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IMPACT OF SUPER ABSORBENT POLYMER AND A BENTONITE AS SOIL AMENDMENTS UNDER IRRIGATION REGIMES IN OLIVE ORCHARD

M.A. Fayek[1], M.A. Abdel-Mohsen[1], Sanaa I. Laz[2] and S.M. EL-Sayed[2]

[1]Pomology Department, Faculty of Agriculture, Cairo University, Cairo, Egypt.
[2]Horticulture Research Institute, Agricultural Research Centre, Cairo, Egypt.

Abstract

This study was carried out during three growing season on 10 years old Picual trees cultivated at 3×6m in sandy soil. The objectives of this study to save the irrigation water requirements to the olive trees by adding soil amendments, super absorbent polymer (SAP) and bentonite (BENT).

Soil amendments was applied once to the soil with compost around the olive tree at the first season and compared to control. The best results found in full (100%) irrigation requirements (IR) (control treatment), followed by 75% IR with SAP then BENT for leaf surface area, number of leaves per meter, leaf transpiration, fruit weight and yield. Moreover, the results revealed the favorable use of SAP, over the control, to counter act the deleterious effect of high temperature prevailing at the period of flower initiation and the subsequent effect on yield. Lack of water leads to an increase in both polyphenols and oleic acid and decrease in palmatic acids in oil. Finally, addition of SAP to soil led to save at least 25% of irrigation water in olive farms.

Key words: Olive, Irrigation, Water stress, SAP, Bentonite.

Introduction

Olive (*Olea europaea* L.) is an important perennial crop in many agricultural regions of the Mediterranean countries, whereas consider one of cash crop of a great sector. According to Egyptian ministry of Agriculture and Land Reclamation (2017) olive trees cover 241933 feddan of Egyptian land and it increase yearly. As assessment by Egyptian Ministry of Water Resources and Irrigation (2014), total Egyptian water consumption was 79.5 Billion cubic meter per year (BCM/year), where 85% was used in agriculture. Currently water shortage in Egypt is 13.5 (BCM/year) and is expected to continuously increase (Mohie El Din and Mousa, 2016). Olive is a species known for its resistance to water stress compared to other fruits (Tombesi and Tombesi, 2007), although water deficit and abiotic stress are some of the environmental constraints limiting olive productivity (Sebastiani, 2011).

Egypt's standing is below the level of water poverty and the country is suffering from water scarcity, so to meet Egypt's desire to expand on olive cultivation, soil amendment may be required like Super absorbent polymer (SAP) and Bentonite (BENT). Recently, SAP as water-retaining polymers have been introduced for this purpose in many crops and tree species. For instance, Stockosorb® 660 is a cross-linked potassium poly-acrylatecan absorb and retains large quantities of water from 70 up to 290 times of its own weight, depending on water quality and soil type (information from the manufacturer). Treating sandy soil with SAP enhances water-holding capacity to be like that retained in loamy soils (Hüttermann *et al.,* 1999). Moreover, Bhardwaj *et al.,* (2007) found that, amendments of SAP contribute to delay wilting points and to reduce drought stress on plants. Chehab *et al.,* (2017) showed that soil amendment Super absorbent polymer "Stockosorb" may positively affect in productive effectiveness (shoot growth and oil yields) of olive trees. Further, Altarawneh (2012) found that SAP concentration of 0.2% (w/w) resulted the highest growth rate, biomass and fruit yield significantly higher than from control.

BENT is a rock consisting predominantly of the clay mineral montmorillonite has been recognized as a very good material for the improvement of coarse textured soils in different parts of the world. BENT has an ability to absorb large quantities of water with an accompanying increase in volume of as much as 12-15 times its dry bulk and a high cation exchange capacity (Adamis *et al.,* 2005). However, Bentonite application improved growth and yield of vegetable crops (Croker *et al*., 2004). Ding *et al*., (2009) reported that the special properties of bentonite were due to its ability to form thixotropic gels with water, which is the ability to absorb large quantities of water and negative charge on its surface, which led to a high cation exchange capacity.

The objective of the study was to quantify the growth, fruit, yield and oil quality response of Picual olive trees to the degree of water deficit and the impact of two soil amendments in this concern.

Material and Methods

Field experiment

The present study was conducted throughout the three growing seasons (2015/ 2016, 2016 /2017 and 2017/ 2018) to assess the impact of both Superabsorbent polymers (SAP) and Bentonite (BENT) on soil hydraulic properties to increase the tolerance of Picual olive trees to deficit irrigation.

The study was conducted in a drip irrigation olive farm located at Cairo-Alexandria desert road about 64 kilometer distance from Cairo. The trees were 10 years old, propagated by leafy cutting with 3×6m spacing in sandy soil and using groundwater. The characteristics of soil and irrigation water were determined in 2015 and presented in tables 1 and 2.

Table 1: Chemical and Mechanical characteristics of the tested soil sample collected from the experimental area (2015).

pH 1:2.5	E.C. ds/M (1:5)	Soluble cations (meq/ 100g soil)				Soluble anions (meq/ 100g soil)			
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^-	Hco_3^-	Cl^-	So_4^-
7.12	0.56	1.8	0.7	2.5	0.2	-	0.29	4.51	0.4

Mechanical analysis (%)				
Coarse sand %	Fine sand %	Silt %	Clay %	Textural classes
38.4	43.3	13.0	5.3	Sandy Soil

Table 2: Chemical and Mechanical characteristics of the tested soil sample collected from the experimental area.

pH 2.5:1	E.C. ds/M (1:5)	E.C. ppm	Soluble cations (mq/L)				Soluble anions (mq/L)			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^-	Hco_3^-	Cl^-	So_4^-
7.99	5.31	4248	125.2	103.35	259.50	0.95	-	2.40	479.70	6.90

Table 3: Strategies of the irrigation requirements applied during experiments based on ETO.

Quantity / Months	100 %	75 %	50 %
January	87	65	43
February	102	76	51
March	146	110	73
April	229	172	114
May	486	364	243
June	602	451	301
July	608	456	304
August	554	415	277
September	395	296	198
October	246	185	123
November	91	68	46
December	74	55	37
Total	3619	2714	1809

Treatments

The ETo value was calculated using the metrological conditions data prevailing at El-Khatatba, Where the method of Penman Monteith was used to calculate ET crop for Picual olive trees under this region during 2015 through 2018. seasons of study using CROPWAT model (Smith, 1991). The Estimated crop irrigation requirement (IR), was calculated by the same methodology adopted by many studies (Farag *et al.,* 2017) and the average was presented in table 3.

IR= Kc × ETo × LF × IE × R × Area (Feddan)/1000.

IR: Irrigation requirements (m^3/fed), Kc: Crop coefficient, 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, Area: the irrigated area the irrigated area (one feddan = 4200 m^2), 1000= to convert from liter to cubic meter.

Three levels of irrigation were applied under three irrigation regimes, full non-stressed "control" 100% and regulated deficit irrigation 50% and 75% level of irrigation requirements. With added soil amendments Superabsorbent polymer (SAP) and Bentonite (BENT), in a powdered form. The SAP used in this study was Stockosorb 660 (granular type, cross-linked poly potassium-co-(acrylic resin polymer)-co-polyacrylamide hydrogel) that was manufactured by Evonik Company. 0.4% (W/W), *i.e.* 4g/Kg soil (Altarawneh, 2012). While Bentonite was from ICMI Egypt International for Mining and Investment and added at 200 g/Kg soil (Pruangka *et al*., 2012). Both amendments were added in December of the first season then results were tracked during

Table 4: Effect of irrigation level and soil amendments on Number of leaves per meter.

Irrigation level	Soil Amendments (2016)			Soil Amendments (2017)			Soil Amendments (2018)		
	SAP	**Bent**	**Mean**	**SAP**	**Bent**	**Mean**	**SAP**	**Bent**	**Mean**
100%	132.1 a	132.1 a	132.1 A	132.1 a	132.1 a	132.1 A	136.1 a	136.1 a	136.1 A
75%	128.6 b	123.2 c	125.9 B	128.6 b	115.7 d	122.2 B	131.8 b	126.9 c	129.4 B
50%	115.7 d	111.7 e	113.7 C	125.0 c	113.2 e	119.1 C	119.7 d	115.5 e	117.6 C
Mean	125.5 A	122.3 B		128.6 A	120.4 B		129.2 A	126.2 A	

the three following years. The schedule of applied water regimes was outlined in the following (Table 3).

Each amendment was mixed with compost then added under the emitters of the two lateral lines of drip irrigation system and under upper soil layer to 40 cm depth. The irrigation water levels were applied by install flow-meter and valve to control the applied water quantity.

Measurement

They determined at the harvest date, but number of leaves per meter, leaf surface area and leaf transpiration rate in July.

• Number of leaves per meter.

Was counted on 10 shoots at each replicate and calculated as following:

$$No.of\ leaves\ per\ meter = \frac{Number\ of\ leaves \times 100}{Shoot\ length\,(m)}$$

• Leaf surface area (cm^2).

Samples of 40 adult leaves taken from the middle section of selected shoots at each replicate were taken to determine average leaf surface area according to Ahmed and Morsy (1999) using the following equation

Leaf area = 0.53 (length × width) + 1.66

• Leaf transpiration rate "LT" (mg/cm^2).

LT was determined by using a portable prometer apparatus (model LI-1600 LI-COR, INC.).

• Fruit Weight (g)

Thirty fruits from each tree were randomly selected and used to determine average Fruit weight for each treatment.

• Yield (Kg)

Fruits of each experimented tree were harvested at maturation stage (olive with superficial pigmentation on less that 50% of the exo-carp) and the average yield was calculated.

• Oil content

Oil percentage on fresh weight bases was measure for each replicated tree using Soxhlet fat extraction apparatus as described in the AOAC (2000). Olive oil yield calculated by multiplying yield per tree by oil percentage content.

• Oil quality parameter

Phenols substances which are responsible for stability of olive oil against oxidation were measured colorimetrically at 725nm after the Folin-Ciocalteau reagent to the extract (AOAC, 2000). Also Fatty acid profile of the oil, *i.e.* composition of C16:0 and C18:1 was determined in methyle esters of fatty acids of olive oil using gas chromatography with GC-Capillary column according to the method reported by International Olive Council (2013).

• Statistical analysis

The experiment was arranged in a randomized complete block design with two factors, considering the row as a block replicated three times. The experimental plot of each treatment consisted of three trees, with the central plants used as the experimental unit and two other trees used as borders between treatments, to avoid influence between neighboring treatments. Averages were compared using MSTAT program and the treatment means were compared by using Duncan's Multiple Range Test (Duncan, 1955).

Results and Discussion

Effect of irrigation level and soils amendments on the following items

• Vegetative growth

For growth parameter determination the density of

Table 5: Effect of irrigation level and soil amendments on leaf surface area (cm^2).

Irrigation level	Soil Amendments (2016)			Soil Amendments (2017)			Soil Amendments (2018)		
	SAP	**Bent**	**Mean**	**SAP**	**Bent**	**Mean**	**SAP**	**Bent**	**Mean**
100%	8.92 a	8.92 a	8.92 A	8.70 a	8.70 a	8.70 A	8.90 a	8.90 a	8.90 A
75%	7.76 b	7.71 b	7.74 B	7.44 b	7.32 b	7.38 B	7.80 b	7.76 b	7.78 B
50%	7.58 b	7.16 b	7.37 B	7.44 b	6.96 b	7.20 B	7.55 b	7.16 b	7.36 B
Mean	8.09 A	7.93 A		7.86 A	7.66 A		8.08 A	7.94 A	

Table 6: Effect of irrigation level and soil amendments on leaf transpiration (L.T.R).

Irrigation level	Soil Amendments (2016)			Soil Amendments (2017)			Soil Amendments (2018)		
	SAP	Bent	Mean	SAP	Bent	Mean	SAP	Bent	Mean
100 %	33.63 a	33.63 a	33.63 A	32.33 a	32.33 a	32.33 A	31.03 a	31.03 a	31.03 A
75%	30.41 b	29.17 c	29.79 B	28.91 b	28.54 b	28.73 B	27.41 b	26.84 bc	27.13 B
50%	30.24 b	26.49 d	28.36 C	28.27 b	26.09 c	27.18 C	27.37 b	25.69 c	26.53 B
Mean	31.43 A	29.76 B		29.84 A	28.99 B		28.60 A	27.85 A	

leaves per meter and leaf surface area were determine. The number of leaves per meter seemed to be significantly highest by using Full irrigation level, while the lowest irrigation rate achieved a significant lowest number of leaves, the same trend was found at three seasons. Soil amendments, in the average revealed that the highest level of leaves number per meter found with SAP during 2016 and 2017 seasons while no significant value occurred between SAP and BENT through 2018 (Table 4).

The interaction between irrigation level and soil amendments also showed the maximum leaves number per meter under 100% of irrigation requirement, followed significantly by using SAP under 75% of irrigation requirement at three seasons, while the lowest number found with 50% of irrigation levels with BENT additive at the three seasons of study (Table 4).

The highest significant in leaf surface area was recorded with using the full irrigation requirements 100 % followed by 75% and 50 % of irrigation level. In general, there was no significant difference in the area of leaf surface when using any of soil amendments (Table 5). Also, the interaction between treatments revealed the best results with full irrigation requirements, followed by the deficit water treatments. However, using of SAP as a soil amendment resulting in greater leaf surface area than adding BENT especially at 50%, irrigation level without significant differences. This result was detected at the three seasons of study.

The obtained results supported evidenced of Martín-Vertedor *et al.* (2011), as the vegetative growth in olive trees was mainly affected by the level of water supply. However, an improvement of the growth in leaves numbers and leaf area was detected in our study by adding soil amendments. This finding suggested that the tested amendments may enhance growth under both water regimes by improving water statues. In this concern, previous studies revealed that the use of soil amendments increases both saturated and residual water content, water holding capacity and available water content (Adamis *et al.,* 2005, Andry *et al.,* 2009, Dorraji *et al.,* 2010). Also Salim (2013) found that increasing the quantity of applied water reach to significantly highest value in vegetative growth, shoot length and leaf surface area cm^2 in olive tree.

• Leaf transpiration rate (L.T.R)

The leaf physiological characteristics was used to evaluate the response of olive tree to deficit irrigation water and the tested alleviating treatments. The best results of L.T.R obtained from 100% irrigation, followed by 75% irrigation level, while at 50% water level it came in the lowest value (Table 6). However, The interaction between irrigation level and soil amendments reveled that, full irrigation give the best results, followed by SAP with 75% irrigation, whereas the lowest significant value recorded in BENT with 50% irrigation level during the three seasons of study. This may indicate the successful use of SAP as soil improves to enhance the water holding capacity compared to Bent.

The obtained results also reveled a stomatal closure and the subsequent reduction in photosynthetic due to changes in leaf statues in plants under low available water. Similarity Pliakoni and Nanos (2011) found that olive tree irrigated with 30% of control 100 % of irrigation level from late July to early September, indicate loss of leaf productivity. Chai *et al.,* (2016) assumed that the fraction of the root system of olive trees under the drying soil may respond to drying by sending a root-sourced signal to the shoot where stomata may close to reduce water loss through transpiration which helps reduce water loss.

• Fruit weight

Olive fruit weight (g) as a presented in table 7, was affected by irrigation level and the tested soil amendments. Fruits from full irrigation requirements had the heaviest

Table 7: Effect of irrigation level and soil amendments on fruit weight.

Irrigation level	Soil Amendments (2016)			Soil Amendments (2017)			Soil Amendments (2018)		
	SAP	Bent	Mean	SAP	Bent	Mean	SAP	Bent	Mean
100 %	8.03 a	8.03 a	8.03 A	7.98 a	7.98 a	7.98 A	8.51 a	8.51 a	8.51 A
75%	7.11 b	6.81 c	6.96 B	7.04 b	6.64 c	6.84 B	7.8 b	7.23 c	7.52 B
50%	7.08 b	6.81 c	6.95 B	6.27 d	6.28 d	6.28 C	7.12 c	7.05 c	7.09 C
Mean	7.40 A	7.22 A		7.09 A	6.97 A		7.81 A	7.59 B	

Table 8: Effect of irrigation level and soil amendments on yield (kg/tree).

Irrigation level	Soil Amendments (2016)			Soil Amendments (2017)			Soil Amendments (2018)		
	SAP	Bent	Mean	SAP	Bent	Mean	SAP	Bent	Mean
100 %	35.00 b	35.00 b	35.00 B	40.67 bc	40.67 bc	40.67 AB	10.00 c	10.00 c	10.00 B
75%	47.00 a	31.25 d	39.13 A	44.20 a	40.08 c	42.14 A	23.50 a	18.00 b	20.75 A
50%	37.58 b	30.50 d	34.04 B	41.77 b	38.10 d	39.93 B	1.14 d	2.43 d	1.79 C
Mean	39.86 A	32.25 B		42.21 A	39.62 B		11.55 A	10.14 A	

weight, followed by 75% irrigation level, meanwhile the lowest fruit weight was obtained in 50% of irrigation level at 2017 and 2018 seasons. SAP soil amendment gave higher fruit weight then Bent amendments but the difference was only significant at the third season (2018).

Interaction between Irrigation level and amendments recorded a significant higher of fruit weight at 100 % irrigation requirement in the three seasons, followed by SAP then BENT with 75% irrigation level respectively. Meanwhile, no significant difference were detected between the two soil amendments at 50% irrigation requirement on the second and third seasons of the study (2017 and 2018).

These results are in line with Moriana *et al.,* (2007) whereas the fruit weight decreased drastically in response to the level of water stress. Gucci *et al.,* (2009) and Lodolini *et al.,* (2011) revealed that severe water stress affects mesocarp weight, in both cell size and number, in olive fruits since photo assimilate synthesis and partitioning were more limited by water stress rather than by competition among sinks. In this scenario, there is a greater dependency on irrigation to achieve higher yields, despite olive trees being young and with high levels of crop load.

• Yield (kg /tree)

As shown in table 8, it has been stated that SAP amendments with 75% of irrigation level affected the yield (kg) during the three seasons and gave a significant higher values compared with all of the treatments including full irrigation level.

On the opposite by using BENT amendment yielding was inferior at either tested level of irrigation. At the third season (2018) yielding of olive trees was greatly reduced that may due to the effect of high temperature prevailing at the period of floral initiation that have affect at bud differentiation process. Therefore, the present results may indicate the favorable effect of using SAP amendments at 75% to restrict the deleterious effect of high temperature on flowering and yield of olive tree even at full irrigation.

These results support the observations indicated by (Malik and Bradford, 2006, Malik and Perez, 2011), demonstrating that 30°C temperatures inhibit floral initiation and bud break, even when sufficient chilling occurred. Moreover, Caruso *et al*., (1995) during their studies on inflorescence structure and fertility of several olive cultivars recorded years to year's variations due to climatic effect. Also, Yield per tree varied according to cultivar and season (Fouad *et al.,* 1992, El-Sayed, 2014), fertilization and irrigation (El-Gmaal, 2008).

• Olive oil yield per tree

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 (Mailer and Ayton, 2011). The results showed a significant increase in olive oil yield as results to add SAP to the soil at the stats of experiments. Moreover, Irrigation level at 75 % with added SAP soil amendments gave the significant highest olive oil yield at the three seasons even compared with 100% irrigation level. Meanwhile the lowest oil yield found in 50% irrigation level with BENT (Table 9).

Oil content was directly related to the amount of water received. as detected by Girona *et al.,* (2002) and Grattan *et al.,* (2006) with summer irrigation deficits. Martín -Vertedor *et al.,* (2011) and Naor *et al.,* (2013), indicated the impact of water stress on oil yield and quality increases with crop load. Also, Beyá-Marshall *et al.,* (2018) showed that, oil content and yield were reduced by 54% and 50% for each MPa and effect was intensified as crop load increased.

Table 9: Effect of irrigation level and soil amendments on total oil yield per tree (kg/tree).

Irrigation level	Soil Amendments (2016)			Soil Amendments (2017)			Soil Amendments (2018)		
	SAP	Bent	Mean	SAP	Bent	Mean	SAP	Bent	Mean
100 %	4.16 c	4.16 c	4.16 C	5.03 b	5.03 b	5.03 A	1.24 c	1.24 c	1.24 B
75%	6.48 a	3.69 d	5.09 A	5.20 a	4.47 c	4.84 B	3.02 a	2.09 b	2.56 A
50%	5.12 b	3.63 d	4.38 B	4.01 d	3.68 e	3.85 C	0.13 d	0.27 d	0.20 C
Mean	5.25 A	3.83 B		4.75 A	4.39 B		1.46 A	1.20 B	

Table 10: Effect of irrigation level and soil amendments on oil composition.

Irrigation level	Soil Amendments (2016)			Soil Amendments (2017)			Soil Amendments (2018)		
	SAP	Bent	Mean	SAP	Bent	Mean	SAP	Bent	Mean
100 %	143.1 d	143.1 d	143.1 C	18.29 a	18.29 a	18.29 A	62.88 d	62.88 d	62.88 C
75%	171.0 b	166.2 c	168.6 B	17.66 c	17.11 e	17.39 C	64.42 c	64.83 b	64.63 A
50%	185.1 a	165.3 c	175.2 A	17.44 d	18.01 b	17.73 B	65.55 a	62.54 d	64.04 B
Mean	166.4 A	158.2 B		17.80 A	17.80 A		64.28 A	63.42 B	

• Oil composition

Data shown in table 10, illustrate the effect of investigated regime and tested amendments on oil quality of Picual olive, Reduction of irrigation levels increased polyphenols content in olive oil, The present results also revealed significant increase in oil polyphenols content due to add SAP to the soil.

Regarding interaction between the treatments, the highest polyphenol content was found in 50% irrigation level with SAP amendment, followed by 75% irrigation with SAP additive; meanwhile the lowest value recorded in full irrigation requirement.

The mainly saturated fatty acid in olive oil is palmitic, The highest content of palmitic acid obtain in oil of full irrigation treatment 100 %. On the opposite, at both tested water regimes (75% and 50%) a significant reduction in palmatic acid was detected. The highest reduction of palmatic acid was recorded in 75% and 50% irrigation levels with BENT and SAP soil additive respectively, However, there is no significant difference was found between two amendments.

Oleic acid as the major monounsaturated fatty acids in all olive oils was determined in the present study. It was at the highest level at 75% irrigation level, followed by 50% irrigation requirements; meanwhile the lowest value found in full irrigation 100 % treatment. The results also showed a significant increase in oleic acid as results to add SAP to the soil.

With respect to interaction between treatments, oleic acid content recorded highest value in 50 % irrigation level with SAP soil amendments, followed by 75% irrigation level with added BENT soil additives. In contrast the lowest value was apparently detected in Full irrigation (control treatment).

Concerning olive oil quality, Virgin olive oils contains phenolic substances responsible for their stability against oxidation (Del Carlo *et al.*, 2004). Our results are supported by that detected by Servilli *et al*., (2007) and Romero *et al.,* (2002). They observed a clear reduction of total phenol content in response to the increase of water supply. More recently, Caruso *et al.,* (2014) noted that olive trees with high water status yielded oils with lower concentrations of total phenols comparing with oils from severely stressed trees. Polyphenol content is important for the fruit pungency but also for increased shelf life as illustrated by the induction time. Water reduction may be utilized to improve antioxidant activity in olives and to produce longer shelf life oil (Mailer and Ayton, 2011).

Conclusion

Our results illustrated that adding soil amendments with 75% of irrigation level gave a result of the approach to full irrigation level in vegetative growth. Adding of super absorbent polymer had a positive effect in leaf transpiration, since increase in yield and had a good olive fruit weight. Regarding to olive quality composition SAP gave the best quality rather than BENT. In conclusion adding super absorbent polymer could save reduce irrigation by at least 25%.

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