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Review Article

The Key to Increasing Yield and Quality in Pomegranate Cultivation: Fruit Thinning Techniques

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Abstract

Pomegranate (*Punica granatum* L.) is a globally important fruit species with high nutritional value and health benefits and requires various cultural practices to increase quality and yield in commercial production. Excessive fruit set of pomegranate trees reduces quality by limiting individual fruit development, causes periodicity problem and increases fruit cracking. In this context, fruit thinning practices are widely applied to optimize yield and quality, increase fruit size, reduce cracking rates, and provide effectiveness in disease and pest control. This review examines fruit thinning methods used in pomegranate production and evaluates the effects of different techniques on yield, quality, chemical composition, pests, disease and fruit cracking. Fruit thinning methods are divided into three groups: manual thinning, chemical thinning and mechanical thinning, and the advantages and limitations of each method are compared. Manual thinning produces high quality fruit but is limited in large-scale production due to labor costs. Chemical thinning balances fruit load by using plant growth regulators, while mechanical thinning provides ease of application over large areas. Studies have shown that thinning practices carried out 30-40 days after full flowering increase fruit size, improve quality, reduce fruit cracking and provide effectiveness in disease and pest control. In conclusion, determining appropriate thinning strategies for optimum quality and sustainable yield in pomegranate production is of great importance, and this study provides a comprehensive resource for producers to make science-based decisions.

Keywords: Punica granatum; Fruit thinning; Fruit quality; Pomegranate diseases and pests; Manual thinning; Chemical thinning

Introduction

Pomegranate (*Punica granatum* L.) is recognized as an important fruit species worldwide for both fresh consumption and industrial processing [1]. The rich antioxidant content, vitamin and mineral values of pomegranate continuously increase the demand for this fruit [2]. Pomegranate fruit is rich in fiber, antioxidants, unsaturated fats, minerals and other nutrients [3-5]. Although it is cultivated in a wide area in the world, it is a type of fruit that can be grown in areas similar to the Mediterranean climate, where excellent quality fruits can be obtained. Pomegranate is cultivated in Mediterranean and Asian countries such as Türkiye, Iran, Pakistan, Afghanistan, Spain, Morocco, Morocco, Egypt, Israel, Tunisia, Saudi Arabia, Azerbaijan, India and China. Among these countries, India, Iran, China and Türkiye are the most important pomegranate producing countries. However, pomegranate trees have a natural tendency to bear too much fruit, which can lead to a decrease in fruit quality and fluctuations in yield. Fruit trees bear more fruit than they can feed and grow. By bearing excessive fruit, fruit trees, in a way, guarantee the continuation of their own generation. Due to the excessive fruit set on the tree, the fruits compete with each other for the carbohydrates accumulated by the tree and the water and nutrients taken from the soil in order to develop. In this competition, the first flower on the pomegranate plant to bloom, fertilize and set fruit is usually the winner [6]. In a flower cluster, 1-5 and sometimes more flowers are formed. If all of these flowers are fertilized and bear fruit, 4-5 or more fruits will try to develop together on a fruit branch. In this context, fruit thinning stands out as a critical practice to optimize yield and quality in pomegranate production [6].

Fruit thinning aims to reduce the fruit load on the tree so that the remaining fruits can grow, develop and ripen better [6-8]. This process increases fruit size, improves quality characteristics such as color and taste, provides balanced nutrition to the tree, and reduces the problem of periodicity (one year of high yields and one year of low yields) [9]. In pomegranate production, fruit thinning practices have been found to reduce cracking rates and reduce disease and pest pressure [10]. Fruit thinning in pomegranate production is an indispensable practice for sustainable production, especially in high-yielding varieties and densely planted orchards [6,9,10]. Fruit thinning is an important horticultural practice that aims to achieve optimal fruit size, quality and yield by regulating the fruit load on the tree [11,12]. Fruit thinning should be carried out in pomegranate to obtain commercially higher quality, larger fruits, increase the taste, aroma and color of the fruits, reduce the risk of diseases and pests, and increase the total income of the producer [6,8,10]. Removing excess fruit at an early stage improves fruit characteristics by reducing competition for resources among developing fruits. Furthermore, this practice maintains tree health, reduces the tendency for irregular fruiting and reduces susceptibility to pests and diseases [11].

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Fruit thinning is carried out by three main methods: manual thinning, chemical thinning and mechanical thinning. Manual thinning has limited application due to labor costs, while chemical thinning offers a more efficient and cost-effective alternative [13]. Mechanical thinning, on the other hand, provides ease of application in large-scale orchards but may cause fruit damage [8].

This article aims to provide a comprehensive review of the importance of fruit thinning and different thinning methods in pomegranate production. The paper will provide detailed information on manual thinning, chemical thinning and other thinning techniques, the effects of thinning on fruit yield, quality, chemical composition, disease and pests, and its relationship with fruit cracking. In addition, optimal thinning strategies and future research directions to ensure sustainability in pomegranate production will be discussed.

The Importance of Thinning and Fruit Thinning Methods

Fruit thinning is a widely used agronomic practice in commercial fruit growing that regulates the fruit load in the plant, allowing more efficient use of resources. Removing excess fruit at an early stage improves fruit characteristics by reducing competition for resources between developing fruits. Furthermore, this practice maintains tree health, reduces the tendency for irregular fruiting and reduces susceptibility to pests and diseases [7,11]. Especially in species with excessive fruit set, such as pomegranate (*Punica granatum* L.), thinning is of great importance in terms of fruit size and uniformity [6,9]. The thinning process is carried out by three basic methods: manual thinning, chemical thinning and mechanical thinning [12,14]. Each method has its advantages and disadvantages, and the effectiveness of the method used depends on many factors.

Manual Thinning

Manual thinning is the process of removing excess fruit directly by hand or by using suitable shears. Although this method is labor intensive, it is widely used especially in fruit species with high commercial value due to its potential to improve fruit quality [7,12]. During thinning, fruits that are in contact with the ground, damaged by disease or pests, deformed, protruding beyond the tree crown and at risk of sunburn should be removed as a priority [15]. In addition, while it is recommended to preserve the fruits formed from the first blossoms [16], the elimination of other fruits through thinning provides a healthier development [6,17].

During thinning, the distribution of fruits on the branches should be taken into account. Depending on the fruit setting capacity of the tree, only one or two fruits can be left, especially among fruits that develop in groups of three or four (Table 1). If fruit set has caused overloading at the ends of the branches, the fruits developing from the first blossoms should be preserved and thinning should be carried out by leaving a distance of at least 10-15 cm between the fruits on the branches. In the parts of the branch closer to the trunk, a distance of 7-10 cm is sufficient [17].

Manual thinning is one of the most widely used methods, especially in pomegranate production. It is often preferred in small-scale orchards and organic farming practices [6,9]. The main advantage of this method is that it offers selective intervention and allows for more homogeneous fruit distribution [13,18]. However, its application in large-scale commercial orchards may be economically disadvantageous due to its labor-intensive nature.

It is recommended to remove the smallest and weakest growing fruits among the fruits that come into contact with each other in

Table 1: Some plant growth regulators and chemicals used for flower and fruit thinning in pomegranate and manual thinning method.

Chemical / Plant Growth Regulator	Purpose	Pomegran-ate Variety Used	Applica-tion Dosage	Application Time/Stage	Results Obtained	References
Gibberellic Acid (GA_3)	Reducing fruit cracking, improving fruit quality	Manfalouty	50, 100, 150 ppm (twice applica-tion)	June-early July	Fruit cracking was significantly reduced; fruit weight and quality increased.	El-Mahdy et al.; Mohamed [18,26]
Gibberellic Acid (GA_3)	Flower thinning and increasing fruit set	Manfalouty	50-150 ppm	21-35 days after flowering	Better fruit set, lower fruit drop	El-Mahdy et al. [18]
Gibberellic Acid (GA_3)	Increase in fruit size and yield	Bhagwa	50-75 ppm	After flowering	Increase in fruit weight, increase in TSS content	Kishor et al. [27]
Gibberellic Acid (GA_3)	Reducing cracking, fruit quality	Wonderful	100-150 ppm	During fruit develop-ment	Reduction in cracking rate, increase in juice content	Harhash et al. [28]
Gibberellic Acid (GA_3)	Increasing fruit set and fruit size	Wonderful	50-100 ppm	After flowering	Fruit yield increased by 15-20%, fruit weight increased	Shulman et al. [29]
Gibberellic Acid (GA_3)	Increasing fruit size, promoting flowering	Wonderful	50-100 ppm	At the beginning of flowering	20-30% increase in fruit set, increase in fruit weight	Mirdehghan et al. [30]
NAA (Naphthalene Acetic Acid)	Fruit thinning and increasing fruit size	Ganesh	500-1500 ppm	Flowering period	500 ppm: Fruit weight increased by 6.45%. 1500 ppm: Yield decreased by 9.21%.	Sheikh [12]
Etefon (Ethrel)	Flower thinning, increasing fruit size	Manfalouty	100-300 ppm	30-40 days after flowering	Fewer but larger fruit set, increased juice content	El-Mahdy et al. [18]
Etefon (Ethrel)	Fruit thinning and yield increase	Ganesh	250-500 ppm	Flowering period	250 ppm: Yield increased by 40.5%, fruit weight increased by 13.14%. 500 ppm: Ineffective.	Sheikh [12]
Manual Thinning	Increase in fruit size and quality	Malase Yazdi	20-25% thinning	After fruit set	20% thinning: Fruit weight increased by 26% and TSS by 14%.	Fattahi et al. [7]
Manual Thinning	Increase in fruit size and quality	Malase Torshe Saveh	30-40% thinning	Fruit diameter ~30 mm	40% thinning: Fruit weight increased by 47%, TSS/TA ratio increased.	Jafari et al. [14]
Manual Thinning	Fruit size and antioxidant increase	Wonderful	One fruit / shoot	After fruit set	Fruit weight increased by 210%, anthocyanin increased by 25%.	Mohsen & Osman [16]

clusters or clusters [15]. This is because contact points create a favorable environment for the development of diseases and pests. In addition, removal of fruits damaged by diseases and pests improves overall plant health by contributing to the reduction of pest populations in the orchard [6,7].

During thinning, the fruits facing the sun (south, southwest) and on the outer part of the crown of the tree should be prioritized. This practice helps to maintain fruit quality by reducing the formation of sunburn in the following periods. As a result, when applied properly, manual thinning method offers significant advantages to producers by increasing fruit size, quality and market value [9].

Application Times for Manual Thinning: Hand thinning is a traditional method applied in pomegranate production by leaving a certain number of fruits per shoot. In some studies on manual thinning, it was reported that thinning by leaving 1 or 2 fruits per shoot resulted in about 15.15% increase in fruit weight [8,12]. However, the effects of this method on yield and fruit quality show lower improvements compared to chemical thinning.

Chemical Thinning

In the first experiment, 2,4-D (15, 30, 45 mg/L), NAA (25, 50, 100 mg/L) and NAD (50, 100, 200 mg/L) were applied 45 and 90 days after full flowering. In the second experiment, 2,4-D (15, 30, 45 mg/L) was applied only 30, 60 and 90 days after full flowering. In both experiments, the regulators significantly increased the fruit length/diameter ratio, weight, volume, peel and grain weight, and leaf area index. The results of this experiment showed that 30 mg/L of 2,4-D, 50 mg/L of NAA and 100 mg/L of NAD gave the most successful results in qualitative and quantitative improvements in pomegranate fruits [19].

In another study on 'Ganesh' pomegranate cultivar, 250 ppm etefon application for flower thinning resulted in 40.5% yield increase compared to the control. However, manual thinning and NAA applications (500, 1000 and 1500 ppm) showed negative effects on yield. In the study, 15.15% increase in average fruit weight was recorded with manual thinning method applied by leaving one fruit per shoot; 13.11% increase with 250 ppm etefon and 14.41% increase with 500 ppm etefon, while 500 ppm NAA application caused a decrease in fruit size. In addition, the percentage of peel, which was 32.89% in control fruits, increased to 40.21% in 250 ppm etefon treatment [12]. Roberts & Hooley (1988) reported that 500 ppm dose of etefon was effective in flower thinning, while the optimum etefon dose for 'Ganesh' pomegranate variety in India was determined to be 250 ppm.

- Commonly used chemicals:**NAA (Naphthalene Acetic Acid):** Applied at 500-1500 ppm, it reduces fruit set and increases the size of the remaining fruits [7,12].

- **Etefon (Ethrel):** It is applied in the range of 250-500 ppm and promotes fruit drop by increasing ethylene production. According to the application results, the thinning ratio can vary between 1:3 and 1:5 [12,18].

The optimum application time was determined to be early in fruit development, approximately 35-40 days after full flowering. This is the period when cell division and fruit growth are most active, allowing for optimal fruit size and quality [11,20]. In addition, it has been reported that, in general, fruit thinning in pomegranate at the beginning of the flowering period or immediately after fruit set until early June provides positive effects [10,13].

The Role and Effectiveness of Chemical Thinning Practices in Pomegranate Production: Chemical thinning is a practice that promotes fruit drop and improves fruit quality through the use of plant growth regulators (PGRs). In pomegranate production, this method is generally preferred by large-scale commercial producers. It offers a highly effective solution, especially in terms of reducing labor costs and increasing yield [12,18]. Among the plant growth regulators commonly used in pomegranate, naphthaleneacetic acid (NAA) and ethrel (Ethrel) stand out [12,21].

Chemical thinning alters the hormonal balance of plants, accelerating the shedding of particularly undesirable fruits and promoting the growth of the remaining fruits. In this way, fruit load is reduced and the quality of the remaining fruits is improved. However, the effectiveness of this practice depends on a number of variables such as the dosage of chemicals used, the time of application and environmental factors [12].

Effectiveness of Chemical Thinning and Application Parameters: The effectiveness of plant growth regulators used in chemical thinning practices depends on the correct dosage and timing. Studies show that different dosages have different effects on fruit characteristics. NAA is usually applied in the range of 500-1500 ppm and etefon in the range of 250-500 ppm [12,18]. Studies have shown that chemical thinning treatments increase fruit size, improve fruit homogeneity and reduce cracking rates [11]. However, the success of the application may vary depending on the environmental conditions and the type of chemical used.

2,4-D (2,4-dichloro phenoxy acetic acid), NAA (naphthalene acetic acid) and NAD (naphthalene acetamide) were used for fruit thinning in 'Shisheh Cup' pomegranate variety. In the first experiment, 2,4-D (15, 30, 45 mg/L), NAA (25, 50, 100 mg/L) and NAD (50, 100, 200 mg/L) were applied to pomegranate branches 45 and 90 days after full flowering [19]. In the second experiment, only 2,4-D (15, 30, 45 mg/L) was applied to the branches of pomegranate trees 30, 60 and 90 days after full flowering [19]. In both experiments, plant growth regulators significantly increased fruit length/diameter ratio, fruit weight, fruit volume, peel weight, grain weight and leaf area index. In pomegranate fruits, the best effects of plant growth regulators on qualitative and quantitative fruit characters were obtained from the application of 2,4-D (30 mg/L), NAA (50 mg/L) and NAD (100 mg/L), indicating that these chemicals can be successfully used in pomegranate thinning [19].

In 'Ganesh' pomegranate cultivar, 250 ppm ethrel application for flower thinning resulted in a 40.5% yield increase compared to the control [12]. However, manual thinning and NAA (500, 1000 and 1500 ppm) treatments resulted in a decrease in yield compared to the control. In the same study, manual thinning with 1 fruit per shoot resulted in a 15.15% increase in average fruit weight compared to the control, 250 ppm ethrel treatment resulted in a 13.11% increase and 500 ppm ethrel treatment resulted in a 14.41% increase, while 500 ppm NAA treatment resulted in a decrease in fruit size [12]. The

percentage of peel, which was 32.89% in control fruits, increased to 40.21% in 250 ppm ethrel treatment [12].

Roberts & Hooley [22] reported that 500 ppm dose of ethrel was successfully used for flower thinning in pomegranates. In a study conducted in India on 'Ganesh' pomegranate variety, it was determined that the most suitable dose of ethrel for flower thinning in pomegranate was 250 ppm. El-Mahdy et al. [18] determined that manual flower thinning and 100 ppm GA_3 application in Manfalouty pomegranate cultivar maximized "First Class" fruit yield.

The researchers stated that flower thinning reduced the total number of fruits and improved fruit quality.

Advantages and Potential Risks of Chemical Thinning: Chemical thinning is a method that can be applied quickly and efficiently over large areas. In this respect, it significantly reduces labor costs in large-scale pomegranate production [8]. However, using the wrong dosage can lead to fruit loss, while low dosages can cause inadequate thinning. Environmental conditions and correct application timing are important factors that directly affect the effectiveness of this practice. It should also be taken into consideration that excessive use of chemicals can lead to negative changes in fruit quality.

In order to achieve success in chemical thinning applications, it is necessary to choose the right plant growth regulator and to carefully determine the appropriate dosage and timing. Farmers should consider local environmental conditions to ensure maximum yield and quality. In the future, further optimization of chemical thinning practices is of great importance for sustainability in fruit production.

Plant Growth Regulators (Pgrs) Used in Chemical Thinning and Application Timing: In pomegranate production, flower or fruit thinning is a widely used technique to improve fruit quality and commercial value by balancing the fruit load per tree. Plant growth regulators (PGRs) are often preferred for this purpose, with gibberellic acid (GA_3), ethrel (ethephon) and NAA (naphthaleneacetic acid) being among the most widely used chemicals. These regulators prevent excessive fruit set, resulting in larger, higher quality and homogeneous fruits.

Mechanical Thinning

Mechanical thinning is a practice using specialized agricultural machinery or mechanical means to remove excess fruit from the tree [23]. This method is carried out with vibrating devices or water spray systems and helps to reduce production costs by reducing the need for labor, especially in large-scale pomegranate orchards [12]. While mechanical thinning offers a faster solution compared to manual thinning, it can lead to irregularities in fruit set and risk damaging the remaining fruit [12,23].

Advantages and Disadvantages of Mechanical Thinning: Mechanical thinning offers significant advantages in terms of time and labor savings in large-scale production areas. However, this method can lead to irregular fruit set and physical damage to the remaining fruits [12]. Mechanical thinning stands out as an efficient solution, especially in densely planted areas and large orchards, and can increase production efficiency when applied correctly [12,23].

Other Thinning Methods: Flower Thinning

In pomegranate production, in addition to mechanical and chemical thinning methods, alternative techniques such as flower thinning are also practiced. Flower thinning is the process of removing some of the flowers before fruit set and this method can be used to control early fruit drop rates [13,18]. This technique helps to direct fruit set in a healthy way and prevents excessive fruit set. El-Sese & Mohamed [13] divided the fruit set period after flowering in pomegranate (Manfalouty cultivar) into five distinct stages. The researchers obtained the best success from manual flower thinning during the third fruit set stage, which coincided with May 7-13 under Egyptian conditions. The researchers found that manual flower thinning in Manfalouty pomegranate cultivar between May 7-13 decreased the number of fruits by 20.7% and increased the total yield by 7.5%. El-Mahdy et al. [18] suggested that manual flower thinning in pomegranate after June can be applied to obtain better quality and larger fruits, increase the yield of first grade fruit and reduce fruit cracking rate.

Effects of Fruit Thinning in Pomegranate

Fruit thinning practices have a number of important effects on pomegranate trees. These effects are manifested in several areas such as fruit yield, fruit quality, chemical composition of the fruit, fruit cracking and disease and pest control.

Effects of Fruit Thinning on Fruit Yield and Fruit Quality in Pomegranate

Fruit thinning is one of the main practices used in pomegranate cultivation to improve yield and quality. This method increases fruit weight, diameter and the total soluble solids content (TSS), thereby improving the marketability of the product. Studies have shown that manual thinning results in a 15% increase in fruit weight, while etefon treatments increase total yield by 40% [12].

In a study conducted in Egypt, the effect of thinning on fruit quality in 'Wonderful' pomegranate cultivar was examined and it was determined that the thinning treatment leaving two fruits in each cluster provided the highest fruit yield. On the other hand, the lowest fruit yield was found in the treatment where only one fruit was left on the cluster. Leaving two fruits per cluster increased the yield per tree by 33.7% in 2012 and 47.1% in 2013 compared to the method leaving only one fruit [16].

While fruit thinning in pomegranate production increases fruit size and quality, its effect on total yield may vary according to variety and intensity of application. In a study conducted by Jafari et al. [24] on 'Malase Torshe Saveh' pomegranate variety, the average fruit weight increased from 292 grams to 359 grams by thinning the number of fruits from 87 to 66; however, no significant difference was detected in terms of total fruit yield per tree.

Similarly, in a study conducted on 'Manfalouty' pomegranate cultivar, the effects of flower thinning and GA_3 (50, 100 and 150 ppm) treatments on fruit yield and quality were investigated and it was determined that the combination of flower thinning and 100 ppm GA_3 produced the highest yield of grade 1 (>400 g) fruit [18]. Furthermore,

in another study conducted on 'Wonderful' pomegranate cultivar in 2012 and 2013, it was reported that thinning significantly increased the average fruit weight in both years. The highest average fruit weight was observed in the treatment with one fruit left on the cluster (624.5 g and 607.3 g), while the lowest average fruit weight was observed in the control group (200.9 g and 211.0 g) [16].

The effects of thinning treatments on the yield of low quality fruit have also revealed significant findings. In a study conducted in Egypt, manual flower thinning and 100 ppm GA_3 application reduced the proportion of low quality (Grade III) fruit to 11.5% and 16.0%, respectively [18]. In addition, it was found that there was a significant increase in the weight of fruit peel and other tissues due to increasing thinning severity (3 fruits/bunch, 2 fruits/bunch, 1 fruit/bunch) [16].

In another study on the 'Wonderful' pomegranate variety in Egypt, significant increases in fruit size (length and diameter) were observed at the highest thinning levels (2 or 1 fruit/cluster) compared to the control group [16].

In addition to improving fruit quality, thinning reduces periodicity and promotes annual yield stability by regulating the nutritional balance of the trees. A study by Mustafa et al. [8] emphasized the important role of thinning in increasing fruit size and market value. Other studies also reveal that this practice is a critical method for quality improvement in pomegranate cultivation [2,13]. It was found that early thinning significantly increased fruit weight and total soluble solids (TSS) values, while decreasing the proportion of low quality fruit. In a study conducted by El-Sese & Mohamed [13], the fruit weight in the earliest thinning group reached up to 415.3 grams, while the TSS content increased to 16.4%; in the control group, this value was 14.8%. These findings suggest that fruit thinning provides significant improvements not only in yield but also in quality parameters and has an important place as a sustainable agricultural management strategy in pomegranate cultivation.

Effects of Thinning on the Chemical Composition and Bioactive Components of Pomegranate Fruit

Thinning is an important agricultural practice that increases the concentration of bioactive components such as polyphenols, organic acids and antioxidants in fruits [16]. Studies have shown that fruits remaining after thinning exhibit higher phenolic content and antioxidant activity [8]. In addition, thinning improves the visual quality by increasing the level of anthocyanins that make up the fruit color and stands out as an important factor that increases the market value.

Studies on pomegranate fruit have revealed that thinning significantly increases the proportions of bioactive compounds such as punicalagin and ellagic acid. These compounds have high commercial potential for the food and pharmaceutical industries [11,25].

Thinning increases the total soluble solids content (TSS) of pomegranate fruit, while decreasing the titratable acidity. For example, in a study on 'Wonderful' pomegranate cultivar, intensive thinning applied at the rate of 1 fruit/bunch increased the TSS content to 17.4% in the second season, while it remained 14.4% in the control group [16]. This practice also positively affected fruit quality by increasing the pH value and decreasing the titratable acidity.

Citric acid, an important component of total acidity in pomegranate fruit, plays a critical role in the formation of the flavor profile of the juice. The balance of sweetness and tartness of pomegranate juice is directly related to the ratio of TSS/TA. Thinning improves the flavor profile of the fruit by increasing this ratio, especially in 1 fruit/bunch treatments [16].

Thinning treatments also significantly increase the total phenolic content and antioxidant activity of pomegranate fruit. In a two-year study on 'Wonderful' pomegranate cultivar under Egyptian conditions, it was reported that all thinning treatments resulted in higher phenolic content and antioxidant activity compared to the control group [16].

Dilution also increases the activity of the antioxidant enzymes superoxide dismutase (SOD) and catalase (CAT). These enzymes play an important role in maintaining fruit quality by reducing oxidative stress. In particular, studies on 'Wonderful' and 'Mollar de Elche' pomegranate cultivars revealed a significant increase in SOD and CAT activity after thinning [8,11]. However, thinning is also known to improve organoleptic characteristics such as fruit color, taste and aroma [11,16].

Effects of Thinning on Fruit Cracking in Pomegranate Fruit

In pomegranate production, fruit cracking is an important quality problem and leads to economic losses by reducing the amount of marketable product [11]. If all of the mature flowers turn into fruits, it is possible that the fruits will remain small, the tree will weaken, sunburn will increase and the plant will become more susceptible to diseases and pests. Therefore, appropriate thinning practices are critical in pomegranate production.

In a study conducted by El-Mahdy et al. [18], the effects of flower thinning and gibberellic acid (GA_3) applications on fruit cracking were examined. The results revealed that the combination of flower thinning and GA_3 significantly reduced the fruit cracking rate. In particular, GA_3 treatments were reported to significantly reduce fruit cracking. This treatment increased the number of first-grade fruits (>400 g) and decreased the number of third-grade fruits (<300 g).

Fruit thinning practices reduce competition for nutrients and water between fruits by balancing the fruit load on the tree, resulting in a thicker and more durable fruit skin and a reduced risk of cracking. In addition, thinning improves the overall health of the tree, ensuring balanced fruit growth and increasing resistance to cracking.

Proper fruit thinning practices prevent fruit cracking and reduce crop losses [12]. Chemical thinning agents such as GA_3 and etefon have been found to have significant effects on yield components and reduce fruit cracking. In a study conducted on 'Manfalouty' pomegranate cultivar in Egypt, it was found that 50, 100 or 150 ppm GA_3 treatments in combination with 1000 ppm etophosone significantly reduced fruit cracking rates compared to the control group [18].

Fruit cracking is often associated with environmental factors, especially sudden changes in humidity, over-irrigation and high temperatures [1,17]. Flower thinning was found to be an effective method to reduce the rate of fruit cracking. In a study conducted by El-Sese & Mohamed [13], manual and chemical flower thinning was

applied to 'Manfalouty' pomegranate cultivar during the early stages of the flowering period (between May 7-13 under Egyptian conditions). It was reported that the fruit cracking rate decreased to 11.2% in the early thinning group at the first stage of flowering.

Foliar applications of gibberellic acid (GA_3) and paclobutrazol play an important role in reducing fruit cracking [18]. GA_3 application provided a significant reduction in fruit cracking, especially when applied at a dose of 100 ppm in 'Wonderful' cultivar. The effects of chemical thinning treatments on fruit cracking are also important. Application of etaphone (Ethrel) at 250 ppm increased the thickness of the fruit peel and reduced fruit cracking by 30-40% [18]. Studies on pomegranate fruits reported that the peel ratio was 40.21% in the etaphos-treated fruits and 32.89% in the control group [12]. In addition, 1500 ppm application of NAA increases the durability of the fruit peel, reduces water loss and decreases the rate of fruit cracking [12]. This effect was associated with a firming of the cell walls inside the fruit.

Effects of Fruit Thinning on Pomegranate Diseases and Pests

Fruit thinning has emerged as a critical cultural practice for disease and pest management in pomegranate cultivation. This method improves intra-tree air circulation and light penetration by reducing fruit density, which creates an unfavorable microclimate for the development of pathogens. Better ventilation significantly reduces disease rates by limiting the development of fungal pathogens, especially *Alternaria* spp. and *Botrytis cinerea* [6,17]. It also prevents fruit cracking, increasing both quality and market value [12].

Thinning plays a strategic role in managing not only diseases but also pest populations. The cluster-shaped growth of pomegranate fruits creates an ideal environment for pest development, especially between fruits in contact with each other [16]. This provides a suitable shelter for pests such as mealybug (*Planococcus citri*) and pomegranate whitefly (*Siphoninus phillyreae*), while thinning eliminates this environment and significantly reduces population density [8]. In particular, leaving only healthy fruits in each cluster limits the areas where pests can host. Studies on pests such as the carob moth (*Ectomyelois ceratoniae*) have shown that thinning is successful in population control [18].

Another important element in disease and pest control is the removal of physically damaged, sunburned or hail damaged fruits from the orchard during thinning. This not only prevents sick fruit from becoming hosts for pathogenic agents but also removes the food source for pests [16]. This practice is important for sustainable agriculture because it reduces the use of chemical pesticides and protects ecosystem health.

Studies have shown that the incidence of fungal diseases was reduced by as much as 25% in thinned orchards [12]. Similarly, pest populations have also been reported to decrease significantly [20]. These results suggest that fruit thinning not only improves yield and quality but also functions as a holistic pest management strategy within sustainable farming methods. A healthy and balanced fruit load increases the natural resistance of pomegranate trees to diseases and pests, thus providing an economically valuable production model [31,32].

Conclusions

Fruit thinning is an indispensable practice in pomegranate production to increase yield and quality. Thinning is highly effective in increasing fruit weight, improving quality and reducing fruit cracking. Flower or fruit thinning until the beginning of June provides significant advantages by increasing fruit weight, improving quality and reducing fruit cracking. Different thinning methods (manual, chemical and mechanical) are used in pomegranate cultivation and each method has its own advantages and disadvantages.

Manual thinning provides the highest fruit quality but increases labor costs. Chemical thinning provides advantages in large-scale production by reducing the need for labor, while mechanical thinning offers an effective solution in large orchards but may cause irregular fruit set. The choice of thinning strategy should be carefully determined by crop type, economic factors and environmental conditions.

Fruit thinning not only improves yield and quality but also helps to achieve a healthier crop by reducing fruit cracking and disease and pest pressure. Thinning improves the size, color, taste and chemical composition of pomegranate, while increasing resistance to diseases and pests. Therefore, it is important to identify and implement appropriate thinning strategies to ensure sustainability in pomegranate production.

Future research should focus on more comprehensively evaluating the effects of thinning techniques in different pomegranate cultivars and growing conditions to identify the most efficient method specific to each situation. Furthermore, optimizing chemical thinning protocols could increase the efficacy of these methods while minimizing potential side effects.

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