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Response of Rawa Seedless Pomegranate Fruits to Different Types of Packaging and Spraying with Calcium.

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ABSTRACT

A study was conducted in the district of Rawah, which is located 224 km from the city of Ramadi, on the pomegranate trees of the seedless Rawa cv. The trees were 8 years old. The study investigated the effect of fruit Packaging and calcium spray on some fruit traits. Two factors were studied during the research: the first involved using different types of bags to cover the fruits, including (uncovered control, double-layer muslin cloths, saran, and white paper bags). The second factor included calcium spraying at concentrations of 0, 1, and 2 g L^{-1}. Calcium was sprayed three times (the first at the beginning of the flower buds opening, the second a month after the first spray, and the third a month after the second spray). Using two factors (3 x 4), a factorial experiment was conducted in accordance with the RCBD. There were 36 trees utilized in total for the experiment because there were 12 treatments, 3 replications, and one tree for each experimental unit. The Genstat statistical program was used to statistically analyze the data and compare the averages using (L.S.D.) test at a probability level of 5%. The results indicated that fruit bagging treatments had a significant effect on all studied characteristics except for the percentage of calcium in the fruit peels. Saran bagging contributed to achieving the best results for characteristics (fruit weight and yield) at 407.04 g and 23.27 kg tree-1, respectively. Furthermore, the above treatment resulted in the lowest percentage of cracked fruits at 13.43%. Conversely, the treatment of bagging with white paper bags achieved the highest value for the fruit firmness characteristic at 2.43 kg cm2. As for the calcium spray, it showed a significant effect on all studied characteristics. The high concentration (2 g L^{-1}) achieved the best values for fruit weight, fruit firmness and yield, at 415.72 gm, 2.49 kg cm2 and 24.03 kg $tree^{-1}$) respectively. Additionally, the above treatment resulted in the lowest percentage of cracked fruits at 15.24%, while the treatment (1 g L^{-1}) achieved the best value for percentage of calcium in the fruit peels at 1.32%. The interaction between the two study factors reached a significant level of influence on all studied characteristics. The interaction treatment (B2C2) excelled in achieving the best values for most studied characteristics, while the control treatment (B0C0) showed the lowest values for the studied characteristics.

***Keywords*:** Punica granatum, Packaging Type, Calcium, Fruit cracking.

INTRODUCTION

Pomegranate (*Punica granatum* L.) is a temperate fruit belonging to the Punicaceae family. It holds a significant place in Islamic culture, being mentioned in the Quran in multiple verses. According to most sources, the pomegranate originated in Southwest Asia, including Iran, Iraq, Yemen, the southern Arabian Peninsula, and the Mediterranean Basin. It was later introduced to European countries such as Spain, Italy, and France, and eventually to the Americas [1], [2] Iraq is home to a large pomegranate crop, with about 23 different types growing there [3].

From the end of summer all the way into the middle of winter, you may find pomegranate fruits in stores. This is because their thick skin prevents the fruit from spoiling and allows it to keep more of its nutritious value for a longer period of time. Vitamin C is one of several nutrients found in pomegranates, which also include pigments, lipids, carbs, sugars, acids, fiber, proteins, and more [4], [5]. The medicinal and therapeutic uses of pomegranate are numerous. It is a heart tonic, astringent, and vermifuge. It is used to treat stomach diseases and indigestion because its juice contains compounds with therapeutic properties such as anthocyanins, phenolic and tannin substances, and some vitamins such as B1 and B2. These compounds have been proven effective against cancer and various pathogens. Pomegranate juice is one of the most important antioxidants [6], [7].

Packaging, or covering fruit with different materials, is a physical process that creates favorable conditions for successful pollination, improves fruit quality, and protects fruit from unfavorable conditions, especially in hot and dry areas. It also protects fruit from insects, birds, and mechanical damage that can negatively affect tree productivity and fruit quality [8], [9]. Several studies have shown the potential of using different types of covers, including paper, saran, polyethylene, and muslin cloth. Covers are also available in different colors, depending on the purpose of the cover [10], [11], [12] .

The supporting of plants with fertilizer through the total vegetative mass increases the efficiency of fertilization, as well as reducing the amount of loss fertilizer and reducing the stabilization of added elements. The foliar spraying is supplemental to ground fertilization which is used because of several conditions concerned with soil like high salinity, high content of lime, and high pH, and also used when the roots infection by fungus pathogens. Adding fertilizer elements to the soil during the period of high water requirements leads to the loss of quantities of fertilizers, especially nitrogen fertilizer, because they quickly turn into easy movable nitrates in the soil texture and are quick to lose [13].

Nutrition is a key factor in plant growth and development. One of the vital components crucial for the development of cell walls, particularly in the middle lamella, is calcium. During the development of the cell wall, pectic acid and calcium combine to generate insoluble calcium pectate, which then combines with magnesium pectate to hold cellulose strands together [14]. Consequently, calcium is necessary for quickly developing tissues like the cambium and the meristems of the stem and roots [15]. Additionally, it is crucial to the success of fertilization because it draws the pollen tube into the ovary [16], [17]. Many studies have been conducted on the effect of calcium on the growth and production of pomegranate trees [18], [19], [20]

Pomegranate cultivation in Iraq has been neglected recently, with a decline in the number of trees due to prevailing circumstances. These include inefficient fertilizer use, lack of advanced techniques, and poor agricultural practices. These factors are crucial for the success of pomegranate cultivation and determine its productivity. Due to the scarcity of research in this area, this study was conducted to investigate the effect of using different types of fruit packaging and foliar calcium application on some traits of fruits and the percentage of cracking of the seedless pomegranate fruit variety "Rawa."

Materials and methods

A study was conducted in the district of Rawa, located 224 km from the city of Ramadi, on seedless pomegranate trees of the "Rawa" variety. The study investigated the effect of fruit packaging and foliar calcium application on some traits of fruits and percentage of cracking. The trees were 8 years old with a planting distance of 3 x 3 m. Animal fertilization (chicken manure) has been the starting point for all trees care procedures and irrigation (Surface irrigation). Analyses of the chemical and physical properties of the orchard's soil are shown in Table 1.

Table (1): Some chemical and physical properties of soil

P Av. mg Kg^{-1}	Total N %	$CaCO_3$ g Kg^{-1}	Bulk density g cm^{-3}	O.M %	EC ds m^{-1}	pH
1.16	0.23	137.68	1.56	2.28	2.83	7.87
Cl^- Mq L^{-1}	$HCO3^=$ Mq L^{-1}	$CO_3^=$ Mq L^{-1}	Na^+ Mq L^{-1}	Mg^{++} Mq L^{-1}	Ca^{++} Mq L^{-1}	K Av. mg Kg^{-1}
46.79	4.94	Nil	0.63	46.72	31.85	142.51
		Texture	Clay g Kg^{-1}	Silt g Kg^{-1}	Sand g Kg^{-1}	$SO_4^=$ Mq L^{-1}
		Sandy Clay Loam	241.4	166.3	592.3	27.40

Treatments Used in the Experiment

In the experiment, two factors were used as follows:

First: Fruit packaging type (M) includes the following four treatments:

- Non-packaged (control treatment) (B0);

Double-layer *Muslin Cloths* (B1); Saran (B2) and White paper bags (B3).

Second: Spraying with calcium (C) (Calcium chloride) by using (Disper Ca) produced by the Spanish company (Eden Modern Agriculture) and includes the following treatments:

- Spraying with distilled water only (C0); 1 g L^{-1} (C1) and 2 g L^{-1} (C2) (Manufacturer's recommendation).

Calcium was sprayed three times (the first at the beginning of the flower buds opening, the second a month after the first spray, and the third a month after the second spray).

Experimental Design

Using two factors (3 x 4), a factorial experiment was conducted in accordance with the RCBD. There were 36 trees utilized in total for the experiment because there were 12 treatments, 3 replications, and one tree for each experimental unit. The Genstat statistical program was used to statistically analyze the data and compare the averages using (L.S.D.) test at a probability level of 5% [21].

Studied Traits

Measurements were taken at the end of the experiment on 25/10/2023 including:

1- Fruit weight (gm).

2- Peel firmness (kg cm^2): using a Magness and Taylor pressure tester with 7/18 inch plunger.

3- Percentage of calcium in the fruit peels that measured according to the method described by [22].

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

Fruit cracking (%) = Number of cracked fruits ÷ Total numbers of fruits ×100

5- Fruits yield (kg tree^{-1}): At harvest time, the number of fruits per treated tree was counted and reported then the yield (kg) per tree was weighed and recorded

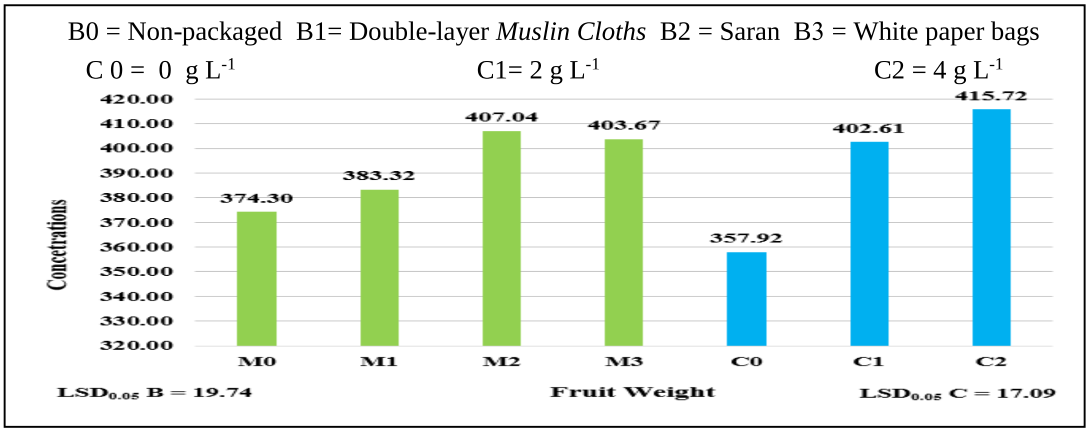

Figure (1): Effect of packaging type and calcium spraying on fruit weight (gm) of seedless Pomegranate variety Rawa.

Results

1. Fruit weight (gm)

The results in Figure (1) show that fruit bagging treatments had a significant effect on the weight of seedless pomegranate fruits of the Rawah cultivar. This is evident as treatments (B2 and B3) provided the highest values of 407.04 and 403.67 gm respectively, while the uncovered fruit treatment (B0) recorded the lowest value of 374.30 gm. On the other hand, it was observed that calcium spraying significantly affected this characteristic, as treatment (C2) recorded the highest value of 415.72 gm, followed by treatment (C1) with 402.61 gm, while fruits reached their lowest weight with the non-sprayed treatment (C0) at 357.92 gm. The results also indicated significant differences in fruit weight due to the interaction between the study factors, especially with treatment (B2C2), which yielded the highest value of 451.84 gm, while the lowest value was observed with the control treatment (B0C0) at 334.60 gm (Table 2).

2. Fruit firmness (kg cm^2)

The statistical analysis results shown in Figure (2) indicate that fruit bagging treatments had a significant effect on fruit firmness. Treatment (B1) recorded the highest value of 2.43 kg cm^2, followed by treatments (B0 and B2) with values of 2.41 and 2.39 kg cm^2 respectively, while the lowest value was observed with treatment (B3) at 2.33 kg cm^2. On the other hand, calcium spraying treatments demonstrated a significant effect, with treatment (C2) recording the highest value of 2.49 kg cm^2 compared to treatments (1C and C0), which resulted in decreased fruit firmness to the lowest levels of 2.36 and 2.32 kg cm^2 respectively.

Additionally, the results indicated significant differences in fruit firmness due to the interaction between the study factors, especially with treatment (B1C2), which yielded the highest mean of 2.62 kg cm^2, while treatment (B3C0) achieved the lowest value at 2.25 kg cm^2 (Table 2)

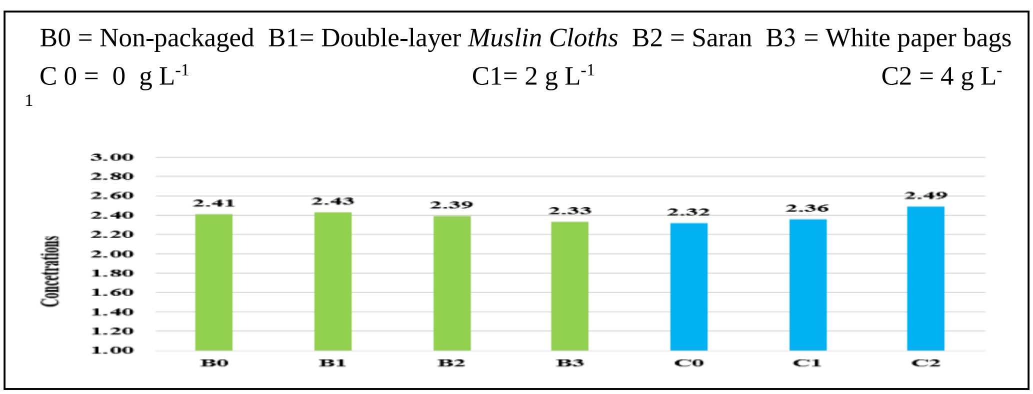

Figure (2): Effect of packaging type and calcium spraying on peel firmness (kg cm^2) of seedless Pomegranate variety Rawa.

3. Calcium (%)

The results in Figure (3) showed that fruit bagging treatments had no significant effect on the fruit peels content of calcium. Additionally, it was observed that spraying fruits with calcium had a significant effect with treatment (C1) recording the highest percentage at 1.32%, followed by treatment (C2) at 1.13%, while the lowest percentage was for the untreated control

(C0) at 1.07%. Furthermore, the results indicated significant differences in the calcium content of fruit peels due to the interaction between both study factors, especially in treatment (C2B2) which showed the highest percentages at 1.56%. The lowest percentage, at 0.76%, was observed in the control treatment (C0B0) (Table 2).

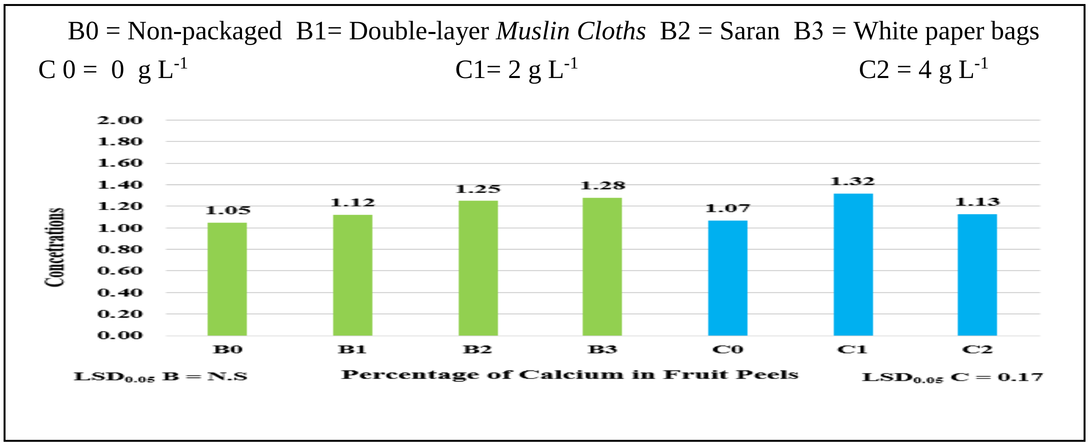

Figure (3): Effect of packaging type and calcium spraying on percentage of calcium in the fruit peels of seedless Pomegranate variety Rawa

4. Percentage of cracked fruits

The results from Figure (4) indicate significant differences in the percentage of cracked fruits, particularly concerning fruit bagging treatments. Treatment (B2) had the lowest percentage at 13.43%, followed by treatment (B3) at 15.38%, then treatment (B1) at 18.57%, On the other hand, the highest percentage was showed with treatment (B0) at 23.48%. While calcium spraying treatments reached a significant level of influence on the studied characteristic. Treatment (C2) recorded the lowest percentage at 15.24%, followed by treatment (C1) at 17.41%, while the highest percentage was observed with the control treatment (C0) at 20.50%. Additionally, the results indicated significant differences in the percentage of cracked fruits due to the interaction between the study factors, especially with treatment (C2B2), which yielded the lowest percentage at 11.94%, while the highest percentage was observed with the control treatment (C0B0) at 32.47% (Table 2).

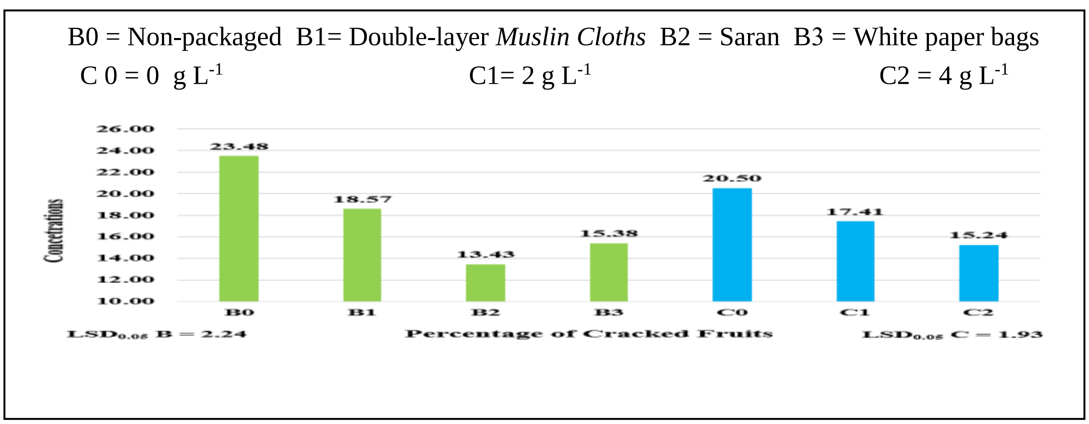

Figure (4): Effect of packaging type and calcium spraying on percentage of cracked fruits of seedless Pomegranate variety Rawa

5. yield (kg $tree^{-1}$)

The statistical analysis results shown in Figure (5) indicate that fruit bagging treatments had a significant effect on the yield of the seedless pomegranate trees, Rawah variety. Treatments (B2 and B3) outperformed with the highest yields at 23.27 and 23.06 kg $tree^{-1}$ respectively, while the lowest yields were observed with treatments (B0 and B1) at 21.33 and 21.69 kg $tree^{-1}$ respectively. Conversely, calcium spraying treatments demonstrated a significant effect, with treatment (C2) recording the highest yield at 24.03 kg $tree^{-1}$, followed by treatment (C1) at 22.97 kg $tree^{-1}$, whereas the lowest yield was observed with the non-sprayed treatment (C0) at 20.01 kg $tree^{-1}$. Additionally, the results indicated significant differences in the yield Owing to the way the research components interact, particularly with therapy (C2B2), which yielded the highest yield at 25.90 kg $tree^{-1}$. On the other hand, at 18.40 kg $tree^{-1}$, the comparison treatment (C0B0) produced the lowest value (Table 2).

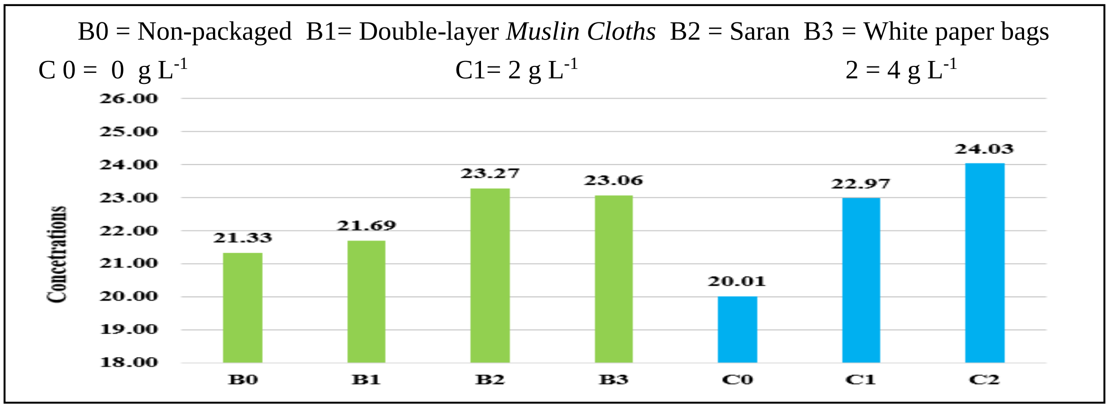

Figure (5): Effect of packaging type and calcium spraying on yield (kg tree^{-1}) of seedless Pomegranate variety Rawa

table (2): Effect of packaging type and calcium spraying interaction on some traits of fruits of seedless Pomegranate variety Rawa.

(C) Spraying with calcium (g L^{-1})	(B) packaging type	Fruit weight (gm)	Fruit firmness (kg cm^2)	percentage of calcium in the fruit peels	Percentage of cracked fruits	Fruit yield (kg tree^{-1})
C0 (0 g L^{-1})	B0 Control (Non-packaged)	334.60	2.36	0.76	32.47	18.40
	B1 (Double-layer *Muslin Cloths)*	341.90	2.27	1.18	17.78	19.09
	B2 (Saran)	366.37	2.39	0.98	14.84	20.53
	B3 (White paper bags)	388.81	2.25	1.35	16.90	22.01
C1 (1 g L^{-1})	B0 Control (Non-packaged)	394.65	2.34	1.47	21.34	22.11
	B1 (Double-layer *Muslin Cloths)*	391.75	2.40	1.35	18.72	22.02
	B2 (Saran)	402.91	2.37	1.20	13.53	23.38
	B3 (White paper bags)	421.13	2.31	1.24	16.05	24.39
C2 (2 g L^{-1})	B0 Control (Non-packaged)	393.67	2.54	0.91	16.63	23.48
	B1 (Double-layer *Muslin Cloths)*	416.29	2.62	0.83	19.21	23.96
	B2 (Saran)	451.84	2.40	1.56	11.94	25.90
	B3 (White paper bags)	401.08	2.42	1.23	13.18	22.79
LSD $_{5\%}$		34.19	0.11	0.35	3.87	1.92

Discussion

The process of fruit bagging During its growth and development, training trees is one of the important techniques used to effectively enhance the appearance and quality of fruits and reduce cracking. This method is also important for controlling the fruit's surrounding environment, including regulating light intensity, temperature, and humidity. Thus, it plays a crucial role in both biotic and abiotic resistance [23], [24]. [25] mentioned that temperature plays a significant role in the cracking ratio of fruits, as the cracking ratio increases with temperature rising from 10 to 40 degrees Celsius. Temperature also affects other factors such as cell wall permeability and cellular biochemical processes.

The positive impact of covering pomegranate fruits on improving their quantitative traits can be attributed to the role that covering plays in shielding the fruits significantly from external environmental influences, leading to a reduction in water loss from the fruits [26],[27]. [28] demonstrated that fruit bagging is an effective technique for modifying climatic conditions around the fruits, reducing fruit drop and preventing photooxidation, thus increasing the concentration of internal hormones that accelerate growth. Additionally, [29] highlighted the importance of covering pomegranate fruits in protecting their peel from cracking.

Calcium contributes to binding protein molecules in the cell membrane, making it more durable and less permeable. Consequently, fruits treated with calcium can withstand the pressure exerted on them due to internal fruit growth, reducing the incidence of cracking [30]. [31] Also mentioned this aspect. Covering the fruits of Red Table Grape (Autumn Royal) and White Table Grape (Italia and Regal Seedless) effectively increased the yield for all three varieties. Similarly, [32] found an increase in the weight of clusters and berries for the grape variety Muscat Hamburg, which was covered with polypropylene bags. These results are consistent with findings by [33] for pears, [34] for grapes, [35] for peaches, and [36] for kiwi fruit.

As for the role of calcium in improving the studied fruit characteristics, it may be attributed to its status as one of the major nutrients with numerous important physiological functions for plant growth and development. Calcium plays a fundamental role in cell structure as it is the main component of the middle lamella, where it is present in the form of calcium pectate. It is essential for cell division, chromosome stability, mitochondria production, cell hydration, and expansion [37],[38]. Additionally, Calcium is an essential biological component that facilitates numerous metabolic activities, In addition to triggering a variety of enzyme systems, supporting healthy plant development [39]. Additionally, it plays a fundamental role in stabilizing the membrane and cell integrity. An increase in the leakage of low molecular weight solutes from plant tissue cells suffering from severe calcium deficiency has been observed, contributing to the collapse of cell membrane structures and loss of cell activity in division [40]. Moreover, calcium treatment has been shown to inhibit chlorophyll loss and increase leaf content of it [41]. Calcium is also essential in improving the nutritional status of trees by increasing chlorophyll quantity, leaf area, and water absorption, thus enhancing the fruit content of major and minor nutrients [42]. This consequently enhances the efficiency of the photosynthetic process, positively impacting the improvement of vegetative growth and yield characteristics.

Many studies have shown that calcium regulates plant responses to various environmental stresses, including heat [43]. External calcium treatment has been proven to improve heat tolerance in many plants, which may be associated with increased activities of antioxidant enzymes and reduced lipid peroxidation in cell membranes [44]. Additionally, calcium contributes to reducing water stress damage through its role in forming calcium pectate in cell walls and regulating cell wall permeability, as well as assisting in carbohydrate transport processes [45].

The effect of calcium in increasing the thickness of the fruit peel and fruit firmness may be attributed to the formation of calcium pectate, resulting from the union of calcium with pectic acid in the fruits. Calcium pectate contributes to the strength and cohesion of cell walls, thus preserving membrane integrity and enhancing cell elongation [46]. Similar results were found by [47] on mango fruits and by [48] on pomegranate. As for the positive role of calcium spray in increasing the moisture content of the fruit peel, it may be attributed to its role in enhancing the permeability of cell walls, allowing water and nutrients to move from leaves to fruits [49]. Additionally, calcium plays an important role in improving fruit growth and maintaining a balance of moisture between the fruit peel and its internal tissues, while also preserving cell wall elasticity [50].

Because the calcium salt of the fatty material lecithin is engaged in the composition of the cell membrane, calcium also plays a part in the production of cellular membranes. It is thought that calcium plays a crucial role in cell elongation and division, and that a calcium deficit decreases the permeability of cell membranes [51], [52]. Additionally, spindle formation and the stability and shape of chromosomes are influenced by calcium. Furthermore, a number of enzymes, including phospholipase, triphosphatase, arginine, adenosine, and kinase, are activated by calcium [53]. It seems that calcium is necessary for the absorption of nitrate nitrogen, as sugars and starches accumulate in plants growing in calcium-deficient environments, rendering them unable to absorb nitrate nitrogen, although this situation changes rapidly [54], [55]. Nitrates appear quickly when fertilized with calcium, and most of the calcium accumulates in plant leaves. Plants absorb it in the form of calcium ions Ca^{++} and use it to neutralize the organic acids produced in plant cells, therefore avoiding harm brought on by an increase in these acids' concentration [56].

Conclusion

Bagging fruit during its growth and development on trees emerges as an important technique to effectively enhance the visual appearance and quality of the fruits. Additionally, this method plays a fundamental role in controlling the surrounding environment of the fruits, including light intensity, temperature, and humidity, thereby contributing to both biotic and abiotic resistance and consequently improving both the fruits' quantitative and fruits' qualitative. Moreover, spraying pomegranate trees with calcium has shown improvement in fruit characteristics and yield, especially at high calcium concentrations (2 grams liter-1). This underscores the importance of using calcium as an additive to enhance fruit growth and improve its overall quality.

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Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication and/or funding of this manuscript.

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استجابة ثمار الرمان صنف راوة عديم البذور لأنواع مختلفة من الأغطية والرش بالكالسيوم.

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الخلاصة

نفذت دراسة في قضاء راوة والتي تبعد بمسافة 224 كم عن مدينة الرمادي على اشجار الرمان صنف راوة عديم البذور بعمر 8 سنوات ، وتم خلالها البحث في تأثير تكييس الثمار ورش الأشجار بالكالسيوم في بعض صفات الثمار والحاصل. تم خلال البحث دراسة عاملين الأول تمثل باستخدام أنواع مختلفة من الأكياس في تغطية الثمار وشملت (معاملة المقارنة بدون تكييس ، قماش الململ المزدوج ، الساران ، أكياس ورقية بيضاء(. أما العامل الثاني فشمل الرش بالكالسيوم وذلك بالتراكيز (0 ، 1 و 2 غم لتر-1) تمت عملية رش الأشجار بالكالسيوم لثلاث مرات (الأولى في بداية تفتح البراعم الزهرية 2023/3/25 ، والثانية بعد شهر من الرشة الأولى ، والثالثة بعد شهر من الرشة الثانية). نفذت تجربة عاملية بعاملين (3×4) وذلك وفقا لتصميم القطاعات العشوائية الكاملة ***(RCBD)*** ، تم اختيار 36 شجرة ، ونفذت 12 معاملة في التجربة وبثلاثة قطاعات وبمعدل شجرة واحدة لكل وحدة تجريبية ، حللت البيانات احصائيا باستخدام برنامج الجنستات وقورنت المتوسطات بواسطة اختبار ***(L.S.D.)***وعلى مستوى احتمال 5%. بينت النتائج ان معاملات التغطية للثمار أثرت معنوياً في كافة الصفات المدروسة باستثناء نسبة الكالسيوم في قشور الثمار ، وقد أسهم التغطية بالساران في تحقيق أفضل النتائج للصفتين (وزن الثمرة والحاصل) وبلغت على التتابع 407.04 غم و 23.27 كغم شجرة-1. كما وأعطت المعاملة أعلاه أقل نسبة للثمار المتشققة بلغت 13.43% ، وبالمقابل حققت معاملة التغطية بالاكياس الورقية البيضاء اعلى قيمة لصفة صلابة الثمرة وبلغت 2.43 كغم سم2) أما فيما يتعلق بالرش بالكالسيوم فقد أظهر تأثيرا معنويا ولكافة الصفات المدروسة وقد حقق التركيز العالي (2 غم لتر-1) أفضل القيم للصفات (وزن الثمرة ، صلابة الثمرة والحاصل) وبلغت 415.72 غم ، 2.49 كغم سم2 و 24.03 كغم شجرة-1 على التتابع. كما وأعطت المعاملة أعلاه أقل نسبة للثمار المتشققة بلغ 15.24%. أما التركيز (1 غم لتر-1) فقد حقق أعلى نسبة للكالسيوم في قشرة الثمار وبلغت 1.32%. بلغ التداخل بين عاملي الدراسة مستوى المعنوية في التأثير في كافة الصفات المدروسة ، وقد تميزت معاملة التداخل ***(B2C2)*** في تحقيق أفضل القيم ولأغلب الصفات المدروسة ، فيما اظهرت معاملة المقارنة ***(B0C0)*** أدنى القيم للصفات المدروسة**.**

الكلمات المفتاحية: ***Punica granatum*** ، أنواع التعبئة ، الكالسيوم ، تشقق الثمار.