4384m³)	10.34f	21.56b	19.32c	17.07B	12.07fg	24.33a	16.67d	17.69B
85% (3738 m³)	8.92f	15.52d	29.38a	17.94A	11.70gh	20.33c	23.00b	18.34A
70% (3090 m³)	19.17c	15.26d	13.51e	15.98C	11.33h	13.00e	12.60ef	12.31C
Mean	12.81C	17.45B	20.74A		11.70C	19.22A	17.42B	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

Fruit Set (%) and Yield: Displayed data in Table (11-a & b) showed the effect of irrigation levels and SAP on fruit set and yield in both growing seasons. Regarding the effect of different irrigation levels, it was evident that, irrigation at 85% (3738m³/feddan) attained the highest values of the yield in both seasons shared with first fruit set% of Manzanillo and second of Maraki. On the other hand, irrigation at 70% had the lowest ones. With respect to the soil condition, it noticed that two doses of SAP amendment especially 1/2 kg gave better results than control and apply SAP soil amendment at high dose have more effective to improve the yield. These results were consistent with both cultivars under investigation. As for the effect of interaction between Irrigation level and

amendments, it was different from Manzanillo to Maraki cultivars. The deficit water irrigation of 85% with medium and high dose of SAP soil amendment gave better results.

These results are in a line with these mentioned by Puertas *et al.* [47] who detected that, the trees gave inferior yield that may due to the effect of high temperature prevailing at the period of floral initiation that have affect at bud differentiation process. Moreover, irrigation of olive trees by suitable amount of water 85 % levels enhanced the fruit set characteristics as well as fruit yield may be due to availability of water and mineral nutrients in the root zone of plant [48].

Fruit Characteristics:
Fruit Weight (g), Fruit Length (cm) and Width (cm):
Data in Table (12-a & b) demonstrated that, each of irrigation levels and SAP affected on the average fruit weight, fruit length, fruit diameter of each of Manzanillo and Maraki cultivars.

Concerning the effect of irrigation levels, using 85% of irrigation water resulted in the highest length and heaviest weight of Manzanillo and Maraki fruits shared with Manzanillo fruit width in the both seasons (Table 12-a & b). Positive correlation was evident from fruit width of Maraki in the second season by full irrigation requirement (100%). The present data revealed that SAP treatments gave the highest values of the investigated parameters especially high does (1kg). The interaction between the two factors of study had significant differences in two cultivars and differs from season to another. The interaction between 85% irrigation level and polymer at 1/2 and 1kg in the first season and 1/2 and 1kg in the second season attained the highest values of Manzanillo cultivar. Whereas, 100% irrigation level combined with 1kg of polymer gave the highest values of previous fruit characteristics in both growing seasons for Maraki cultivar.

The outstanding effect of irrigation on fruit weight may be due to the enhancement effect of water on tree growth without suffered stress and that encouraged root system absorption of nutrients and available water, which led to an increase photosynthesis rate as well as fruit weight [48]. Our results support the observations of Fayek *et al.* [13] who mentioned that, fruit weight is strongly affected by fruit set percentage and soil moisture content and the weight of fruit was affected by the yield and level of irrigation.

Seed Weight (g), Length (cm) and Width (cm):
Concerning the seed characterizes of Manzanillo and Maraki cultivars in Table (13-a & b), it could be noticed that, a deficit irrigation treatments at 85% gave the highest value of seed length and width and each of levels 85% and 70% significantly affected in seed weight of Manzanillo culivar. As regard to the trend of Maraki stone weight, it did not record any significant difference due to irrigation level in the first season, while, in the second season each of 85% and 70% achieved the highest value. Moreover, 100% of irrigation water and deficient of 70% in the second season attained the highest seed length. Additionally, either at 85% and 70% of irrigation water achieved the highest seed width in the first season, while no difference was noticed in the second season. Similarly, applying SAP soil amendments have more effective in the seed characteristic during two studied seasons.

Flesh Weight, Flesh/Seed Ratio and Fruit Oil Content (%): Concerning flesh weight and flesh/seed ratio, water deficit at 85% of irrigation requirements recorded the highest values in flesh weight shared with full irrigation water in flesh/seed ratio of Manzanillo and Maraki cultivars, Meanwhile, doses of soil amendments recorded a significant better flesh weight and flesh/seed ratio than without amendment. The highest values mostly appeared in high dose (1kg). With respect to interaction between treatments, flesh weight and flesh/seed ratio, it was affected by water tree status 85% of irrigation level with SAP amendments especially 1 kg.

Oil yield is an important indicator of producer profit and the cost of water for irrigation needs to be measured against increased yield with more water [49]. As for the effect of different irrigation levels, SAP amendments and their interactions on the oil content of Manzanillo (dull) and Maraki (oil) cultivars. It could be noticed that, applying irrigation water at the rate of 85% enhanced the oil formation in both cultivars (Table 14-a & b). SAP soil amendments especially with 1 kg gave the significant highest olive oil yield in both Manzanillo (Table 14-a) and Maraki (Table 14-b) as compared with 100% irrigation level. Interaction between irrigation level and amendments recorded a significant higher of oil content at 85% irrigated level with high dose of SAP (1 kg). These results could be interpreted in the light of the fact that decreasing irrigation water amount led to increase the oil concentration in fruit. Our results go in parallel with those of Gucci *et al.* [50], Rinaldi *et al.* [51] and Puertas *et al.* [47].

Table 12-a: Effect of different irrigation water levels and SAP on fruit weight (g), length (cm) and width (cm) of Manzanillo cv. during 2014 and 2015 seasons

	Fruit weight (g)				Fruit length (cm)				Fruit width (cm)			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	3.23d	3.26d	3.97b	3.49C	2.06c	2.12c	2.25b	2.14C	1.64e	1.68d	1.80b	1.71C
85% (3738 m³)	3.62c	4.23a	4.30a	4.05A	2.25b	2.34a	2.29ab	2.29A	1.76c	1.86a	1.85a	1.82A
70% (3090 m³)	4.25a	3.58c	3.91b	3.91B	2.29ab	2.12c	2.24b	2.22B	1.78b	1.68d	1.77bc	1.74B
Mean	3.70B	3.69B	4.06A		2.20B	2.19B	2.26A		1.73B	1.74B	1.81A	
	Second season, 2015											
100% (4384m³)	3.42f	3.50f	4.10c	3.67C	2.05d	2.20c	2.30b	2.18B	1.78e	1.80d	1.90b	1.83B
85% (3738 m³)	3.85e	4.30b	4.50a	4.22A	2.35b	2.50a	2.30b	2.38A	1.80d	1.92a	1.85c	1.86A
70% (3090 m³)	4.10c	4.00d	3.80e	3.97B	2.20c	2.20c	2.20c	2.20B	1.90b	1.65f	1.80d	1.78C
Mean	3.79C	3.93B	4.13A		2.20B	2.30A	2.27A		1.83B	1.79C	1.85A	

Table 12-b: Effect of different irrigation water levels and SAP on fruit weight (g), length (cm) and width (cm) of Maraki cv. during 2014 and 2015 seasons

	Fruit weight (g)				Fruit length(cm)				Fruit width(cm)			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	4.39cd	5.74b	3.58g	4.57AB	2.38c	2.32cd	2.63b	2.44B	1.78c	1.70d	2.06a	1.85A
85% (3738 m³)	4.19f	3.70fg	6.16a	4.68A	2.42c	2.95a	2.21d	2.53A	1.81c	1.99b	1.64e	1.81B
70% (3090 m³)	4.41c	4.09e	4.24de	4.25B	2.36c	2.33cd	2.41c	2.37C	1.82c	1.82c	1.79c	1.81B
Mean	4.21C	4.51B	4.66A		2.39B	2.53A	2.42B		1.80B	1.84A	1.82A	
	Second season, 2015											
100% (4384m³)	6.27b	3.95d	3.78d	4.67C	2.15e	2.29d	2.75a	2.40B	1.66d	2.22b	2.37a	1.99A
85% (3738 m³)	5.32c	5.18c	7.80a	6.10A	2.77d	2.44c	2.45c	2.55A	2.23b	1.95c	1.92c	2.03A
70% (3090 m³)	3.85d	6.27b	4.88c	5.00B	2.38c	2.59b	2.27d	2.41B	1.88c	1.71d	1.75d	1.88B
Mean	5.15B	5.13B	5.49A		2.43B	2.44B	2.49A		1.92B	1.96AB	2.01A	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

Table 13-a: Effect of different irrigation water levels and SAP on seed weight (g), length (cm) and width (cm) of Manzanillo cv. during 2014 and 2015 seasons.

	Seed weight (gm)				Seed length (cm)				Seed width (cm)			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	0.49c	0.56b	0.59ab	0.55B	1.36b	1.40c	1.45b	1.40B	0.76f	0.77ef	0.80cd	0.78C
85% (3738 m³)	0.59ab	0.63ab	0.63ab	0.62A	1.43bc	1.49a	1.40c	1.44A	0.79cd	0.87a	0.83b	0.83A
70% (3090 m³)	0.61ab	0.64a	0.62ab	0.62A	1.45b	1.37b	1.43bc	1.42AB	0.78d-f	0.80c	0.79c-e	0.79B
Mean	0.56B	0.61A	0.61A		1.41A	1.42A	1.43A		0.79B	0.81A	0.81A	
	Second season, 2015											
100% (4384m³)	0.50c	0.52c	0.60b	0.54B	1.30e	1.40d	1.49ab	1.40C	0.75f	0.79de	0.82c	0.79B
85% (3738 m³)	0.61b	0.70a	0.69a	0.67A	1.45c	1.51a	1.48b	1.48A	0.78e	0.92a	0.84b	0.85A
70% (3090 m³)	0.60b	0.65ab	0.64ab	0.63A	1.50a	1.25f	1.50a	1.42B	0.75f	0.80cd	0.75f	0.77C
Mean	0.57B	0.62A	0.64A		1.42B	1.39C	1.49A		0.76C	0.84A	0.80B	

Table 13-b: Effect of different irrigation water levels and SAP on seed weight (g), length (cm) and width (cm) of Maraki cv. during 2014 and 2015 seasons.

	Seed weight (gm)				Seed length (cm)				Seed width (cm)			
	Superabsorbent polymer (SAP)											
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	0.75ef	0.76ef	0.96a	0.82A	1.49e	1.57d	1.68a	1.58A	0.85cd	0.84d	0.94a	0.88B
85% (3738 m³)	0.85d	0.90b	0.74f	0.83A	1.55d	1.66b	1.49e	1.57B	0.96a	0.93a	0.87c	0.92A
70% (3090 m³)	0.89bc	0.77e	0.86cd	0.84A	1.56d	1.49e	1.62c	1.56B	0.94a	0.90b	0.94a	0.93A
Mean	0.83B	0.81B	0.85A		1.53C	1.57B	1.60A		0.92A	0.89B	0.92A	
	Second season, 2015											
100% (4384m³)	1.27a	0.83fg	0.80g	0.97B	1.65a	1.54d	1.47d	1.55A	1.03a	0.88e	0.88e	0.93A
85% (3738 m³)	1.02d	0.85f	1.20b	1.02A	1.50c	1.45d	1.65a	1.53B	0.92cd	0.92cd	1.00ab	0.95A
70% (3090 m³)	0.92e	1.03d	1.08c	1.01A	1.53b	1.56b	1.56b	1.55A	0.90de	0.94c	1.00ab	0.95A
Mean	1.07A	0.90C	1.03B		1.56A	1.52B	1.56A		0.95A	0.91B	0.96A	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

Table 14-a: Effect of different irrigation water levels and SAP on flesh weight (g), flesh/seed ratio and oil content (dry weight) of Manzanillo cv. during 2014 and 2015 seasons

	Flesh weight (gm)				Flesh/seed ratio				Oil content (%)			
					Superabsorbent polymer (SAP)							
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
					First season, 2014							
100% (4384m³)	2.74ef	2.70f	3.38bc	2.94C	5.59c	4.82e	5.73b	5.38B	26.87bc	26.69c	25.79e	26.45B
85% (3738 m³)	3.03d	3.60ab	3.67a	3.43A	5.14cd	5.71b	5.83ab	5.56A	26.93bc	26.33b	30.04a	28.10A
70% (3090 m³)	3.64a	2.94de	3.29c	3.29B	5.97a	4.59f	5.31c	5.29B	26.08de	26.78c	26.48cd	26.45B
Mean	3.14B	3.08B	3.45A		5.56A	5.04B	5.62A		26.63C	26.94B	27.44A	
					Second season, 2015							
100% (4384m³)	2.92f	2.98f	3.50bc	3.13C	5.84a	5.73ab	5.83a	5.80A	28.67b	28.63b	27.40c	28.23C
85% (3738 m³)	3.24de	3.60b	3.81a	3.55A	5.31d	5.14de	5.52c	5.33B	27.36c	28.77b	29.63a	28.59B
70% (3090 m³)	3.50bc	3.35cd	3.16e	3.34B	5.83a	5.15de	4.94f	5.31B	28.43b	29.95a	29.61a	29.33A
Mean	3.22B	3.31B	3.49A		5.66A	5.34B	5.43B		28.15B	29.12A	28.88A	

Table 14-b: Effect of different irrigation water levels and SAP on flesh weight (g), flesh/seed ratio and oil content (dry weight) of Maraki cv. during 2014 and 2015 seasons

	Flesh weight (gm)				Flesh/seed ratio				Oil content (%)			
					Superabsorbent polymer (SAP)							
Irrigation levels	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
					First season, 2014							
100% (4384m³)	3.64c	4.98b	2.62	3.75A	4.85c	6.55b	2.73g	4.71A	41.03cd	41.39c	40.57de	41.00B
85% (3738 m³)	3.34d	2.80e	5.42a	3.85A	3.93e	3.11f	7.32a	4.79A	41.02cd	42.14b	43.63a	42.26A
70% (3090 m³)	3.52c	3.32d	3.38d	3.41B	3.96e	4.31d	3.93e	4.07B	40.67de	40.30e	40.50de	40.49C
Mean	3.50B	3.70A	3.81A		4.25B	4.66A	4.66A		40.91B	41.27A	41.57A	
					Second season, 2015							
100% (4384m³)	5.00b	3.12e	2.98f	3.70B	3.94d	3.76de	3.73de	3.81B	39.90e	41.00cd	41.93b	41.94B
85% (3738 m³)	4.30c	4.33c	6.60a	5.08A	4.22c	5.09b	5.50a	4.94A	40.83cd	40.67cd	43.50a	41.67A
70% (3090 m³)	2.93f	5.24	3.80d	3.99B	3.18g	5.09b	3.52f	3.93B	42.10b	40.43de	41.10c	41.21B
Mean	4.08C	4.23B	4.46A		3.78C	4.65A	4.25B		40.94B	40.70B	42.18A	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05

Leaves Mineral Content: Data in Table (15-a & b) revealed that, the irrigation water at level 85% (3738 m³/feddan) was adequate to give high values of the studied macronutrient concentrations (N, P and K) in the leaves of Manzanillo cultivar. Moreover, each of 85% and 70% irrigation water level in the first season and only 70% in the second season increased the (N) content in Maraki cultivar, while, 85% in both seasons acquired the highest (P) content, similarly, full non-stressed "control" 100% attained the highest (K) content (Table 15-b). With respect to the SAP effect, the macronutrient concentrations increased with increasing the amount of doses in both of Manzanillo and Maraki cultivars during both seasons these results may be due to that sufficient water obviously has good effect on plant growth. It is known that water plays vital role in all physiological processes of mineral absorption from the soil up to building different components inside the plant [52]. Several researchers found positive correlation between applying polymers and promoting plants growth and their yields, due to their role of enhanced plant absorption of nutrients from the soil [12, 13].

Water Use Efficiency (WUE): Data in Fig. (4) illustrates the effect of different irrigation levels, SAP application and cultivars of olives on water use efficiency (WUE) Kg / m³ in both growing seasons. Generally, the values of WUE were high for both cultivars at the first season, 2014 (year on) compared with the second season, 2015 (year off) that maybe due to the alternate bearing phenomenon in the olives trees. In addition, the lowest water consumed the highest values of WUE were obtained because WUE is a ratio between amount of consumed water (m³) and total yield of plant, so that the highest values of WUE were observed in 70% irrigation level. On the contrary, the highest amount of irrigation level (100%) gave the lowest values of WUE in both growing seasons. On the other hand, soil application of SAP had a significant effect on WUE in both olive cultivars, the application rate of 1/2 Kg per tree gave the highest values of WUE but the response of Manzanillo was better than Maraki. Whereas, the interaction between irrigation by 85% and 1/2 Kg SAP soil application attained the highest values of WUE followed by the interaction between 70% irrigation level and 1/2 Kg SAP soil application. The increasing of SAP application

Table 15-a: Effect of different irrigation water levels and SAP on leaves nitrogen, phosphor and potassium content of Manzanillo cv. during 2014 and 2015 seasons

Irrigation levels	N (%)				P (%)				K (%)			
					Superabsorbent polymer (SAP)							
	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	1.47cd	1.59b	1.49c	1.52B	0.19d	0.21cd	0.23bc	0.21B	0.89b	0.89b	0.91b	0.90B
85% (3738 m³)	1.58b	1.63b	1.69a	1.63A	0.24ab	0.26a	0.26a	0.25A	0.90b	0.92b	0.99a	0.94A
70% (3090 m³)	1.42d	1.46cd	1.58b	1.49B	0.20d	0.21cd	0.21cd	0.21B	0.76c	0.78c	0.80c	0.78C
Mean	1.49B	1.56A	1.59A		0.21B	0.23A	0.23A		0.85B	0.86B	0.90A	
	Second season, 2015											
100% (4384m³)	1.39f	1.43f	1.57bc	1.46C	0.16d	0.20bc	0.21b	0.19B	0.87b	0.87b	0.90ab	0.88A
85% (3738 m³)	1.55cd	1.59bc	1.71a	1.62A	0.21b	0.24a	0.24a	0.23A	0.86bc	0.89ab	0.93a	0.89A
70% (3090 m³)	1.51de	1.49e	1.61b	1.54B	0.19c	0.19c	0.20bc	0.19B	0.79d	0.80d	0.81cd	0.80B
Mean	1.48B	1.50B	1.63A		0.19B	0.21A	0.22A		0.84B	0.85AB	0.88A	

Table 15-b: Effect of different irrigation water levels and SAP on leaves nitrogen, phosphor and potassium content of Maraki cv. during 2014 and 2015 seasons

Irrigation levels	N (%)				P (%)				K (%)			
					Superabsorbent polymer (SAP)							
	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean	Control	1/2 kg	1 kg	Mean
	First season, 2014											
100% (4384m³)	1.55f	1.51h	1.53g	1.53B	0.220d	0.240bc	0.240bc	0.233B	0.93b	0.98a	1.01a	0.97A
85% (3738 m³)	1.64e	1.88b	1.99a	1.84A	0.230cd	0.250ab	0.260a	0.247A	0.75e	0.85d	0.93b	0.84B
70% (3090 m³)	1.80d	1.83c	1.89b	1.84A	0.220d	0.240bc	0.260a	0.240AB	0.71f	0.85d	0.89c	0.82C
Mean	1.66C	1.74B	1.80A		0.223B	0.243A	0.253A		0.80C	0.89B	0.94A	
	Second season, 2015											
100% (4384m³)	1.59f	1.53g	1.62e	1.58C	0.230b	0.270a	0.260a	0.253AB	0.97a	0.95a	0.97a	0.96A
85% (3738 m³)	1.69d	1.73c	1.82a	1.75B	0.240b	0.270a	0.270a	0.260A	0.78d	0.90bc	0.92b	0.87B
70% (3090 m³)	1.71cd	1.78b	1.83a	1.77A	0.230b	0.240b	0.270a	0.247B	0.70e	0.88c	0.92b	0.83C
Mean	1.66C	1.68B	1.76A		0.233B	0.260A	0.267A		0.82C	0.91B	0.94A	

Means followed by the same letter in a column or row do not differ significantly according to Duncan's Multiple Range t-Test at P = 0.05
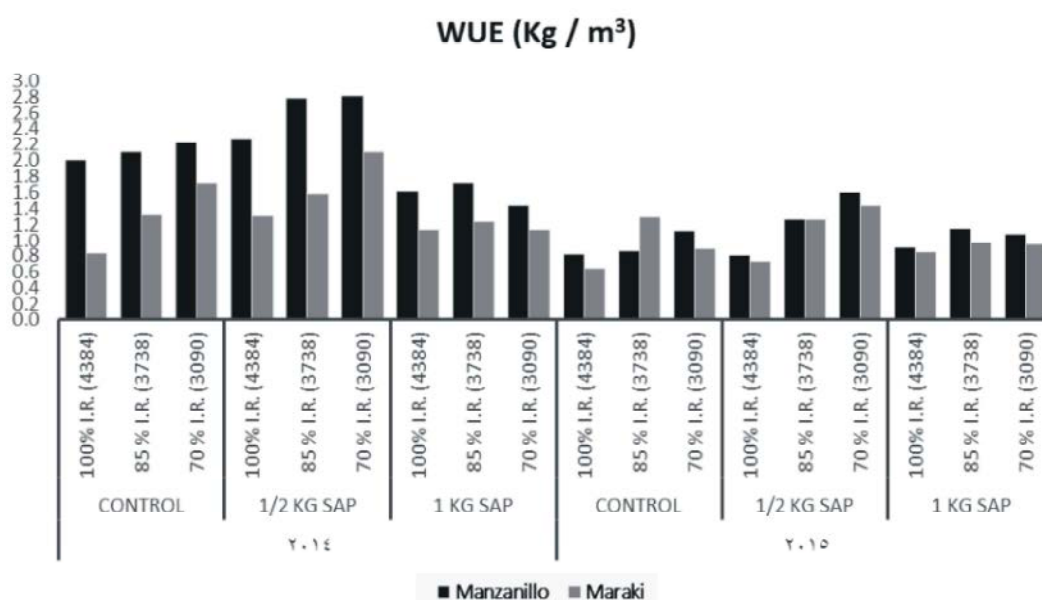

Fig. 4: Effect of irrigation levels and SAP application on WUE of Manzanillo and Maraki cultivars

Table 16: Economic evaluation of olive fruits production of Manzanillo and Maraki cultivars under different irrigation levels and SAP during average two seasons (2014 & 2015)

Irrigation levels	SAP	Cvs.	Yield (Kg/feddan)	Yield price (EGP/feddan)	Fixed operation cost	Water price (EGP/feddan)	SAP price (EGP/feddan)	Total cost (EGP)	Net income (EGP)
4384 m³ -100%	Control	cv.1.	6174.5	33960	5500	2411	0.00	7911	26049
		cv.2	3231.7	14543	5500	2411	0.00	7911	6631
	1/2kg	cv.1	6505.4	35779	5500	2411	2330	10241	25538
		cv.2	5746.9	25861	5500	2411	2330	10241	15620
	1 kg	cv.1	7339.5	40367	5500	2411	4660	12571	27796
		cv.2	5708.5	25688	5500	2411	4660	12571	13117
3738 m³ -85%	Control	cv.1.	5778.4	31781	5500	2056	0.00	7556	24225
		cv.2	3809.6	17143	5500	2056	0.00	7556	9587
	1/2 kg	cv.1.	7572.5	41649	5500	2056	2330	9886	31763
		cv.2	5319.4	23937	5500	2056	2330	9886	14051
	1 kg	cv.1	8233.1	45282	5500	2056	4660	12216	33066
		cv.2	6602.1	29709	5500	2056	4660	12216	17493
3039 m³ -70%	Control	cv.1.	3882.9	21356	5500	1671	0.00	7171	14185
		cv.2	3067.4	13804	5500	1671	0.00	7171	6632
	1/2 kg	cv.1.	4427.0	24349	5500	1671	2330	9501	14847
		cv.2	3416.9	15376	5500	1671	2330	9501	5875
	1kg	cv.1	3882.9	21356	5500	1671	4660	11831	9525
		cv.2	3215.4	14469	5500	1671	4660	11831	2638

I.L. = irrigation levels, cvs. = cultivars. cv. 1 = Manzanillo, cv 2= Maraki , SAP = Superabsorbent polymers, fixed operation cost = pruning, fertilizer, pesticides, labors and etc…; EGP = Egyptian pound

in the soil decreased the WUE values. That maybe due to the reverse effect of this water absorbing material which increase the amount of irrigation water surrounding the root zone of trees and this useless water harm the root system of tree. The lowest values of WUE obtained by applying 70% irrigation level in the control treatment (without SAP application), maybe due to the water deficit effect of this treatment on olive trees which made water stress condition surrounding the root system of trees. These results are in agreement with those of Puertas *et al.* [47]; Vivaldi *et al.* [53] and Ahmed and Aly [36].

Economic Evaluation: Data in Table (16) display the economic evaluation of total fruits yield (Kg/feddan) of olive cultivars (Manzanillo and Maraki) and net return in Egyptian pound. The price of Kilogram of olive fruits was five and half EGP in Manzanillo cultivar and four and half EGP in Maraki cultivar in average two seasons 2014 and 2015. The price of irrigation water was 0.55 piaster per m³ in average two 2014 and 2015 seasons, respectively. In light of farm's owner information the total operation cost such as water, fertilizers, labor, pesticides and others were calculated and estimated about 5500 EGP. The maximum average net income resulted from using the irrigation amount of 85% of irrigation amount combined with application of 1 kg & 1/2 Kg of SAP and the value of net income for Manzanillo cultivar was 33066 and 31763 EGP, respectively. Besides, the highest values of net income for Maraki were 17493 EGP and 14051 EGP in the average of

two seasons resulted from using, respectively. On the contrary, the lowest value of net income resulted from using the lowest amount of irrigation water (70%) combined with all different doses of SAP in both growing seasons, in this concern the average net income for both growing seasons of Manzanillo and Maraki were 9525 EGP and 2638 EGP. Data showed that irrigation and soil conditioner played an important role of olive production income. Thus, we can recommend with applying irrigation water in rate of 85% from ETo combined with using 1/2 Kg SAP dose to get the highest economic return.

CONCLUSION

Water scarcity problem is globally getting worse. The vast of majority of annual water supply in Egypt is used for irrigation. Hence, water saving and conservation is essential object to support agricultural sector especially in the new reclaimed land. SAP can act as a controlled release system by favoring the uptake of some nutrient elements, holding them tightly and prolonging their dissolution. Consequently, the plant could still obtain nutrients retained by polymers in the late growth period, resulting in improved growth and performance rates.

The results illustrated that adding each of low and high doses of soil amendments (SAP) with deficit irrigation levels at (3738 m³/feddan) 85% of irrigation level gave a distinct result while approaching to full irrigation.

The dose of SAP at 1/2 kg/tree increased the vegetative growth, flowering in Manzanillo cultivar and fruit set. Adding of higher dose (1kg/tree) of super absorbent polymer had a positive effect in increasing flowering characteristics in Maraki cultivar and fruit characteristics in both cultivars. Regarding to olive yield, oil content and leaves mineral content, each of 1/2 and 1kg/tree of SAP gave better effect rather than untreated. Thus, we recommended adding 85% of irrigation level for olive trees in sandy soil which produce the best yield and quality of olive fruits, in addition gave the highest net income, this is due to the enhancing effects of SAP on physical and chemical properties of soil such as EC and water holding capacity which led to savings in irrigation water comparing with 100 % of irrigation level.

REFERENCES

1. Andria, R., A. Lavini, A. Alvino and R. Tognetti, 2008. Effects of Deficit Irrigation on Water Relations of Olive Trees (*Olea europaea* L. Cultivars Frantoio and Leccino). Acta Hort., 792: 217-224.

2. Tangu, N.A., 2014. Effects on plant morphology of drought in olive. Turkish Journal of Agricultural and Natural Sciences, 1: 900-904.

3. Haggag, L.F., M.F.M. Shahin, E.A.E. Genaidy and N.S. Mustafa, 2013. Growth curve of fruit development stages of three olive cultivars. Middle East Journal of Applied Sciences, 3: 24-30.

4. Sebastiani, L., 2012. Physiological response of olive (*Olea europaea* L.) to water deficit: an overview. Acta Horticulturae, 888: 137-147.

5. Chai, Q., Y. Gan, C. Zhao, H.L. Xu, R.M. Waskom, Y. Niu and K.H. Siddique, 2016. Regulated deficit irrigation for crop production under drought stress. A review. Agron. Sustain. Dev., 36: 1.

6. El-Hady, O.A., A.A. El-Kader and A.M. Shafi, 2009. Physico-biochemical properties of sandy soil conditioned with acrylamide hydrogels after cucumber plantation. Aust. J. Basic Appl. Sci., 3: 3145-3151.

7. Mohie El-Din, M.O. and A.M. Moussa, 2016. Water management in Egypt or facing the future challenges. J. Adv. Res., 7: 403-412.

8. Fereres, E.D., R. Anria, G. Morlli and M. Fragnitto, 2003. Utilization del agua de riego. Mercacel Magazine. Mercado Aceitero. Julio-Septiembre., 4: 40-44.

9. Iniesta, F., L. Testi, F. Orgaz and F.J. Villalobos, 2009. The effects of regulated and continuous deficit irrigation on the water use, growth and yield of olive trees. Eur. J. Agro., 30: 258-265.

10. Chehab, H., M. Tekaya, B. Mechri, A. Jemai, M. Guiaa, Z. Mahjoub, D. Boujnah, S. Laamari, B.Chihaoui, H. Zakhama and M., Hammami, 2017. Effect of the Super Absorbent Polymer Stockosorb® on leaf turgor pressure, tree performance and oil quality of olive trees cv. Chemlali grown under field conditions in an arid region of Tunisia. Agri. Water. Mgmt., 192: 221-231.

11. Ahmadipour, S., I.Arji, A. Ebadi and V. Abdossi, 2018. Physiological and biochemical responses of some olive cultivars (*Olea europaea* L.) to water stress. Cellular and Molecular Biology, 64: 20-29.

12. Farag, A.A., A.A. Eltaweel, S.H. Abd-Elrahman, A.A. Ali and M.S.M. Ahmed, 2017. Irrigation regime and soil coeditor to improving soil properties and Pomegranate production. Asian Journal of Soil Science and Plant Nutrition., 1: 1-18.

13. Fayek, M.A., M.A. Abdel-Mohsen, I.L. Sanaa and S.M. EL-Sayed, 2020. Impact of super absorbent polymer and a bentonite as soil amendments under irrigation regimes olive orchard. Plant Archives, 1: 723-730.

14. Klute, A., 1986. Methods of soil analysis, part I, 2nd ed, Madison, Wisconsin, USA.

15. Page, A.L., R.H. Miller and D.R. Keeny, 1982. Methods of Soil Analysis Part 2 Chemical and Biological Properties. Amer. Soc. Agron. Inc. Mascson, Wisconsin USA.

16. Baruah, T.C. and H.P. Barthakur, 1997. A textbook of soil analysis. Vikas Publishing Housing, PVTLTD, New Delhi.

17. Allen, R.G., L.S. Pereira, D. Raes and M. Smith, 1998. Crop evapotranspiration: Guidelines for computing crop requirements. Irrigation and Drainage Paper No. 56, FAO. Rome, Italy.

18. FAO, 1997. Yield response to water. FAO Irrigation and Drainage paper No. 33 (Doorenbos J, Kasam AH). Italy: Rome.

19. Gafar, K., 2009. Egyptian meteorological authority. International Meteorological Research Bulletin, pp: 24.

20. Goldhamer, D.A., J. Dunai and L. Ferguson, 1994. Irrigation requirements of olive trees and responses to sustained deficit irrigation. Acta Horticulturae, 356: 172-176.

21. Ahmed, A., 1992. Applications of functionalized polymers in agriculture; J. Islam. Acad. Sci., 3: 49-61.

22. Aly, E.A., 2005. Physiological studies on the effect of salt stress on some olive cultivators. Ph.D. Thesis, Fac. Agric. Benha Univ., Egypt.

23. Hegazi, E.S. and G.R. Stino, 1982. Dormancy, flowering and sex expression in 20 olive cvs. *Olea europaea* L. under Giza conditions. Acta Agrobotanica, 35: 79-86.

24. Hegazi, A.A., 2001. Studies on shotberries formation in olives. Ph.D. Thesis, Fac. Agric., Cairo Univ., Egypt.

25. Hegazi, E.S. and A.A. Hegazi, 2005. Floral biology and fruiting. Proceeding of the Sixth Arabian Conference for Horticulture, March 20-22, Suez Canal University Ismailia, Egypt, pp: 48-57.

26. Hegazi, E.S., M.R. El-Sonbaty, M.A. Eissa and T.F.A. El-Sharony, 2007. Effect of organic and biofertilization on vegetative and flowering of Picual olive trees. World J. Agric. Sci., 3: 210-217.

27. Fouad, M.M., A.K Omima and M. El-Said, 1992. Comparative studies on flowering fruit set and yield of some Olive Cultivars under Giza, Conditions. Egypt J. Appl. Sci., 7: 630-644.

28. A.O.A.C, 2000. Official Methods of Analysis. 17th Edition, The Association of Official Analytical Chemists, Gaithersburg, MD, USA.

29. Pergel, F., 1945. Quantative organic micro-analysis 4th Ed. J. and A. Churvhill, Ltd. London.

30. Murphy, J. and J.P. Riely, 1962. A modified single doltion method for determination of phosphate in natural water. Anal. Chem. Acta., 27: 31-36.

31. Brown, J.D. and D. Lilleland, 1946. Rapid determination of potassium and sodium in plant material and soil extracts by flame. Proc. Amer. Soc. Hort. Sci., 48: 341-346.

32. FAO, 1982. Crop water requirements irrigation and drainage. Paper No. 24, Rome, Italy.

33. Radinovic, S., J. Gugic and Z. Grgic, 2004. Economic Efficiency of Olive Growing. Agriculturae Conspectus Scientificus, 69: 115-120.

34. SAS. Statistical Analysis System, SAS User's Guide: Statistics, SAS Institute Inc., Cary, USA. 2000.

35. Duncan, D.B., 1955. Multiple range and multiple F. tests. Biometrics, 11: 1-42.

36. Ahmed, M.S.M. and A.A. Aly, 2017. Effect of Deficit Irrigation Regimes and Rice Straw Mulching on Growth and Yield of Olive Trees (*Olea europaea* L.) in Sandy Soil . J. Plant Production, Mansoura Univ., 2: 283-296.

37. Farag, A.A., M.A.A. Abdrabbo and M.S.M. Ahmed, 2014. GIS Tool for Distribution Reference Evapotranspiration under Climate Change in Egypt. International Journal of Plant & Soil Science, 3: 575-588.

38. Ikpe, F.N. and J.M. Powell, 2002. Nutrient cycling practices and changes in soil properties in the crop livestock farming systems of western Niger Republic of West Africa. Nutr. Cycl. Agro Ecosys., 62: 37-45.

39. Ahmed, S.A., 2007. Impact of use of treated wastewater on some eco-agricultural characteristics in Bahr El–Bakar area. M. Sc. Thesis, Fac. Agric., Ain Shams Univ.

40. Abu, S.T. and W.B. Malgwi, 2012. Effects of irrigation regime and frequency on soil physical quality, water use efficiency, water productivity and economic returns of paddy rice. ARPN J. Agric. Biol. Sci., 7: 86-99.

41. Maghchiche, A., A. Haouam and B. Immirzi, 2010. Use of polymers and biopolymers for water retaining and soil stabilization in arid and semiarid regions. JTUSCI, 4: 9-16.Page, A.L., R.H. Miller and D.R. Keeney. 1982. Methods of soil analysis, part II, 2nd ed., Wisconsin.

42. Kassim, F.S., M.F. El-Koly and S.S. Hosny, 2017. Evaluation of super absorbent polymer application on yield and water use efficiency of Grand Nain banana plant. Middle East J. Agric. Res., 6: 188-198.

43. Abd El-Mohdy, H.L. and H.A. Abd El-Rehim, 2009. Radiation synthesis of kappa carrageenan/ acrylamide graft copolymers as super absorbents and their possible applications. J. Polym. Res., 16: 63-72.

44. Ekebafe, L.O., D.E. Ogbeifun and F.E. Okieimen, 2011. Polymer applications in agriculture. Biokemistri, 23: 81-89.

45. Andria, R., G. Morelli, M. Patumi and G. Fontanazza, 2002. Irrigation Regime Affects Yield and Oil Quality of Olive Trees. Acta Hort., 586: 273-276.

46. Caruso, G., R. Gucci and H.F. Rapoport, 2011. Deficit Irrigation Effects on Yield Components of Olive Trees during the onset of fruit production. Acta Hort., 889: 291-296.

47. Puertas, C.M., E.R. Trentacoste, J.A. Morabito and J. Perez Pena, 2011. Effects of Regulated Deficit Irrigation during Stage III of Fruit Development on Yield and Oil Quality of Olive Trees (Arbequina). Acta Hort., 889: 303-310.

48. El-Taweel, A.A. and A.A. Farag, 2016. Effect of different water quantities on growth and fruit quality of Olive trees under new reclined lands conditions. J. Plant Production, Mansoura University, 7: 13-27.

49. Mailer, R. and J. Ayton, 2011. Effect of irrigation and water stress on olive oil quality and yield based on a four year study. Olive irrigation and oil quality. Acta Hortic., 888: 63-72.

50. Gucci, R., G. Caruso and E.M. Lodolini, 2011. Irrigation Differently Affects Endocarp and Mesocarp Growth during Olive Fruit Development. Acta Hort., 889: 297-302.

51. Rinaldi, R., M.L. Amodio, G. Colelli, G.D. Nanos and E. Pliakoni, 2011. Effect of Deficit Irrigation on Fruit and Oil Quality of 'Konservolea' Olives. Acta Hort. 924: 445-452.

52. Sebastiani, L., C. Michelazzo, G. Morelli, A. Lavini and R. Andria, 2012. Physiological and Productive Parameters of Olive Trees (*Olea europaea* L.) under Different Irrigation Scheduling in Central-South Italy. Acta Hort., 949: 115-122.

53. Vivaldi, G.A., G. Strippoli and S. Composeo, 2013. Ecophysiological response to irrigation of two olive cultivars grown in a high-dencity orchard. Agric. Sci., 4(8): 16-20.