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Effect of Hydrogel and Foliar Spray with Potassium and Calcium on the Yield, Fruit Physical and Chemical Properties of Wonderful Pomegranate.

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ABSTRACT

This study was conducted at Orchard, which was located in the El-Bustan district, El-Behera Governorate, Egypt, in the 2019 and 2020 seasons. The main purpose of the work is to investigate the impact of applying hydrogel soil at three different rates (0.0, 50, and 100 g/tree) and five concentrations of potassium citrate and calcium chloride spray (0.0, 1.5 % potassium citrate, 3 % potassium citrate, 2 % calcium chloride and 3 % calcium chloride) on the yield and fruit quality (especially fruit cracking and sunburn damage) of Wonderfull pomegranate trees. The results revealed that the maximum number of fruits per tree, yield (kg/tree), and the minimum number of fruit cracking and sunburn damage were recorded in the trees that treated with the addition of hydrogel at 100 g/tree combined with calcium chloride foliar spray at 3%, while the best fruit physical and chemical properties were obtained with the addition of hydrogel at 100 g/tree combined with potassium citrate at 3%. It could be concluded that the application of hydrogel at 100g/tree combined with either $CaCl_2$ at 3% or Potassium citrate at 3% effectively reduced fruit cracking, and sunburn and improved the yield and fruit quality on "Wonderful" pomegranate.

Keywords: Pomegranate- Hydrogel- Potassium citrate- Calcium chloride- Sunburn damage.

INTRODUCTION

Pomegranate (*Punica granatum* L.) is an essential fruit crop grown in dry and semi-dry regions. High temperatures, irregular, low rainfall, and frequent droughts are characteristics of arid regions, and the soils have limited nutrient availability and water-holding capacity. Wonderful, among the most important cultivars of pomegranates efficiently grown in Egypt, ripens in the autumn and endures a summer of high temperatures and strong sun radiation. Summer temperatures in Egypt typically reach above 40 °C, making late cultivars much more susceptible to fruit cracking and sunburn damage. The main factors believed to be in charge of the reduction in pomegranate output are fruit issues like cracking and sunburn damage. Pomegranate fruit cracking is an essential problem that significantly inhibits the crop's cultivation. Cracking in pomegranate orchards causes a loss of roughly 50 percentage of the fruit's market value, (Bakeer, 2016). Cracked fruits further cause sunburn, ranging between 30-60 percentages of fruit unmarketable, (Melgarejo et al., 2004 and Bakeer et al., 2016). Fruit cracking is caused by several variables, such as changes in soil moisture regimes, the environment, tree nutrition, and cultivars, (Kumar et al., 2010). It could also be caused by an imbalance in moisture levels or by sharp differences in day and nighttime temperatures, (Abd El-Rhman, 2010). The main factor for cracking and sunburn is the combination of high solar radiation, low humidity, high temperatures, and low calcium concentrations, (Torres-Olivar et al., 2014). Therefore, irrigating the pomegranate trees regularly and maintaining the stability of the moisture content in the areas where the roots spread reduces fruit cracking and sunburn damage.

Hydrogel is one of the most crucial substances that is mixed into the soil to keep the root region moist. A superabsorbent polymer hydrogel may absorb water up to a hundred times its dry mass. When water is

scarce, the hydrogel's soil nutrients and water are gradually released to support plant growth (Yazdani et al., 2007). Hydrogel, also known as root watering crystals or water retention granules, swells when in contact with water, increasing soil water holding capacity and reducing irrigation frequency (Koupai et al., 2008 and Jamnicka et al., 2013). Different SAP levels can absorb and hold water, reducing drought stress effects, improving growth characteristics, and reducing catalase and peroxidase enzyme activity (Tongo et al., 2014). Abobatta (2018) noted that Hydrogel polymer has been used successfully as a soil conditioner to boost agricultural output and prevent soil water loss.(Abobatta and Khalifa, 2019), mentioned that adding the hydrogel increasing the productivity and fruit quality of Navel Orange trees. Additionally, Abdel-Aziz et al. (2020) found that in arid and semi-arid regions, applying a hydrogel agent can enhance the yield and quality of fruit produced by "Murcott" mandarin trees.

Some elements, such as potassium, also have an important role in maintaining the water balance within the plant. It is considered to be crucial for maintaining membrane potential and turgor balance, triggering enzymes and controlling osmotic pressure, stomata movement, and tropisms (Yanhai et al., 2008). Potassium is regard as a major osmotically active cation of the plant cell and plays an important role in photosynthesis, increasing enzyme activity, improving the synthesis of protein, carbohydrates, and fats, translocating photosynthesis, and improving the resistance of plants to pests and diseases, (Mehdi et al., 2007) . Moreover, Hemate et al., (2017) found that, the foliar application of some mineral nutrients, such as calcium chloride, potassium oxide, and a mix of mineral compounds at the early stages of fruit growth during two and eight weeks after full bloom in a pomegranate “Wonderful” trees improved fruit characteristics. Chidananda et al. (2020) found that, foliar application of different potassium sources produced a significant increase in all quality parameters of pomegranate cv. Bhagwa.

Also, Calcium treatment was the most effective for improving fruit qualitative characteristics including TSS, and reducing the cracking disorder, (Mahbob et al., 2019). Adel et al. (2022) found that, application of calcium nitrate and kaolin significantly reduced fruit cracking and sunburn, improved fruit content, total sugars, anthocyanin and improved fruit weight and firmness. Compared to the untreated trees, treating "Wonderful" pomegranates with 0.5% calcium chloride greatly increased the growth of shoots, fruit length, weight, and aril weight while decreasing fruit splitting, fruit sunburn, and peel anthocyanin (Attia, 2017). Calcium application to fruits improves fruit quality, increases fruit maturity, and guards against physiological deterioration (Irfan et al., 2013). Calcium is a key component in controlling how much water is absorbed by plant roots. According to reports, applying calcium treatments may decrease pomegranate cracking (Sharma, 2011 and El- Akkad et al., 2016). Calcium foliar applications enhanced fruit, quality and productivity while lowering fruit cracking, which greatly raised economic returns (Morwal and Das, 2021; Mitra, 1997; Frazier and Bowers, 1974; Young, 1957; Bakeer, 2016 and Hegazy et al., 2014).

The purpose of the current study is to evaluate the effects of three different hydrogel rates, five different spray concentrations of potassium citrate and calcium chloride, and their combinations on the Wonderful Pomegranate fruit's yield, quality, cracking, and sunburn damage.

MATERIALS AND METHODS

This study was conducted during two successive seasons of 2019 and 2020 at a private orchard which was located in the El Bustan district, El Behera Governorate, Egypt. Ten years old Wonderful pomegranate trees (*Punica granatum L.*) grown in sandy soil and spaced 4 x 3.5 m apart and subjected to a drip irrigation system from a well. Physical and chemical analysis of the experimental soil is shown in **Table (1).** Meanwhile, the chemical

analysis of the used water for irrigation is recorded in **Table (2).** Ninety trees healthy, nearly uniform in shape size and productivity and received the same horticultural practices were selected as test plants. The present study was a factorial experiment with two factors i.e. the first factor consisted of three levels of hydrogel (0.0, 50.0 and 100.0 g/tree) and the second one involved five concentrations of potassium citrate and calcium chloride spray (0.0, 1.5 (%) potassium citrate, 3 (%) potassium citrate, 2 (%) calcium chloride and 3 (%) calcium chloride). The experiment was designed as a randomized complete block design with three replicates for each treatment and each replicate was represented by two trees. However, the hydrogel was added as soil application at 20 cm depth and 1 m from the trunk at one time at the end of December. Moreover, Potassium citrate and calcium chloride treatments were sprayed four times in the first week of March, May, July and September. Meanwhile, the control trees were sprayed with tap water. Spraying was carried out using compression sprayers (5 L solution/tree) at the previously mentioned times.

Table (1). Analysis of experimental soil.

Soil depth (cm)	Texture Class	pH soil past	E.Ce (dSm^{-1})	Organic matter (%)	Soluble cations (meq/l)				Soluble anions (meq/l)			
					Ca^{++}	K^{+}	Na^{+}	Mg^{++}	Cl^{-}	$SO_4^{=}$	HCO_3^{-}	$CO_3^{=}$
0-30	Sand	7.3	1.79	0.19	7.9	0.81	4.13	5.1	4.2	5.63	6.3	-
30-60	Sand	7.9	1.73	0.17	8.5	0.79	3.11	4.8	5.8	4.7	6.5	-

Table (2). Chemical analysis of irrigation water.

PH	EC	Soluble cations mg/L				Soluble anions mg/L			
		Ca^{++}	Mg^{++}	K^{+}	Na^{+}	HCO_3^{-}	CO_3^{-}	SO_4^{-}	Cl^{-}
7.84	0.94	3.5	3.3	0.18	2.4	3.4	0	3.7	2.4

The response of Wonderful pomegranate trees to the tested treatments was evaluated through the following determinations:

- **No. of fruits/tree and yield kg/tree:** At harvest time, the number of fruits per treated tree was counted and reported then the yield (kg) per tree was weighed and recorded.
- **Fruit cracking and sunburn percentage:** Trees were observed for fruit cracking and sunburn degrees. Cracked and sunburned fruit percentages were calculated relative to the total number of fruits per tree.

Fruit cracking (%) was counted on each tree and the percentage of spilled fruit was calculated according to the equation:

$$\text{Fruit cracking (\%)} = \frac{\text{Number of cracked fruits}}{\text{Total number of fruits}} \times 100$$

Fruit Sunburn (%) was calculated as a percentage of the total number of fruits on each tree before the time of harvest according to this formula:

$$\text{Fruit sunburn\%} = \frac{\text{Number of sunburned fruits}}{\text{Total number of fruits}} \times 100$$

- **Fruit physical and chemical properties:** Ten normal fruits were taken at harvest from each treated tree for quality determination. Fruit weight (g), fruit length (cm), fruit diameter (cm), aril weight (%), peel thickness (mm) and peel weight (%) of total fruit weight were calculated. The juice was extracted and a total soluble solid (T.S.S percentage) was determined by using a hand refractometer (Chen and Mellenthin, 1981). Total acidity percentage was determined as a percentage of citric acid by titration with sodium hydroxide and using phenolphthalein 1(%) as an indicator according to the official methods of analysis (Chen and Mellenthin, 1981). The ascorbic acid content of the juice was determined by titration with 2, 6 dichloro phenol-indo-phenol (A.O.A.C., 2005), and calculated as milligrams per 100 ml of juice. Total sugars (%) determined in fresh fruit sample according to (Malik and Singh, 1980).

Statistical analysis

The measured data were statistically analyzed by MSTAT-C software and means

were differentiated using the Range test at the 0.05 level (Duncan, 1955).

RESULTS AND DISCUSSIONS

I- Yield:

- No. of fruits/tree:-

Hydrogel rates were found to increase the amount of fruits per tree **(Table 5).** In the meanwhile, hydrogel rate at 100 g/tree produced the greatest quantity of fruits per tree during both study seasons. Furthermore, in both research seasons, the high concentration of calcium chloride rate increased fruit number when compared to the control treatment. The most successful form of action in this regard was generally determined to be 3% calcium chloride therapy. However, the quantity of fruits/tree increased significantly in both seasons as a result of the hydrogel and foliar spray containing calcium chloride and potassium citrate. In this regard, 100 g hydrogel/tree in combination with a 3% calcium chloride treatment was found to be the most effective treatment.

- Yield kg/tree:-

Table (3) indicates a significant improvement in yield as hydrogel rates increased. In general, in the 2019 and 2020 seasons, the 100 g hydrogel /tree treatment scored (38.4 and 37.5 kg/tree) as opposed to (26.9 and 24.0 kg/tree) for the 0.0 g hydrogel/tree treatment (water spray), respectively. Furthermore, in both study seasons, the calcium chloride treatments had a substantial impact on the excellent productivity of pomegranate trees as compared to the control treatment. In summary, in the 2019 and 2020 seasons, the 3% calcium chloride treatment scored (39.0 and 37.8 kg/tree) compared to (21.8 and 19.5 kg/tree) for the control treatment (water spray). As compared to the control treatment, the hydrogel and foliar spray combination with the potassium citrate and calcium chloride treatments had a significantly higher beneficial impact on yield. In general, the application of 100 g hydrogel/tree in conjunction with 3% calcium chloride produced yield values that were similarly greatest in this regard.

Table (3). Effect of hydrogel, potassium citrate, calcium chloride and their combinations on fruit number and yield of Wonderful pomegranate trees (2019&2020).

Foliar spray	Hydrogel							
	0	50g	100g	Mean	0	50g	100g	Mean
	First season; 2019				Second season; 2020			
	No. of fruits/tree							
Control	57.3 k	63.0 j	72.3 i	**64.2 E**	48.6 i	55.6 h	60.6 gh	**55.0 D**
Potassium citrate at 1.5%	74.3 i	93.3 fg	99.0 de	**88.8 D**	63.3 g	83.0 e	98.0 cd	**81.4 C**
Potassium citrate at 3 %	88.3 gh	95.6 ef	102.6 cd	**95.5 C**	71.3 f	95.0 d	105.6 b	**90.6 B**
Calcium chloride at 2 %	85.3 h	104.6	112.6 b	**100.8 B**	72.3 f	93.0 d	103.3 bc	**89.5 B**
Calcium chloride at 3 %	90.6 f-h	111.0 b	119.3 a	**107.0 A**	85.0 e	99.3 b-d	115.0 a	**99.7 A**
Mean	**79.2 C**	**93.5 B**	**101.2 A**		**68.1 C**	**85.2 B**	**96.5 A**	
	Yield (kg/tree)							
Control	18.4 k	21.3 j	25.7 i	**21.8 D**	16.3 j	19.9 i	22.3 h	**19.5 E**
Potassium citrate at 1.5%	25.3 i	32.8 g	37.5 de	**31.9 C**	22.2 hi	30.9 f	38.2 cd	**30.4 D**
Potassium citrate at 3 %	31.2 g	35.3 f	40.7 bc	**35.7 B**	26.0 g	36.3 de	42.2 b	**34.8 B**
Calcium chloride at 2 %	28.4 h	36.0 ef	42.1 b	**35.5 B**	25.0 g	34.2 e	39.7 c	**33.0 C**
Calcium chloride at 3 %	31.4 g	39.4 cd	46.2 a	**39.0 A**	30.6 f	37.6 cd	45.1 a	**37.8 A**
Mean	**26.9 C**	**33.0 B**	**38.4 A**		**24.0 C**	**31.8 B**	**37.5 A**	

Means having the same letter (s) in each row, column or interaction is insignificantly different at the 5% level.

The use of hydrogel polymer had a positive impact on fruit physical qualities and yield (kg/tree) by keeping the soil wet for a longer time, which enhanced microbial activity and nutrient availability. The current findings corroborate those of Abbotta and Khalifa

(2019), who discovered that the addition of hydrogel promoted vegetative development as measured by plant height, circumference, and number of leaves per plant. Furthermore, the fruit's total soluble solids and total sugar content were increased by various hydrogel treatments, leading to an increase in fruit quality, weight, and average yield. According to Abdel-Aziz et al. (2020), in arid and semi-arid regions, applying a hydrogel agent can increase the yield and quality of fruit produced by "Murcott" mandarin trees. The findings reported by (Attia, 2017 and Adel et al., 2022) coincide with these findings.

II- Fruit cracking and sunburn percentage:

- Fruit cracking percentage:

Fruit cracking was found to be greatly reduced when hydrogel treatments were increased from 0.0 g/tree to 100 g/tree, as indicated by the results displayed in **Table (6).** In summary, the most effective treatment for lowering the fruit's propensity to break was hydrogel applied at a rate of 0.0 g/tree over both seasons. Additionally, the application of 3% calcium chloride through foliar spray treatment was successful in reducing the percentage of fruit cracking, which was previously (11.7% and 13.0%) in the control treatment for the 2019 and 2020 seasons, respectively. The fruit cracking percentage was shown to be significantly reduced in both seasons by the hydrogel and calcium chloride treatments, according to the interaction of the evaluated parameters. In both seasons, the combination of 100 g/tree treatment and 3% calcium chloride demonstrated a significant reduction in the percentage of fruit cracking, outperforming other combinations in this regard.

- Fruit sunburn percentage:

Table (4) results showed that increasing the hydrogel rates from 0.0 g/tree to 100 g/tree significantly reduced fruit sunburn damage in both seasons. When 100 g of hydrogel was applied to each tree in both seasons, the lowest significant fruit sunburn damage percentage (10.6% and 10.0%) was discovered. The lowest hydrogel rate, 0.0 g/tree, was achieved in the 2019 and 2020 seasons, respectively, and this resulted with the most serious fruit sunburn damage percentages of 12.9% and 15.5%. On the other hand, in both seasons, foliar spraying with calcium chloride decreased the percentage of sunburned fruit in wonderful pomegranate cultivars. For the 2019 and 2020 seasons, the lowest sunburn value (9.5% and 9.9%) was achieved by applying the maximum calcium chloride concentration in contrast to the control (water spray) treatment (16.9 and 18.4). However, the interaction between the two components under test revealed that, in comparison to other treatments, hydrogel plus calcium chloride treatments had a significant reductive effect on fruit sunburn damage during both seasons. In summary, the combination of 100 g hydrogel/tree treatment and 3% calcium chloride treatment outperformed other treatments in terms of lowering fruit sunburn damage during both seasons.

The fact that a cement substance is essential to keep fruit firmer, which lowers water evaporation and boosts the trees' resistance to water and drought pressures, may account for the beneficial effect of calcium in preventing fruit cracking. According to Jackman & Stanly (1995) and Tuckey (1986), calcium is linked to the stabilization of membrane systems as well as the production of calcium pectates and cell walls, which strengthen the rigidity of the fruit's central section and cell wall. The above results completely concur with the findings of El-Salhy et al. (2022), Nazan et al. (2016) and Bakeer (2016). These demonstrated how calcium chloride, either alone or in combination, improved fruit quality traits, yield, and vegetative growth parameters while lowering fruit cracking and sunburn damage. It also improved fruit protection from direct sunlight and demonstrated the role of calcium in regulating fruit physiological disorders. Furthermore, foliar calcium sprays yielded significantly higher economic returns by

increasing fruit quality, yield, and reducing fruit cracking (Sheikh and Manjula, 2012; Goargiuas, 2016; Korkmez et al., 2016, Masoud et al., 2018 and Morwal & Das, 2021). The results of studies (Attia, 2017, Abobatta and Khalifa, 2019 and Adel et al., 2022) concur with these findings.

Table (4). Effect of hydrogel, potassium citrate, calcium chloride and their combinations on fruit cracking and fruit sunburn of Wonderful pomegranate trees (2019&2020).

Foliar spray	Hydrogel							
	0	50g	100g	Mean	0	50g	100g	Mean
	First season; 2019				Second season; 2020			
	Fruit cracking (%)							
Control	15.9 a	9.8 b-d	9.4 c-e	**11.7 A**	17.4 a	11.1 bc	10.5 c	**13.0 A**
Potassium citrate at 1.5%	11.0 b	9.0 c-e	7.2 fg	**9.0 B**	12.0 b	8.9 de	7.5 f-h	**9.5 B**
Potassium citrate at 3 %	8.7 d-f	8.1 e-g	6.8 gh	**8.1 C**	10.3 c	8.7 ef	6.9 gh	**8.9 BC**
Calcium chloride at 2 %	10.3 bc	8.4 d-f	5.6 hi	**7.9 C**	11.9 b	8.5 ef	6.3 hi	**8.6 C**
Calcium chloride at 3 %	8.9 c-e	7.9 e-g	5.2 i	**7.3 C**	10.0 cd	7.9 e-g	5.6 i	**7.8 D**
Mean	**10.9 A**	**8.6 B**	**6.8 C**		**12.3 A**	**9.0 B**	**7.4 C**	
	Fruit sunburn (%)							
Control	18.3 a	16.8 b	15.7 c	**16.9 A**	20.1 a	18.3 b	16.8 c	**18.4 A**
Potassium citrate at 1.5%	14.6 d	11.9 f	11.3 h	**12.6 B**	15.4 d	13.1 f	11.2 g	**13.2 B**
Potassium citrate at 3 %	11.7 g	11.1 i	8.5 n	**10.5 C**	15.1 d	11.8 g	7.8 i	**11.5 C**
Calcium chloride at 2 %	10.3 k	12.2 e	9.0 m	**10.4 D**	13.9 e	11.4 g	8.0 i	**11.1 D**
Calcium chloride at 3 %	9.6 l	10.5 j	8.5 n	**9.5 E**	13.1 f	10.4 h	6.4 j	**9.9 E**
Mean	**12.9 A**	**12.5 B**	**10.6 C**		**15.5 A**	**12.9 B**	**10.0 C**	

Means having the same letter (s) in each row, column or interaction is insignificantly different at the 5% level.

III- Fruit physical and chemical properties:-

- Fruit weight (g):

Table (5) shows that in the first and second seasons, the weight of the wonderful pomegranate fruits produced as the amount of hydrogel increased. In both seasons, the maximum hydrogel rate of 100 g/tree produced the largest fruit weight, whereas the control treatment (water spray) produced the lowest fruit weight. Furthermore, in the first and second seasons, potassium citrate at a 3% treatment has a significantly good impact on fruit weight when compared to the control. Moreover, a high fruit weight value was obtained from the hydrogel and foliar spray combination containing calcium chloride and potassium citrate. In all seasons, the combination of 100 g hydrogel/tree treatment with a high concentration of potassium citrate (3%) therapy outperformed other combinations in this regard.

- Fruit length (cm):

Results from the first and second seasons, as displayed in **Table (5),** demonstrated that increasing hydrogel rates led to an insignificant rise in fruit length. In a short while, 100 g of hydrogel per tree produced a more positive result in his eyes. Additionally, in both seasons, the potassium citrate foliar spray increased fruit length when compared to the water spray control. In the first and second seasons, it was shown that the most beneficial treatment in this regard was the 3% potassium citrate treatment. But according to the interaction between the hydrogel and foliar spray with calcium chloride and potassium citrate treatments, in the first season of 2019, a combination of 100 g of hydrogel per tree and 3% of potassium citrate spray treatment had a highly favorable impact on fruit length. In contrast, in the second season of 2020, 100 g of hydrogel per tree in combination with two high concentrations of potassium citrate (1.5%, 3%), as well as high concentrations of calcium chloride (3%), produced a comparable and highly favorable effect on fruit length.

- Fruit diameter (cm):

Table (5) shows that the fruit's diameter considerably expanded as the hydrogel content increased. In this case, the 100 g hydrogel/tree treatment rapidly proven to be the best course of conduct. Furthermore, in both seasons, fruit diameter rose with potassium citrate foliar spray as compared to the control. In short, the best treatment for this concern was found to be 3% potassium citrate. Fruit diameter increased in both seasons when hydrogel and potassium citrate treatments were combined, according to the interaction between the two components that were studied. In general, the most effective treatment in this regard was a high dose of potassium citrate treatment (3%), combined with a high application of hydrogel treatment (100 g/tree).

Table (5). Effect of hydrogel, potassium citrate, calcium chloride and their combinations on fruit weight, fruit length and fruit diameter of Wonderful pomegranate trees (2019&2020).

Foliar spray	Hydrogel							
	0	50g	100g	Mean	0	50g	100g	Mean
	First season; 2019				Second season; 2020			
	Fruit weight (g)							
Control	321.6 k	338.6 i	355.3 f	**338.5 E**	335.3 n	357.3 k	368.3 h	**353.6 E**
Potassium citrate at 1.5%	340.6 i	351.6 g	378.6 c	**357.0 C**	350.3 l	373.0 g	390.3 c	**371.2 C**
Potassium citrate at 3 %	353.0 fg	369.3 e	397.0 a	**373.1 A**	365.0 i	382.6 e	409.6 a	**385.7 A**
Calcium chloride at 2 %	333.6 j	344.0 h	374.0 d	**350.5 D**	346.0 m	368.3 h	384.3 d	**366.2 D**
Calcium chloride at 3 %	346.6 h	355.0 f	387.3 b	**363.0 B**	360.6 j	379.3 f	392.6 b	**377.5 B**
Mean	**339.1 C**	**351.7 B**	**378.4 A**		**351.4 C**	**372.1 C**	**383.0 A**	
	Fruit length (cm)							
Control	7.51 h	7.69 gh	7.70 gh	**7.63 D**	7.24 h	7.32 gh	7.41 f-h	**7.32 D**
Potassium citrate at 1.5%	7.96 e-g	8.32 cd	8.66 ab	**8.31 B**	7.51 f-h	7.96 cd	8.52 a	**8.09 AB**
Potassium citrate at 3 %	8.22 c-e	8.39 bc	8.85 a	**8.49 A**	7.61 ef	8.23 bc	8.68 a	**8.17 A**
Calcium chloride at 2 %	7.77 f-h	8.15 c-e	8.25 c-e	**8.06 C**	7.45 f-h	7.86 de	8.43 ab	**7.91 C**
Calcium chloride at 3 %	8.04 d-f	8.34 cd	8.39 bc	**8.26 B**	7.54 fg	8.07 cd	8.66 a	**7.99 BC**
Mean	**7.90 C**	**8.18 B**	**8.37 A**		**7.47 C**	**7.88 B**	**8.34 A**	
	Fruit diameter (cm)							
Control	7.78 g	8.12 fg	8.53 de	**8.14 D**	7.26 i	7.69 hi	7.80 gh	**7.58 C**
Potassium citrate at 1.5%	8.16 e-g	8.64 d	9.43 ab	**8.81 B**	7.93 gh	8.17 e-g	8.95 a-c	**8.35 B**
Potassium citrate at 3 %	8.72 cd	8.87 cd	9.77 a	**9.12 A**	8.09 f-h	8.69 b-d	9.37 a	**8.71 A**
Calcium chloride at 2 %	8.03 g	8.61 d	9.07 bc	**8.57 C**	7.88 gh	8.70 b-d	8.49 d-f	**8.35 B**
Calcium chloride at 3 %	8.50 d-f	8.83 cd	9.10 bc	**8.74 BC**	8.07 f-h	8.58 c-e	9.09 ab	**8.58 AB**
Mean	**8.24 C**	**8.61 B**	**9.18 A**		**7.84 C**	**8.36 B**	**8.74 A**	

Means having the same letter (s) in each row, column or interaction is insignificantly different at the 5% level.

- Fruit aril percentage:

According to **Table (6)**, increasing hydrogel rates had significant effects on the percentage of fruit aril. In summary, hydrogel at 100 g/tree showed out to be a better treatment in this regard. Additionally, in both seasons, the potassium citrate foliar spray treatment increased the percentage of fruit arils when compared to the control. The most successful treatment in this regard was generally found to be the 3% potassium citrate treatment. Furthermore, the results of the study indicate that the combination of hydrogel at a rate of 100 g/tree and potassium citrate at a treatment of 3% produced the highest fruit aril percentage in both seasons when applied as foliar spray alongside calcium chloride and potassium citrate treatments.

- Fruit peel percentage:-

As seen in **Table (6),** increasing the hydrogel rates from 0.0 g/tree to 100 g/tree results in a significant decrease in the percentage of fruit peel. Using 100 g of hydrogel per tree in both seasons produced the lowest noted fruit peel percentage. In

contrast, the control treatment in 2019 and 2020 yielded the highest significant fruit peel percentage. In both study seasons, the magnificent pomegranate cultivar produced the highest fruit peel percentage when treated with a 3% calcium chloride foliar spray. In the first and second seasons, the non-addition hydrogel treatment (control) in combination with 3% calcium chloride treatment yielded the highest fruit peel percentage, according to the interaction between the two evaluated parameters.

- Fruit peel thickness

Table (6) demonstrates that higher hydrogel rates had a detrimental effect on fruit peel thickness. In general, the non-addition of hydrogel (control treatment) achieved the highest fruit peel thickness values for both seasons. Furthermore, compared to the control treatment (water spray), a high concentration of calcium chloride (3%), enhanced fruit peel thickness significantly. Additionally, it was found that the combination of a high concentration of calcium chloride (3%), along with the absence of hydrogel treatment (control), produced the highest value of fruit peel thickness in the first season when hydrogel rates and foliar spray with potassium citrate and calcium chloride treatments were combined. In contrast, a statistically comparable and significantly positive impact on fruit skin thickness was observed in the second season when the non-addition hydrogel treatment (control) was supplemented with 2% or 3% calcium chloride.

The use of hydrogel polymer had a positive impact on fruit physical qualities and yield (kg/tree) by keeping the soil wet for a longer period of time, which enhanced microbial activity and nutrient availability. These findings on pomegranates are consistent with those of Abobatta and Khalifa, 2019 and Chidananda et al., 2020. These findings concur with those of (Attia, 2017, and Adel et al., 2022).

Table (6). Effect of hydrogel, potassium citrate, calcium chloride and their combinations on fruit aril percentage, fruit peels percentage and fruit peel thickness of Wonderful pomegranate trees (2019 & 2020).

Foliar spray	Hydrogel							
	0	50g	100g	Mean	0	50g	100g	Mean
	First season; 2019				Second season; 2020			
	Fruit aril (%)							
Control	54.3 j	55.8 f	58.6 b	**56.2 B**	55.8 g	56.6 f	58.2 d	**56.9 B**
Potassium citrate at 1.5%	54.6 i	56.4 e	57.9 c	**56.3 B**	56.6 f	55.7 g	58.3 d	**56.9 B**
Potassium citrate at 3 %	57.8 c	58.7 b	60.6 a	**59.1 A**	59.2 c	59.4 b	60.1 a	**59.6 A**
Calcium chloride at 2 %	54.1 k	55.6g	57.1 d	**55.6 C**	55.3 h	56.7 f	57.5 e	**56.5 C**
Calcium chloride at 3 %	53.2 l	55.3 h	56.5 e	**55.1 D**	54.6 j	55.1 i	56.7 f	**55.4 D**
Mean	**54.8 C**	**56.3 B**	**58.1 A**		**56.3 C**	**56.7 B**	**58.2 A**	
	Fruit peel (%)							
Control	45.6 c	44.2 g	41.4 k	**43.7 C**	44.2 d	43.3 e	41.7 g	**43.1 C**
Potassium citrate at 1.5%	45.3 d	43.5 h	42.1 j	**43.6 C**	43.3 e	44.3 d	41.6 g	**43.1 C**
Potassium citrate at 3 %	42.1 j	41.2 k	39.4 l	**40.9 D**	40.7 h	40.6 i	39.8 j	**40.3 D**
Calcium chloride at 2 %	45.9 b	44.3 f	42.8 i	**44.3 B**	44.6 c	43.3 e	42.4 f	**43.4 B**
Calcium chloride at 3 %	46.7 a	44.6 e	43.4 h	**44.9 A**	45.3 a	44.9 b	43.3 e	**44.53 A**
Mean	**45.2 A**	**43.6 B**	**41.8 C**		**43.6 A**	**43.3 B**	**41.7 C**	
	Peel thickness (cm)							
Control	0.38 l	0.37 m	0.30 n	**0.35 E**	0.42 i	0.41 j	0.35 k	**0.39 E**
Potassium citrate at 1.5%	0.48 f	0.41 k	0.42 j	**0.44 D**	0.46 f	0.44 g	0.43 h	**0.44 D**
Potassium citrate at 3 %	0.51 d	0.44 h	0.44 i	**0.46 C**	0.49 c	0.47 e	0.44 g	**0.47 C**
Calcium chloride at 2 %	0.52 c	0.52 c	0.47 g	**0.50 B**	0.53 a	0.48 d	0.49 c	**0.50 B**
Calcium chloride at 3 %	0.55 a	0.54 b	0.50 e	**0.53 A**	0.53 a	0.51 b	0.51 b	**0.52 A**
Mean	**0.49 A**	**0.46 B**	**0.42 C**		**0.49 A**	**0.46 B**	**0.44 C**	

Means having the same letter (s) in each row, column or interaction is insignificantly different at the 5% level.

- Fruit total soluble solids (%):

Table (7) shows that there was a significant increase in the total soluble solids content with increasing hydrogel rates. In this regard, the maximum significant total soluble solids content was found at the highest hydrogel rate of 100 g/tree. Furthermore, in both seasons, the total soluble solids content was statistically positively impacted by a high concentration of potassium citrate treatments at 3%. Nonetheless, the hydrogel and foliar spray treatments with potassium citrate and calcium chloride showed that the combination of 100 g/tree treatment and 3% potassium citrate treatment had a very favorable impact on the total soluble solids content. Conversely, the hydrogel application at 0.0 g/tree treatment in conjunction with the water spray treatment produced the lowest value in this regard. An intermediate value was assigned to this concern by another combination.

- Fruit Ascorbic acid content"

Table (7) indicates a constant but significant rise in the ascorbic acid concentration with increasing hydrogel rates. In short, the better treatment in this case showed out to be the 100 g/tree therapy. In contrast, a 3% potassium citrate therapy had a significant beneficial impact on the ascorbic acid content during the first and second seasons. Furthermore, a combination of 100 g hydrogel/tree treatment with a high concentration of potassium citrate at 3% extracts a strong favorable effect in this concern, as demonstrated by the interaction between the hydrogel and foliar spray with potassium citrate and calcium chloride.

- Fruit total acidity (%):

Comparing the fruit's overall acidity to the control, **Table (7)** showed that high hydrogel application rates of 50 and 100 g/tree produced a significant reductive impact. Throughout both seasons, the most effective therapy for lowering the overall acidity of fruit was the 100 g hydrogel/tree treatment. In addition, fruit total acidity was successfully decreased in the first and second seasons by applying a foliar spray treatment of potassium citrate at 3%.

Table (7). Effect of hydrogel, potassium citrate, calcium chloride and their combinations on total soluble solids content, vitamin C and total acidity of Wonderful pomegranate trees (2019&2020).

Foliar spray	Hydrogel							
	0	50g	100g	Mean	0	50g	100g	Mean
	First season; 2019				Second season; 2020			
	TSS (%)							
Control	15.11 h	15.22 h	15.35 h	**15.23 C**	15.82 m	16.14 l	16.24 k	**16.06 D**
Potassium citrate at 1.5%	15.81 g	15.92 e-g	16.39 bc	**16.04 B**	16.72 i	16.82 g	17.31 c	**16.95 C**
Potassium citrate at 3 %	16.13 d-f	16.17 c-e	16.67 a	**16.32 A**	17.04 f	17.07 e	17.58 a	**17.23 A**
Calcium chloride at 2 %	15.95 e-g	15.82 g	16.28 b-d	**16.02 B**	17.02 f	16.72 i	17.19 d	**16.98 B**
Calcium chloride at 3 %	15.78 g	15.89 fg	16.46 ab	**16.02 B**	16.68 j	16.80 h	17.36 b	**16.95 C**
Mean	**15.76 B**	**15.80 B**	**16.23 A**		**16.65 C**	**16.71 B**	**17.13 A**	
	Vitamin C (mg/100ml)							
Control	11.34 o	13.12 n	13.50 m	**12.65 E**	12.91 o	13.52 n	14.15 m	**13.53 E**
Potassium citrate at 1.5%	14.76 h	14.83 g	16.83 b	**15.47 B**	14.48 j	15.79 e	16.48 b	**15.70 B**
Potassium citrate at 3 %	15.03 f	15.27 e	16.99 a	**15.76 A**	14.96 i	15.74 f	16.77 a	**15.82 A**
Calcium chloride at 2 %	13.92 l	14.42 j	16.35 d	**14.90 D**	14.60 k	15.18 h	15.89 d	**15.22 D**
Calcium chloride at 3 %	14.23 k	14.62 i	16.69 c	**15.18 C**	14.51 l	15.62 g	16.22 c	**15.45 C**
Mean	**13.85 C**	**14.45 B**	**16.07 A**		**14.36 C**	**15.17 B**	**15.90 A**	
	Total acidity (%)							
Control	1.46 a	1.40 b	1.38 b	**1.41 A**	1.36a	1.31 bc	1.28 c	**1.31 A**
Potassium citrate at 1.5%	1.30 c	1.13 e	0.88 h	**1.10 D**	1.21 d	1.05 g	0.84 j	**1.03 D**
Potassium citrate at 3 %	1.27 c	1.10 e	0.81 i	**1.06 E**	1.17 e	1.02 g	0.75 k	**0.98 E**
Calcium chloride at 2 %	1.41 ab	1.21 d	1.04 f	**1.22 B**	1.32 b	1.12 f	0.98 h	**1.14 B**
Calcium chloride at 3 %	1.29 c	1.15 e	0.98 g	**1.14 C**	1.19 de	1.05 g	0.92 i	**1.05 C**
Mean	**1.34 A**	**1.20 B**	**1.01 C**		**1.25 A**	**1.11 B**	**0.95 C**	

Means having the same letter (s) in each row, column or interaction is insignificantly different at the 5% level.

On the other hand, a high reductive effect on fruit total acidity was caused in both seasons by hydrogel foliar spray with potassium citrate and calcium chloride treatments, according to the interaction of two evaluated components. Overall, the combination of 100 g hydrogel/tree treatment and 3% potassium citrate had a significant reductive effect on the overall acidity of the fruit, outperforming other combinations in both seasons.

A review of the aforementioned findings, it is possible to conclude that the hydrogel polymer application improved the chemical characteristics of the fruit by keeping the soil moist for an extended period of time, increasing microbial activity, and increasing nutrient availability. The use of potassium citrate improved fruit quality, yield, plant development, and nutrient uptake. The results given are consistent with the pomegranate research conducted by Mahbob et al., 2019 and Abdel-Aziz et al., 2020. The outcomes that (Attia, 2017, Abobatta and Khalifa, 2019 and Adel et al., 2022) obtained concur with these findings.

Conclusion:

Results show that applying hydrogel to the soil at a rate of 100g/tree and calcium chloride foliar spray at a concentration of 3% alone or in combination, as well as applying hydrogel to the soil at a rate of 100g/tree and potassium citrate foliar spray at a concentration of 3% alone or in combination, improved productivity, and fruit quality of the Wonderful pomegranate cultivar and reduced fruit cracking and sunburn damage.

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تأثير الهيدروجيل والرش الورقى بالبوتاسيوم والكالسيوم على المحصول والصفات الطبيعية والكيماوية لثمار الرمان وندرفول

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تم تنفيذ هذه التجربة في منطقة البستان بمحافظة البحيرة بمصر خلال موسمي 2019 و2020. وكان الهدف الرئيسي من هذه التجربة هو دراسة تأثير ثلاثة معدلات من الإضافة الأرضية بمادة الهيدروجيل (0.0، 50، 100 جرام/شجرة) والرش الورقى بخمسة تركيزات هي: معاملة المقارنة (الكنترول)، سترات البوتاسيوم (1.5 و 3 %)، كلوريد الكالسيوم (2 و 3 %) على المحصول وجودة الثمار (خاصة تشقق الثمار والأضرار الناتجة عن لسعة الشمس) لأشجار الرمان صنف وندرفول.

أوضحت النتائج أن أعلى عدد ثمار لكل شجرة والمحصول (كجم/شجرة) وأقل عدد لتشقق الثمار وأضرار لسعة الشمس تم تسجيلها في الأشجار المعاملة بالإضافة الأرضية بالهيدروجيل بمعدل 100 جم/شجرة مع الرش الورقي بكلوريد الكالسيوم بتركيز 3 %، بينما تم الحصول على أفضل الخواص الفيزيائية والكيميائية للثمار بالإضافة الأرضية بالهيدروجيل بمعدل 100 جم/شجرة مع سترات البوتاسيوم بتركيز 3 %. وعموما الإضافة الأرضية بالهيدروجيل بتركيز 100 جرام/شجرة مع كلوريد الكالسيوم بتركيز 3 % أو مع سترات البوتاسيوم بتركيز 3 % قلل بشكل فعال من تشقق الثمار ولسعة الشمس وأعطى أعلى محصول وجودة لثمار الرمان صنف وندرفول.