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Efficacy of Chemical Thinning by Some Plant Growth Regulators on Regulating Alternate Bearing in Balady Mandarin Trees

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Abstract: This experimental study was conducted on eight-year-old Balady mandarin trees (*Citrus reticulata L.*) budded on sour orange (*Citrus aurantium* L.) with a planting distance of four by five meters. The study extended over four consecutive seasons (2020, 2021, 2022, and 2023) in a sandy loam soil under a drip irrigation system in a private orchard in the Nubaria area of Beheira Governorate, Egypt. The study included six treatments: acetic acid at 0.20% (AA 2000 ppm), 0.25% (AA 2500 ppm) and 0.30% (AA 3000 ppm); and naphthalene acetic acid at 0.03% (NAA 300 ppm) and 0.04% (NAA 400 ppm) in addition to the control treatment. These treatments were applied twice as foliar sprays during on-year: at full bloom stage (approximately 75% of the flowers are opened in the first week of April) and after the fruit setting stage (the fruit diameter is approximately 0.5 cm in the first week of May). The aim of this research work was to improve the quality of the fruits during the on-year by increasing productivity while increasing production in the off-year. The treatments that resulted in the best outcomes were acetic acid 0.30% (AA 3000 ppm) and naphthalene acetic acid 0.04% (NAA 400 ppm), with the same efficiency and without significant differences between the two treatments.

Key words: Balady mandarin trees, chemical thinning, naphthalene acetic acid, and acetic acid.

1. Introduction

Citrus fruits are one of the most important fruit crops worldwide. They occupy the third place among fruit crops, preceded only by grapes and apples. In Egypt, it is considered the supremely imperative fruit crop. Balady mandarins are the second crop in area after oranges and characterized by high quality and considered as one of the most popular fruits in the local and export markets due to their nutritional value and ease of peeling (**El-Salhy *et al.*, 2006**).

The phenomenon of alternate bearing is a countless problem in citrus orchards that causes unstable annual fruit production. These phenomena are carefully connected to flowering behavior, as alternate bearing mainly results from repression of flowering during the "off-year" due to the high fruit production in the heavy-loaded season. In alternate-bearing mandarin varieties, the yield of heavy crops during the heavy-loaded season is high but small in size and consequently low quality (**El-Sayed *et al.*, 2017; Haim *et al.*, 2021; Griebeler *et al.*, 2023 and Jangid *et al.*, 2023)**. One characteristic of Balady Mandarin is its alternating bearing tendency. Large harvests of mandarins result in smaller, unmarketable fruits of little commercial value, delayed maturity, and a worsening of the fruit's exterior color. Heavy crops of mandarins are also destructive to the health of the tree. It not only causes limb breakage in trees but also results in the dieback or death of the tree **(Kihara *et al.*, 1995).**

There are two approaches for increasing production in the off-year or reducing the crop load in the on-year used to manage alternating bearing. The ability to increase yield during the off-years is limited, although some increase in yield in the off-year was achieved by girdling branches in the previous summer (**Augusti *et al.*, 1992)**. There are a number of ways to reduce yield in the on-year, such as mass reduction through mechanical hedging or topping, chemical thinning, hand thinning, and changing management techniques (**Wheaton, 1986**).

Another method for lowering alternate bearing is chemical thinning. In Florida, naphthalene acetic acid (NAA) is authorized as a chemical thinning agent. Numerous variables affect the effectiveness of NAA for fruit thinning, including the cultivar, application timing, concentration, and tree conditions (**Wheaton, 1981 and El-Sayed *et al.*, 2017**). It was concluded that the application of NAA at 250 to 500 ppm was the most reliable approach for thinning and increasing fruit size and improving quality in cultivars such as hybrid mandarins (Dancy, Murcott, as well as Valencia oranges) **(Hilgeman *et al.*, 1964; Guardiola and Garcia-Luis, 2000 and Singh and Chahil, 2020).**

Acetic acid, or ethanoic acid (CH3COOH), is a weak organic acid best known as a frequent by-product of the alcoholic fermentation carried out by Saccharomyces cerevisiae. Most commonly, it is understood to be a byproduct of lactic and acetic acid bacteria's metabolism, alcoholic fermentation, or the pretreatment of lignocellulosic biomass (**Chaves *et al.*, 2021**). Acetic acid is a common preservative in foods and drinks and a significant inhibitory component in industrial bioprocesses (**Ribeiro *et al.*, 2021**). Since the middle of the 1980s, a number of investigations have demonstrated that acetic acid enters the intracellular milieu by simple diffusion and is not processed by cells cultured in a medium containing glucose. Acetic acid dissociates upon entering the cell and accumulates as a function of pH since it has a pKa of 4.76 and the intracellular physiological pH is greater than the pH values of routinely employed media (**Cássio *et al.*, 1987**). In 1989, two different forms of cell death were attributed to the cytotoxic effects of acetic acid on yeast cells, according to the first reports on the subject. This showed that there are two kinds of deaths that are caused by acetic acid: high enthalpy deaths and low enthalpy deaths. It was initially shown that yeast exposed to high acetic acid concentrations experienced a late loss of plasma membrane integrity, indicating a decline in metabolic activity (**Prudêncio *et al.*, 1998**). According to **Ludovico *et al.* (2001)**, exponentially developing *S. cerevisiae* cells exposed to modest concentrations of acetic acid (20–80 mM) at pH 3.0 experienced cell death accompanied by standard apoptotic indicators such as DNA strand breaks, chromatin condensation, and phosphatidylserine exposure. The process was referred to as "programmed cell death" at the time, but it is now known as "regulated cell death" (RCD). In fact, PCD is regarded as a form of RCD that happens under physiological conditions, whereas RCD is currently defined as a form of cell death that happens after a mild stress and that can be pharmacologically or genetically altered (**CarmonaGutierrez *et al.*, 2018**).

This study aimed to increase the yield of trees during off-year and improve fruit quality with heavy loaded year by using six treatments applied twice as foliar sprays during on-year: at full bloom stage (approximately 75% of the flowers are open in the first week of April) and after the fruit setting stage (fruit diameter is approximately 0.5 cm in the first week of May).

2. Material and Methods

The present investigation has been carried out during four successive seasons (2020, 2021, 2022, and 2023) on eight-years-old Balady mandarin trees (*Citrus reticulata L.*) budded on sour orange (*Citrus aurantium L.*) to increase the yield at off-year and improve fruit quality during on-year by studying the effect of six treatments as follows: control without thinning, acetic acid at 0.20% (AA 2000 ppm), 0.25% (AA 2500 ppm) and 0.30% (AA 3000 ppm), naphthalene acetic acid at 0.03% (NAA 300 ppm) and 0.04% (NAA 400 ppm) on flower thinning, fruit set as well as yield of Balady mandarin trees. The experimental trees were grown at 4×5 meters in a sandy loam soil under a drip irrigation system in a private orchard in the Nubaria region of El Beheira Governorate, Egypt. The treatments were applied twice as foliar sprays during on-year: at full bloom stage (approximately 75% of the flowers are opened in the first week of April) and after the fruit setting stage (the fruit diameter is approximately 0.5 cm in the first week of May). With the exception of experimental treatments, trees in this study were given the standard horticultural practice. Three replicates and two trees per replicate comprised the randomized complete block design (RCBD) used in the experiment.

The following criteria were used to assess the tested treatments

2.1. Flowering and fruit set

To gather the data, sixteen twigs per tree—four on each side—had been selected. At full bloom, the number of blossoms on each twig was counted and recorded. Following the fruit set stage, the number of set fruitlets per twig was counted and recorded. Finally, the fruit set percentage was calculated according to the following equation: $\text{Fruit set (\%)} = 100 \times \frac{\text{Number of set fruitlet}}{\text{Number of total flowers}}$.

2.2. Fruit physical properties

Random samples were taken, with 16 fruits per tree and 32 fruits each replication. Fruit weight (g), fruit height (cm), fruit diameter (cm), fruit shape index (height/diameter), and juice volume were the factors under investigation.

2.3. Chemical constituents of the fruit juice

The following parameters were considered: Total soluble solids percentage (TSS) was determined using a hand refractometer, total titratable acidity as g citric acid/100 ml of juice was determined by titration against 0.1 N sodium hydroxide in the presence of phenol phthalin as an indicator, values of the TSS/acid ratio were calculated, and ascorbic acid content (mg/100 ml of juice) was determined by titration against 2,6-dichlorophenol indophenol (mg/100 ml) following the method illustrated in the **AOAC (1985).**

2.4. Yield

At harvesting (December), the numbers of harvested fruits per tree were counted, the total weight of all fruits per tree (the yield/tree, in kg) was determined and recorded, and the hypothetic yield/faddan [on the basis of 210 trees/faddan (4x5m apart)] was calculated.

2.5. Alternate bearing intensity (I)

Alternate bearing intensity (I): calculated for the 4 years of the study according to the following equation: $I=\frac{1}{n-1}\left(\frac{a_2-a_1}{a_2+a_1}+\frac{a_3-a_2}{a_3+a_2}+\frac{a_4-a_3}{a_4+a_3}+\cdots+\frac{a_n-a_{(n-1)}}{a_n+a_{(n-1)}}\right)$ where n = number of years, a_1, a_2, …, $a_{(n-1)}$, an represent yields of corresponding years according to **Pearce and Dobersek-Urbanc (1967**). When alternate bearing intensity is 0, there is no alternate bearing and when alternate bearing intensity 1, alternate bearing is 100%.

2.6. Statistical analysis

A randomized complete block design with three replicates and five trees for each replicate was used. The data obtained were statistically analyzed using the analysis of variance method, as reported by **Snedecor and Cochran (1980)**. The differences between means were differentiated by using Duncan's range test **(Duncan, 1955)**.

3. Results and Discussion

Data in Table (1) revealed the chemical thinning impact on the characteristics of the total number of flowers, the total number of set fruitlets, as well as the overall fruit set percentage per branch.

By exploring the chemical thinning impact on the number of flowers per branch characteristic in the first season (on-year), we found that the highest value was in favor of the control treatment, recording a value of 267.75, while the rest of the treatments affected the total number of flowers. The most influential treatment was the AA at 3000 ppm, which achieved 157.46, followed by NAA at 400 ppm, which achieved 165.13. Also, in the third season (on-year), the same effect occurred by the treatments, as the highest value was in favor of the control treatment, with a value reaching 192.44, while the lowest values resulted by AA at 3000 ppm, which achieved 118.55, followed NAA at 400 ppm, which achieved 125.90. In the second season (off-year), the highest values were in favor of AA at 3000 ppm with a value of 36.38, NAA at 400 ppm treatment with a value of 35.70, and NAA at 300 ppm with a value of 35.55. As for the control treatment, it achieved the lowest results this season; the value reached 20.17. As for the fourth season, it almost followed the same trends as the second season. The highest result was in favor of the AA at 3000 ppm treatments, with a value of 44.72, while the lowest result was in favor of the control treatment, with a value of 21.97.

It was noticed that of the number of set fruitlets and the fruit set percentage took the same trend in influence as the number of flowers per branch. Regarding the number of set fruitlets per branch characteristic, in the first season (on-year), we found that the highest value was in favor of the control treatment, recording a value of 18.31, while the rest of the treatments affected the number of set fruitlets per branch. The most influential treatment was the AA at 3000 ppm treatment, achieving a value of 4.24, followed by the NAA at 400 ppm treatment, achieving a value of 4.87. Also, in the third season (on-year), the same trend took place for the treatments, as the highest value was in favor of the control treatment, with a value of 16.37, while the lowest results were attained by the AA at 3000 ppm treatment, which achieved a value of 4.08, followed by the NAA at 400 ppm treatment, achieving a value of 4.77. In the second season (off-year), the highest values were recorded by AA at 3000 ppm treatment, with a value of 5.31, shared with the NAA at 400 ppm treatment, with a value of 5.21. As for the control treatment, it had the lowest value this season, by scoring 1.48. As for the fourth season, it followed almost the same trends as the second season. The best results were achieved by AA at 3000 ppm, with a value of 5.48 shares, and the NAA at 400 ppm, with a value of 5.24, while the lowest result was noticed by the control treatment, with a value of 1.39.

As for the fruit set percentage per branch during the first season (on-year), the highest value was in favor of the control treatment, recording a percentage of 6.84%, while the rest of the foliar spraying treatments affected the fruit set percentage per branch. The most influential treatment was achieved by AA at 3000 ppm, which achieved a percentage of 2.69%, followed by the NAA at 400 ppm, which achieved a percentage of 2.95%. Also, in the third season (on-year), the same effect occurred for the treatments, as the highest value was in favor of the control treatment, with a percentage reaching 8.51%, while the lowest results were in favor of the AA at 3000 ppm treatment, which achieved a percentage of 3.44%, followed by the NAA at 400 ppm treatment, achieving a percentage of 3.79%. As for the second season (off-year), the highest values were for the AA at 3000 ppm with a percentage of 14.60% and the NAA at 400 ppm with a percentage of 14.59%. As for the control treatment, it had the lowest results in this season; the percentage reached 7.35%, and with the AA at 2000 ppm treatment, the value reached 7.64%. As for the fourth season, it followed almost the same trends as the second season. The highest results were in favor of the AA at 3000 ppm, with a percentage reaching 12.26%, and the NAA at 400 ppm, with a percentage reaching 11.99%, while the lowest results were in favor of the control treatment with a percentage of 6.31% and the AA at 2000 ppm with a percentage of 6.86%.

When reviewing the data classified in the table in the on-years, we find that all the applied treatments reduced the values of the aforementioned traits to consistent degrees depending on the treatment concentration compared to the control treatment.

The effect of NAA is due to the formation of separating areas in the flower petioles, which led to their fall as a result of spraying with acetic acid compounds, which led to the development of ethylene production (**Ouma, 2012).**

The other possible mode of action for chemical thinner like NAA appear to have the capability to create a carbohydrates stress by reducing photosynthesis, increasing respiration or impeding carbohydrates movement to the fruit. Many have observed that the greatest fruit abscission caused by thinner is associated with periods to reduced carbohydrates availability immediately following thinner application. It is noteworthy that our results are in line with those reported by **Singh and Chahil (2020).**

On the other way, the impact of acetic acid (AA) may be due to chromatin condensation, phosphatidylserine exposure and DNA strand breaks, which led to cell death of flower petioles (**Ludovico *et al.*, 2001**) or cytotoxic effect of acetic acid toward cells (**CarmonaGutierrez *et al.*, 2018**) of flower petioles, which led to their fall.

Table (1). Effect of chemical thinning on total number of flowers, total number of set fruitlets, and overall fruit set percentage per branch of Balady mandarin trees (2020-2021-2022-2023 seasons)

Characteristics / Treatments	Total number of flowers per branch	Total number of set fruitlets per branch	Overall fruit set percentage per branch
On-year season 2020			
Control	267.75 A	18.31 A	6.84 A
AA at 2000 ppm	236.86 B	13.58 B	5.74 B
AA at 2500 ppm	208.14 D	7.97 D	3.83 C
AA at 3000 ppm	157.46 F	4.24 F	2.69 D
NAA at 300 ppm	220.95 C	8.55 C	3.87 C
NAA at 400 ppm	165.13 E	4.87 E	2.95 D
Off-year season 2021			
Control	20.17 D	1.48 D	7.35 C
AA at 2000 ppm	30.96 C	2.37 C	7.64 C
AA at 2500 ppm	32.01 B	3.31 B	10.35 B
AA at 3000 ppm	36.38 A	5.31 A	14.60 A
NAA at 300 ppm	35.55 A	3.78 B	10.63 B
NAA at 400 ppm	35.70 A	5.21 A	14.59 A
On-year season 2022			
Control	192.44 A	16.37 A	8.51 A
AA at 2000 ppm	176.03 B	12.71 B	7.22 B
AA at 2500 ppm	172.89 C	9.48 C	5.49 C
AA at 3000 ppm	118.55 F	4.08 E	3.44 E
NAA at 300 ppm	150.41 D	6.73 D	4.48 D
NAA at 400 ppm	125.90 E	4.77 E	3.79 E
Off-year season 2023			
Control	21.97 D	1.39 D	6.31 C
AA at 2000 ppm	32.51 C	2.23 C	6.86 C
AA at 2500 ppm	43.10 B	3.50 B	8.12 B
AA at 3000 ppm	44.72 A	5.48 A	12.26 A
NAA at 300 ppm	43.43 B	3.87 B	8.91 B
NAA at 400 ppm	43.72 B	5.24 A	11.99 A

AA= acetic acid and NAA= naphthalene acetic acid
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Tables (2 and 3) showed the chemical thinning influence on the characteristics of the total number of fruits on the tree, the tree's yield in kilograms, and also the mathematical yield per faddan in tons.

By studying the effect of chemical thinning on the number of fruits per tree, we found that the highest results obtained in the first season (on-year) were in favor of the control treatment with a value of 534.92. Also, the results of the third season were similar to the first in the same direction that the control treatment achieved the highest results with a value of 500.71, while results in the second season (off-year) were different from those of the first season, as the highest values were achieved with the AA at 3000 ppm treatment with a value of 263.72. Also, the results of the fourth season had similar trend to the second season, as the best result was in favor of the AA at 3000 ppm treatment with a value of 272.10.

As for the chemical thinning impact on the tree's yield in kilograms and the faddan's yield mathematically in tons, it had a similar trend to that of the number of fruits on the tree in the direction.

The best results for the yield / faddan in tons in the first season (on-year) were recorded by the control treatment with a value up to 14.78 tons per faddan, and the results of the third season had a similar trend to the first (on-year), as the control treatment achieved the highest result with a value of 14.52 tons per faddan, while results of the second season (off-year) were different from those of the first season, as the highest value was achieved by AA at 3000 ppm treatment at a value of 8.03 tons per faddan. Also, the results of the fourth season had similar trend to the second season (off-year), where the best results were in favor of the AA at 3000 ppm treatment at a value of 8.17 tons per faddan confirming its supremacy over the other tested treatments.

Data Table (3) show the chemical thinning impact on alternate bearing intensity of Balady mandarin trees. Reviewing the effect of chemical thinning on the alternate bearing intensity of Balady mandarin trees, we found that the lowest values were obtained by AA at 3000 ppm and NAA at 400 ppm, which reached 0.04 and 0.06, respectively.

Thus, it could be suggested from the foregoing results that thinning treatments were applied in two "strategies" for controlling mandarin alternation which are: thinning of flowering and fruitlets during the early fruit growing period in the heavy crop season and increase flowering or fruit set in the light crop season hence reducing the great difference in yield between heavy and light crop seasons thus attaining a slight balance between tree yields over the study seasons, which is necessary for avoiding alternation (**Gonzatto *et al.*, 2016; El-Sayed *et al.*, 2017 and Singh and Chahil 2020).**

Table (2). Effect of chemical thinning on number of fruits per tree, yield per tree (kg) per tree, and hypothetic yield per faddan (ton) of Balady mandarin trees (2020-2021-2022-2023 seasons)

Characteristics / Treatments	Number of fruits per tree	Yield per tree (kg) per tree	Hypothetic yield per faddan (ton)
		On-year season 2020	
Control	534.92 A	73.89 A	14.78 A
AA at 2000 ppm	470.32 B	66.98 B	13.40 B
AA at 2500 ppm	420.25 C	61.51 C	12.30 C
AA at 3000 ppm	357.71 E	52.92 D	10.58 E
NAA at 300 ppm	400.07 D	60.25 C	12.05 D
NAA at 400 ppm	346.99 F	53.36 D	10.67 E
		Off-year season 2021	
Control	73.57 E	11.49 C	2.30 E
AA at 2000 ppm	135.48 D	20.91 B	4.18 D
AA at 2500 ppm	159.00 C	24.41 B	4.88 C
AA at 3000 ppm	263.72 A	40.16 A	8.03 A
NAA at 300 ppm	168.94 C	25.43 B	5.09 C
NAA at 400 ppm	257.48 B	38.36 A	7.67 B
		On-year season 2022	
Control	500.71 A	72.61 A	14.52 A
AA at 2000 ppm	451.42 B	67.55 B	13.51 B
AA at 2500 ppm	409.73 C	63.06 C	12.61 C
AA at 3000 ppm	328.72 E	51.16 D	10.23 D
NAA at 300 ppm	391.21 D	61.99 C	12.40 C
NAA at 400 ppm	325.47 E	52.69 D	10.54 D
		Off-year season 2023	
Control	68.80 F	10.48 D	2.10 E
AA at 2000 ppm	110.74 E	16.75 C	3.35 D
AA at 2500 ppm	176.33 D	26.59 B	5.32 C
AA at 3000 ppm	272.10 A	40.85 A	8.17 A
NAA at 300 ppm	192.22 C	28.68 B	5.74 C
NAA at 400 ppm	256.60 B	38.07 A	7.61 B

AA= acetic acid and NAA= naphthalene acetic acid
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Table (3). Effect of chemical thinning on alternate bearing intensity of Balady mandarin trees (2020-2021-2022-2023 seasons)

Treatments	Alternate bearing intensity
Control	0.25 A
AA at 2000 ppm	0.20 B
AA at 2500 ppm	0.13 C
AA at 3000 ppm	0.04 D
NAA at 300 ppm	0.12 C
NAA at 400 ppm	0.06 D

AA= acetic acid and NAA= naphthalene acetic acid
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Data shown in Table (4) demonstrated the chemical thinning impact on some physical characteristics of fruits, such as fruit weight, fruit size, and peel thickness.

Reviewing the chemical thinning effect on the character of fruit weight in grams, we found that the best results obtained in the first season (on-year) were in favor of the AA at 3000 ppm treatment, with a value reaching 152.82 grams, shared with the NAA at 400 ppm treatment, which achieved a value reaching 151.63 grams, and both treatments ranked (A). While the second season (off-year) results were different from the results of the first season, as there were no statistically significant differences among the treatments. As for the third season, the results were similar to the first season, where the AA at 3000 ppm achieved the highest results with a value of 160.86 grams, and the NAA at 400 ppm achieved a value of 159.57 grams. An analogous trend was obtained in the fourth season to the second one, as there were on significant differences between treatments.

Regarding the chemical thinning impact on the fruit volume, this effect took a similar trend to the fruit weight, as we found that the highest results obtained in the first season (on-year) were attained by AA at 3000 ppm treatment with a value of 163.25 cm^3, shared with the NAA at 400 ppm treatment, which achieved a value of 161.98 cm^3, and both treatments ranked (A), while results of the second season (off-year) were different from those of the first season, as there were no statistically significant differences among the treatments. As for the third season, an analogous trend to the first season was noticeable, as the AA at 3000 ppm treatment achieved the highest results with a value of 171.84 cm^3, with the NAA at 400 ppm treatment achieving a value of 170.46 cm^3, while the results of the fourth season took a similar trend to the second season, as there were on significant differences between transactions. As for the chemical thinning impact on the peel thickness, there was no significant effect in this concern among the treatments during all seasons of the study.

Achieved results showed that, NAA treatments, significantly decreased number of fruit/tree, in both heavy crop seasons and consequently caused a significant increment in final weight and fruit size, as fruit abscission due to thinning treatment resulting in a reduction in inter sink competition between fruitlets allowing remaining fruit to grow and increase in size **(Safaei-Nejad *et al.*, 2015 Gonzatto *et al.*, 2016; El-Sayed *et al.*, 2017 and Singh and Chahil, 2020).**

Table (4). Effect of chemical thinning on fruit weight (g), fruit volume (cm^3), and peel thickness (mm) of Balady mandarin trees (2020-2021-2022-2023 seasons)

Characteristics / Treatments	Fruit weight (g)	Fruit volume (cm^3)	Peel thickness (mm)
On-year season 2020			
Control	138.13 D	148.47 D	2.62 A
AA at 2000 ppm	142.43 C	152.16 C	2.70 A
AA at 2500 ppm	146.57 B	156.57 B	2.78 A
AA at 3000 ppm	152.82 A	163.25 A	2.90 A
NAA at 300 ppm	147.79 B	157.88 B	2.80 A
NAA at 400 ppm	151.63 A	161.98 A	2.88 A
Off-year season 2021			
Control	156.24 A	167.94 A	2.96 A
AA at 2000 ppm	154.35 A	164.88 A	2.93 A
AA at 2500 ppm	153.34 A	163.81 A	2.91 A
AA at 3000 ppm	149.29 A	159.48 A	2.83 A
NAA at 300 ppm	152.50 A	162.90 A	2.89 A
NAA at 400 ppm	150.30 A	160.56 A	2.85 A
On-year season 2022			
Control	145.02 D	155.88 D	2.75 A
AA at 2000 ppm	149.66 C	159.88 C	2.84 A
AA at 2500 ppm	154.12 B	164.64 B	2.92 A
AA at 3000 ppm	160.86 A	171.84 A	3.05 A
NAA at 300 ppm	155.44 B	166.05 B	2.95 A
NAA at 400 ppm	159.57 A	170.46 A	3.03 A
Off-year season 2023			
Control	152.27 A	163.67 A	2.89 A
AA at 2000 ppm	151.25 A	161.58 A	2.87 A
AA at 2500 ppm	150.71 A	161.00 A	2.86 A
AA at 3000 ppm	148.52 A	158.66 A	2.82 A
NAA at 300 ppm	150.25 A	160.51 A	2.85 A
NAA at 400 ppm	149.07 A	159.24 A	2.83 A

AA= acetic acid and NAA= naphthalene acetic acid
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

The data recorded in Table (5) showed the chemical thinning on some of the physical characteristics of the fruit, including fruit height and diameter, along with fruit shape.

Regarding the chemical thinning impact on the two characteristics of fruit height and fruit shape index, there was no significant effect on these characteristics among the treatments during all over seasons of the study.

As for the effect of chemical thinning on the fruit diameter characteristic, we found that the highest results obtained in the first season (on-year) were in favor of the AA at 3000 ppm treatment with a value reaching 7.08 cm, shared with the NAA at 400 ppm, which achieved a value reaching 7.02 cm; both treatments were ranked (A), whereas the second season (off-year) trend was different from the results of the first season, as the same two treatments achieved the lowest results. The AA at 3000 ppm treatment achieved a value that reached 6.88 cm, while NAA at 400 ppm achieved a value that reached 6.94 cm without any significant differences between the two treatments. As for the third season, most of the treatments were significantly equal at rank A, except for the control treatment and the AA at 2000 ppm treatment, which ranked at rank B. As for the fourth season, there was no significant effect on this characteristic among the treatments during all seasons of the study.

Our findings go along with thereof **Atwood *et al.* (2012)** who mentioned that, spraying Murcott' trees with NAA at 250 ppm or500ppm markedly increased fruit weight and fruit diameter. Also, the same result was obtained by **Mostafa and Abdel-Aal (2009); Gonzatto *et al.* (2016) and Singh and Chahil (2020).**

Table (5). Effect of chemical thinning on fruit length (L) (cm), fruit diameter (D) (cm), and fruit shape index (L/D) of Balady mandarin trees (2020-2021-2022-2023 seasons)

Characteristics / Treatments	Fruit length (L) (cm)	Fruit diameter (D) (cm)	Fruit shape index (L/D)
	On-year season 2020		
Control	5.42 A	6.40 B	0.85 A
AA at 2000 ppm	5.56 A	6.61 B	0.84 A
AA at 2500 ppm	5.72 A	6.80 B	0.84 A
AA at 3000 ppm	5.96 A	7.08 A	0.84 A
NAA at 300 ppm	5.77 A	6.86 B	0.84 A
NAA at 400 ppm	5.92 A	7.02 A	0.84 A
	Off-year season 2021		
Control	6.14 A	7.33 A	0.84 A
AA at 2000 ppm	6.02 A	7.17 A	0.84 A
AA at 2500 ppm	5.98 A	7.08 A	0.84 A
AA at 3000 ppm	5.83 A	6.88 B	0.85 A
NAA at 300 ppm	5.95 A	7.05 A	0.84 A
NAA at 400 ppm	5.87 A	6.94 B	0.85 A
	On-year season 2022		
Control	5.70 A	6.76 B	0.84 A
AA at 2000 ppm	5.84 A	6.95 B	0.84 A
AA at 2500 ppm	6.02 A	7.15 A	0.84 A
AA at 3000 ppm	6.28 A	7.48 A	0.84 A
NAA at 300 ppm	6.07 A	7.20 A	0.84 A
NAA at 400 ppm	6.23 A	7.41 A	0.84 A
	Off-year season 2023		
Control	5.98 A	7.09 A	0.84 A
AA at 2000 ppm	5.90 A	7.02 A	0.84 A
AA at 2500 ppm	5.88 A	6.99 A	0.84 A
AA at 3000 ppm	5.80 A	6.87 A	0.84 A
NAA at 300 ppm	5.86 A	6.98 A	0.84 A
NAA at 400 ppm	5.82 A	6.90 A	0.84 A

AA= acetic acid and NAA= naphthalene acetic acid
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

Data in Table (6) displayed the chemical thinning effectiveness on some chemical properties of fruit juice, such as the TSS and acidity of the juice, as well as the ratio of TSS to the juice acidity.

As for the tested chemical thinning impact on the character of the TSS in juice, the resultant data indicate that the highest results obtained in the first season (on-year) were in favor of application AA at 3000 ppm with a value reaching 10.98%, shared with the NAA at 400 ppm treatment, which achieved a value reaching 10.82%. Both treatments occupied the rank (A). While data of the second season (off-year) were inconsistent with the results of the first season, the control treatment had the best results, achieving a value that reached 11.02%. As for the third season, the results were similar to the first season, as the AA at 3000 ppm treatment achieved the highest results with a value of 10.99%, with the NAA at 400 ppm treatment achieving a value of 10.92%, while the results of the fourth season were completely similar to the second season in the direction, as the control treatment achieved the highest results with a value of 11.12. %.

As for the chemical thinning impact on the juice acidity, in the first season (on-year), the highest value was recorded by the control treatment, with a value reaching 1.38%. The results of the third season had a similar trend to the first season, as the highest value was recorded by the control treatment, with a value reaching 1.32%. As for the second season (off-year), the highest results were achieved with the AA at 3000 ppm treatment, with a value reaching 1.34%, and NAA at 400 ppm treatment in the same rank (A), with a value reaching 1.30%. Fourth season data reflected a parallel trend to the second one as the highest results were achieved with the AA at 3000 ppm treatment, with a value reaching 1.37%, and NAA at 400 ppm treatment in the same rank (A), with a value reaching 1.32%.

Regarding the chemical thinning impact on the TSS/acid ratio, this effect was similar to trend observed by TSS as the highest results obtained in the first season (on-year) were in favor of the AA at 3000 ppm treatment, with a value reaching 9.18 shares with the NAA at 400 ppm treatment, which achieved a value that reached 9.01, and both treatments ranked (A), while the second season (off-year) results were inconsistent with the results of the first season, as the control treatment ranked the best results, achieving a value that reached 9.40. As for the third season, its results were similar to the first season, as the AA at 3000 ppm treatment achieved the highest results with a value of 9.37, shared with the NAA at 400 ppm treatment, which achieved a value of 9.15, while the results of the fourth season were completely similar to the second season in the direction, as the control treatment achieved the highest results with a value of 9.61.

It's quite evident that thinning treatments significantly increased TSS and TSS to acid ratio in fruit juice for off-year seasons that may be due to the increase in the leaf/fruit ratio that leads to an increase in fruit quality. The same result was obtained by **Mostafa and Abdel-Aal (2009); Gonzatto *et al.* (2016) and Singh and Chahil (2020).**

4. Conclusion

Trials were conducted to evaluate the effect of foliar applications of acetic acid and naphthalene acetic acid as means to implement fruit thinning of Balady mandarin trees. The results indicated that using all chemical thinning treatments as spraying at on-year twice: during the full bloom stage (approximately 75% of the flowers are open in the first week of April) and after the fruit setting stage (the fruit diameter is approximately 0.5 cm in the first week of May) inclined to get the best results compared to the control treatment. In addition, both the naphthalene acetic acid (NAA) and acetic acid (AA) treatments at a concentration of 400 ppm and of 3000 ppm, respectively gave the best results, sharing the same rank without any significant differences between them. Finally, we recommend treating Balady mandarin trees with acetic acid (AA) at a concentration of 3000 ppm at on-year twice: during the full bloom stage and after the fruit setting stage to regulate production and get rid of the phenomenon of alternate bearing. It is noteworthy that acetic acid is a natural compound that is present in abundance and its harmful effects are less than other industrial compounds in addition, beside it is economically feasible and cheaper.

Table (6). Effect of chemical thinning on juice TSS (%), juice acidity (%), and TSS / acid ratio of Balady mandarin trees (2020-2021-2022-2023 seasons)

Characteristics / Treatments	Juice TSS (%)	Juice acidity (%)	TSS / acid ratio
		On-year season 2020	
Control	10.23 D	1.38 A	7.41 D
AA at 2000 ppm	10.37 C	1.29 B	8.03 C
AA at 2500 ppm	10.48 B	1.24 C	8.47 B
AA at 3000 ppm	10.98 A	1.20 D	9.18 A
NAA at 300 ppm	10.52 B	1.22 C	8.66 B
NAA at 400 ppm	10.82 A	1.20 D	9.01 A
		Off-year season 2021	
Control	11.02 A	1.17 C	9.40 A
AA at 2000 ppm	10.79 B	1.19 C	9.08 B
AA at 2500 ppm	10.66 C	1.22 B	8.76 C
AA at 3000 ppm	10.31 D	1.34 A	7.71 F
NAA at 300 ppm	10.61 C	1.24 B	8.55 D
NAA at 400 ppm	10.45 D	1.30 A	8.04 E
		On-year season 2022	
Control	10.24 D	1.32 A	7.79 D
AA at 2000 ppm	10.39 C	1.27 B	8.17 C
AA at 2500 ppm	10.54 B	1.23 C	8.60 B
AA at 3000 ppm	10.99 A	1.17 D	9.37 A
NAA at 300 ppm	10.61 B	1.21 C	8.77 B
NAA at 400 ppm	10.92 A	1.19 D	9.15 A
		Off-year season 2023	
Control	11.12 A	1.16 D	9.61 A
AA at 2000 ppm	10.99 B	1.22 C	9.03 B
AA at 2500 ppm	10.78 C	1.23 B	8.74 C
AA at 3000 ppm	10.45 D	1.37 A	7.61 F
NAA at 300 ppm	10.72 C	1.25 B	8.58 D
NAA at 400 ppm	10.54 D	1.32 A	8.01 E

AA= acetic acid and NAA= naphthalene acetic acid
Mean followed by the same letter\s within each column are not significantly different from each other at 0.5% level.

References

AOAC (1985). Official Methods of Analysis of the Association of Official Agric. Chemists. 13th Ed. Benjamin Franklin Station, Washington, D. C., B. O. Box450, USA.

Atwood, R.; Faryna, N. and Stover, E. (2012). NAA thinning of 'W. Murcott'. In: Proceedings of the Florida State Horticultural Society, 124 (1): 76-78.

Augusti, M.; Almela, V. and Pons, J. (1992). Effect of girdling on alternate bearing in citrus. Journal of Horticultural Sciences, 67 (2): 203-210.

Carmona-Gutierrez, D.; Bauer, M. A.; Zimmermann, A.; Aguilera, A.; Austriaco N. and Ayscough, K. (2018). Guidelines and recommendations on yeast cell death nomenclature. Microb. Cell 5, 4–31. doi: 10.15698/mic2018. 01.607.

Cássio, F.; Leão, C. and Uden, N. V. (1987). Transport of lactate and other shortchain monocarboxylates in the yeast Saccharomyces cerevisiae. Applied and Environmental Microbiology, .53: 509–513. doi:10.1128/aem.53.3.509-513.1987.

Chaves, S. R.; Rego, A.; Martins, V. M.; Santos-Pereira, C.; Sousa, M. J. and Côrte-Real, M. (2021). Regulation of Cell Death Induced by Acetic Acid in Yeasts. Frontiers in Cell and Developmental Biology, 9:642375.

Duncan, D. B. (1955). Multiple range and multiple "F" test. Biometrics, (11): 1- 42.

El-Salhy, A. M.; Marzouk, H. M. and Ali, T. M. (2006). Physio-logical studies on the effect of active dry yeast application on Balady mandarin trees. II- Yield and fruit quality. Proceeding of the 3rd Int. Conf. for Develop and Env. In The Arab World, Assiut Univ., pp. 615-622.

El-Sayed, F. S.; Ahmed, H. S. and Elazazy, A. M. (2017). Effect of hand and chemical thinning on regulating alternative bearing in Murcott trees. Journal of Horticultural Science & Ornamental Plants, 9 (3): 98-105.

Gonzatto, M. P.; Böettcher G. N.; Schneider L. A.; Lopes Â. A.; Júnior J. C. S.; Petry H. B.; Oliveira, R. P. and Schwarz, S. F. (2016). 3,5,6-trichloro-2-pyridinyloxyacetic acid as effective thinning agent for fruit of 'Montenegrina' mandarin. Ciência Rural Santa Maria, 46(12): 2078-2083.

Griebeler, S. R.; Gonzatto, M. P.; Böettcher, G. N. and Schwarz, S. F. (**2023).** Successive applications of gibberellic acid in alternate bearing mandarins. Revista Brasileira de Fruticultura, 45(445):1-8.

Guardiola, J. L. and Garcia-Luis, A. (2000). Increasing fruit size in Citrus. Thinning and stimulation of fruit growth. Plant Growth Regulation, 31: 121-132.

Haim, D.; Shalom, L.; Simhon, Y.; Shlizerman, L.; Kamara, I.; Morozov, M.; Albacete A.; Rivero R. M. and Sadka, A. (2021). Alternate bearing in fruit trees: fruit presence induces polar auxin transport in citrus and olive stem and represses IAA release from the bud. Journal of Experimental Botany, 72(7): 2450–2462.

Hilgeman, R. H.; Time, L. and Dunlop, J. A. (1964). Effect of NAA and hand thinning on size of Kinnow and Mandarin fruit in Arizona. Proc. Az. State Hort, Soc., 77: 84-87.

Jangid, R.; Kumar A.; Masu, M. M.; Kanade, N. and Pant, D. (2023). Alternate Bearing in Fruit Crops: Causes and Control Measures. Asian Journal of Agricultural and Horticultural Research, 10 (1): 10-19.

Kihara, I.; Iwagaki, I.; Okuda, H. and Kawase, K. (1995). Alternate branch fruit cluster in Satsuma mandarin: New fruit control methods for biennial bearing prevention and quality improvement. Bulletin of the Fruit Tree Research Station, 27: 11-26.

Ludovico, P.; Sousa, M. J.; Silva, M. T.; Leão, C. L. and Côrte-Real, M. (2001). Saccharomyces cerevisiae commits to a programmed cell death process in response to acetic acid. Microbiology, 147, 2409–2415.

Mostafa, R. A. A. and Abdel-Aal, A. H. (2009). Effect of manual fruit thinning on alternate bearing, yield and fruit quality of Balady mandarin trees. Assiut Journal of Agricultural Sciences, 40 (1); 37-50.

Ouma, G. (2012). Fruit thinning with specific reference to citrus species: A review. Agriculture and biology journal of north America, 3(4): 175-191.

Pearce, S.C. and Dobersek-Urbanc, S. (1967). The measurement of irregularity in growth and cropping. J. Hort. Sci., 42: 295-305.

Prudêncio, C.; Sansonetty, F. and Côrte-Real, M. (1998). Flow cytometric assessment of cell structural and functional changes induced by acetic acid in the yeasts Zygosaccharomyces bailii and Saccharomy cescerevisiae. Cytometry, 31(4): 307–320.

Ribeiro, R. A.; Vitorino, M. V.; Godinho, C. P.; Bourbon‑Melo, N.; Robalo, T. T.; Fernandes, F.; Rodrigues, M. S. and Sá‑Correia, I. (2021). Yeast adaptive response to acetic acid stress involves structural alterations and increased stiffness of the cell wall. Scientific Reports, 11:12652.

Safaei-Nejad, G.; Ali-Reza, S. and Abbas, M. (2015). Journal of Chemical Health Risks, 5(2): 137-144.

Singh, G. and Chahil, B. S. (2020). Effect NAA of crop Regulation on Kinnow Decline. International Journal of Current Microbiology and Applied Sciences, 9(6): 147-155.

Snedecor, G.W. and Corchran, W. G. (1980). Statistical Methods. Oxford and J. B. H. Publishing Co. 7th Ed. lowa State University, Press, Am., Lowa, USA.

Wheaton, T. A. (1981). Fruit thinning of Florida Mandarins using plant growth regulator. Proc. Intl. Soc. Citriculture, pp: 263-208.

Wheaton, T. A. (1986). Alternate bearing. In citrus flowering, fruit set and development. Univ. Fla. Citrus Short Course pp. 67-72.