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Article

Effect of Different Rates of Irrigation, Soil Conditioners and Potassium Fertilizer on the Productivity and Fruit Characters of Valencia Orange Trees (*Citrus sinensis* L.) Under Arid Region Conditions

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Abstract: Due to the water scarcity crisis that faces various regions worldwide, there is a greater need for new management practices to sustain citrus production in arid regions. The investigation of different rates of irrigation, soil conditioners, and potassium fertilizer on the growth and productivity of Valencia orange trees was conducted in the Baloza area of North Sinai, Egypt. The treatments include two levels of irrigation (100% and 75% of water requirements) and soil application of two soil conditioners, namely Super absorbent polymer (SAP) and Polyvinyl Chloride (PVC) were added (50 g/tree) in mid-January, and two rates of potassium fertilizers (480g and 360 g/tree/year). The maximum tree growth parameters like canopy volume and chlorophyll leaf content were recorded in the trees that received 50 g of SAP and 480 g of potassium per tree under full water requirements; furthermore, various treatments enhanced the nutrition status of trees in terms of N, K and P leaf contents and reduced proline content. The highest fruit yield per tree (55.2 and 60.2 kg), total yield (9.40 and 10.23 ton/feddan), and fruit weight (190.0 and 191.9 g) were recorded in the trees that received 480 g potassium and 50g PVC under a full water requirements, while the number of fruits per tree (303.8 and 359.3) were maximized in the treatment of the lowest irrigation rate with PVC polymer and a low rate of K in the first season and in the treatment of a full water requirements with SAP polymer and a low rate of K in the second one. Furthermore, various treatments improved fruit characteristics such as fruit shape index, juice ratio and TSS/acid ratio.

Key words: Citrus trees, fruit characters, irrigation, polymer, potassium, Valencia orange, yield.

Abbreviation

RWC%: Leaf relative water content ratio

PVC: Polyvinyl Chloride SAP

Super Absorption Polymer

TLW: Turgidity leaf weight

WR: Water requirement

INTRODUCTION

The southern Mediterranean region, including the Egyptian desert regions, is characterized by hot, dry summer and water shortages, which cause annual drought stress and negatively affect crop productivity **(Zittis *et al.*, 2022)**.

Therefore, supply sufficient irrigation water is the determined factor for the growth and productivity of various crops in these regions, and moreover, constitutes water shortages are a major threat to crops grown in such areas.

Currently, there are water scarcity crises facing various arid and semiarid regions worldwide. Egypt, as a part of an arid region, has limited water resources and is facing water scarcity circumstances, which are accompanied by rising temperatures **(Daher, 2022)**. Therefore, there is more interest in coping with water shortages and improving water productivity through the use of various substances that reserve water, reduce irrigation rates, increase water efficiency and sustain the productivity of citrus varieties.

Polymer substances may play a significant role in improving agricultural production, particularly in arid and semi-arid regions, moreover, polymers are used as soil applications to enhance water holding capacity, improve water use efficiency, increase the longevity of irrigation intervals and reduce water run-off. Furthermore, hydrogels were claimed to decrease NPK leaching and reserve nutrients, particularly under sandy soil conditions, consequently improving the growth and fruiting of various crops **(Patra *et al.*, 2022; Feng *et al.*, 2020; Abobatta, 2019; Francesco *et al.*, 2015)**. Super Absorption Polymer (SAP) is one of the major polymers used for agricultural purposes due to its higher absorbing capacity and ability to preserve water **(Abrisham *et al.*, 2018)**. The hydrogel polymer compound seems to be extremely effective as a soil conditioner in fruit trees to boost fruit tree tolerance and growth in sandy or light-weight gravel substrate soils **(Abobatta and Khalifa, 2019)**.

Citrus spp., is one of the main economic fruit crops in different countries worldwide, particularly in Mediterranean climates, with citrus growing in approximately 140 countries around the world, it occupies the third position among fruit trees globally after grapevines and apples **(Zhong and Nicolosi, 2020).**

Oranges, lemons, tangerines, and grapefruits are among the most commonly grown citrus types, and they are mainly traded and consumed as fresh fruit, juice, or as concentrates. Citriculture is considered the main industry in the fruit production sector in Egypt, concerning its cultivated area, which reaches up to 493925 feddan, therefore, the harvested citrus area is increased rapidly from one year to another, with about 440210 feddan as a productive orchard that produced approximately 4.503 million tons in 2021 and was exported (1.7 million tons) in the 2020/2021 season **(Annual Reports of the Statistical Institute and Agricultural Economic Research in Egypt, 2021)**. Valencia orange (*Citrus sinensis* (L.) Osbeck), one of the important citrus varieties in Egypt and ranking second in Egyptian citriculture, with cultivated area of about 100388 feddan, represents 20.32% of total citrus cultivated area in Egypt (493925 feddan) **(Annual Reports of the Statistical Institute and Agricultural Economic Research in Egypt, 2021)**, also expressed as the late maturing orange variety since the fruit is harvested from mid-February to May **(Abobatta, 2019)**.

Mineral nutrition contributes significantly to improving plant growth. K^+, one of the main nutrients for plants, plays an important role in the growth and productivity of various crops under water shortage conditions **(Ahanger *et al.*, 2017)**.

Increasing water use efficiency, improving tree growth, and sustaining citrus crop production, under those circumstances, comparing the effect of two different types of soil conditioners, i.e., Super absorbent polymer (SAP) and Polyvinyl Chloride (PVC) are considered the main goals of this work.

This study aims to:

1) Compare the effects of various irrigation levels and soil conditioners on growth, yield, and fruit quality of Valencia orange trees.

2) Determine tree responses to various doses of potassium.

MATERIALS AND METHODS

A field experiment was carried out during two seasons (2020/21 and 2021/22) on 6-year-old Valencia orange trees (*Citrus sinensis*) budded on Volkamer lemon (*Citrus volkameriana*) planted at 5 x 5 meters apart (160 trees/feddan) grown in sandy soil under drip irrigation system with two adjustable emitters/trees (8 litter/h) through two irrigation lines in the Research Station of the Desert Research Center at Baluza, North Sinai.

Thirty-six fruitful orange trees were selected on the basis of uniformity in their size, shape, and disease-free status; furthermore, they were subject to the same horticultural practices based on the guidelines of the Ministry of Agriculture, Egypt. The experiment was laid out in a randomized complete block design (RCBD) that includes nine treatments with three replicates for each treatment.

Two irrigation level treatments were performed as follows: the control was irrigated at 100% of water requirement (WR) over the season. The treatment of deficit irrigation was 75% of water requirement, obtaining an irrigation volume corresponding to 75% of control. The tested irrigation levels were based on the water requirements of citrus and the irrigation rates used in commercial orchards under the same conditions, which ranged between 3500 and 4500 m^3/year (**El-Hamady *et al.*, 2009**).

Two types of polymers were used, namely Super Absorption Polymer (SAP) (Polymer 1) and Polyvinyl Chloride (PVC) (Polymer 2). Both types were added to the soil once at the same rate (50g/tree) in winter (mid-January) each season under the drip lines at 25-30 cm depth in both tree sides.

Two rates of potassium fertilization are used: K1 (100%) of the recommended dose (480 g/tree) and K2 (75%% of the recommendation) (360 g/tree). Potassium doses were divided into two equal portions and added as soil application in January and September each year.

Treatments

This experiment included nine treatments, as follows:

T1: Control (100% of water requirements).

T2: Irrigation 1 (100% of water requirements) + K1 (480g/tree) + polymer1 SAP

T3: Irrigation 1 (100% of water requirements) + K1(480g /tree) + polymer2 PVC

T4: Irrigation 1(100% of water requirements) + K2 (360 g/tree) + polymer1 SAP

T5: Irrigation 1(100% of water requirements) + K2 (360 g/tree) + polymer2 PVC

T6: Irrigation 2 (75% of water requirements) + K1 (480g/tree) + polymer1 SAP

T7: Irrigation 2 (75% of water requirements) + K1(480g/tree) + polymer2 PVC

T8: Irrigation 2 (75% of water requirements) + K2 (360 g/tree) + polymer1 SAP

T9: Irrigation 2 (75% of water requirements) + K2 (360 g/tree) + polymer2 PVC

This work sought to shed light on how adding a hydrogel agent, which may be employed as a water reservoir and potassium fertilization under various rates of irrigation on the growth, yield, and fruit quality of Valencia orange trees.

Data obtained and conclusions formed the response of the following parameters was used to measure the influence of various treatments.

Canopy volume (m^3)

The vegetative growth of the tree expressed as the canopy volume and was calculated according to **Zekri (2000)** equation as follows:

$$\text{Canopy volume} = 0.52 \times \text{tree height} \times (\text{diameter}^2).$$

Leaf sampling and analysis

Orange leaves were sampled once in September in each year. The leaves were sampled from the third or fourth position, 5 to 6 months old, newly flush, and non-fruiting twig on the outer canopy.

Total Chlorophyll content

Ten leaves were taken and chlorophyll content was determined using a SPAD – 502 MINOLTA chlorophyll meter.

Leaf Dry Matter %

The same leaves sample were weighted, then oven dried at 70°C until a constant weight and leaf dry matter % was calculated using equation

Leaf Dry Matter % = (leaves dry weight/ leaves fresh weight) *100.

Leaf water relation

Ten desks from ten fresh leaves were taken for each replicate and immediately weighed to obtain a leaf fresh weight, then immersed in a Petri dish overnight under dark conditions. Desks will become fully hydrated and weighed to determined turgid weight according to **(Pieczynski *et al,* 2013)**.

$$\text{Relative water content} = \frac{(\text{Fresh W.} - \text{Dry W.})}{(\text{Turged W.} - \text{Dry W.})} \quad 100$$

Determination of nitrogen, phosphorus and potassium in dry leaves of plant

Plant leaves were washed with distilled water and dried at 70 ºC. Plant samples were wet digested using H_2O_2 and H_2SO_4 according to procedure described by **Nicholson (1984)**. N, P and K were determined in acid digested solution, which was prepared according to **(Cottenie *et al.*, 1982).** Proline content: free proline content (µg/ml) in leaves was measured according to (**Bates *et al.*, 1973**).

Yield and its components

Valencia orange fruits were picked up at second half of February each season (2021 and 2022) at harvesting time, yield as number and weight of fruit per tree was determined, ten fruits from each tree were used to get the average fruit weight. This average was multiplied by the number of fruits/tree to get the yield/tree in (kg), yield (ton)/fed, and yield efficiency (kg/m^3) were calculated according **(Bassal, 2009)**.

Fruit Quality

At fruit maturity stage in each season, fruits samples were colleted from each tree to measure the following fruit physical and chemical properties.

Fruit physical characteristics

Fruit weight (g), fruit volume (cm3), juice weight (g), juice ratio (w/w), fruit length (cm) (from the top to the base of the fruit), and fruit width (cm) (the broadest width) were measured by caliper and means was used to calculate fruit shape index.

Fruit chemical properties

TSS % was determined using hand refractometer. Total titratable acidity percentage in fruit juice was determined as grams of citric acid per 100 ml of juice by titration against 0.1 N sodium hydroxide in presence of phenol phthalin as an indicator, and Vitamin C (as mg/ 100 g pulp) was determined according **(A.O.A.C., 2000)**, then TSS/acid ratio was calculated.

Statistical Analysis

The obtained data during the experiment was subjected to analysis of variances (ANOVA) according to **(Snedecor and Cochran, 1989)**. The significant differences between the means of the treatments were considered at 5% level according to Duncan's multiple test range **(Duncan, 1955)**.

Soil sampling and analysis

Soil samples were collected from the studied plots at two depths (0-30 cm and 30-60 cm) before initiating the experiment for physical and chemical properties of the used soil are shown in Tables (1) according to **(Page *et al.*, 1982)**.

Table (1). Initial status of some chemical and physical properties of the experimental soil

Depth	0-30 cm	30-60 cm
Particle size distribution %		
Sand	89.12	90.73
Silt	6.34	5.56
Clay	4.54	3.71
Texture class	sandy	Sandy
pH saturated soil paste	8.20	8.06
EC(ds/m)	1.37	1.21
Soluble ions in saturated soil extract (meq/L)		
Na	5.13	2.84
K	0.54	3.91
Ca	3.65	4.89
Mg	4.40	0.48
Cl	3.30	3.12
HCO_3	3.85	3.54
SO_4	6.57	5.47
Available nutrients (mg/kg)		
N	35	39
P	2.66	1.74
K	44	52

Determination of available nitrogen, phosphorus and potassium in soil

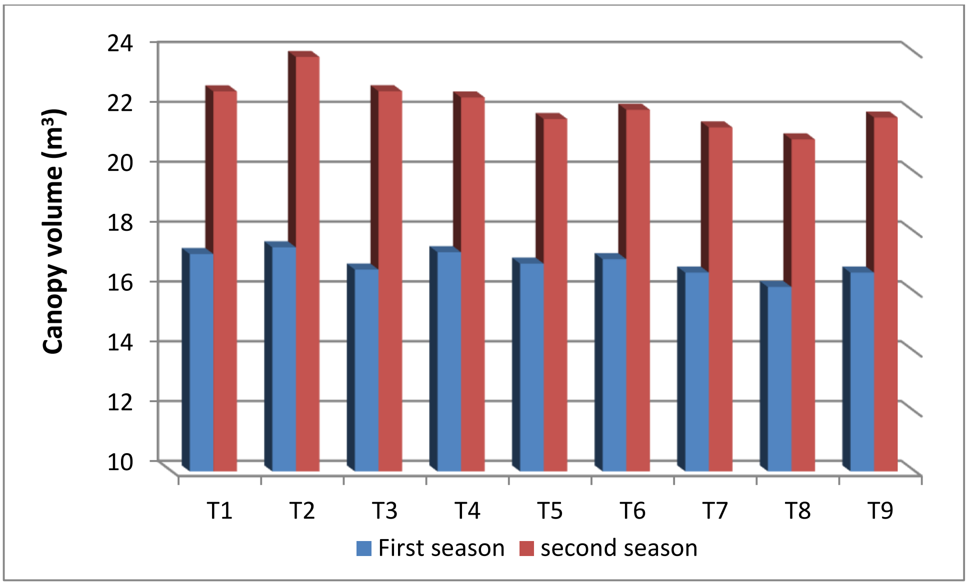
Available nitrogen in soil samples was extracted by a 2 M potassium chloride solution and determined according to **Dhank and Johnson (1990)**. Available potassium and phosphorous were measured according to the method described by **Soltanpour (1991).**

RESULTS AND DISCUSSION

Tree canopy

Data in Figure (1) showed that the T2 significantly increased tree canopy volume in both seasons (17.494 & 23.854 m^3) compared to all other treatments. Followed by T4 (17.330 m^3) in the first season and T3 (22.710 m^3) in the second one. While the lowest significant value of canopy volume (16.170 &21.00 m^3) was recorded with the T8 in both seasons.

Fig. (1). Effect of different rates of irrigation, soil conditioners, and potassium fertilizer on canopy volume of Valencia orange cultivar in 2020 and 2021 seasons.



T1 (Control), T2 (Irrigation 1 (100% of WR) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of WR.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of WR.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of WR) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of WR) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of WR.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer2 PVC).

The results indicated that using polymers and potassium increased water and nutrient absorption as well as improved soil cation exchange. The above results are in line with the findings of **Abobatta and Khalifa (2019)**, who revealed that using hydrogel composite treatment in Navel orange orchards grown in sandy soil increased tree canopy and improved tree growth. Also, **Abdel-Aziz *et al.* (2020)** claimed that using hydrogel increases the canopy of Murcott mandarin. In addition, **Pattanaaik *et al.*, (2015)** stated that polymer application increased shoot and leaf growth and increased the canopy volume of Assam lemon (*Citrus limon*).

Table (2). Effect of different rates of irrigation, soil conditioners type and potassium fertilizer rate on leaves water relations of Valencia orange in 2020 and 2021 seasons

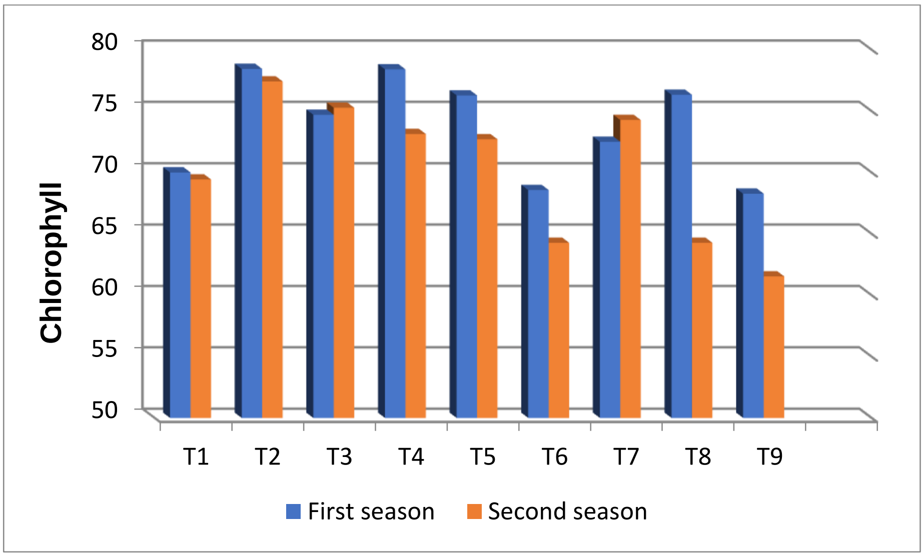
Treat.	Relative water content%		Turgidity weight (g)		Dry matter %	
	First season	second season	First season	second season	First season	second season
T1	43.040 B	40.234ABC	1.8938 D	1.8356 D	58.879 A	60.411 A
T2	54.881 A	50.063 A	1.6100 F	1.8300 D	58.687 A	60.411 A
T3	39.273 BCD	43.737 AB	1.8700 D	1.8497 D	57.470 AB	54.947 B
T4	53.060 A	41.287ABC	1.7300 E	1.9000 CD	56.100 BC	53.563 BC
T5	42.377 BC	31.833 C	1.7100 E	2.1400 A	55.270 C	54.713 B
T6	25.787 E	37.047 BC	2.2700 A	2.0600 AB	54.803 C	52.740 BC
T7	37.767BCD	36.067 BC	2.0006 C	2.0100 BC	54.130 C	54.713 B
T8	36.087 CD	30.440 C	1.8600 D	2.14٢0 A	51.120 D	54.920 B
T9	34.757 D	39.360 BC	2.1200 B	2.0300 AB	44.030 E	50.660 C

* Mean followed by the same letter\s within each column are not significantly different from each other at 0.5 % level.
* T1 (Control), T2 (Irrigation 1 (100% of WR) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of WR.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of WR.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of WR) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of WR) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of WR.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer2 PVC).

Chlorophyll content

Data in Figure (2) revealed that most of the treatments statistically increased chlorophyll content, while T2 recorded the highest significant values (77.418 & 78.435) in both seasons, while T9 recorded the lowest values (61.533 & 68.270) compared to other treatments during both seasons, the results indicated that treatments of polymer with K fertilizer improved the vegetative growth and nutritional status of Valencia orange.

Fig. (2). Effect of different rates of irrigation, soil conditioners type and potassium fertilizer rate on chlorophyll content of Valencia orange leaves in 2020 and 2021 seasons.



T1 (Control), T2 (Irrigation 1 (100% of WR) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of WR.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of WR.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of WR) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of WR) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of WR.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer2 PVC)

This finding agrees with that found by **Solanki *et al.*, (2021)** who indicated that using hydrogel improves chlorophyll leaf content in acid lime. Also, as stated by **Zoghdan and Abo El-Enien (2019)**, adequate irrigation with hydrogel and organic materials improves the vegetative growth parameters of Washington Navel orange trees.

Leaves water relation

Generally, there is a notable change in leaf water relations, such as leaf relative water content ratio (RWC%) and turgidity leaf weight (TLW), among most treatments in both seasons. Data in Table (2) showed that T2 has the highest significant increment of RWC (54.881 & 50.063%) when compared to other treatments in both seasons. While T6 recorded the lowest value (25.787) in the first season and T8 (30.440) in the second one, respectively.

Furthermore, trees that subjected to T6 was recorded the highest significant turgidity weight value (2.270) compared to other treatments in the first season, and T8 (2.142) in the second one. Contrary, the lowest significant values (1.610 & 1.830) was recorded from tree that subjected to T2 in both experimental seasons.

Leaves chemical composition

In this regard, tabulated data in Table (3) showed that T6 recorded the highest significant level of N content (2.30 & 2.31) compared to other treatments, and leaves from trees that were subjected to T9 had the lowest N values (1.96 & 2.02) in both seasons, and there was a fluctuation of other treatments effects in both seasons.

Regarding leaf content of phosphorus, the above data shows that T5 has the highest values of phosphorus (0.248 & 0.167), while, T9 recorded the lowest P values (0.118 & 0.1200) compared to other treatments in both seasons.

Moreover, results in Table (3) indicated that all treatments increased leaf K content in comparison with the control treatment. T2 recorded the highest rate of leaf K (2.21 & 2.25), followed by T4, which recorded (2.05 & 2.11), while, the lowest K leaf content (1.88 & 1.92) was recorded in the control treatment in both seasons.

Table (3). Effect of different rates of irrigation, soil conditioners type and potassium fertilizer rate on leaves chemical composition of Valencia orange in 2020 and 2021 seasons

Treat.	N%		P%		K%		Proline (µg/ml)	
	First season	second season	First season	second season	First season	second season	First season	second season
T1	2.19 BC	2.23 BC	0.165 AB	0.155 B	1.88C	1.92 C	69.88 C	78.51 C
T2	2.26 AB	2.30 AB	0.152 AB	0.147 C	2.21A	2.25 A	48.64 D	51.86 E
T3	2.05 D	2.18 C	0.147 AB	0.152 B	1.91 BC	2.01 BC	85.47 AB	61.58 D
T4	2.25ABC	2.20 C	0.150 AB	0.154 B	2.05 AB	2.11 AB	50.18 D	67.64 D
T5	2.05 D	2.09 D	0.248 A	0.167 A	1.95 BC	1.97 BC	88.06 A	88.60 A
T6	2.30 A	2.31 A	0.152 AB	0.165 A	1.97 BC	2.04 BC	76.47 BC	80.03 BC
T7	2.18 C	2.29 AB	0.135 B	0.142 D	1.94 BC	1.94 C	88.10 A	87.60 AB
T8	2.06 D	2.06 D	0.145 AB	0.147 C	2.04 BC	2.10 B	76.57 BC	85.02 ABC
T9	1.96 E	2.02 D	0.118 B	0.120 E	1.99 BC	1.99 BC	89.15 A	88.95 A

* Mean followed by the same letter\s within each column are not significantly different from each other at 0.5 % level.
*T1 (Control), T2 (Irrigation 1 (100% of WR) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of WR.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of WR.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of WR) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of WR) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of WR.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer2 PVC).

Various treatments affected leaf proline content, data in Table (4) indicated that soil application of polymer and k reduced the synthesis and accumulation of proline in tissue, which improved the growth of Valencia orange trees during the experiment.

Thus, T2 had the greatest reduction of proline in leaves and had the lowest significant values (48.64 & 51.86 µg/ml) in both seasons. On the contrary, trees subjected to T9 recorded the highest significant values (89.15 & 88.95 µg/ml), followed by T7 which recorded (88.10 & 87.60 µg/ml), then T5 (88.06 & 88.60 µg/ml) in both seasons, respectively.

The above results might be due to the positive effect of polymer in reserving humidity in sandy soil for a longer time, which increases nutrient availability and uptake, consequently, causing better assimilation of nutrients in plants and improving tree nutritional status, furthermore, increasing K availability that stimulating metabolism activity.

It could be concluded from the above results that there are significant differences between the applied treatments, especially at a high level of water and potassium, and the control treatment regarding canopy volume and the nutritional status of the tree.

These results are in agreement with **Solanki *et al.*, (2021**) on acid lime, who indicated that using hydrogel as a soil application improves nutrient retention in sandy soil.

Furthermore, the previous results are in the same line with those maintained by **(Gimeno *et al.*, 2014)** on *Citrus macrophylla* L. seedlings, who found that foliar application of potassium nitrate improved growth and reduced proline content in tissues under water deficiency conditions.

Fruit yield per tree

Data in Table (4) cleared that, the highest fruit yield in both seasons (55.20v kg/tree & 60.20 kg/tree) was recorded in trees that were subjected to T2, followed by trees that were subjected to control treatment and T9 which recorded (53.20 kg/tree & 60.04 kg/tree) in both seasons. While the lowest yield was recorded with T8 (50.81 kg/tree) in the first season and from trees that were subjected to T7 (54.50 kg/tree) in the second one.

Table (4). Effect of different rates of irrigation, soil conditioners type and potassium fertilizer rate on yield characters of Valencia orange in 2020 and 2021 seasons

Treat.	Yield (kg/tree)		Yield efficiency (kg/ m3)		Total yield (Ton/ Feddan)		Fruit number	
	First season	second season	First season	second season	First season	second season	First season	second season
T1	53.20 B	60.04 A	3.19 B	2.55 A	9.03 B	10.21 A	277.15 AB	320.39 C
T2	55.20 A	60.20 A	3.30 A	2.65 A	9.40 A	10.23 A	285.30 A	313.60 D
T3	47.64 D	57.70 ABC	2.72 F	2.57 A	8.00 D	9.80 ABC	284.05AB	359.30 A
T4	50.90 C	56.00 BCD	3.01 CD	2.58 A	8.63 C	9.50 BCD	293.00 A	327.00 B
T5	52.70 B	58.30 AB	3.08 C	2.65 A	8.97 B	9.90 AB	291.00 A	310.50 DE
T6	52.90 B	55.80 BCD	2.97 DE	2.59 A	8.20 D	9.27 CD	248.97 B	312.30 D
T7	48.20 D	54.50 CD	3.28 AB	2.60 A	9.00 B	9.47 BCD	284.20 A	319.50 C
T8	50.81 C	54.60 CD	2.91 E	2.51 AB	8.65 C	9.27 CD	303.80 A	305.43 E
T9	53.20 B	60.04 A	3.19 B	2.55 A	9.03 B	10.21 A	277.15 AB	320.39 C

* Mean followed by the same letter\s within each column are not significantly different from each other at 0.5 % level.
*T1 (Control), T2 (Irrigation 1 (100% of WR) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of WR.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of WR.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of WR) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of WR) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of WR.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer2 PVC).

Total yield per feddan

Total yield (ton/fed.) has the same trend, whereas T2 had the highest values (9.40 &10.23 ton/fed) during the experiment, which was closely followed by T1 which recorded (9.03 &10.21 ton/fed) and T9 (9.03 &10.21 ton/fed) in both seasons, respectively.

Yield increases with polymer application and potassium fertilizers may be due to increased water and nutrient availability for a longer time. Adequate K fertilizers help improve nutrient absorption under water shortage conditions.

The above results are consistent with the previous studies on mandarin, navel orange, lemon, and banana plants, which found that increasing the amount of hydrogel increased the yield (kg/tree) **(Abdel-Aziz *et al.*, 2020; Abobatta and Khalifa, 2019 and Pattanaaik *et al.*, 2015)**.

Under sandy soil conditions, there are various differences in the tree canopy volume due to many factors. Yield efficiency considers proper measurement to determine the actual effect of various treatments. Thus, data in Table (4) showed that T2 had the highest significant values (3.30 & 2.653

kg/m^3) of yield efficiency compared to other treatments without significant differences with T7 (3.28 &2.60 kg/ m^3) in both seasons, respectively.

The above-tabulated data makes it clear that trees subjected to T9 produced the highest fruit number (303.80 fruit/tree) and T6 recorded the least significant values (248.97 fruit/tree) in the first season. In the second season, T3 recorded the highest significant fruit number (359.30 fruit/ tree), whereas, the lowest values (305.43 fruit/tree) were noticed under T8 conditions.

These results agree with the study of **Abdel-Aziz *et al.* (2020)** who stated that hydrogel application improved growth, tree yield, and fruit characteristics of 'Murcott' mandarin. In addition, with those mentioned by **Zoghdan and Abo El-Enien (2019)** on Washington Navel orange trees, who claimed that acceptable irrigation with soil conditioner and organic materials increases yield and fruit quality. Also, these results conform with those of **Abobatta and Khalifa (2019)** on 'Washington Naval' orange and **Pattanaaik *et al.* (2015)** on Assam lemon (*Citrus limon*).

Fruit physical and chemical characters

According to data from Table (5), different treatments had a positive impact on fruit physical parameters such as fruit weight (g), fruit number, fruit volume (mm), and juice volume (mm) in both seasons. Meanwhile, most treatments of polymer and K fertilizer with different irrigation rates increased fruit volume and juice weight.

Tabulated data showed that the highest fruit weight (190 & 191.90 g) was recorded in trees that were subjected to T3 in both seasons. While the lowest fruit weight (156.90 g) was recorded from the control treatment in the first season and (165.50 g) from trees that were subjected to T4 in the second one.

Results in Table (5) showed that T7 recorded the highest significant increment of juice weight (73.80 g) without significant differences with, T5 (72.40 g), T1 (69.65 g) and T9 (69.50 g), while, the lowest values (58.80 g) were recorded in fruit from the application of T8 in the first season.

In the second season, T6 recorded the highest significant juice weight (92.60 g), followed by T5 (76.70 gm), while the lowest juice value (66.00 g) was recorded from trees that were subjected to T4. In addition, there were fluctuations in the effects of other treatments in both seasons respectively.

Furthermore, the highest juice ratio (43.50 %) was recorded with T7, followed by (42.08 %) from control trees in the first season. Furthermore, in the second one, trees that were subjected to T6 recorded the highest significant values (49.34 %), followed by T5 (44.75 %), while, T8 recorded the lowest values (31.37 & 31.50 %) in both seasons.

Regarding fruit volume, T4 recorded the highest values (164.71 &163.30 ml) in both seasons. While the lowest fruit volume (116.70 ml) was noticed from T7 in the first season and from T3 (135.50 ml) in the second one. Furthermore, there were fluctuations in the effects of other treatments on fruit volume in both seasons.

Concerning the effect of various treatments on fruit shape index (from round to oval shape), data in Table (5) showed that there are non-significant differences between all treatments on fruit shape index in the first season. While in the second season, T4 & T9 recorded the highest values (1.033& 1.033) and T2 recorded the lowest significant values (0.970).

Table (5). Effect of different rates of irrigation, soil conditioners type and potassium fertilizer rate on some physical characteristics of Valencia orange fruits in 2020 and 2021 seasons

Treat.	Fruit weight (g)		Juice weight (g)		Juice % (W/W)		Fruit volume (ml)		Fruit shape index	
	First season	second season	First season	second season	First season	second season	First season	second season	First season	second season
T1	156.90 F	169.64 CD	69.65A	67.80 EF	42.08 AB	39.85 DE	155.00 BC	155.04 C	0.995A	1.011 AB
T2	184.78 AB	186.53 AB	61.33B	72.38 CD	33.33 C	38.87 E	164.70 A	157.15 BC	1.028A	0.970B
T3	190.00 A	191.90 A	60.40B	70.20 DE	31.79C	36.58 F	126.00 E	135.50 G	1.000A	1.000 AB
T4	165.35 E	165.50 D	61.60B	66.00 F	39.26B	39.89D	164.71 A	163.30 A	1.000A	1.033 A
T5	173.70 D	171.40 CD	72.40A	76.70B	41.67 AB	44.75B	135.00 D	139.60 F	1.040A	1.000 AB
T6	165.35 E	187.70 A	59.60B	92.60A	32.89C	49.34A	133.30 D	143.30 E	1.000A	1.000 AB
T7	187.40 AB	178.70 C	73.80A	73.10C	43.50A	42.23C	116.70 F	149.70 D	1.000A	1.000 AB
T8	169.60 DE	170.70 CD	58.80B	56.30G	31.37C	31.50G	164.69 A	150.80 D	1.000A	1.000 AB
T9	175.10 CD	178.90 BC	69.50A	72.90C	39.69B	40.74D	154.33 C	158.50 B	1.000A	1.033A

* Mean followed by the same letter\s within each column are not significantly different from each other at 0.5 % level.
*T1 (Control), T2 (Irrigation 1 (100% of WR) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of WR.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of WR.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of WR) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of WR) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of WR.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer2 PVC).

Previous results are in agreement with **(Solanki *et al.*, 2021)** who reported that polymer and irrigation arrangement improve yield and fruit quality of acid lime.

In addition, **Nissi *et al.*, (2021)** found that the application of polymer improves fruit characters and increases the yield of sweet oranges. Also, with those mentioned by **(Abobatta and Khalifa, 2019)** observed that using hydrogel composite treatment in Navel orange trees increased tree yield and improved fruit quality.

Various treatments improved the physio-chemical characteristics of Valencia orange fruit such as TSS, acidity, TSS/acidity ratio, and vitamin C in both seasons compared to the control.

Results in Table (6) showed that T6 recorded the highest significant TSS percentage (14.00) compared to the control, followed by T7 (13.45) without significant differences with T3, T4, T7 and T8 in the first season. While in the second season, T4 recorded the highest significant values (13.70) of TSS %, on the contrary, the control treatment recorded the lowest significant values (11.53 & 11.88) in both seasons.

Regarding acidity % in fruit juice, T8 recorded the highest significant acidity ratios (1.48 & 1.39), while T7 gave the greatest significant reduction values (1.32 & 1.28) in both seasons.

Tabulated data revealed that T7 recorded the highest significant ratios of TSS/acid (10.20 & 10.90) in both seasons. On the contrary, T4 recorded the lowest significant value (7.133) in the first season and control treatment had the lowest ratio (8.735) in the second one.

Table (6). Effect of different rates of irrigation, soil conditioners type and potassium fertilizer rate on some Chemical characteristics of Valencia orange fruits in 2020 and 2021 seasons

Treat.	T S S %		Tss/acid		Acidity %		V.C (mg/100g)	
	First season	second season	First season	second season	First season	second season	First season	second season
T1	11.53 C	11.88 C	7.56 AB	8.74 B	1.42 B	1.37ABC	35.07 D	37.31 DE
T2	12.58 BC	12.31 BC	9.72 A	9.38 B	1.34 CD	1.31 CD	35.57 D	41.70 A
T3	12.90 AB	12.40 ABC	9.50 AB	9.40 B	1.36 C	1.32BCD	40.10 B	40.20 ABC
T4	13.27 AB	13.70 A	7.133 B	10.10 AB	1.35 CD	1.36ABC	37.00 C	38.20 CD
T5	12.45 BC	12.67 ABC	9.40 AB	9.70 AB	1.33CD	1.30 CD	44.100 A	42.20 A
T6	14.00 A	13.43 ABC	9.50 AB	9.80 AB	1.47 A	1.37 AB	37.00 C	35.33 E
T7	13.45 AB	13.60 AB	10.20 A	10.90 A	1.32 D	1.28 D	43.20 A	41.40 AB
T8	13.43 AB	13.10 ABC	9.10 AB	9.40 B	1.48 A	1.39 A	39.30 B	40.87 AB
T9	12.57 BC	12.67 ABC	9.30 AB	10.00 AB	1.36 C	1.27 D	37.10 C	39.00 CD

T1 (Control), T2 (Irrigation 1 (100% of WR) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of WR.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of WR.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of WR) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of WR) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of WR.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of WR) + K2 (360 g/tree)+ polymer2 PVC).

Concerning vitamin C, data in Table (6) showed that all treatments had a positive impact on vitamin C in the fruit juice compared to the control. T5 recorded the highest significant values (44.10 &44.2 mg/100 g) of vitamin C, while, the control treatment recorded the lowest values (35.07& 37.31 mg/100 g) of vitamin C in both experimental seasons.

The positive effects of treatments may be due to polymer application, which increases soil moisture for longer and improves nutrient uptake, thus stimulating growth and enhancing fruit characters, furthermore, K treatments increase soluble solids, decrease acidity in fruit, and increase fruit quality. These results are in line with those of **(Abdel-Aziz *et al.*, 2020)** on 'Murcott' mandarin; **(Abobatta and Khalifa, 2019)** on Navel orange **(Torkashvand *et al.*, 2017)**; on olive trees. **(Pattanaaik *et al.*, 2015)** on Assam lemon.

Economic study

It is clear from the data in Table (7) that yield per feddan reached 9.40 and 10.23 ton fruits in the recommended treatment, while was 8.11 and 8.93 ton in the untreated trees during both seasons. While, total costs of production if the suggested treatments (T3) were applied in one feddan cultivated with 160 Valencia orange trees reached 17, 270 and 20,750 L. E. comparing with the total costs that that reached 14,555 and 16,500 L.E. of the control treatment.

So, total income per feddan with application of the recommended treatment reached 28200 L.E. and 30,690 L.E. while, reached 18,240 L.E. and 23,520 L.E in the control treatment during experimental seasons, respectively.

Expect net profit for the recommended treatment when applied in one feddan contained 160 Valencia orange trees reached 10,930 L.E and 9,940 L.E. while, reached 3,685 L.E and 7,020 L.E in the control treatment during experimental seasons, respectively.

Table (7). Economic study of total Cost, productivity and net profit per feddan

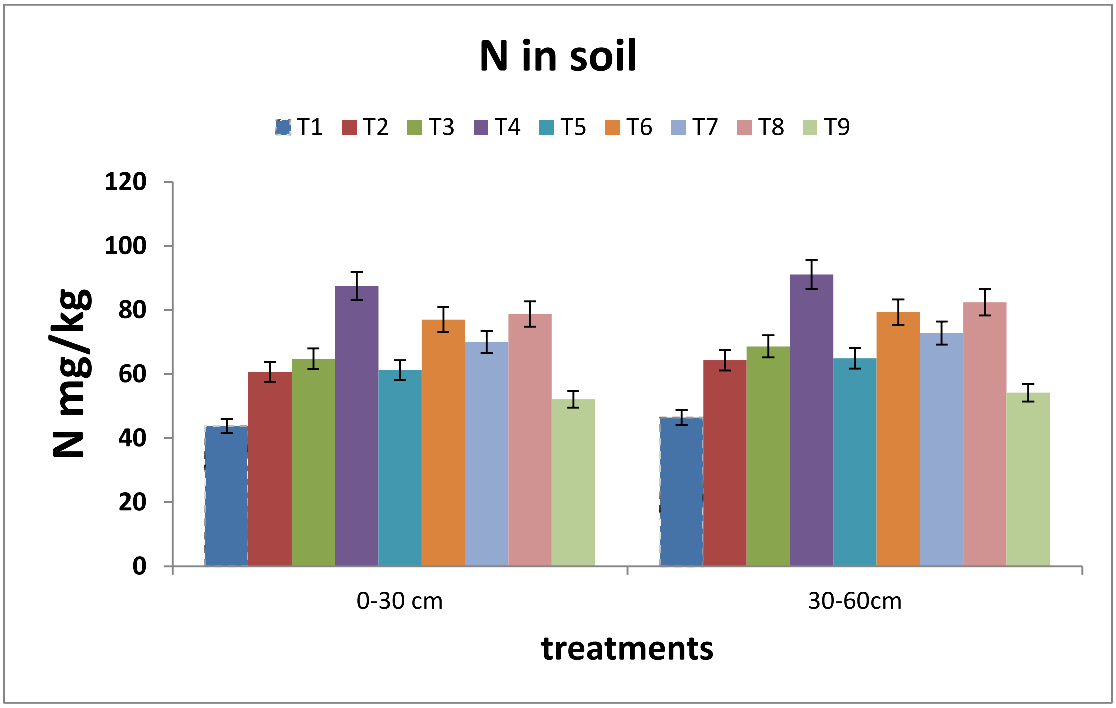
	Control		Recommended treatment (L.E.)	
	First season	**Second season**	**First season**	**Second season**
Total cost (L.E.)	14555	16500	17270	20750
Yield (ton)	6.080	6.720	9.40	10.23
Total income	18240	23520	28200	30690
Net profit	3685	7020	10930	9940

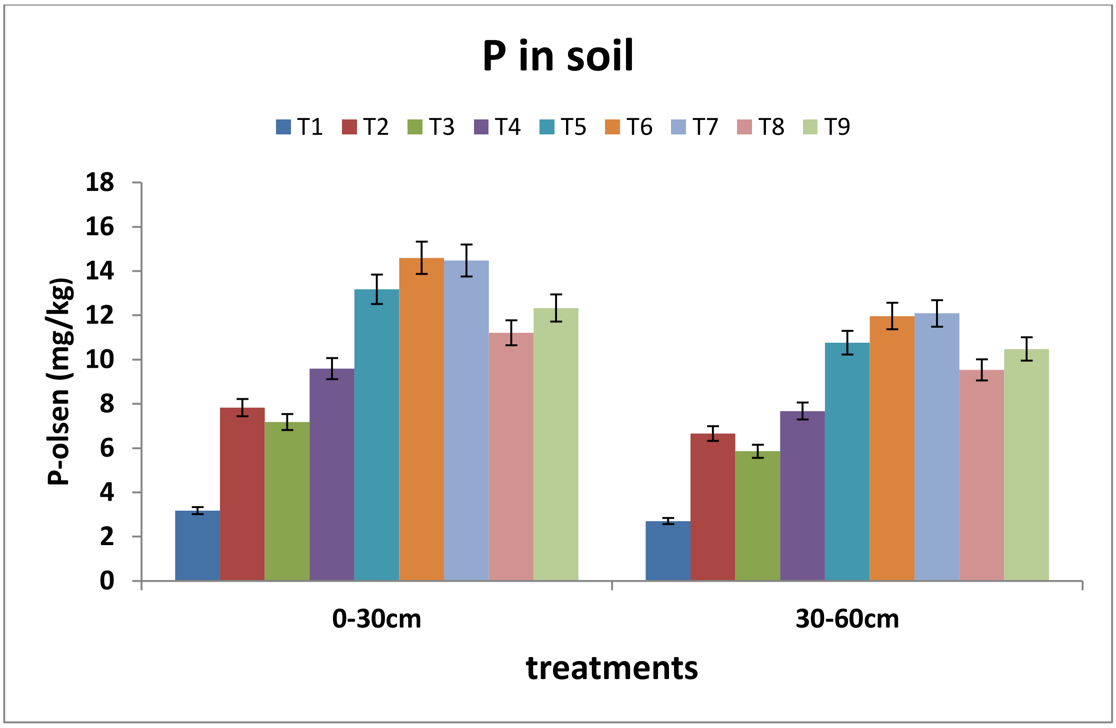
Available nitrogen, phosphorus and potassium contents in soil

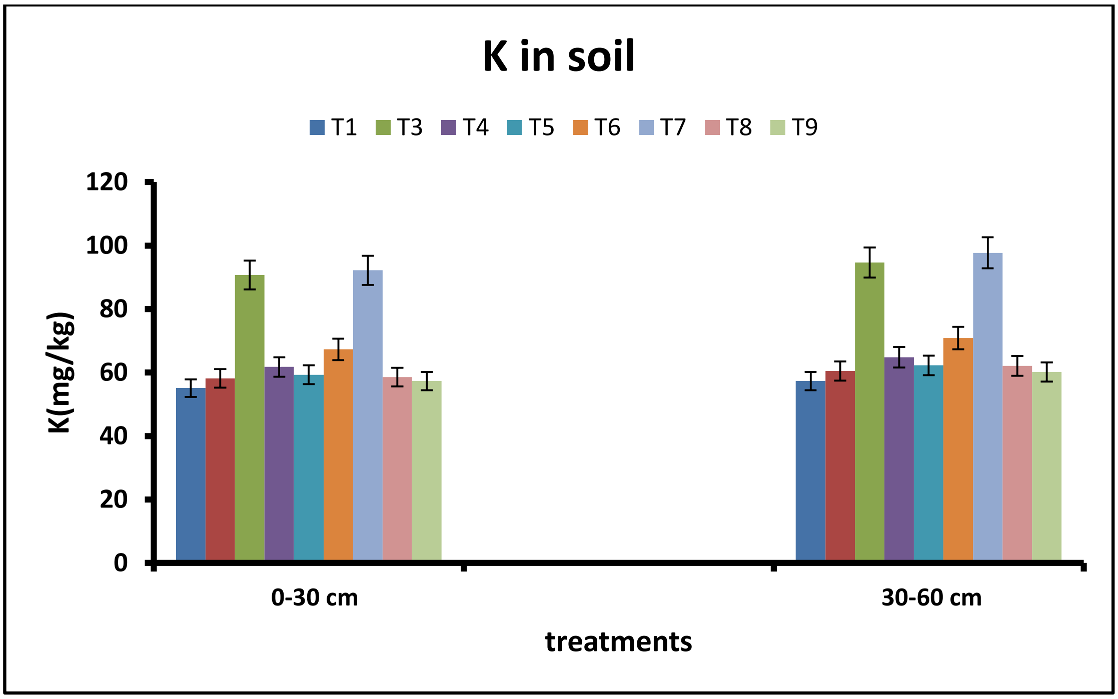
The availability of N, P and K in soil at the end of the experiment is presented in Figure (3). The addition of source of polymer and rate of potassium fertilizer under rates of irrigation were significantly increased availability N P K in soil. T3 treatment was higher increasing N availability in soil when compared with the other studied treatments and control (91.117 mg/kg). While T7 gave highest significant values of P and K availability in soil (12.087 and 97.73 mg/kg), respectively. Addition of SAP and PVC polymers in drought stress condition compares with control lead improved the nutrient availability in soil.

This result showed that SAP and PVC polymers decrease the effect of drought stress with increasing water holding capacity in soil and this cause the plant needs water later. **(Shakesby, 2000)**, who exposed that application of hydrophilic polymers with fertilizers reduced nutrient losses from soils and improved plant growth due to increase the capacity of the soil cation exchange and enhanced absorption of water and nutrition availability.

Fig. 3. Nutrient availability (NPK) in soil at two depths







T1 (Control), T2 (Irrigation 1 (100% of Fc.) + K1 (480g/tree) + polymer1 SAP), T3 (Irrigation 1 (100% of Fc.) + K1(480g /tree) + polymer2 PVC), T4 (Irrigation 1(100% of Fc.) + K2 (360 g/tree)+ polymer1 SAP), T5 (Irrigation 1(100% of Fc.) + K2 (360 g/tree)+ polymer2 PVC), T6 (Irrigation 2 (75% of Fc.) + K1 (480g/tree) + polymer1 SAP), T7 (Irrigation 2 (75% of Fc.) + K1(480g/tree) + polymer2 PVC), T8 (Irrigation 2 (75% of Fc.) + K2 (360 g/tree)+ polymer1 SAP), T9 (Irrigation 2 (75% of Fc.) + K2 (360 g/tree)+ polymer2 PVC)

The previous results seemed to be supported by those obtained by other researchers **Hegab, (2018) and Yaseen, *et al*, (2020)**. The highest N K concentration was found at soil depth 0-30 cm while the lowest N K concentration was found at soil surface (30-60 cm). It was indicated that N and K were moved downward and concentrated at the depth (30-60 cm). While the available soil P was decreased with increasing soil depth. Due to the P element had limited movement through the soil.

Conclusion

Under arid region conditions, water scarcity affected plants growth, reduce yield, and produce poor fruit quality. Therefore, using polymer substances that reserve water and increase availability of nutrients for plants for longer time, in addition adequate K fertilizers, improving growth of Valencia orange trees and the production in addition to enhancing fruit quality under water shortage conditions.

480 g K+ 50 g SAP/ tree under highest irrigation rate treatment has the vigorest tree canopy (17.49 &12.85 m^3) and highest fruit yield per tree (55.20 & 60.20 kg), fruit yield (9.40 & 20.23 ton/feddan) and highest yield efficiency (3.303&2.653), while, treatment of 50 g PVC + 480 g k/ tree under highest irrigation rate conditions maximizing fruit weight (190.0 & 191.9 g). Furthermore, various treatments improved fruit characters such as fruit shape index, Juice ratio, and TSS/acid ratio.

The promising influence of polymer and K treatments may be due to improve water holding capacity, which reserve water and nutrients, then increase continuous supply for trees which reflected in enhancing vegetative growth, increase yield, and improve fruit quality. The use of these treatments will be beneficial for improved tree growth and increase productivity under arid region conditions.

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