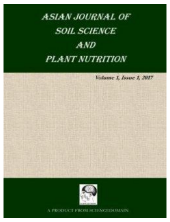

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Irrigation Regime and Soil Conditioner to Improve Soil Properties and Pomegranate Production in Newly Reclaimed Sandy Soil

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Authors' contributions

This work was carried out in collaboration between all authors equally. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted during the two successive seasons of 2014 and 2015 on pomegranate trees cv. Wonderful (*Punica granatum* L.). The trees were grown in newly reclaimed sandy soil located at the 64 km on the Cairo-Alexandria desert road, El-Behira Governorate, Egypt. The studied soil was treated with different levels of soil conditioner (polyacrylamide polymer) i.e. 500 and 1000 g/tree/two years, in addition to control (without polymer addition). Also, different levels of irrigation water were applied i.e. 70% (3610 m^3/fed), 85% (4105 m^3/fed) and 100% (4790 m^3/fed) of ET_o. The experiment was designed in a split plot with three replicates. Irrigation water levels were randomly arranged in the main-plots and the applied polymer treatments were distributed randomly in the sub-plots. Data revealed that using irrigation water level 85% of ET_o gave, in general, the highest values of growth and yield indices compared to other treatments. Soil conditioner level at 1000 g/tree showed, also, the highest values, followed by 500 g/tree with significant difference between the studied treatments. The irrigation water treatment of 4105 m^3/fed

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with soil conditioner 1000 g/tree was the best combined treatment in giving high fruit yield. This treatment caused, also, significant effect on water and nutrients saving, and improved the tested soil physical and chemical properties rather than the other treatments.

Keywords: Pomegranate; irrigation water levels; polyacrylamide polymer; sandy soil; soil physical and chemical properties.

1. INTRODUCTION

Pomegranate tree (*Punica granatum* L.) belongs to the family *Punicaceae* and is a crop tolerant to water deficit and needs, relatively, low water requirements for producing optimal crop as compared to other fruit trees [1]. It is mainly confined to semi-arid mild-temperate to subtropical climates. Commercial orchards of pomegranate trees are now grown in many regions of the world, particularly in the Mediterranean Basin, where high quality fruits are obtained and trees are considered as a crop tolerant to soil water deficit [2,3]. Pomegranate possesses drought tolerance characteristics, common in xeromorphic plants, such as high leaf relative apoplectic water content and the ability to confront water stress by developing complementary stress avoidance and stress tolerance mechanisms [4]. However, [5] found that 8 liters of water per hour through trickle irrigation gave the highest number of fruits per plant, fruit weight, fruit length, fruit diameter, total soluble solids content, sugar content, pomegranate yield and water use efficiency and the lowest acidity.

Water shortage and low water quality are becoming an international issue, to overcome this problem especially when reclaiming some efficient horticulture principals in water consuming known as Xeriscaping, choose the appropriate and accustomed plant to dry regions and/or use drip irrigation and other relevant techniques to save irrigation water units. Also, use one of the soil amendments such as super absorbent polymer which considered as environmentally friendly material. These materials cause more efficient water consumption, reduction in irrigation costs and intervals by 50%, increase soil's water holding capacity up to 2 to 4 times and soil porosity, providing plants with eventual moisture and nutrients as well as improving plant viability and ventilation and root development [6]. Thus, the main objective of this study is to determine the effect of different levels of irrigation water in the presence of different levels of soil conditioner applied under drip irrigation system on the yield and quality of pomegranate trees cultivated on newly reclaimed sandy soil at the North West desert of Egypt. Some soil physical and chemical properties of the tested soil were also studied.

2. MATERIALS AND METHODS

2.1 Field Experiment

The present experiment was conducted during the two successive seasons of 2014 and 2015 on pomegranate trees cv. Wonderful (*Punica granatum* L.). The trees were grown in private orchard located at the 64 km on the Cairo-Alexandria desert road, El-Behira Governorate, Egypt. The pomegranate trees were about 5 years old were considered for this investigation. They were planted at 3 x 3 m^2 apart in a sandy soil. Some physical and chemical characteristics of the studied soil before cultivation are shown in Table 1.

Considered trees were irrigated with deep well water using a drip irrigation system with 8 adjustable discharge emitters/trees through 2 irrigation lines. The chemical analyses of the water used for irrigation are given in Table 2.

2.2 Treatments

The experiment contained two factors with nine treatments; first factor was irrigation water levels i.e. 100% (4790 m^3/fed), 85% (4105 m^3/fed) and 70% (3610 m^3/fed) from the farmer regular irrigation quantity. The second factor was the soil conditioner levels (without, 500 g/tree and 1000 g/tree). The soil conditioner was added in the soil under irrigation lines at 20 cm depth in both sides of trees. It was added to the soil in first of February 2015 for one time only. Soil conditioner (composites) samples were obtained from the Agriculture Research Center (ARC). Some chemical features of the composites are shown in Tables 3 and 4. These composites are mixtures of polyacrylic of super absorption polymer (SAPs) and clay deposits (Bentonite) at ratio 1:5 according to [7]. Also, the trees received the recommended fertilization program applied to all trees on equal bases according to the extensions of the Ministry of Agriculture, Egypt.

2.3 Climatic 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 (ET_o). ET_o was calculated using FAO-Penman-Monteith procedure presented by [8], as shown in Fig. 1.

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

Particle size distribution, %		pH (1:2.5)	7.71
Sand	85.2	EC_e, dS m^{-1}	3.03
Silt	8.63	**Soluble cations, meq L^{-1}**	
Clay	6.17	Ca^{2+}	8.88
Textural class	Loamy sand	Mg^{2+}	7.65
Bulk density, g cm^{-3}	1.68	Na^{+}	12.8
Real density, g cm^{-3}	2.71	K^{+}	0.98
Total porosity, %	38.0	**Soluble anions, meq L^{-1}**	
Field Capacity (FC)*	12.6	HCO_3^-	11.8
Wilting Point (WP)*	4.38	Cl^-	14.9
Available Water (AW)*	8.22	SO_4^{2-}	3.60
Water Holding Capacity (WHC)*	28.1	SAR	6.29
Hydraulic conductivity, cm Sec^{-1}	$1.9x10^{-3}$	CEC, $cmol_c$ kg^{-1}	9.33
$CaCO_3$, %	17.5	OM, %	0.06

** % on dry weight basis, carbonate ions were not detected*

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

pH	EC_w dS m^{-1}	Soluble ions, meq L^{-1}								SAR
		Ca^{2+}	**Mg^{2+}**	**Na^{+}**	**K^{+}**	**CO_3^{2-}**	**HCO_3^-**	**Cl^-**	**SO_4^{2-}**	
6.50	6.44	20.4	8.95	33.0	2.01	0	20.5	39.3	4.59	12.2

Table 3. List of major components of super absorbent polymers (SAPs) and composites

	Super absorbent polymers (SAPS)		Major components
A	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%
3	B2		-
4	K2		-
5	N15		-
6	N20		-

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, %	61.0
Water Holding Capacity (WHC), cm^3 g^{-1}	60.0

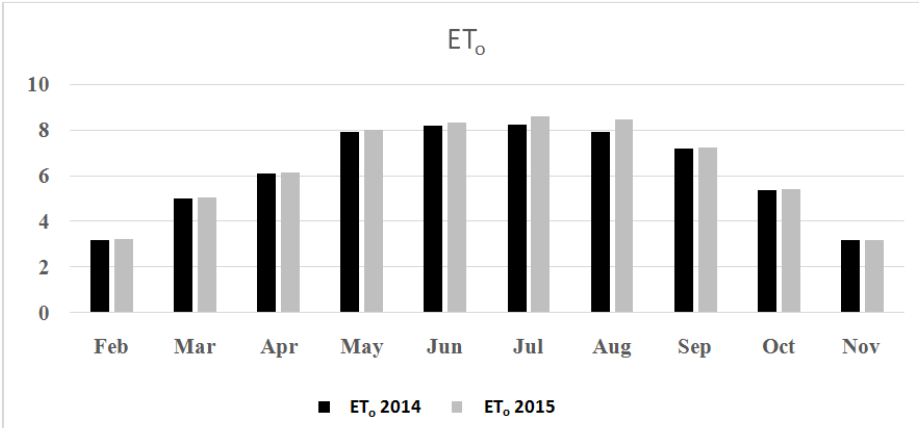

Fig. 1. Reference Evapotranspiration (ET_o) during the two growing seasons of 2014 and 2015 at Cairo-Alexandria desert road

2.4 Estimation of Irrigation Water Requirements for Pomegranate Tree

Most of the effects of the various weather conditions are incorporated into the ET_o multiplying the reference crop Evapotranspiration, ETo, by a crop coefficient, K_c according to [9], the same methodology was adopted by many studies [8,10], Table 5.

$$IR = K_c * ET_o * LF * IE * R * Area (fed)/1000$$

Where:

IR = Irrigation requirements (m^3/fed).

K_c = Crop coefficient [0.40-0.80] according to [8,11].

ET_o = 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 m^2).

1000 = to convert from liter to cubic meter.

Table 5. Applied and estimated water during the two growing seasons of 2014 and 2015 for pomegranate tree

Month	Applied water m^3/feddan in both seasons			Estimated water m^3/feddan		
	100% (3 h)	85% (2.40 h)	70% (2.20 h)	2014 season	2015 season	Average for both seasons
Feb	135	110	95	67	68	67
Mar	260	225	200	186	188	187
Apr	390	340	300	293	296	294
May	780	670	590	504	509	507
Jun	780	670	590	629	629	629
Jul	780	670	590	653	682	668
Aug	780	670	590	629	671	650
Sep	390	330	290	551	557	554
Oct	390	330	290	426	430	428
Nov	105	90	75	118	120	119
Total	**4790**	**4105**	**3610**	**4057**	**4149**	**4103**

The irrigation water levels were applied by install flow-meter and valve to control the applied water quantity. The trees received irrigation one time weekly in months February and November; in months April, September and October irrigated three times/week; in months May, June, July and August irrigated six times/week.

2.5 Soil Analyses

Soil samples were randomly collected at the end of the experiment from the zone of the end of root ramification of the canopy at depth 60 cm in November 2015 and 2016, respectively. Some soil physical properties were determined as described by [12]. Soil pH was measured using pH meter in 1:2.5 soil:water suspension, and EC_e in the extract using EC meter according to [13]. Chemically available N, P and K were determined according to the methods described by [14]. Organic matter content was determined by the method of Walkely and Black as described by [15].

2.6 Vegetative, Floral and Yield Measurements

Vegetative growth measurements of pomegranate trees cv. "Wonderful" as affected by different irrigation levels and additions of soil conditioner levels were evaluated through determining the response of the following parameters: No. of leaves per twig/tree by recording No. of leaves in eighth twig of each replicate tree (2/each direction) in the last week of August, and leaf area (cm^2) using the Planimeter.

Sex ratio was calculated as percentage of hermaphrodite (perfect) to total male and hermaphrodite tree flowers according to the following equation used by [16]:

> Sex ratio (%) = Number of perfect flowers/Total number of flowers × 100

Fruit set was recorded after 70% of the petal fall. Percentage of final fruit set was calculated according to the following equation used by [16]:

> Final fruit set percentage = Total No. of persistent fruits/Total No. of perfect flowers at full bloom x 100.

At harvest time (October, 1st) in both seasons, fruits of each treated tree were picked and total yield/tree was calculated as yield weight kg/tree and total fruit number/tree was recorded. The percentages of cracked & sunburned and marketable fruits/tree were calculated at mature stage.

2.6.1 Fruit physical properties

Fruit volume (cm^3) was calculated by a liquid displacement method. After whole fruit size measurements, the arils were manually separated from the fruits, and total arils and peel per fruit were measured. Then, fruit juice content (ml) was measured by extraction of total arils per fruit using an electric extractor.

2.6.2 Fruit juice chemical composition

Total soluble solids percentage (% TSS) of fruit juice was determined using an Atego N-20 refractometer at 20 ^{0}C. Titrable acidity (TA) was measured using method of back titration to pH 8.1 with 0.1 N NaOH solution and phenolphthalein as indicator then expressed as gram of citric acid per 100 g of juice [17]. The maturity index (MI) was calculated by dividing TSS by TA. Total sugars percentage was determined according to the method described by [18]; and Ascorbic acid/100 ml juice was determined by employing the method described by [17]. Total anthocyanin content (%) was estimated according to the methods described by [19]. Tannins content were determined in fruit juice according to the method of [20].

Leaf mineral contents were determined at the first week of August in both seasons; leaf samples of twenty leaves were taken from middle position of non-fruiting shoots of each replicate tree. Total N in the leaves, digested by H_2SO_4/H_2O_2 mixture, was determined using Kjeldahl method; total P was determined using Spectrophotometer according to [21] and total K in leaves was determined using Flame photometer as described by [22].

2.7 Experimental Design and Statistical Analysis

Split plot design with three replicates of trees was used. These trees were nearly similar in their growth vigor, size and shape diseases-free. Irrigation water levels were randomly arranged in the main-plots and the applied polymer treatments were distributed randomly in the sub-plots. Data were statistically analyzed using statistical analysis system (SAS) program [23]. The means that were significant were separated using Duncan's New Multiple Range Test at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Soil Physical and Chemical Properties

Data in Table 6a represent the effect of different irrigation water levels and applied soil conditioner 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 important parameters of soil structure. Data in Table 6a revealed that the treatment of full irrigation without addition of soil conditioner had significantly higher bulk density which consistently decreased with increase in deficit water level. The reports of [24] were in conformity with such findings. The increment of soil bulk density under high irrigation level may be due to decrease in SOM, as mentioned later in Table 6b, 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 [25]. 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 [26]. Wong and Ho [27] 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 [28]. In addition, hydraulic conductivity is one of the most important soil characteristics which play 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 6a show the effect of the applied treatments on soil hydraulic conductivity values. In general, addition of 1 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 6a 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 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. Recently, [29] stated that a close relation exists between the supply of polyacrylamide and water regime. These results may be related 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.

Data in Table 6b present some soil chemical properties after harvesting of pomegranate fruits 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. Regarding the source of salts in the studied soil is due to irrigation with saline water (Table 2). Abd El-Mohdy and Abd El-Rehim [30] mentioned that superabsorbent hydrogels were three dimensional hydrophilic cross-linked networks, which were able to absorb and retain many times their weight of water, saline or biological fluids, without dissolution.

The studied 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. Ekebafe et al. [31] reported that hydrogels were claimed to reduce fertilizer (NPK) leaching. Increasing irrigation water level is causing a significant decrease in the available amount of N, P and K in the studied soil, due to increase leachability. 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. Treatment of 85% irrigation water level + 1 kg 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.

3.2 Vegetative Growth Characteristics

Data in Table 7 show that treatment of irrigation level (IL) at 85% increased significantly shoot length, No. of leaves and leaf area (15.3 and 19.5 cm), (18.0 and 27.6) and (8.00 and 9.22 cm^2) in both first and second seasons, respectively. Number of leaves decreased with increasing the soil moisture tension which is associated with low irrigation levels. These findings go parallel with those obtained by [32] on pomegranate.

Regarding the effect of soil conditioner (SC) the results show that, SC at 500 g/tree/two years increased significantly shoot length (14.7 cm) in the first season; in the second season, however, the highest mean value was (19.2 cm) for trees received polymer at 1000 g/tree/two years. As for number of leaves, polymer at 1000 g gave the highest mean value (17.6 and 25.4) in both first and second seasons, respectively. Concerning leaf area, the highest mean values (8.89 and 9.37 cm^2) were recorded with trees receiving polymer at 500 g in both studied seasons. These results are in line with those stated by [33] who mentioned that leaf area of pomegranate was increased by incorporation of hydrophilic polymer in the soil. These results were probably due to that polyacrylamide led to improve the water holding capacity and reduce the infiltration rate of the sandy soil, thus the soil can reserve an enough amount of water needed for roots and buds [34].

Table 6a. Some physical properties of the studied soil after harvesting of pomegranate fruits during the two tested seasons of 2014 and 2015

Treatment	Bulk density, g cm^{-3}	HC, $\times 10^{-3}$ cm Sec^{-1}	FC	WP %	AW
First season					
70% irrigation level without polymer	1.62c	1.93h	12.6f	4.35a	8.25g
85% irrigation level without polymer	1.68b	2.01g	13.0e	4.09b	8.91f
100% irrigation level without polymer	1.71a	2.06fg	13.0e	4.03c	8.97e
70% irrigation level with 500 g polymer	1.60cd	2.11f	13.5d	3.97d	9.53d
85% irrigation level with 500 g polymer	1.56e	3.45c	13.9c	3.88e	10.0c
100% irrigation level with 500 g polymer	1.59d	3.26d	13.8c	3.85e	9.95c
70% irrigation level with 1000 g polymer	1.51f	2.98e	14.1b	3.78f	10.3b
85% irrigation level with 1000 g polymer	1.43h	4.29a	14.3a	3.71g	10.6a
100% irrigation level with 1000 g polymer	1.47g	3.67b	14.3a	3.70g	10.6a
Second season					
70% irrigation level without polymer	1.65c	1.91h	12.3f	4.37a	7.93f
85% irrigation level without polymer	1.69b	1.96g	12.8e	4.11b	8.69e
100% irrigation level without polymer	1.73a	1.97g	12.9e	4.01c	8.89e
70% irrigation level with 500 g polymer	1.58d	2.25f	13.7d	3.95d	9.75d
85% irrigation level with 500 g polymer	1.53e	3.51c	14.1c	3.81f	10.3c
100% irrigation level with 500 g polymer	1.55e	3.22d	14.5b	3.87e	10.6b
70% irrigation level with 1000 g polymer	1.47f	3.17e	14.4b	3.75g	10.7b
85% irrigation level with 1000 g polymer	1.41g	4.60a	14.8a	3.70g	11.1a
100% irrigation level with 1000 g polymer	1.45f	3.81b	14.7a	3.72g	11.0a

Table 6b. Some chemical properties of the studied soil after harvesting of pomegranate fruits during the two tested seasons of 2014 and 2015

Treatment	pH	EC_e	Chemically available macronutrients, %			OM	C/N
	(1:2.5)	dS m^{-1}	N	P	K	%	Ratio
First season							
70% irrigation level without polymer	7.97h	2.71a	0.56e	0.23e	4.39g	1.07f	1.11c
85% irrigation level without polymer	8.03g	2.64b	0.51f	0.19f	4.16h	1.04g	1.18b
100% irrigation level without polymer	8.05fg	2.58c	0.49f	0.18f	4.02h	1.02h	1.21a
70% irrigation level with 500 g polymer	8.08e	2.01e	0.61d	0.25e	6.65f	1.19e	1.13c
85% irrigation level with 500 g polymer	8.43d	1.99e	0.80a	0.39b	9.38b	1.27b	0.92e
100% irrigation level with 500 g polymer	8.48c	0.92f	0.69c	0.29d	7.78d	1.23d	1.03d
70% irrigation level with 1000 g polymer	8.06efg	2.51d	0.70c	0.31d	7.57e	1.24cd	1.03d
85% irrigation level with 1000 g polymer	8.51b	0.89f	0.90a	0.46a	10.2a	1.29a	0.83f
100% irrigation level with 1000 g polymer	8.54a	0.62g	0.77b	0.36c	8.54c	1.25c	0.94e
Second season							
70% irrigation level without polymer	8.02f	2.74a	0.51f	0.21f	4.21g	1.03f	1.17c
85% irrigation level without polymer	8.05e	2.67b	0.48f	0.18g	4.11g	1.00g	1.21b
100% irrigation level without polymer	8.06e	2.62b	0.44g	0.17g	4.03g	0.99h	1.31a
70% irrigation level with 500 g polymer	8.09d	1.97d	0.67e	0.26e	6.73f	1.23e	1.06d
85% irrigation level with 500 g polymer	8.45c	1.93d	0.83b	0.42b	9.44b	1.28a	0.89f
100% irrigation level with 500 g polymer	8.50b	0.90e	0.71d	0.33d	7.85d	1.26c	1.03d
70% irrigation level with 1000 g polymer	8.11d	2.42c	0.76c	0.35cd	7.68e	1.25d	0.95e
85% irrigation level with 1000 g polymer	8.54a	0.82f	0.92a	0.49a	10.1a	1.28a	0.81g
100% irrigation level with 1000 g polymer	8.55a	0.61g	0.80b	0.37c	8.70c	1.27b	0.92ef

Data in Table 7 show that interaction between IL and SC significantly affected shoot length of pomegranate trees. The longest shoots were obtained by trees irrigated at level 85% with SC at 500 g (15.7 cm) in the first season; in the second one, however, IL at 85% with 1000 g SC gave the highest values (22.3 cm). As for No. of leaves, in the both seasons, IL at 85% with 1000 g gave the highest values (19.3 and 30.0, respectively). As for leaf area, IL at 100% with 500 g gave the highest value in the first season. Meanwhile, in the second season, IL at 85% with 500 g gave the highest one. These results are in harmony with those reported by [35] who found that the combination between soil conditioner and irrigation water levels improved leaf area in pomegranate trees.

3.3 Sex Ratio and Fruit Set

Data in Table 8 show sex ratio and fruit set percentages as affected by the irrigation water levels and polymer addition during the two growing seasons. Irrigation level at 85% gave the highest sex ratio and fruit set percentages of Wonderful pomegranate cultivar compared to other treatments during the two studied seasons.

Data indicate that the effect of SC treatments on sex ratio and fruit set were significant in both studied seasons. The highest mean values (53.3 and 54.5% for sex ratio, and 64.9 and 66.3% for fruit set) were obtained from applying 1000 g/tree/two years, respectively.

Wonderful pomegranate was influenced significantly during both studied seasons, when irrigated with level 85% and addition of 1000 g polymer, than other treatments.

3.4 Number of Fruits/Tree, Yield and Fruits Weight

Data in Table 9 reveal that the greatest number of fruits/tree (51.3 and 67.0) and yield (20.8 and 30.6 kg/tree) were gained by irrigation level 85% in both studied seasons, respectively. Regarding the fruit weight, Table 9 shows that application of 70% irrigation level recorded the highest mean values (433 and 475 g) in both seasons, respectively.

Table 7. Effect of soil conditioner and different irrigation water levels on vegetative growth parameters of pomegranate trees cv. "Wonderful" during 2014 and 2015 seasons

Irrigation level \ SC (g/tree)	Shoot length (cm)				No. of leaves/twig				Leaf area (cm^2)			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
First season 2014												
100%	14.17c	14.17c	13.73d	**14.02C**	16.67d	16.33de	15.67e	**16.22C**	7.00e	10.00a	6.33f	**7.78B**
85%	14.80b	15.67a	15.43a	**15.30A**	18.33b	16.33de	19.33a	**17.99A**	8.00c	8.67b	7.33d	**8.00A**
70%	14.77b	14.10c	14.33c	**14.40B**	17.67c	16.67d	17.67c	**17.34B**	8.00c	8.00c	7.33d	**7.78B**
Mean B	**14.58A**	**14.65A**	**14.50A**		**17.56A**	**16.44B**	**17.56A**		**7.67B**	**8.89A**	**7.00C**	
Second season 2015												
100%	16.33e	15.43f	17.93bc	**16.56B**	23.00e	18.33g	26.33c	**22.55B**	6.62g	8.91cd	9.33b	**8.29B**
85%	17.87c	18.30b	22.27a	**19.48A**	28.67b	24.00d	30.00a	**27.56A**	7.73f	10.88a	9.06c	**9.22A**
70%	16.53e	14.73g	17.33d	**16.20C**	18.67g	17.33h	20.00f	**18.67C**	8.73d	8.31e	8.16e	**8.40B**
Mean B	**16.91B**	**16.15C**	**19.18A**		**23.45B**	**19.89C**	**25.44A**		**7.69C**	**9.37A**	**8.85B**	

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

Table 8. Effect of soil conditioner and irrigation water levels on sex ratio and fruit set (%) of pomegranate trees during 2014 and 2015 seasons

Irrigation level \ SC (g/tree)	Sex ratio (%)				Fruit set (%)			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
First season 2014								
100%	48.07e	49.80d	51.83c	**49.90B**	60.57d	61.70c	64.60b	**62.29B**
85%	52.23c	58.20b	62.30a	**57.58A**	64.27b	61.97c	68.43a	**64.89A**
70%	43.63g	44.50g	45.83f	**44.65C**	62.23c	49.47e	61.67c	**57.79C**
Mean B	**47.98C**	**50.83B**	**53.32A**		**62.36B**	**57.71C**	**64.90A**	
Second season 2015								
100%	50.10e	56.90bc	54.10d	**53.70B**	64.73d	62.03g	65.63c	**64.13B**
85%	56.17c	57.68b	63.10a	**58.98A**	67.17b	62.83f	69.23a	**66.41A**
70%	50.53e	44.80g	46.37f	**47.23C**	63.47ef	52.13h	64.10de	**59.90C**
Mean B	**52.27C**	**53.13B**	**54.52A**		**65.12B**	**59.00C**	**66.32A**	

See footnotes of Table 7

The SC at 1000 g/tree produced the highest mean values (52.9 and 65.6) for No. of fruits/tree and (21.8 and 30.1 g) for yield in the both tested seasons, respectively. As for the weight, the control treatment recorded the highest mean values of fruit weight in the both studied seasons. The fruit weight is indication of fruit quality, that the heaviest one in weight is the lowest one in quality.

All tested combination between IL and SC revealed significant effects in both seasons. As for number of fruits/tree and yield, the highest values came from the combinations of 85% IL +1000 g/tree SC. As for weight, data in Table 9 showed that, the 70% IL with control gave the highest fruit weight (497 g) in the first season; the treatment of 85% IL with 500 g SC gave the highest fruit weight (517 g) in the second season. These results agree with those obtained by [35] on pomegranate. Also, [36] found that, fruits yields of young apple trees was not affected by using polymer. On contrast, [37] reported that the application of polymer increased fruit weight of tomato.

3.5 Fruit Volume, Average Rind and Aril Weights

Data in Table 10 showed that, the highest values of volume of fruit and aril weight/fruit in the both seasons were given by applying the treatment of 70% from irrigation requirements. These results came in parallel with the results obtained for fruit weight (Table 9). However, the highest value of average rind weight was obtained from the treatment of full irrigation in the first season; the treatment of 70% IL gave the highest value in the second season.

Regarding the effect of soil conditioner levels in the both seasons, the control treatment gave the highest values of volume of fruit and aril weight/fruit. For average rind weight, the treatment of control gave the highest value in the first season, but the treatment of 1 kg SC was superior in the second season. Fruit quality was improved by the application of polymers to growing media due to the reduced impact of water stress during the growing cycle [38]. Also, [31] stated that the use of synthetic polymers as aids to water retention in sandy soils is an important development to assist plant growth in arid regions for creating a climate beneficial to plant growth.

Regarding the interaction between the studied treatments data showed that, the treatment of 70% from irrigation water requirements without any addition of SC gave the highest values of fruit volume and aril weight in the both seasons. Meanwhile, the treatments of 85 and 100% IL without any addition of SC gave the highest values of rind weight in both seasons, respectively.

3.6 TSS, Acidity and TSS/Acid Ratio

Data in Table 11 clarify that the highest total soluble salts (TSS) and acidity values were achieved by applying 85% from irrigation requirements in the both studied seasons. Concerning TSS/acid ratio, the highest value was obtained with irrigation at 85% from irrigation requirements in first season; the treatment of 70% IL gave the highest ratio in the second season. These results go in harmony with those of [32,35] on pomegranate.

Results in Table 11 elucidate that SC at 1000 g/tree/two years gave significantly the highest TSS and acidity in both tested seasons. However, SC at 500 g recorded the highest values of the ratio between them.

Regarding the interaction data show that, the IL at 85% with SC at 1000 g/tree/two years achieved the highest values of TSS (%) in the both studied seasons. The treatment of 70% IL with SC at 1000 g/tree gave the highest value for acidity (%) in the first season without any significant difference with the other used irrigation levels; in the second season, irrigation level at 85% with SC at 1000 g/tree gave the highest value without any significant difference with using full irrigation. As for TSS/acid ratio, data illustrate that the highest ratio came from the combined treatment between IL at 70% with SC at 500 g/tree/two years in the first season; in the second season, IL at 70% with SC at 1000 g/tree gave the highest ratio. Many studies in general mentioned that polyacrylamide caused an improvement by increasing nutrient absorption, osmotic potential and water holding capacity [29,39].

3.7 Total Sugars, Anthocyanin, Tannins and Vitamin C Concentrations

Data in Tables 12 and 13 indicate that the irrigation water treatment at 85% achieved the highest values of juice total sugar percentage and total anthocyanin in both studied seasons. Similar results were stated by [40] on peach and showed that, the highest values of total sugars were attributed to adequate level of supplement irrigation. It can be clearly observed that soil moisture is important for fruit development and productivity. As for tannins and vitamin C, the highest values came from IL at 70% from irrigation requirements.

Data in Tables 12 and 13 demonstrate that SC at 1000 g/tree/two years gave the highest total sugar and vitamin C (%) in both studied seasons. These results are in agreement with those obtained by [35] on pomegranate and [37] on tomato. They reported that vitamin C content was significantly higher in plants treated with polymer. Regarding tannins and total anthocyanin, the highest values were obtained from applying SC at the rate of 500 g/tree/two years in the both tested seasons.

It is clear from the data in Tables 12 and 13 that the treatment of irrigation level at 85% with SC at 1000 g/tree/two years gave the highest juice total sugar percentage in both studied seasons. As for total anthocyanin, the highest value was obtained from applying IL at 85% with SC at 500 g/tree/two years in both studied seasons. Regarding the values of vitamin C, the irrigation water level at 70% with SC at 1000 g/tree/two years achieved the highest value. However, the irrigation water level at 70% with SC at 500 g/tree/two years gave the highest value of tannins in the first season; the highest irrigation water level at 100% with SC at 500 g/tree/two years resulted in the highest value of tannins in the second season.

3.8 Fruit Cracking, Sun Burnt and Marketable Fruits

The effect of IL on No. of cracking fruits was significant in the both studied seasons (Table 14). The average No. of fruits cracking is caused by increasing irrigation level up to 100%. According to [41], fruit cracking is caused by several factors, mainly associated with the water balance of the fruit. On the opposite, for sun burnt fruits, the highest values were recorded by IL treatment at 70% in both studied seasons. As for the marketable fruits, the highest values were obtained from IL at 85% in the both seasons.

Data in Table 14 show that, the treatment without addition of polymer recorded the highest average No. of fruit cracking and average No. of sun burnt fruits in both tested seasons. As for the marketable fruits (%), the highest marketable fruits values were obtained by applying polymer at rate of 1000 g in both seasons.

Data in Table 14 show that the highest irrigation water level applied without addition of polymer achieved the highest No. of fruit cracking in the both studied seasons. Regarding the No. of sun burnt fruits, the lowest IL treatment (at 70% from irrigation requirements) without addition of polymer surpassed other treatments during the two tested seasons. Concerning the marketable fruits percentage, the IL at 85% with SC at 1000 g improved the obtained values compared to the other treatments.

3.9 Elemental Content of Pomegranate Trees Leaves

Data in Table 15 show the concentration of N, P and K in leaves of pomegranate trees cultivated in the studied soil under the tested treatments during the two studied seasons of 2014 and 2015. Data revealed that, in general, the treatment of irrigation water at level 85% was adequate to give high values of the studied macronutrient concentrations inside the pomegranate leaves. It 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 [31].

Generally, data in Table 15 show that the macronutrient concentrations in pomegranate leaves increased with increasing the amount of applied polymer, due to the conserve of these nutrients from leaching or loss from the soil. Several researchers found positive correlation between applying polymers and promoting plants growth and their yields. Results of [42,43,44] showed similar responses for safflower, ficus seedlings and cotton, respectively, especially when cultivated on sandy soil or newly reclaimed soil.

Results in Table 15 show that the macronutrient concentrations increased with increasing the amount of applied polymer while decreased with increasing irrigation water level. The treatment of 85% irrigation water level + 1 kg polymer gave the highest concentrations of macronutrients in leaves, compared to the other treatments.

Table 9. Effect of soil conditioner and irrigation water levels on number of fruits/tree, yield and fruit weight of pomegranate trees during 2014 and 2015 seasons

SC (g/tree) / Irrigation level	No. of fruit/tree				Yield (kg/tree)				Fruit weight (g)			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
					First season 2014							
100%	32.00g	35.00f	54.67b	**40.56B**	12.90g	14.53f	24.37a	**17.27B**	444.5c	368.3i	422.3e	**411.7C**
85%	38.00e	51.67c	64.33a	**51.33A**	19.73b	18.53c	24.03a	**20.76A**	486.7b	382.7f	373.7h	**414.4B**
70%	32.00g	30.00h	39.67d	**33.89C**	11.30h	15.90e	16.87d	**14.69C**	497.2a	376.7g	425.8d	**433.2A**
Mean B	**34.00C**	**38.89B**	**52.89A**		**14.64C**	**16.32B**	**21.76A**		**476.2A**	**375.9C**	**407.3B**	
					Second season 2015							
100%	50.67g	64.33d	69.67c	**61.56B**	18.23g	26.60c	29.59b	**24.81B**	504.6b	385.0g	399.0e	**429.5C**
85%	52.33f	72.00b	76.67a	**67.00A**	20.99f	35.48a	35.36a	**30.61A**	397.0f	399.0e	500.8c	**432.3B**
70%	33.67h	56.33e	50.33g	**46.78C**	13.43h	22.36e	25.21d	**20.33C**	516.7a	403.6d	505.0b	**475.1A**
Mean B	**45.56C**	**64.22B**	**65.56A**		**17.55B**	**28.15A**	**30.05A**		**472.3A**	**395.9C**	**468.0B**	

See footnotes of Table 7

Table 10. Effect of soil conditioner and different irrigation water levels on fruit volume (cm^3), average rind weight (g) and aril weight/fruit (g) of pomegranate trees during the tested seasons of 2014 and 2015

SC (g/tree) / Irrigation level	Fruit volume (cm^3)				Average rind weight (g)				Aril weight/fruit (g)			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
					First season 2014							
100%	336.7b	270.0f	310.0d	**305.6C**	215.5d	249.0c	210.8e	**225.1A**	229.0b	119.3g	211.5d	**186.6C**
85%	333.3b	303.0e	315.0c	**317.1B**	256.7a	181.1g	155.0i	**197.2C**	230.0b	201.6f	218.7c	**216.8B**
70%	353.3a	303.3e	316.7c	**324.7A**	252.2b	168.4h	207.5f	**209.3B**	245.0a	208.3e	218.3c	**223.9A**
Mean B	**341.1A**	**292.1C**	**313.9B**		**241.4A**	**199.2B**	**191.1C**		**234.7A**	**176.4C**	**216.2B**	
					Second season 2015							
100%	366.7c	263.3g	340.0e	**323.3C**	290.8a	197.2d	185.2f	**215.2C**	213.8b	187.8e	213.8b	**205.1B**
85%	408.3b	323.0f	350.0d	**360.4B**	169.1g	200.5c	286.7b	**218.8B**	227.9a	198.5d	214.1b	**213.5A**
70%	425.0a	325.0f	353.3d	**367.8A**	287.2b	192.5e	289.3a	**255.9A**	229.5a	211.1c	215.7b	**218.8A**
Mean B	**400.0A**	**303.8C**	**347.8B**		**248.6B**	**187.6C**	**253.8A**		**223.7A**	**199.1C**	**214.5B**	

See footnotes of Table 7

Table 11. Effect of soil conditioner and different irrigation water levels on TSS (%), acidity (%) and TSS/acidity ratio of pomegranate trees during the tested seasons of 2014 and 2015

SC (g/tree) / Irrigation level	TSS (%)				Acidity (%)				TSS/acid ratio			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
First season 2014												
100%	14.97e	15.53d	16.10c	**15.53B**	1.47c	1.33d	1.80a	**1.53B**	10.18b	11.68ab	8.94d	**10.27B**
85%	16.53b	16.90a	16.83a	**16.75A**	1.63b	1.43cd	1.83a	**1.63A**	10.14b	11.82a	9.20c	**10.39A**
70%	14.23f	14.33f	15.40d	**14.65C**	1.57bc	1.20e	1.87a	**1.55AB**	9.06c	11.94a	8.24de	**9.75C**
Mean B	**15.24C**	**15.59B**	**16.11A**		**1.56B**	**1.32C**	**1.83A**		**9.79B**	**11.81A**	**8.79C**	
Second season 2015												
100%	17.51d	17.53d	17.03e	**17.36B**	1.30b	1.27bc	1.50a	**1.36A**	13.47c	13.80c	11.35de	**12.87C**
85%	18.00c	18.30b	18.80a	**18.37A**	1.37b	1.17cd	1.57a	**1.37A**	13.14cd	15.64ab	11.97d	**13.58B**
70%	16.10f	16.13f	17.30de	**16.51C**	1.50a	1.07d	1.07d	**1.21B**	10.73e	15.07b	16.17a	**13.99A**
Mean B	**17.20C**	**17.32B**	**17.71A**		**1.39A**	**1.17B**	**1.38A**		**12.45C**	**14.84A**	**13.16B**	

See footnotes of Table 7

Table 12. Effect of soil conditioner and different irrigation water levels on total sugars and total anthocyanin (%) of pomegranate trees during the tested seasons of 2014 and 2015

SC (g/tree) / Irrigation level	Total sugars (%)				Total anthocyanin (%)			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
First season 2014								
100%	12.90c	13.37b	13.60b	**13.29B**	2.90cd	3.20bc	2.47d	**2.86B**
85%	14.77a	14.73a	14.80a	**14.77A**	3.13bc	3.63a	3.50ab	**3.42A**
70%	11.67f	12.47d	12.20e	**12.11C**	2.93cd	3.27bc	3.17bc	**3.12B**
Mean B	**13.11B**	**13.52A**	**13.53A**		**2.99B**	**3.37A**	**3.05B**	
Second season 2015								
100%	12.90d	13.30b	13.40b	**13.20B**	3.27f	3.40e	3.20f	**3.29C**
85%	13.20bc	13.47b	14.00a	**13.56A**	3.63d	4.40a	4.20b	**4.08A**
70%	12.53e	12.03f	12.70de	**12.42C**	3.50e	3.80c	3.90c	**3.73B**
Mean B	**12.88B**	**12.93B**	**13.37A**		**3.47C**	**3.87A**	**3.77B**	

See footnotes of Table 7

Table 13. Effect of soil conditioner and different irrigation water levels on vitamin C and tannins (%) of pomegranate trees during the two studied seasons of 2014 and 2015

Irrigation level / SC (g/tree)	Vitamin C (%)				Tannins (%)			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
				First season 2014				
100%	7.70cd	7.83bc	7.77bc	**7.77B**	1.77b	2.37a	1.90b	**2.01B**
85%	7.47e	7.53de	7.70cd	**7.57C**	1.13d	1.77b	1.47c	**1.46C**
70%	7.93ab	7.80bc	8.00a	**7.91A**	2.37a	2.57a	2.47a	**2.47A**
Mean B	**7.70B**	**7.72AB**	**7.82A**		**1.76C**	**2.24A**	**1.95B**	
				Second season 2015				
100%	7.34d	7.35d	7.64c	**7.44C**	2.07d	2.67a	2.37bc	**2.37A**
85%	7.69c	8.31b	8.37b	**8.12B**	1.27f	1.57e	1.37ef	**1.40B**
70%	7.43b	7.37b	9.31a	**8.04A**	2.57ab	2.17cd	2.20cd	**2.31A**
Mean B	**7.49C**	**7.68B**	**8.44A**		**1.97B**	**2.14A**	**1.98B**	

See footnotes of Table 7

Table 14. Effect of soil conditioner and different irrigation water levels on average No. of cracked fruits, average No. of sun burnt fruits and marketable fruits (%) of pomegranate trees during the two tested seasons of 2014 and 2015

Irrigation level / SC (g/tree)	Average no. cracked fruits				Average no. sun burnt fruits				Marketable fruits (%)			
	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)	Control	500 g	1000 g	Mean (A)
						First season 2014						
100%	2.00a	1.33b	0.67cd	**1.33A**	6.33b	6.33bc	6.33bc	**6.33B**	22.67f	27.33e	47.67b	**32.56B**
85%	0.33d	0.33d	nil	**0.22C**	7.00b	5.00d	3.33e	**5.11C**	30.67d	46.33b	61.00a	**46.00A**
70%	1.00bc	0.67cd	0.33d	**0.67B**	11.67a	6.67b	5.33cd	**7.89A**	22.67f	22.67f	34.00c	**26.45C**
Mean B	**1.11A**	**0.78B**	**0.33C**		**8.33A**	**6.00B**	**5.00C**		**25.34C**	**32.11B**	**47.56A**	
						Second season 2015						
100%	2.33a	0.67cd	1.00bc	**1.33A**	7.00b	5.00cd	4.00d	**5.33B**	39.00f	53.00c	61.67b	**51.22B**
85%	0.67cd	0.33de	nil	**0.33C**	5.67bc	4.00d	5.00cd	**4.89B**	45.67e	64.00a	65.00a	**58.22A**
70%	1.33b	0.67cd	0.33de	**0.78B**	7.67a	5.67bc	6.00bc	**6.45A**	24.67g	50.00d	44.00e	**39.56C**
Mean B	**1.44A**	**0.56B**	**0.44B**		**6.78A**	**4.89B**	**5.00B**		**36.45C**	**55.67B**	**56.89A**	

See footnotes of Table 7

Table 15. Effect of soil conditioner and different irrigation water levels on N, P and K (%) of pomegranate trees during the two studied seasons of 2014 and 2015

SC (g/tree) / Irrigation level	N (%)				P (%)				K (%)			
	Control	**500 g**	**1000 g**	**Mean (A)**	**Control**	**500 g**	**1000 g**	**Mean (A)**	**Control**	**500 g**	**1000 g**	**Mean (A)**
First season 2014												
100%	1.54f	1.96d	1.82e	**1.77B**	0.75d	0.75d	0.81c	**0.77B**	0.61f	0.64e	0.55g	**0.60B**
85%	2.24c	2.66a	2.38b	**2.43A**	0.81c	0.85b	0.89a	**0.85A**	0.73c	0.80b	0.82a	**0.78A**
70%	1.26h	1.40g	1.82e	**1.49C**	0.53g	0.59f	0.63e	**0.58C**	0.39i	0.47h	0.67d	**0.51C**
Mean B	**1.68B**	**2.01A**	**2.01A**		**0.70C**	**0.73B**	**0.78A**		**0.58C**	**0.64B**	**0.68A**	
Second season 2015												
100%	1.28i	1.84f	1.51h	**1.54C**	0.71e	0.75d	0.82c	**0.76B**	0.56e	0.62d	0.52f	**0.57B**
85%	1.61g	1.89e	2.01d	**1.84B**	0.82c	0.85b	0.92a	**0.86A**	0.74c	0.83b	0.85a	**0.81A**
70%	2.29c	2.43b	2.76a	**2.49A**	0.52h	0.58g	0.60f	**0.57C**	0.33h	0.39g	0.62d	**0.45C**
Mean B	**1.73C**	**2.05B**	**2.09A**		**0.68C**	**0.73B**	**0.78A**		**0.54C**	**0.62B**	**0.66A**	

See footnotes of Table 7

4. CONCLUSION

It could be concluded that, the newly reclaimed sandy soils are considered promising areas, if put under concern and made special fertilization and irrigation requirements program, taking calculated amounts and water quality into account. The treatment of 85% irrigation water level from irrigation requirements calculated for pomegranate trees combined with 1 kg soil conditioner added per every tree/two years considered, generally, superior in improving soil physical and chemical properties, saving nutrients from leaching out from soil profile and supplying the trees with them, which should be reflected on tree vegetative growth vigor and yield quality.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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