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(Original Article)

The Impact of Calcium Chloride, Potassium Nitrate and Flower Thinning on Yield Component and Fruit Quality of Manfalouty Pomegranate Cultivar

Aiman K.A. Mohamed*; Mokhtar M. Shaaban; Aliaa M. Abd El-Hamid and Azza S. Hussein

Pomology Department, Faculty of Agriculture, Assiut University, Assiut, Egypt

*Corresponding author email: azza.mohamed@agr.aun.edu.eg
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Abstract

Pomegranate growers in Egypt have been struggling with a variety of production issues, including splitting, sunburn, and a lack of proper colour intensity and consistency, which are major barriers to attaining high quality fruit. The current research aims to evaluate the impacts of calcium chloride ($CaCl_2$), potassium nitrate (KNO_3), and flower thinning on reducing these problems and enhancing fruit quality. Seven treatments were carried out, including foliar application with $CaCl_2$ 2 and 4%, KNO_3 250 and 500 ppm alone or combined with flower thinning and control (spraying with water). The spraying treatments took place three times, at the beginning of flowering (in Apr.), after fruit set completion (first Jul.), and before harvest (first Sept.), during the two study seasons. Hand flower thinning was done to all of the flowers that surged from the last week of May until the end of the flowering period. The obtained results indicated that spraying 500 ppm KNO_3 or 4% $CaCl_2$ alone or combined with flower thinning are regarded as the best treatments in terms of their impact on the yield components, fruit quality, anthocyanin content, and reducing fruit cracking.

Keywords: *Flower thinning, Anthocyanin, Fruit cracking*

Introduction

One of the best fruits for tropical, subtropical, and even temperate regions is the pomegranate (Reddy and Prasad, 2012; Sheikh and Manjula, 2012 and Bakeer, 2016). In many areas of the Middle East, North Africa, Asia, and the Mediterranean, it is a significant commercial fruit crop that is widely grown (Sarkhosh *et al*., 2006). Its fruits are regarded as attractive, abundant sources that are popular for giving consumers vitamin C, vitamin K, fibre, and calorie-free juice (Gunnaiah *et al*., 2010 and Fawole and Opara, 2013).

The high concentration of bioactive phytochemicals like polyphenolic compounds, flavonoids, vitamins, and anthocyanin in pomegranate fruits, however, has recently led to a rapid increase in both production and consumption (Liu *et al*., 2021; Sau *et al*., 2021 and Tozzi *et al*., 2022). Manfalouty is regarded

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as one of the most substantial pomegranate cultivars that was successfully established in Upper Egypt, particularly in Assiut Governorate.

Fruit cracking is one of the key issues that pomegranate growers deal with. About 30-60% of fruit is rendered unmarketable due to sunburn when fruits are cracked (Abd El-Rhman, 2010 and Bakeer, 2016). The variables that cause fruit cracking include changing soil moisture, hot, dry weather, climatic circumstances, tree nutrition and cultivars (Sheikh and Manjula, 2012; Galindo *et al*., 2014; Hegazi *et al*., 2014 and Thomidis, 2014).

The most crucial mineral for maintaining the strength and stability of cell structures is calcium (Ca) (Elmer *et al*., 2007). It has been thoroughly examined as both a necessary element and its possible role in preserving the quality of fruit crops after harvest by helping to bind pectin molecules within the cell wall (Arhtar *et al*., 2010).

Potassium (k) is essential for several processes, including protein synthesis, enzyme activation, ion absorption and transport, and photosynthesis (Mengel, 2007). Fruit quality is enhanced by potassium through an increase in fruit size, juice content, colour, and flavour (Ashraf *et al*., 2010). Due to its significant roles in wide range of plant processes, including the biosynthesis of proteins like cytochrome and ferredoxin, nitrogen fixation, the electron transport chain complex, and the structure of nitrate-absorbing enzymes, K fertilization has been shown to increase pomegranate fruit yield (Al-Bamarny *et al*., 2010; Marschner, 2012 and Hamouda *et al*., 2015).

Flower thinning is considered an important horticultural practice that commonly used in fruit orchards in order to enhance the fruit quality. In pomegranate, El-Sese (1988a), El-Sese and Mohamed (2005) and El-Mahdy *et al*. (2010) found that flower thinning of Manfalouty pomegranate cultivar resulted in decreased fruit splitting and increased fruit quality.

Therefore, the purpose of the present investigation was to ascertain how the Manfalouty pomegranate cultivar's yield components and fruit quality indices were affected by the application of calcium chloride, potassium nitrate, and flower thinning.

Materials and Methods

Plant materials and Treatments

This study was conducted during two successive seasons of 2020 and 2021 on Manfalouty pomegranate cultivar grown at the Experimental Orchard of the Faculty of Agriculture, Assiut University. Twenty-eight uniform trees were chosen and divided into seven treatments, including the control, and each treatment was applied to four trees (replicates).The trees grown in heavy loam soil and spaced at 5x5 m apart. Regular agricultural managements were applied to all experimental trees as recommended. The treatments were carried out including foliar application with $CaCl_2$ 2 and 4%, KNO_3 250 and 500 ppm alone or combined with flower thinning and control (spraying with water).

Treatments were sprayed three times, at the beginning of flowering (in Apr.), after fruit set completion (first Jul.), and before harvest (first Sept.), during the two study seasons. Hand flower thinning was done to all of the flowers that surged from the last week of May until the end of the flowering period as recommended by El-Sese (1988a,b) and (El-Sese and Mohamed 2005).

Plant measurements

Yield components

At harvest, the fruits of all the treated trees were picked at mid-October in both seasons. Fruits were counted and weighted to determine the total yield weight (kg/tree) and calculate the average fruit weight (g). Additionally, the cracked fruits were sorted, counted, and weighted. The percentage of fruit cracking in relation to the total number of fruits was then calculated.

Fruit sensory attributes

Total acidity was determined using titration with 0.1 N NaOH and phenolphthalein as an indicator, then expressed as citric acid, according to the following equation (AOAC, 1995):

$$\text{Acidity \%} = \frac{\text{NaOH volume in titration x NaOH molarity x equivalent weight of citric acid}}{\text{1000 x sample volume}} \times 100$$

Where Equivalent weight of citric acid = 64, NaOH molarity = 0.1M, Sample vol. = 5 ml.

Total soluble solids (TSS %) was measured using the hand refractometer, and then the ratio of TSS to acidity was calculated. The percentage of reducing sugars in juice was determined, according to AOAC (1995).

Total anthocyanin content (TAC) of juice

Extracts were prepared by the method described by Onayemi *et al*. (2006). 1 ml fresh juice samples were pulverized with 20 ml solution of 85 ethanol and 1.5 M HCL (by volume). The samples were covered and kept overnight in a deep freeze. The extracts were completed to 50 ml of the solvent and then the solution absorbance was measured at a wavelength of 530 nm, using spectrophotometer (Unico 1200-USA). The result is expressed as mg/100 g of fresh juice. Total anthocyanin was calculated using the following equation developed by Lees and Francis (1971).

$$\text{Total anthocyanin (mg/100 g fresh juice)} = \frac{\text{A } 530 \times \text{V}}{98.2 \times \text{W}}$$

Where: A530 is the rate of absorption of the sample at the wavelength of the subtitle A. for example, A530 is the absorption at a wavelength of 530 nm., V = total volume of extract (ml), W = weight of fresh sample (mg).

Statistical analysis

The experiment was designed as a complete randomized block design (CRBD) with seven treatments and four replicates for each treatment. Combined analysis over seasons was used. The SAS program version 9.2 (SAS, 2008) was used for the analysis of variance (ANOVA), and the means were compared using the LSD values at the 5% level of probability (Snedecor and Cochran, 1990).

Results

Yield components and fruit cracking %

The results displayed the extent to which all the treatments were positive in their effect on the total yield/tree compared to the control during the two seasons of study (Fig. 1 A). In addition, the best influencing treatment on the yield was KNO_3 at 500 ppm followed by the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) and $CaCl_2$ at 4%, which gave an average yield 69.5, 66.5 and 61.4 (kg/tree) with an increment of 43.0, 36.8 and 26.3% over the control treatment, respectively, while the lowest impact influence was the control treatment.

The results indicated that there were no significant differences between the two $CaCl_2$ concentrations and KNO_3 at 250 ppm, however, the concentration of $CaCl_2$ at 4% was more effective than the two other treatments in its effect on fruit weight (Fig. 1 B). Moreover, the best treatment in its effect on the average fruit weight was KNO_3 at 500 ppm, which gave the highest enormousness of average fruit weight 475.5 g with an increment of 26.3%, followed by the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) and $CaCl_2$ at 4% which gave an average fruit weight of 450.6 and 442.4 g with an increment of 19.6 and 17.5% over the control, respectively, whereas, the control treatment gave the lowest value as an average of the two seasons of study.

The results exposed that all treatments caused a decrease in the percentage of fruit cracking in comparison to the control treatment, and these differences were significant as an average of two successive seasons (Fig. 1 C). Likewise, the KNO_3 at 500 ppm treatment is considered the best in obtaining the least fruit cracking compared to other spraying treatments and the control. It gave 2.8% of fruit cracking as an average of two seasons, with a decrement of 70.5% than control, followed by each of the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) and KNO_3 at 250 ppm, while the control treatment gave the highest values (9.5%) as an average of the two successive seasons.

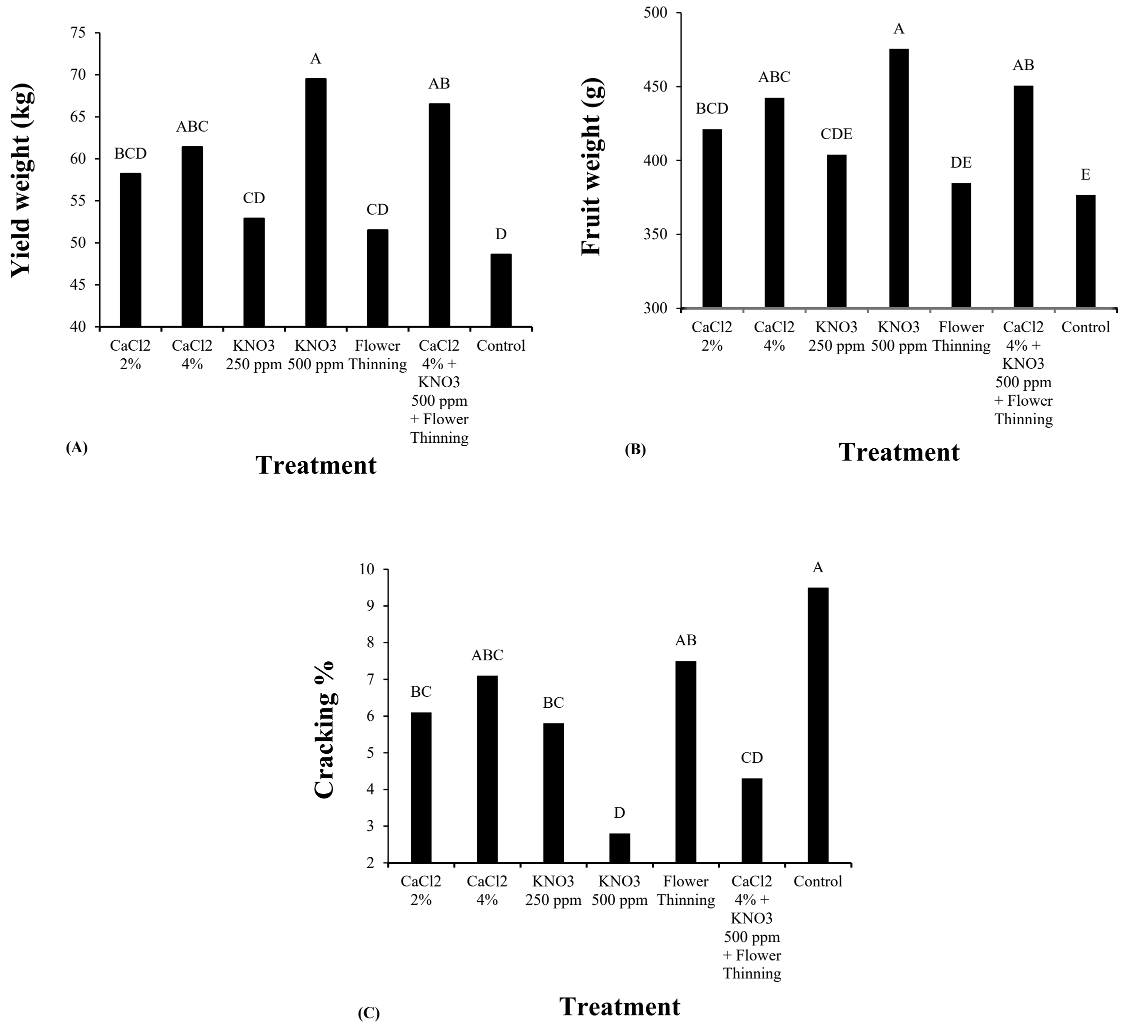

Fig. 1. Effect of $CaCl_2$, KNO_3 and flower thinning spraying on (A): yield weight (kg), (B): fruit weight (g) and (C): Cracking % of Manfalouty pomegranate cultivar (average the two seasons of study)

Fruit sensory attributes

Total Soluble Solids (TSS) %, Total Acidity % and TSS/Acid ratio

Data illustrated in Fig. 2 A suggested that there were no significant differences between $CaCl_2$ at 4% and the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) in its effects on TSS%, which gave a value of 16.5%. Moreover, the best treatment in respecting the TSS% was KNO_3 at 500 ppm followed by each of the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) and $CaCl_2$ at 4%. The percentages of these later treatments were 16.9, 16.5 and 16.5% as an average of the two seasons of study, respectively, while the flower thinning and the control treatments gave the lowest value of the TSS%.

The presented data in Fig. 2 B suggested that all the treatments provided a significant lower acidity percentage compared to the control as an average of the two studied seasons. Furthermore, KNO_3 at 500 ppm treatment gave the lowest acidity percentage (0.93%) compared to the other treatments, followed by the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) , which gave a total acidity of 1.00%, while the control gave the highest value of total acidity 1.37% as an average of the two seasons of the study.

In addition, the highest TSS/acid ratio was taken from KNO_3 at 500 ppm treatment followed by the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning). They gave a value ratio of 18.4 and 16.9, respectively, whereas the control treatment gave the lowest ratio 12.3 as an average of the two studied seasons (Fig. 2 C).

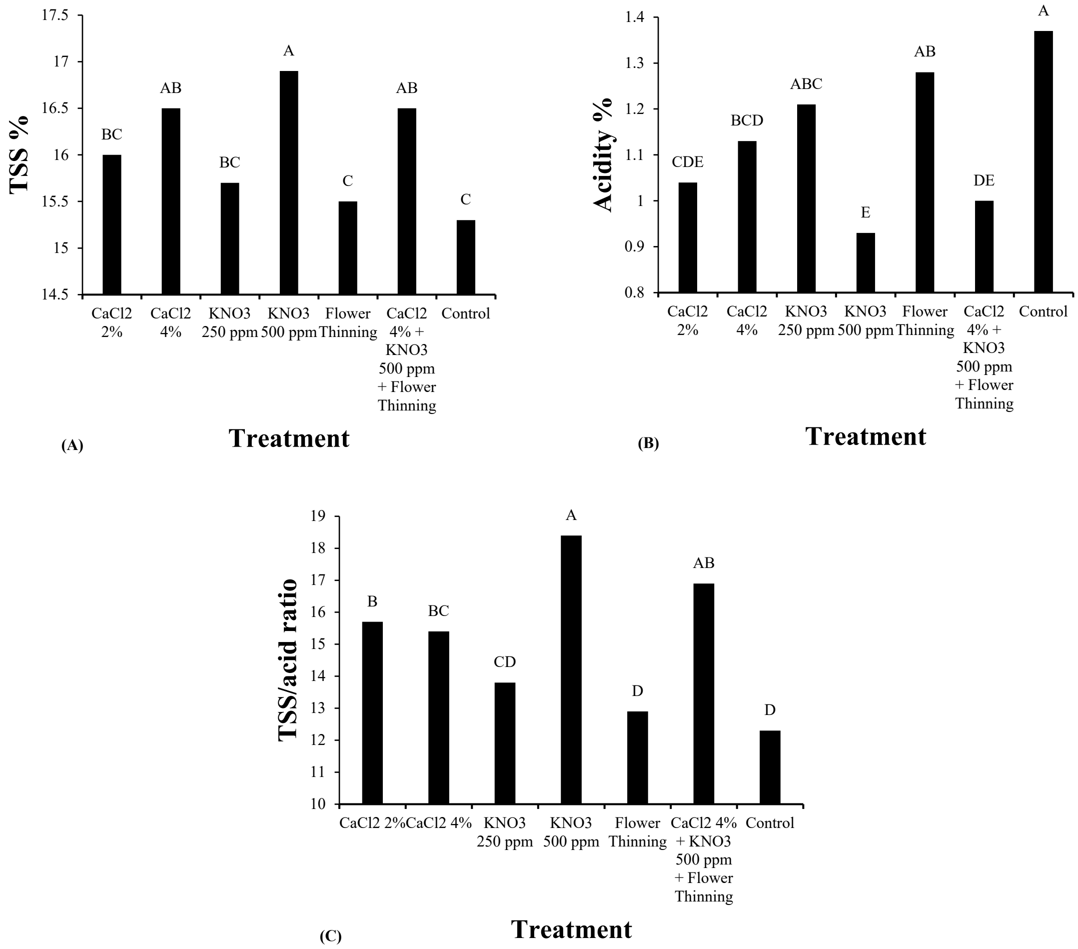

Fig. 2. Effect of $CaCl_2$, KNO_3 and flower thinning spraying on (A): TSS %, (B): Acidity % and (C): TSS/Acid ratio of Manfalouty pomegranate cultivar (average the two seasons of study)

Reducing Sugars %

The results showed that all treatments had a positive effect and caused a significant increase in reducing sugars % compared to the control treatment during the two study seasons (Fig. 3). Likewise, the best influencing treatment on the reducing sugars % was KNO_3 at 500 ppm which gave an average of 14.51% with an increment of 49.1% over the control, followed by the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) and $CaCl_2$ at 4% treatments which gave an average of 12.44 and 11.63% with an increment of 27.9 and 19.5%

over the control, respectively, with no significant differences between them, whereas the lowest value was the control treatment which gave 9.73% as an average of both seasons of the study.

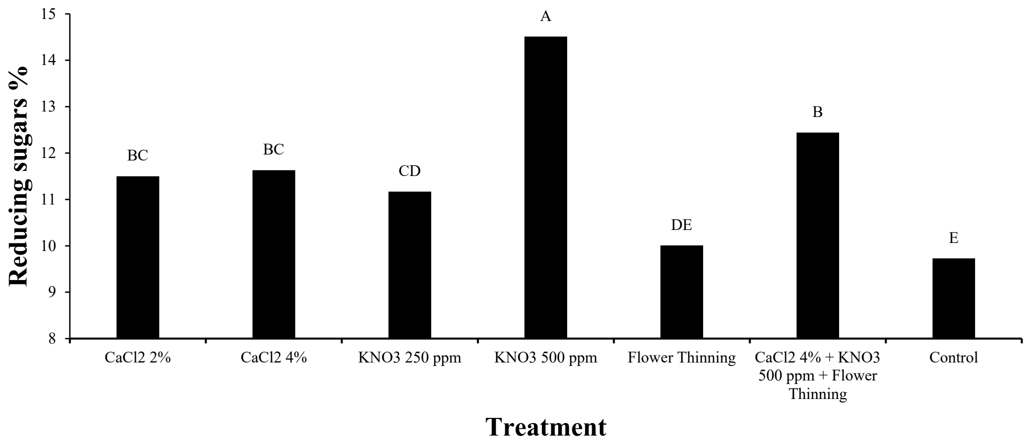

Fig. 3. Effect of $CaCl_2$, KNO_3 and flower thinning spraying on reducing sugars % of Manfalouty pomegranate cultivar (average the two seasons of study)

Total anthocyanin (mg/100g FW)

All treatments showed superiority in their effect on the total anthocyanin content compared to the control treatment during the two study seasons (Fig. 4). Also, results represented that there were no significant differences between most of the treatments in their effects on the total anthocyanin content, while the flower thinning treatment gave the lower effect. Likewise, the KNO_3 at 500 ppm gave the highest value of total anthocyanin content. It gave a value of 14.51 mg with an increment of 112.8% followed by the combined treatment ($CaCl_2$ 4% + KNO_3 500 ppm + Flower Thinning) and $CaCl_2$ at 4% treatment, which gave an average of 11.50 and 11. 29 mg with an increment of 68.2 and 65.5% over the control, respectively, whereas the control treatment gave the lowest values.

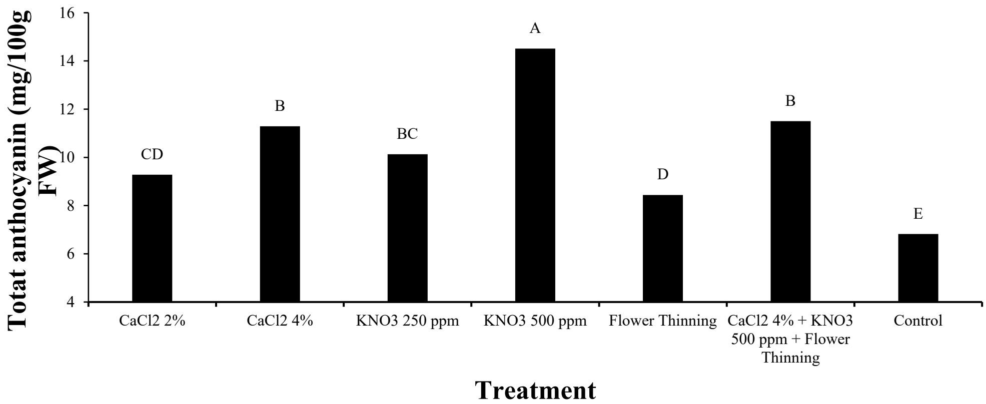

Fig. 4. Effect of $CaCl_2$, KNO_3 and flower thinning spraying on total anthocyanin (mg/100g FW) of Manfalouty pomegranate cultivar (average the two season of study)

Discussion

Plant nutritional status is one of the basic factors affecting the growth, yield and quality of fruit trees. Calcium (Ca) is regarded as an essential macronutrient that is very efficient against fruit physiology disorders in many fruit species, especially those associated with ripening (Hernandez-Munoz *et al*., 2006; Korkmaz *et al*., 2016). This element accomplishes numerous structurally imperative functions including stabilizing the integrity of plant cell walls and membranes, regulation as a second messenger in the cytoplasm, and acting as a counter-ion for organic and inorganic anions in the vacuole (White and Broadley, 2003).

Regarding the effect of calcium treatments on pomegranate trees, it was clear that all concentrations of calcium treatments significantly increased total yield/tree (kg), fruit quality and decreased cracking % over both seasons compared to the control. Plants treated with 4% $CaCl_2$ achieved the greatest tree yield, while control plants yielded the least. Furthermore, calcium application improved fruit physical and chemical properties and resulted in higher fruit and arils weights, fruit size, TSS%, reducing sugars and anthocyanin content compared to control plants in both study seasons.

Our results are consistent with many previous studies, in which Khalil and Aly, 2013 and Hegazi *et al*., 2014 found that application of 3 or 4% $CaCl_2$ in the leaves of pomegranate cultivar Manfalouty significantly reduced fruit cracking, while juice %, TSS % and acidity have been increased. Total yield, fruit weight and anthocyanin percentage also increased with calcium chloride application. In addition, Kamel *et al*., 2017; Harhash *et al*., 2019 and Abd El-Wahed *et al*., 2021 reported that spraying "Wonderful" pomegranate trees with 4% calcium chloride decreased the percentage of fruit cracks and significantly increased yield (kg/tree) and fruit physical parameters such as fruit weight and fruit size compared to other treatments. The use of this treatment also had a positive effect on fruit biochemical properties such as TSS %, ascorbic acid mg/100ml, anthocyanins and colour improvement compared to other treatments.

Potassium (k) is a major macronutrient in pomegranates, with the highest concentrations in pomegranate peels and arils aginst other macronutrients (Al-Maiman and Ahmad, 2002 and Mirdehghan and Rahemi, 2007). It is commonly referred to as a high-quality nutrient due to its significant impact on quality factors (Lester *et al*., 2006). Furthermore, the fruit quality parameters, especially the total soluble solids content, total sugars, ascorbic acid and anthocyanins, play an important role in the harvesting process as they are critical to fruit quality and post-harvest shelf life of the product (Aly *et al*., 2015). Due to its significant roles in wide range of plant processes, including the biosynthesis of proteins like cytochrome and ferredoxin, nitrogen fixation, the electron transport chain complex, and the structure of nitrate-absorbing enzymes, K fertilization has been shown to increase pomegranate fruit yield (Al-Bamarny *et al*., 2010; Marschner, 2012 and Hamouda *et al*., 2015). Furthermore, potassium enhances the production of the enzyme carboxylation, which in turn stimulates the fixation of CO_2 and promotes photosynthesis (Almeselmani *et al*., 2009). Additionally, the vital functions of K in plants, in particular its role in cell expansion that results in the formation of a large central vacuole in fruit cells, can be linked to the increase in fruit size following K fertilization (Talaie, 2008).

Hamouda *et al*. (2015) and Davarpanah *et al*. (2017) reveled that potassium spraying on Manfalouty pomegranate cultivar led to significant increases in fruit yield per shrub, fruit weight (peel and arils) and juice volume. Also, foliar spraying with K had a positive effect on nutrients in leaves and improved fruit chemical properties (TSS, total sugars, vitamin C and anthocyanin content) and deceased the acidity of fruit, which related to the quality. Furthermore, the highest values of total yield/tree, fruit weight, number of arils/fruit, TSS, total sugars and the minimum cracking values were obtained by spraying potassium on "Wonderful" pomegranate trees (Ismail *et al*., 2018; Chater and Garner, 2018, 2019). Application of potassium nitrate on pomegranate fruit improved the total yield, fruit volume, fruit size, fruit weight, TSS, total sugars and caused a reduction in fruit cracking (Kumer *et al*., 2020 and Fattahi *et al*., 2021). The abovementioned studies are in agreement with the results of the present study.

Even though it degrades the fruit quality, fruit farmers strive for and want to have the highest fruit density per tree. Fruit thinning has, therefore, a significant role. There are typically two times that are appropriate for fruit thinning in fruit trees. The optimal timing is approximately one and a half weeks following petal-fall on the first date, which is when the flower is in full bloom (Bruinsma 1962).

Larger first-quality and earlier harvested fruits were created by the early fruit set periods. While the later fruit set periods produced inferior and non-commercial fruits, since they did not reach their maturity standards (Mohamed, 2004). Fruit thinning should therefore be a standard procedure on pomegranate plantations. In this respect, El-Sese (1988a) found that the percentage of fruit splitting increased with delayed fruit maturity of Manfalouty pomegranate. Furthermore, earlier fruit setting in April and May produced fruits containing a higher percentage of arils weight, a high TSS %, a thin peel, and the least juice acidity, while the fruits that set in June or later had more acidity, a higher peel percentage, and a lower TSS%. Moreover, El-Sese and Mohamed (2005) studies the influence of flower thinning on yield, quality, and splitting of Manfalouty pomegranate fruits. They found that the percentage of fruit splitting was significantly reduced by the treatments. Also, the early flower thinning increased the commercial fruits and TSS/acid ratio was significantly decreased in the later than the early waves of fruit set. Likewise, the hand thinning of pomegranate trees increased the fruit weight, weight of 100 arils, soluble solids contents, anthocyanin, ascorbic acid contents, total phenolic, antioxidant and decreased the yield and total acidity (Ahmed, 2007; El-Mahdy *et al*., 2010; Mohsen and Osman, 2015 and Fattahi *et al*., 2020).

Conclusion

On the light at prior results, it might be concluded that spraying 500 ppm KON3 or 4% $CaCl_2$ alone or combined with flower thinning are regarded as the best treatments in terms of their impact on the yield components, fruit quality, anthocyanin content, and reducing fruit cracking.

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تأثير كلوريد الكالسيوم ونترات البوتاسيوم وخف الأزهار على مكونات المحصول وجودة ثمار صنف الرمان المنفلوطي

أيمن كمال أحمد محمد، مختار ممدوح شعبان، علياء محمد عبد الحميد، عزه سامي حسين

قسم الفاكهة، كلية الزراعة، جامعة أسيوط، أسيوط، مصر

الملخص

يواجه مزارعي الرمان في مصر العديد من مشاكل الإنتاج ومنها ظاهرة تشقق ثمار الرمان، لفحة الشمس ونقص كثافة اللون المناسب وتناسقه. وهي تشكل عوائق رئيسية تحول دون الحصول على ثمار عالية الجودة. ويهدف البحث الحالي إلى تقييم تأثيرات كلوريد الكالسيوم ($CaCl_2$)ونترات البوتاسيوم (KNO_3) وخف الأزهار على الحد أو التقليل من هذه المشاكل وكذلك تحسين جودة الثمار. حيث أجريت سبع معاملات اشتملت الرش الورقي باستخدام $CaCl_2$ 2 , 4 ٪ و KNO_3 250 , 500 جزء في المليون كل على حده أو مختلطين مع خف الأزهار والكنترول (الرش بالماء). وتمت جميع معاملات الرش ثلاث مرات، في بداية التزهير (في شهر أبريل)، بعد اكتمال عقد الثمار (أول يوليو) وقبل الحصاد (أول سبتمبر) خلال موسمي الدراسة. أما خف الأزهار فقد أجرى يدوياً لجميع الأزهار التي ظهرت خلال الأسبوع الأخير من شهر مايو حتى نهاية فترة التزهير. وأشارت النتائج المتحصل عليها إلى أن رش 500 جزء في المليون من KNO_3أو 4٪ $CaCl_2$ سواء كل على حده أو مختلطين مع خف الأزهار من أفضل المعاملات من حيث تأثيرهم على مكونات المحصول وجودة الثمار ومحتوى الأنثوسيانين وكذلك تقليل تشقق الثمار.