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Impact of soil amendments under water stress on growth, fruit production and high quality of Wonderful pomegranate variety

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ABSTRACT
Soil conditioners are one of the promising solutions for improving soil hydraulic properties and mitigate the undesirable impacts of drought conditions. The present study was proceeding during two successive seasons (2021 and 2022) at the experimental farm of the Desert Research Center station, Southeast Al Qantara, Sinai, Egypt. The experiment carried out to investigate and evaluate the impact of soil conditioners under different irrigation water regimes on soil moisture storage, growth and yield parameters of wonderful pomegranate plants. The results showed that the best vegetative growth, yield, fruit quality and the hydraulic soil properties in drought area obtained with applied 150 g/tree of polymer under deficit irrigation treatment (75% of ETc).

Keywords: Pomegranate, deficit irrigation, soil conditioners, polymers, bentonite, productivity, fruit quality.

1. Introduction
The global shortage of water supplies is growing critically. Egypt's per-capita water share is among the lowest. In 2025, it is anticipated that this value may drops to 600 to 500 m^3/capita (Ashour *et al*., 2009). The irrigated agriculture demands are more than about 80% of available water budget. Therefore, water security and visible strategies are essential and required. Applying soil amendments, implementing deficit irrigation, and growing drought-tolerant crops are some examples of water-saving techniques in agriculture. Pomegranate is a highly valuable crop that can withstand drought (Zahedi *et al*., 2022). Pomegranate has high adaptation capacity to different soil types and weather conditions. Thus led to its widespread cultivation today. Pomegranate fruits, juice, and extracts are extremely beneficial both nutritionally and medicinally. Promising health advantages as effective means for treatment the cancer and others (Sharma *et al*., 2017). The total cultivated area of pomegranate in Egypt is 45,552 ha, of which 31,322 ha in the new reclaimed areas, which produce about 509.3 tons.

To conserve water in arid areas, crops allowed to expose a certain degree of water stress and sometimes causes decreasing in yield with deficit irrigation (DI). Deficit irrigation (DI) refers to the provision of water at levels lower than the total amount needed for irrigation or the total amount of evapotranspiration (ETc) during the growing season. Numerous studies have demonstrated the potential benefits of using DI in the field. With little impact on fruit development, DI lowers the amount of water used, lowers the chance of nutrient leaching, and decreases vegetative growth. Fruit postharvest performance is improved, fruit-ripening time is controlled, and DI enhances fruit composition.

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Many researches considering pomegranate response and productivity to deficit irrigation (DI) already established. Under DI, as low as 35% ETc, did not significantly affect the productivity and fruit nutritional quality of pomegranate trees (Centofanti *et al*., 2017). Deficit irrigation with 50% ETc produced the same yield of pomegranate under 100% of ETc treatment (Intrigliolo *et al*., 2013). Khattab *et al*., 2011 indicated that the highest irrigation level simulated vegetative growth of pomegranate. In contrast, other studies reported that the applied DI adversely affected significantly pomegranate yield because of reducing fruit size and production (Beelagi *et al*., 2023; Mellisho *et al*., 2012). Further investigation needed to clarify these contradictory results.

Soil amendments like bentonite and polymers can enhance soil moisture storage and protect the plants against soil water stress. The soil with low cation exchange capacity leads to percolate excessive irrigation water beyond the effective root zone and leaching nutrients. Bentonite is a natural and nontoxic soil amendment and consists mainly of montmorillonite clay mineral (Park *et al*., 2016). Therefore, it considers as an effective soil amendment acts as anti-drought stress and conserves soil against deterioration. Hence, the applied of bentonite particularly, in coarse textured soil maximized available water and yield and thus improve water productivity (Mi *et al*., 2017; Tibebe *et al*., 2013) .

Polymers are hydrophilic water-soluble materials has ability to absorb huge amount of water may reach to a hundred times of their weight. Polymers release the stored water back to the soil slowly and steadily with the depletion of moisture content. This creates suitable moisture in the root zone of plants (Kaur *et al*., 2023). High absorptive capacities of Polymers allow them to act as reservoirs of soil water and nutrients. Mixing polymers with soils approved to improve soil moisture storage of the soils and hence increase the available water content, especially at soils with low clay content. The incorporated polymers with soils in drought areas reduced the losses from applied water and increased water productivity (Abobatta and Khalifa, 2019; El-Hady and Wanas, 2006; Sarmah and Karak, 2020).

Many studies devoted to utilize the bentonite and polymers as soil alterations. There is no sufficient reviewed data is available which related to the effect of bentonite and polymers on pomegranate growth and productivity under drought conditions in arid regions. Therefore, the objective of this study was to investigate the response of pomegranate trees to applied bentonite and polymers as soil conditioners under different soil water regimes.

2. Materials and Methods

2.1. Experimental site

The study proceeded on eight years old pomegranate orchard of (*Punica granatum* L. cv. Wonderful), during the two successive growing seasons of 2021 and 2022. The location of experimental site was at the research farm of the Desert Research Center station, Southeast Al Qantara, Sinai, Egypt. The geographic coordinates are 30º 24' 00.9'' E, 30º 49' 22.4" N and 7m above sea level. The average values of temperature (°C), effective precipitation (mm) and reference evapotranspiration (mm/day) were 36.7, 7.2 and 7.8, respectively as shown in Fig.1.

The trees spacing was 5× 5 m (400 plants/ha) and total cultivated area was 0.84 ha. The soil texture is sandy loam. The particle size distribution was as follows: 78.95% sand, 6.34% silt and14.71percentage clay as depicted in table 2. The source of irrigation water was Elsalam canal. Physical and chemical analysis of soil and water at the experimental site are given in table 1 and 2.

2.2. Experimental design and treatments

The experiment performed using a split -plot design. Three levels of irrigation regimes (50, 75 and 100% of ETc) were assessed as a main plot and five rates of soil amendments were as subplot (control, two rates of polymer 100g and 150g/tree, bentonite at two rates of 100g and 150g/tree). Three replicates for each treatment buildup and three trees represented each replicate. Soil amendments (polymer and bentonite) added as the 1 does at the end of December at 20 cm depth and 50 cm from the trunk of the trees. Drip irrigation prepared with two laterals supplied water to the trees. The laterals were faraway 1 m distance from the trees. Lateral lines with 16 mm diameter were equipped with online emitters has discharge of 4 L/h.

The polymer used in the study was a biodegradable potassium polyacrylate-based polymer. Polymer mixed with soil in powder form and jellified upon contact with water. The Polymer had bulk

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density of 600 kg.m^{-3}, pH of 7.1 and water adsorption capacity of 300 (g/g gel). The characteristics of bentonite revealed in tables 1 and 2.

Table 1: Chemical analyses of the soil sample and bentonite

Measureable items	pH Soil past	E.C (dS/m)	Soluble cations (ppm)				Soluble anions (ppm)			
			Ca^{++}	K^{+}	Na^{+}	Mg^{++}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	$CO_3^{=}$
Soil	7.46	1.59	56.2	34.5	267.3	43.4	198.3	157.2	45.9	-
Bentonite	7.70	1.25	16.8	0.5	140	18.1	155.3	16.7	3.4	-

Table 2: Main physical properties of soil in the experimental site

Measureable Items	Particle size distribution (%)			Texture Class	Hydro-physical properties				
	Sand	silt	clay		FC (%)	P.W.P (%)	AW (%)	Ks (cmh^{-1})	ρb (Mg m^{-3})
Soil	78.95	6.34	14.71	**Sandy loam**	20.3	10.9	9.4	1.30	1.50
Bentonite	6.00	24.78	69.22	**Clay**	43.8	22.0	21.9	0.45	1.20

ρb= bulk density, **Ks** = Saturated hydraulic conductivity, **FC**= Field capacity, **PWP**= Permanent welting point, **AW**= Available water

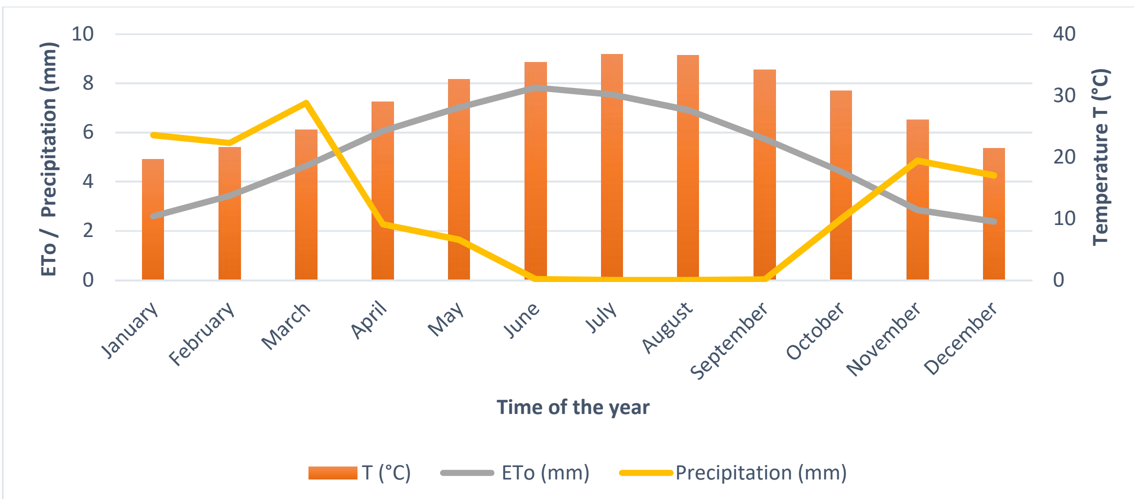

Fig. 1: Average of temperature T (°C), reference evapotranspiration ETo and effective precipitation of the experimental site (Egyptian Meteorological Authority (EMA))

2.3. Irrigation management

Crop water requirement of pomegranate trees was calculated and irrigation scheduling was implemented depends on daily estimation of reference evapotranspiration (ETo). ETo was estimated using CROPWAT program which based on Penman Monteith equation according to (Allen *et al.*, 1998, FAO56). The equation form as follows:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T + 273} U_2(e_s - e_a)}{\Delta + \gamma\ (1 + 0.34U_2)}$$

Where:

ET_o = reference evapotranspiration (mm/day),
Rn = net radiation at the crop surface (MJ/m^2/day^1),
G = soil heat flux density (MJ/m^2/day^1),

T = mean daily air temperature at 2 m height (C°),
U_2 = wind speed at 2 m height (m/s),
es = saturation vapor pressure (kPa),
ea = actual vapor pressure (kPa),
(es – ea) = saturation vapor pressure deficit (kPa),
D = slope of vapor pressure curve (kPa $°C^{-1}$) and
G = psychrometric constant (kPa $°C^{-1}$).

2.4. Vegetative growth

At the end of season, the height of each tree measured in m from the soil's surface to the tip of its main branch and the volume of the canopy volume of each tree in cubic meter was determined using the following formula:

Volume of tree canopy (m^3) = (π) * (radius^2, m^2) *(height of tree, m)

Each tree measured for Crown radius (m) of each tree measured in 8D (Every 45º) Radius measured from the center of the trunk using a compass and a plummet put on the external point of the section of each direction (Smith *et al*., 1997). The summation of measured data were calculated and plant canopy volumes were determined.

A portable planimeter Mod Li3100 Ali (Li-Cor) and a Minolta chlorophyll meter SPAD-502 used to measure the leave area and total chlorophyll content of the leaves, respectively.

2.5. Number of fruits and yield

At harvest time, the number of fruits per each treated tree counted and recorded then the yield (kg) per tree weighted and recorded.

2.6. Fruit characteristics

Damaged fruits percentage of each tree counted and recorded. Ten mature fruits selected and harvested to measure the following parameters: weight of fruit peels (g), thickness of fruit peels (mm), volume of juice (ml), weight of fruit aril (g), and fresh weight of 100 grains (g). In addition the total soluble solids (TSS)/acid ratio, acidity of fruit juice and ascorbic acid measured using a hand refractometer in accordance with AOAC (Cunniff, 1995).

2.7. Statistical analysis

Variance using Statistix 10 analytical software calculated for the obtained data. In addition, Means separated using the least significant difference Test (LSD) at a 5% probability level of significance (Snedecor and Cochran, 1989).

3. Results and Discussion

3.1. Vegetative growth

3.1.1. Tree height (m)

The results in Table 3 showed that the maximum increase in height of trees was under 100 % of ETc followed by 75 % of ETc treatment for the both of growing seasons while the lowest height of trees was under 50 % of ETc treatment. In addition, the applied soil amendments increased the height of trees compared to control treatment in two growing seasons. The superior treatment was adding 150g of polymer per tree.

3.1.2. Volume canopy of tree

The results depicted in Table (3) showed the response of the tree canopy volume to water stress and applied soil amendments. The average of highest values of tree canopy volume (5.97 and 5.31 m^3/tree) obtained under 100 % of ETc treatment in both growing seasons, respectively. The average lowest values of tree canopy volume (5.03 and 4.14 m^3/tree) recorded under 50% of ETc treatment in the growing seasons, respectively. The results showed that the incorporated 150g of polymer per tree into soil increased volume of tree canopy to 7.29 and 5.71 m^3/tree compared to 3.82 and 3.84 m3/tree in control treatment for successive two growing seasons, respectively. We can concluded that the most efficient and promising treatment was 100 % of ETc coupled with applied polymer with rate of 150 g/tree.

Table 3: Impact of water stress and soil amendments on tree height and canopy volume of wonderful pomegranate trees (2021&2022).

Soil amendments	2021				2022			
	Deficit irrigation							
	100%	75%	50%	Mean	100%	75%	50%	Mean
	Tree height (m)							
Control	1.96 i	1.61 k	1.53 l	1.70 E	2.16 h	1.76 j	1.59 k	1.83 E
Polymer at 100g	2.35 c	2.21 f	2.11 g	2.22 C	2.47 c	2.36 e	2.19 g	2.34 C
Polymer at 150g	2.62 a	2.42 b	2.32 d	2.45 A	2.73 a	2.61 b	2.44 d	2.59 A
Bentonite ate 500g	2.12 g	2.08 h	1.73 j	1.97 D	2.31 f	2.28 f	1.81 i	2.13 D
Bentonite ate 1000g	2.42 b	2.34 cd	2.25 e	2.34 B	2.60 b	2.49 c	2.36 e	2.48 B
Mean	2.29 A	2.13 B	1.99 C		2.45 A	2.30 B	2.07 C	
	Tree canopy volume (m^3)							
Control	4.68 i	3.34 m	3.44 l	3.82 E	4.53 j	3.69 m	3.32 n	3.84 E
Polymer at 100g	5.28 f	5.03 h	4.71 i	5.00 B	5.17 d	4.92 f	4.57 i	4.88 B
Polymer at 150g	7.86 a	7.10 b	6.91 c	7.29 A	6.59 a	5.43 b	5.12 e	5.71 A
Bentonite ate 500g	5.13 g	4.61 j	4.36 k	4.70 D	4.84 g	4.73 h	3.78 l	4.45 D
Bentonite ate 1000g	6.93 c	6.55 d	5.75 e	6.41 B	5.44 b	5.27 c	3.91 k	4.87 B
Mean	5.97 A	5.33 B	5.03 C		5.31 A	4.81 B	4.14 C	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

The impact of drought stress one vegetative growth parameters like height of tree and volume of tree canopy may attribute to the higher sensitivity of vegetative growth stage compared to reproductive growth stage to drought conditions. Moreover, water stress has an impact on vegetative growth due to the rise of biosynthesis of abscisic acid (ABA) and decrease of cytokinin synthesis in the roots, branches, and buds (Dodd, 2005). These results are matching with the findings of (Ebtedaie and Shekafandeh, 2016; Xie *et al*., 2015; Volschenk, 2021). They found that 20 to 60% reduction in vegetative growth of pomegranate plants in pot experiment under different water stress lev1es compared to fully watering treatment.

The positive effects of Hydrogel and bentonite on pomegranate tree growth are in harmony with (Pattanaaik, *et al*., 2015; Abobatta and Khalifa, 2019; Hamdy, *et al*., 2020; Ali, *et al*., 2023).They mentioned that addition of polymer and/or bentonite improved trees growth of lemon, orange, mandarin and red globe grapevines.

The positive effect of Hydrogel on tree growth may due to the high ability of hydrogel to retain water, which enhances vegetative growth (Green *et al*., 2004). Consequently, reduce the frequency of applied water and improve the soil's ability to store water for irrigation (Koupai, *et al*., 2008). However, because of its exceptional capacity for absorbing water which may reach to twelve to fifteen times of its dry mass.

Bentonite had a favorable influence on plant growth because of its surface's negative charge and its high cation exchange capacity (Ding, *et al*., 2009; Karimi and Salem, 2011).

3.2. Yield and fruit quality

3.2.1 No. of fruits/tree and yield

The results in Table 4 showed the number of fruits per tree grown under different water stress treatments in amended soil. The highest number of fruits per tree obtained under 75% of ETc followed by 100% of ETc treatments. While, the lowest number fruits per tree obtained with the applied 50% of ETc in both two growing seasons of this study. In addition, the applied soil amendments enhanced fruit number as compared with control treatment in both growing seasons. In general, the applied of 150g polymer/tree was the most efficient treatment for fruit production. It is evidence that the addition soil conditioners with the rate of 150 gram of polymer per pomegranate tree irrigated at depletion of 75% of ETc was the superior treatment to produce optimal fruit yield (average 28.95 Kg/tree compared to 13.32 Kg/tree in control treatments in both growing seasons, about 71.05% (Table 4).

Table 4: Impact of water stress, soil conditioners on no, of fruits/tree, yield and fruit cracking of wonderful pomegranate trees in two growing seasons.

Soil amendments	2021				2022			
	Deficit irrigation							
	100%	75%	50%	Mean	100%	75%	50%	Mean
	No. of fruits/tree							
Control	37.3 j	49.0 h	27.7 n	38.0 E	44.3 i	53.7 g	34.3 k	44.1 D
Polymer at 100g	53.0 g	62.3 c	36.0 k	50.4 C	57.6 e	60.0 d	47.6 h	55.1 B
Polymer at 150g	58.3 d	73.0 a	38.0 j	56.4A	65.7 b	75.3 a	53.6 g	64.9 A
Bentonite ate 500g	47.0 i	56.0 e	32.0 m	45.0 D	55.6 f	56.7 ef	39.3 j	50.6 C
Bentonite ate 1000g	55.00 f	64.6 b	33.3 l	51.0 B	62.6 c	63.0 c	40.6 j	55.5 B
Mean	50.1 B	61.0 A	33.4 C		57.2 B	61.7 A	43.1 C	
	Yield (kg/tree)							
Control	11.76 j	16.19 g	8.24 m	12.06 E	14.88 i	18.46 g	11.21 k	14.85 E
Polymer at 100g	18.19 f	22.59 c	11.94 j	17.57 C	20.44 e	21.99 d	16.20 h	19.54 C
Polymer at 150g	21.42 d	27.96 a	13.05 i	20.81 A	25.15 b	29.94 a	19.59 f	24.89 A
Bentonite ate 500g	15.75 h	19.70 e	10.32 l	15.26 D	19.54 f	20.25 e	13.60 j	17.80 D
Bentonite ate 1000g	19.61 e	23.86 b	11.18 k	18.22 B	22.45 d	23.81 c	14.54 i	20.26 B
Mean	17.34 B	22.06 A	10.94 C		20.49 B	22.89 A	15.03 C	
	Fruit cracking (%)							
Control	8.04 c	7.46 c	10.92 a	8.80 A	8.41 b	5.89 g	9.40 a	7.90 A
Polymer at 100g	5.01 f	3.21 g	5.56 ef	4.59 C	6.28 f	2.92 j	6.53 ef	5.24 C
Polymer at 150g	3.43 g	1.37 h	5.31 ef	3.37 D	3.96 i	1.90 k	5.82 g	3.89 D
Bentonite ate 500g	7.07 cd	5.36 ef	9.43 b	7.29 B	6.71 e	4.67 h	7.24 d	6.21 B
Bentonite ate 1000g	6.06 de	3.10 g	6.03 e	5.06 C	7.73 c	3.20 j	7.86 c	6.26 B
Mean	5.92 B	4.10 C	5.92 B		6.61 B	3.71 C	7.37 A	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

It noted that the deficit irrigation with 75% of ETc allowed the pomegranate trees to maximize utilization of available nutrients by reducing the losses of water and nutrients behind root zone of trees compared to apply excess water led to loss more water and nutrients in 100% of ETc treatment (Mohamed, *et al*., 2022).

The results resulting due to the impact of water stress on the fruits number per tree and yield were matching with the data reported by Koupai, *et al*. (2008) who found that the date palm cluster weight and yield significantly increased by 70% ETc irrigation treatment. Additionally, (Intrigliolo and Castel, 2005) on date pulp, (Cheng *et al*., 2012) on pears, and (Girona *et al*., 2009) on apples. They discovered that certain fruit plants saw an acceptable output increase under water deficit irrigation.

The enhanced impact of polymer (hydrogel) on fruit/tree and pomegranate yield can attributed to the fact that hydrogels also called "root watering crystals" because they expand like sponges, many times their initial volume, when exposed to freely available water. This reduce the number of irrigation because of increasing soil water storage (Koupai, *et al*., 2008). Furthermore, assert that hydrogels lessen nutrient loss (Hamdy, *et al*., 2020). The results of (Abobatta and Khalifa, 2019; Mohamed, *et al*., 2022; Pattanaaik, *et al*., 2015) highlight the fruits/tree and yield generated by polymer rates.

However, the results of the interaction between deficit irrigation and polymer rates in enhancing number of fruits/tree and yield are supported by (Sultana *et al*., 2016) findings, which showed that tomato plants produced more fruit when polymer was combined with the soil. According to (El-Hady and Wanas, 2006), crops cultivated in containers or on fields need less irrigation when grown with polymer addition. In addition, it enhanced water use efficiency by reducing the amount of applied water 15% of crop evapotranspiration.

3.2.2. Fruit cracking percentage, and fruit weight, fruit length and fruit diameter

Results illustrated in Table 4 showed that the applied water at 75% of ETc and adding 150g polymer/tree were most efficient treatments in reducing fruit tendency to cracking. It reached to the minimum values (3.37% and 3.89%) with applied of 150g polymer/tree in comparison with 8.80% and 7.90% in control treatment for two successive growing seasons, respectively. The similar trend obtained for fruit weight under the same treatments as shown in Table (5). The interaction between water stress and applied soil conditioners indicated that irrigation at 75% of ETc plus 150g polymer/tree gave an average value of the highest fruit length 8.6 cm compared applied water at 50% of ETc in control treatment (zero amendments) obtained average lower fruit length 6.8 cm see Table (5). The similar trend obtained for fruit diameters under the same treatments as shown in Table (5).

Table 5: The impact of deficit irrigation, soil amendments on some physical properties of wonderful pomegranate variety during the two growing seasons.

Soil amendments	2021				2022			
	Deficit irrigation							
	100%	75%	50%	Mean	100%	75%	50%	Mean
	Fruit weight (g)							
Control	314.85 j	329.55 h	297.97 k	314.12 E	336.08 j	346.46 h	326.50 k	336.34 D
Polymer at 100g	343.22 f	362.31 c	331.54 h	345.69 C	355.27 f	365.57 d	339.51 i	353.45 C
Polymer at 150g	367.10 b	383.00 a	343.40 f	364.50 A	382.48 b	397.09 a	365.32 d	381.63 A
Bentonite ate 500g	335.14 g	351.79 e	322.52 i	336.48 D	352.07 g	357.29 ef	346.49 h	351.95 C
Bentonite ate 1000g	356.55 d	368.98 b	335.54 g	353.69 B	359.34 e	377.30 c	357.80 ef	364.81 B
Mean	343.37 B	359.13 A	326.19 C		357.05 B	368.74 A	347.12 C	
	Fruit length (cm)							
Control	7.11 l	7.01 m	6.24 o	6.79 E	7.69 j	7.93 h	7.47 k	7.70 B
Polymer at 100g	7.63 f	7.74 e	7.57 g	7.65 B	8.13 f	8.37 d	7.77 i	8.09 C
Polymer at 150g	7.93 b	8.06 a	7.43 h	7.81 A	8.76 b	9.09 a	8.36 d	8.73 A
Bentonite ate 500g	7.38 j	7.91 c	6.77 n	7.35 D	8.06 g	8.18 ef	7.93 h	8.05 D
Bentonite ate 1000g	7.77 d	7.41 i	7.34 k	7.51 C	8.22 e	8.64 c	8.19 ef	8.35 B
Mean	7.56 B	7.63 A	7.07 C		8.17 B	8.44 A	7.94 C	
	Fruit diameter (cm)							
Control	7.74 m	7.96 j	7.15 o	7.62 E	8.34 j	8.61 h	8.11 k	8.35 D
Polymer at 100g	8.52 f	8.66 d	7.81 l	8.33 B	8.82 f	9.08 d	8.43 i	8.78 C
Polymer at 150g	8.84 b	9.00 a	8.33 g	8.72 A	9.50 b	9.86 a	9.07 d	9.48 A
Bentonite ate 500g	7.98 i	8.79 c	7.61 n	8.12 D	8.74 g	8.87 ef	8.61 h	8.35 D
Bentonite ate 1000g	8.64 e	8.25 h	7.86 k	8.25 C	8.92 e	9.37 c	8.88 ef	9.06 B
Mean	8.34 B	8.53 A	7.75 C		8.86 B	9.16 A	8.62 C	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

3.2.3. Fruit aril weight, weight of 100 grain and Juice volume

The interaction between water stress and addition soil amendments showed that the maximum values of fruit aril weight scored with irrigation at 75% of ETc plus 150g polymer addition soil/tree, while irrigation with 50% of ETc combined with non-addition amendments (control) achieve the lowest values in both growing seasons as shown in Table (6). The similar trend obtained for the weight of 100 grain and juice volume under the same treatments as shown in Table (6).

3.2.4. Fruit peel weight and Fruit peel thickness

The water regimes and polymer treatments showed that the applied water at 75% of ETc in soil amended with 150g polymer/tree scored the highest value of fruit peel weight, while the lowest values recorded under irrigation at 50% plus non-addition soil amendments (control) in both growing seasons as shown in Table (7). In general, applied water at 100% of ETc combined with 150g polymer/tree recorded the highest fruit peel thickness in the two growing seasons Table (7).

Table 6: Impact of water stress and soil amendments on some fruit physical properties of wonderful pomegranate variety (2021 and 2022 seasons).

Soil amendments	2021				2022			
	Deficit irrigation							
	100%	75%	50%	Mean	100%	75%	50%	Mean
	Fruit aril weight (g)							
Control	189.86 i	216.13 d	188.29 i	198.09 D	203.36 j	209.65 h	197.57 k	203.53 D
Polymer at 100g	210.44 ef	237.29 b	209.23 f	218.98 B	214.98 f	221.21 d	205.45 i	213.88 C
Polymer at 150g	218.15 d	243.47 a	210.50 ef	224.04 A	231.44 b	240.28 a	221.06 d	230.93 A
Bentonite ate 500g	195.95 h	229.27 c	203.92 g	209.71 C	213.04 g	216.20 ef	209.66 h	212.97 C
Bentonite ate 1000g	209.43 f	235.51 b	212.39 e	219.11 B	217.44 e	228.31 c	216.51 ef	220.75 B
Mean	204.76 B	232.33 A	204.86 B		216.05 B	223.13 A	210.05 C	
	Weight of 100 grains (g)							
Control	31.55 j	35.92 de	31.29 j	32.92 D	34.16 h	35.22 g	33.18 i	34.19 D
Polymer at 100g	34.31 gh	38.53 b	34.77 fg	35.87 B	36.11 ef	37.16 d	34.51 h	35.92 C
Polymer at 150g	36.25 d	43.51 a	35.29 ef	38.35 A	38.88 b	41.37 a	37.13 d	39.12 A
Bentonite ate 500g	32.57 i	37.44 c	33.89 h	34.63 C	35.79 f	36.32 e	35.22 g	35.77 C
Bentonite ate 1000g	34.81 fg	39.14 b	34.98 fg	36.31 B	36.52 e	38.35 c	36.36 e	37.08 B
Mean	33.90 B	38.91 A	34.04 B		36.29 B	37.68 A	35.28 C	
	Juice volume (m^3)							
Control	168.08 i	191.34 d	166.69 i	175.37 D	179.48 j	185.02 h	174.37 k	179.62 D
Polymer at 100g	186.31 ef	210.07 b	185.22 f	193.87 B	189.73 f	195.23 d	181.32 i	188.76 C
Polymer at 150g	193.13 d	215.55 a	186.35 ef	198.34 A	204.26 b	212.06 a	195.10 d	203.81 A
Bentonite ate 500g	173.47 h	202.97 c	180.53 g	185.66 C	188.02 g	190.81 ef	185.04 h	187.96 C
Bentonite ate 1000g	185.40 f	208.50 b	188.03 e	193.98 B	191.90 e	201.50 c	191.08 ef	194.83 B
Mean	181.28 B	205.69 A	181.37 B		190.68 B	196.93 A	185.38 C	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 7: Impact of deficit irrigation and soil conditioners on some physical properties of wonderful pomegranate fruits during 2021 and 2022 seasons.

Soil amendments	2021				2022			
	Deficit irrigation							
	100%	75%	50%	Mean	100%	75%	50%	Mean
	Fruit peel weight (g)							
Control	124.99 d	113.60 g	109.68 h	116.03 D	136.81 h	132.71 j	128.94 k	132.82 D
Polymer at 100g	132.78 c	125.02 d	122.32 e	126.71 C	144.37 d	140.29 f	134.07 i	139.58 C
Polymer at 150g	148.95 a	139.52 b	132.90 c	140.46 A	156.81 a	151.04 b	144.26 d	150.70 A
Bentonite ate 500g	139.19 b	122.53 e	118.60 f	126.77 C	141.10 ef	139.03 g	136.82 h	138.98 C
Bentonite ate 1000g	147.12 a	133.47 c	123.15 de	134.58 B	148.99 c	141.90 e	141.29 ef	144.06 B
Mean	138.61 A	126.79 B	121.33 C		145.62 A	140.99 B	137.08 C	
	Fruit peel thickness (cm)							
Control	0.32 h	0.31 h	0.31 h	0.31 D	0.31 de	0.30 e	0.30 e	0.31 D
Polymer at 100g	0.52 b	0.41 e	0.37 fg	0.43 B	0.32 cd	0.32 cd	0.31 de	0.32 C
Polymer at 150g	0.55 a	0.45 d	0.43 d	0.47 A	0.38 a	0.36 b	0.33 c	0.36 A
Bentonite ate 500g	0.48 c	0.35 g	0.37 fg	0.40 C	0.32 cd	0.31 de	0.30 e	0.32 CD
Bentonite ate 1000g	0.52 b	0.39 e	0.39 ef	0.43 B	0.34 c	0.34 bc	0.32 cd	0.34 B
Mean	0.47 A	0.38 B	0.37 B		0.34 A	0.33 B	0.32 C	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

3.2.5. Fruit T.S.S., Fruit total acidity content and TSS/acid ratio

The water regimes and polymer treatments showed that the applied water at 75% of ETc in soil amended with 150g polymer/tree scored the highest value of T.S.S., while the lowest values recorded when the irrigation water applied at 50% plus non-addition soil amendments (control) in both growing seasons as shown in Table (8). The similar trend obtained for the fruit total acidity content and TSS/acid ratio under the same treatments as shown in Table (8 &9).

Table 8: The impact of deficit irrigation and soil amendments on some fruit chemical properties of wonderful pomegranate variety (2021 &2022 seasons).

Soil amendments	2021				2022			
					Deficit irrigation			
	100%	75%	50%	Mean	100%	75%	50%	Mean
	Fruit T.S.S. (%)							
Control	17.16 i	17.23 h	16.51 n	16.96 E	17.36 g	17.45 ef	16.96 l	17.26 D
Polymer at 100g	17.48 d	17.44 e	16.81 l	17.24 C	17.43 f	17.63 b	17.19 j	17.41 B
Polymer at 150g	17.54 c	17.71 a	16.96 j	17.41 A	17.54 d	17.69 a	17.27 h	17.50 A
Bentonite ate 500g	17.28 g	17.35 f	16.74 m	17.12 D	17.44 f	17.52 d	17.09 k	17.35 C
Bentonite ate 1000g	17.36 f	17.56 b	16.89 k	17.27 B	17.48 e	17.58 c	17.23 i	17.43 B
Mean	17.36 B	17.45 A	16.78 C		17.15 C	17.57 A	17.45 B	
	Acidity (%)							
Control	1.65 b	1.62 c	1.69 a	1.66 A	1.61 a	1.54 b	1.62 a	1.59 A
Polymer at 100g	1.45 h	1.26 k	1.62 c	1.45 D	1.41 e	1.35 f	1.46 cd	1.41 D
Polymer at 150g	1.34 j	1.18 l	1.49 g	1.33 E	1.36 f	1.23 g	1.38 ef	1.32 E
Bentonite ate 500g	1.55 e	1.58 d	1.66 b	1.59 B	1.56 b	1.47 c	1.59 a	1.54 B
Bentonite ate 1000g	1.51 f	1.39 i	1.59 d	1.49 C	1.44 d	1.41 e	1.46 cd	1.43 C
Mean	1.50 B	1.41 C	1.61 A		1.47 B	1.40 C	1.51 A	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

Table 9: The impact of deficit irrigation and soil amendments on some fruit chemical properties of wonderful pomegranate variety (2021 and 2022 seasons).

Soil amendments	2021				2022			
	Deficit irrigation							
	100%	75%	50%	Mean	100%	75%	50%	Mean
	T.S.S./acid ratio							
Control	10.36 i	10.61 h	9.73 k	10.23 E	10.73 g	11.28 f	10.45 h	10.82 E
Polymer at 100g	12.02 e	13.77 b	10.37 i	12.05 B	12.36 c	12.99 b	11.72 e	12.36 B
Polymer at 150g	13.13 c	15.01 a	11.41 f	13.18 A	12.90 b	14.39 a	12.49 c	13.26 A
Bentonite ate 500g	11.13 g	10.99 g	10.06 j	10.73 D	11.16 f	11.86 e	10.71 g	11.24 D
Bentonite ate 1000g	11.47 f	12.66 d	10.60 h	11.58 C	12.14 d	12.50 c	11.81 e	12.14 C
Mean	11.62 B	12.61 A	10.43 C		11.86 B	12.61 A	11.43 C	
	Ascorbic acid (mg/100 ml juice)							
Control	15.08 m	15.22 k	14.91 n	15.07 E	14.86 l	15.29 g	14.43 n	14.86 E
Polymer at 100g	15.55 f	16.53 b	15.25 j	15.78 B	15.17 i	15.41 c	14.91 k	15.16 C
Polymer at 150g	15.74 d	16.93 a	15.53 g	16.07 A	15.43 b	15.57 a	15.27 h	15.42 A
Bentonite ate 500g	15.38 i	15.41 h	15.11 l	15.30 D	14.97 j	15.31 f	14.56 m	14.94 D
Bentonite ate 1000g	15.61 e	16.41 c	15.27 j	15.76 C	15.33 e	15.37 d	14.85 l	15.19 B
Mean	15.47 B	16.10 A	15.21 C		15.15 B	15.39 A	14.81 C	

Means followed by the same letter (s) within each row, column or interaction are not significantly different at 5% level.

3.2.6. Content of fruit ascorbic acid

The water regimes and polymer treatments showed that the applied water at 75% of ETc in soil amended with 150g polymer/tree obtained the highest value of content of fruit ascorbic acid, while the lowest values recorded when the irrigation water applied at

50% plus non-addition soil amendments (control) in both growing seasons as shown in Table (9).

The fruit quality needed best water management by reducing water losses below the root zone of trees to avoid the leaching of nutrients (Mohamed, *et al*., 2022). The results observed were agreement with outputs obtained by Zhang, *et al*., 2017. They found that pomegranate trees' output, fruit number, and weight increased with continuous irrigation at 75% of the ETc. (Galindo *et al*., 2017) also, reported that the dewatering fruit during the ripening stage enhanced quality of fruits quality. Furthermore, (Intrigliolo *et al*., 2013) demonstrated that the applied water at 25% of the ETc to pomegranate trees in at ripening stage and before maturity did not impact fruit weight, number, or yield; instead, it resulted in enhanced fruit quality, including total soluble solids. Moreover, (Laribi *et al*., 2013) discovered that applying 25% of ETc at this time resulted in fruit breaking rather than affecting yield. Fruit that receives deficient water generally has more total soluble solids (TSS) (Guizani, *et al*., 2019; Pérez-Sarmiento, *et al*., 2016). The application of polymers improved hydro-physical properties of soil which may have contributed to increase productivity and enhance fruit quality (Abedi-Koupai and Sohrab, 2004).

However, it released nutrients slowly, which increased nutrient absorption, osmotic moisture of soil and caused a decrease in transplanting stresses that caused an improvement in plant growth reaction and increase in yield. These findings on pomegranates are consistent with those of (Abobatta and Khalifa, 2019; Chidananda *et al.,* 2020). The obtained results were matching with the findings reported by (Hamdy *et al.,* 2020; Hosein-Beigi *et al*., 2019) on the impact of polymer application rates on fruit quality. The results of (Keivanfar *et al*., 2019), demonstrated that fruit production of Granny Smith apples was not significantly influenced by deficit irrigation and polymer treatments, support the interplay between deficit irrigation and polymer rates in improving fruit quality. On the other hand, fruit weight increased by 15% when 200 g/tree of superabsorbent polymer applied, compared to the control.

4. Conclusion

The results of this study indicated that the applied water at 75% of crop evapotranspiration on soil amended with 150g of polymer per tree improved the fruit characteristics of the Wonderful pomegranate variety and reduced the percentage of fruit cracking.

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