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# Effect of Foliar Sprays of Some Growth Regulators on Prolonging Storage Season of Navel Orange Fruits on Trees and Reducing Pre-Harvest Drop

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## ABSTRACT

Due to some sudden price fluctuations, whether in the local market or export of navel orange fruits the producer may be forced to store the fruits on the trees to avoid low prices that cause economic losses and may push him to refrain from expanding citrus cultivation. This study was conducted for two seasons (2021 and 2022) to study the effect of foliar spraying with some growth regulators i.e. Gibberellic acid ($GA_3$) and Isopropyl Ester(2, 4-D) at fruit color break in mid- September on extending the storage season of Washington navel orange fruits on trees and reducing pre- harvest drop. Isopropyl Ester (2, 4-D) at 20 ppm was the best treatment to reduce the average fruit drop rate (%) and achieve the highest fruit weight, juice weight percentage, TSS /acid and make the fruit peel thicker. Gibberellic acid at 20 ppm increased the peel firmness and the fruit content of vitamin C. Also, storing fruits on trees until mid-February (fourth harvest) was the best period for maintaining fruit quality. On the other hand, storing fruits on the trees did not affect the density of leaf inflorescences which considered one of the important things to increase the final yield. The anatomical study clearly showed that no cell division was noted during abscission layer formation. It can be recommended in order to extend the storage period of navel orange fruits on trees while maintaining fruit quality until mid-February, trees should be sprayed with 2,4-D at 20 ppm to achieve an economic return for the grower.

**Keywords:** Navel orange- Tree storage- 2,4-D, $GA_3$- Fruit quality - Anatomical study .

## INTRODUCTION

Washington navel orange (*Citrus sinensis* L. Osbeck) is one of the most important citrus species in the genus Citrus, and ranks first among citrus species in Egypt, occupying about 31.1% of the total cultivated area of citrus (519,788) according to statistics issued by the Ministry of Agriculture in Egypt (2022). Navel oranges are a popular fresh fruit because of their seedlessness, good size, and distinctive flavor and aroma (Wardowski et al., 1985). Navel oranges are also an important early-season source of income for citrus growers in some commercial citrus regions of the world.

In Egypt, some navel orange farmers tend to extend the harvest period by keeping the fruits longer on the trees to prolong the marketing season, and avoid sudden price fluctuations in both the local and export markets. This practice leads to peel aging of the fruits, which ends up in fruit aging and shortening their shelf life and marketability. Controlling peel aging, especially peel softening in navel oranges is important for marketing fresh, high-quality oranges and for prolonging the life of fruits with high quality characteristics as long as possible after harvest.

As the storage period on the tree is prolonged, quality losses associated with aging, puffing and fruit dropping tend to increase and the fruits become more susceptible to many types of disorders and diseases. The rate of fruit dropping depends on many factors including storage time on the tree, climatic conditions, pests and diseases, and the drop rates may rise to 20% if harvest is delayed by one month (Şen et al., 2009).

The use of growth regulators is one of several applications that enable citrus growers to extend the marketing period without losing fruit quality (Ismail, 1997). Pre-harvest application of gibberellic acid has been reported to delay peel aging, deterioration, decay and coloring and reduce disease losses in several citrus species (Garcia-Luis et al., 1992).As a result, it is possible to prolong the harvest period by storing it on the tree. Therefore, the application of gibberellic acid is suggested especially for late-harvest lemon (El-Zeftawi, 1980a), grapefruit (El-Zeftawi, 1980b) and mandarin cultivars (Sen et al., 2009). Pre- harvest gibberellic acid applications have been found to be ineffective or less effective on the internal quality of several citrus fruits (Pozo et al., 2000).

Coloration is also delayed by pre-harvest gibberellic acid applications at concentrations of 5 and 10 ppm. However, the effect was significantly reduced by late applications and especially by applications after coloration has started (Ben Ismail et al., 1995). In addition, pre-harvest spraying with 2,4-D alone or in combination with $GA_3$ has been shown to improve the quality of fruit peel stored on trees, reduce late-season fruit drop, and thus prolong the harvest season, as well as delay peel senescence and decrease fruit decay (Golddchmidt and Eilati 1970 and Ismail, 1997). Information on the absorption and excretion of 2,4-D in several species indicates that the compound is rapidly excreted unchanged and is not stored in mammalian tissues. According to FAO/WHO (1972), the acceptable daily intake of 2,4-D for humans is 0 to 0.3 mg kg-1 of body weight. In this concern, Washington navel oranges were sprayed with 20 mg kg-1 of 2,4-D as usual to regulate growth and fruit drop before harvest. Oranges were sampled before, 1 day after, and 7 days after spraying. Mean 2,4-D residues were calculated as < 0.1 mg/kg before treatment, 0.1 mg/kg after 1 day, and < 0.1 mg/kg after 7 days of (Erickson and Hield, 1962).

On the other hand, leafy inflorescences are known to have a positive effect on fruit set and final fruit yield. This effect can be explained by the carbon demand from fruits developing from neighboring leaves as leafy inflorescences have sufficient photosynthetic capacity to support early fruit development on the same shoots, which contributes significantly to subsequent growth (Moss et al., 1972). Conversely, fruits borne by leafless inflorescences have the opposite negative effect on fruit production; fruit set and yield as they have to obtain all the carbon absorbed from older leaves with insufficient photosynthetic capacity to support full fruit development.

This research aims to study the effect of foliar spraying with some growth regulators, namely Gibberellic acid ($GA_3$) and Isopropyl ester (2,4-D) on the storage of navel orange fruits on trees and reducing pre-harvest drop to extend the marketing season without affecting the physical and chemical quality of the fruits.

## MATERIALS AND METHODS

Thirty-five-year- old of Washington navel orange (*Citrus sinensis* L.) trees, budded on sour orange (*Citrus aurantium* L. Osbeck) rootstock, planted at 5x5m spacing and growing in clay soil, were selected in a private orchard, located in El-Qalyobia Governorate, Egypt for two seasons (2021 and 2022) to study the effect of foliar spraying with some growth regulators i.e. Gibberellic acid ($GA_3$) and Isopropyl Ester (2, 4-D) on extending the storage season of navel orange fruits on trees and reducing pre-harvest drop. The experimental area was irrigated by flood irrigation system. Washington navel orange trees were selected for their growth vigor and production for data collection. A randomized complete block design with three replicates for each treatment was conducted. The experiment included five treatments as follow:

1- Control (untreated)
2- Gibberellic acid ($GA_3$) at 10 ppm
3- Gibberellic acid ($GA_3$) at 20 ppm

4- Isopropyl Ester (2, 4-D) at 10 ppm
5- Isopropyl Ester (2, 4-D) at 20 ppm

All treatments were applied to the same selected trees during the two seasons (2021 and 2022) at fruit color break (mid-September). A non- ionic wetting agent (Triton AG-98) was used at a rate of 12 ml per 100 L of solution. The treatments were applied to the point of run- off by spraying (~8 L) the foliage all over the tree with a pneumatic back sprayer. Nitric acid was added to reduce the pH values of the solution from 7 to 6.

**Parameters:**

**Fruit drop percentage:** Five harvesting periods were conducted monthly from mid-November to mid- March during the two seasons. For each harvest period fruit drop was determined by removing and counting all fruit under the tree canopy, number of dropped fruit was proportioned to the total fruit number per tree and the percentage of dropped fruits was calculated.

**Fruit quality:** For each harvest period, ten fruits were randomly taken from each replicate and the following measurements were made: Fruit weight (g) was determined; Juice weight percentage and peel thickness (mm) were measured for each fruit individually using digital calipers. Peel firmness (strength to resist puncture of the fruit peel) was measured according to **Coggins and Lewis, (1965).** Total soluble solids/acid was calculated according to (A.O.A.C, 1995). Ascorbic acid (Vitamin C mg/100 ml) was calculated according to Horwitz (1972).

**Leafy inflorescence density (No./m$^2$).** During April (flowering season), a square frame (0.5 m$^2$) was used with the same trees during the three years (2021, 2022 and 2023) to count the inflorescences in the four directions of the tree. Counting was done inside the frame at two-thirds of the tree height. The percentage density of inflorescences (number/m$^2$) was calculated. This position approximately represents the average distribution of fruits in the tree (Albrigo et al., 1975).

**Anatomical study of the abscission zone:** Navel orange abscission zone plug containing fruit with straight ½ - 1 cm. stems with peduncles were removed from the tree and others from the peel of fruits (abscission zone were carefully separated) , washed with 10% Clorox solution and re-washed with distilled water three times. The specimens were killed and fixed for 48 h in F.A.A. solution (10 ml formalin, 5 ml glacial acetic acid and 85 ml 70% ethyl alcohol). The selected materials were washed in 50% ethyl alcohol, dehydrated in a regular butyl alcohol series, embedded in paraffin wax at a melting point of 56°C, sectioned to 20 µm thicknesses, stained twice with erythrosine crystal violet, cleared in xylene and mounted in Canada balsam (Nassar and El-Sahhar, 1998). The slides were analyzed microscopically and photographed.

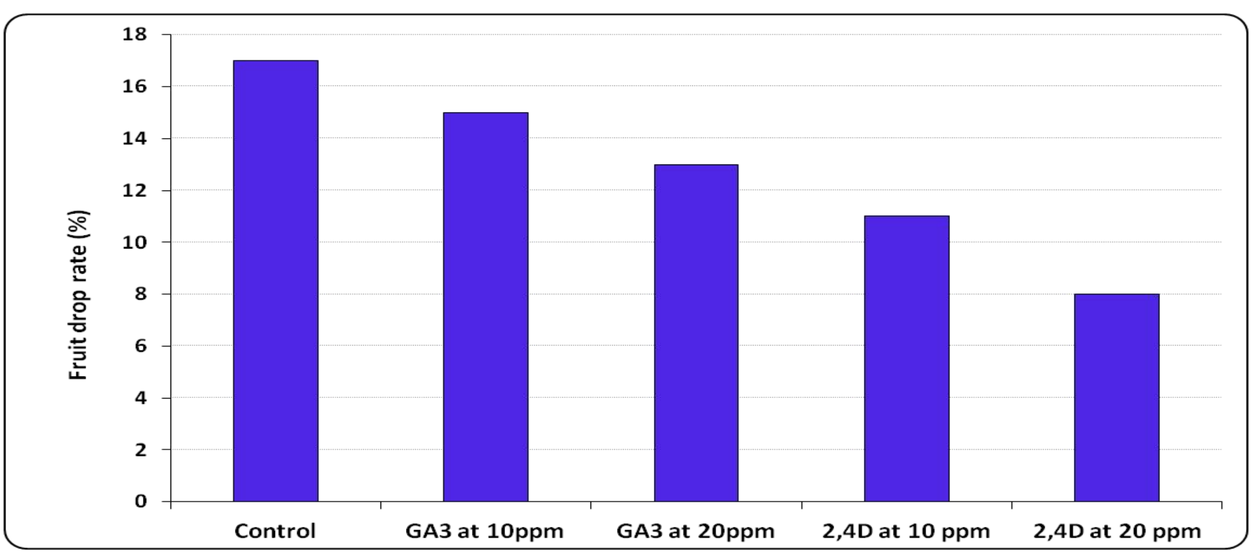
**Statistical analysis**. The experiment was designed in a randomized complete block design with three replicates and each replicate represented by two trees. The data obtained for both seasons were subjected to analysis of variance according to Clarke and Kempson (1997) and the means were differentiated using Duncan's multiple range test at the 5% level (Duncan, 1955).

## RESULTS AND DISCUSSION

**Fruit drop rate (%):** The positive effect of foliar spraying with gibberellic acid ($GA_3$) and Isopropyl ester (2, 4-D) in reducing fruit drop of Washington navel orange trees was shown in **(Figs. 1 and 2)** where (Fig. 1) showed the average percentage of final fruit drop at the fifth harvest (mid-March) and **(Fig. 2)** showed the average percentage of fruit drop during the five harvest periods (from mid-November to mid-March during the two seasons (2021 and 2022). **Fig. (1)** showed that, all treatments reduced the percentage of fruit drop from 17% in the control treatment (untreated trees) to 8% in trees sprayed with (2, 4-D) at 20 ppm, while gibberellic acid treatments gave intermediate values in this regard. **Fig. (2)** also showed that, the average fruit drop rate percent increased with the increase in the storage period of the fruits on the trees and the highest fruit drop rate was in the fifth harvest (mid-March). On the other hand, the fruit drop rate decreased in trees sprayed with the different growth regulators compared to untreated trees especially trees treated by 2, 4-D treatment at 20 ppm which achieved the lowest percentage of fruit drop during the two seasons (2021 and 2022).

Our results are consistent with those of Abd El-Rahman and Mohamed (2017) who found that, application of 2,4-D at a concentration of 15 ppm at fruit color break led to a reduction in fruit drop (9.5%) compared to the control treatment (27%) when extending the storage period of Balady mandarin fruits on the trees until mid-March. In this concern, Sexton and Roberts (1982) reported that, plant growth regulators are involved in controlling fruit drop which explains their effect on reducing fruit drop. Also, 2, 4-D is widely used in citrus to reduce the incidence of ripe fruit drop because its primary action is to delay the development of the abscission layer (Coggins, 1973). Also, according to El-Otmani (1992), who mentioned that the combined use of $GA_3$ and 2, 4-D reduces premature fruit drop through the action of auxin and delays the softening and senescence of the peel, while extending the harvest period. In addition, Almeida et al . (2004) reported that, spraying pera orange trees with 2,4-D at concentrations of 10, 20 and 40 ppm resulted in a reduction in the rate of fruit drop compared to the control treatment and the rates of fruit drop increased with increased the time. In this regard, Stewart and Hield (1950) reported that, ripe fruit drop was mainly characterized by a weakening of the cell walls in the abscission zone and that the main action of plant growth regulators in ripe fruit drop was to strengthen the cell wall material in this zone, thus reducing fruit drop. The dependence of fruit drop on the endogenous content of auxin hormones has been demonstrated by exogenous applications of 2, 4-D or NAA, since auxin hormones are transported by the plant for a long time without ethylene appearing to affect it (Agustí and Almela, 1991).

**Fig. (1). Average of final fruit drop rate at the fifth harvest (mid-March) (%) of two seasons (2021 and 2022).**



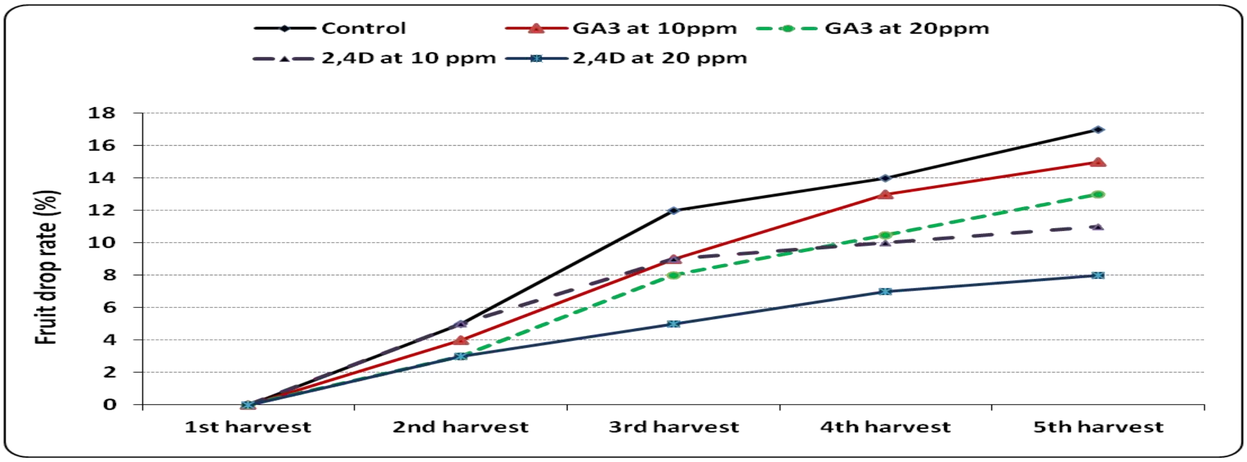



**Fig.( 2). Average of fruit drop rate (%) during different harvest periods of two seasons 2021 and 2022.**

**Fruit weight (g):** The data presented in **(Table 1)** indicated that, fruit weight varied with foliar spray of different growth regulators at different harvest periods. Fruit weight increased significantly in all treatments over the control and maximum mean fruit weight (249.1, 244.7 g) was observed in fruits harvested from trees treated with 2,4-D at 20 ppm compared to the control (239.5, 215.8 g) in the first and second seasons respectively, followed by $GA_3$ treatments. It was also observed that, fruit weight gradually increased with increasing harvest period up to the fourth harvest (mid-February) and then started to decrease significantly in the fifth harvest (mid-March) of both seasons compared to the first harvest (mid-November).These results were consistent with the findings of (Sandhu, 1992) on Kinnow mandarin, (Ladaniya, 1997) on Nagpur mandarin and they found that, an increase in juice content and fruit weight was observed with gibberellic acid. Kaur et al. (2008) also reported that, gibberellic acid at 25 and 50 ppm increased fruit weight in plum and contradicted the observation of (Bose, et al., 1988) who reported three-fold increase in fruit weight in mandarin. The increase in fruit weight may be due to the hormonal transport and accumulation of phytosynthates which resulted in better fruit development as well as accelerated cell division, elongation and enlargement. Also, Kaur et al. (2000) indicated that, fruit weight increased with increasing amount of 2, 4-D in Kinnow mandarin trees.

**Table (1). Fruit weight (g) as affected by some treatments on the storage of Washington navel orange on trees**.

| Treatments (T) | Fruit weight (g) | | | | | |
|---|---|---|---|---|---|---|
| | 1st harvest | 2nd harvest | 3rd harvest | 4th harvest | 5th harvest | Mean (T) |
| | Season, 2021 | | | | | |
| **Control (untreated)** | 240.30 | 241.20 | 242.50 | 243.10 | 230.60 | **239.5 c** |
| **$GA_3$ at 10 ppm** | 250.00 | 251.30 | 253.00 | 255.20 | 241.70 | **250.2 ab** |
| **$GA_3$ at 20 ppm** | 248.20 | 249.00 | 251.30 | 252.00 | 240.60 | **248.2 b** |
| **2, 4-D at10 ppm** | 249.30 | 250.60 | 252.20 | 253.40 | 239.80 | **249.1 ab** |
| **2, 4-D at 20 ppm** | 253.00 | 255.20 | 256.30 | 256.40 | 243.70 | **252.9a** |
| **Mean harvest** | **248.2ab** | **249.5ab** | **251.1a** | **252.0a** | **239.3b** | |
| | Season, 2022 | | | | | |
| **Control (untreated)** | 216.20 | 218.00 | 219.10 | 220.00 | 205.70 | **215.8 d** |
| **$GA_3$ at 10 ppm** | 230.30 | 231.40 | 233.00 | 234.20 | 226.80 | **231.1 c** |
| **$GA_3$ at 20 ppm** | 241.00 | 242.20 | 244.00 | 245.20 | 234.80 | **241.4 b** |
| **2, 4-D at10 ppm** | 245.10 | 246.20 | 247.00 | 247.30 | 237.90 | **244.7 ab** |
| **2, 4-D at 20 ppm** | 249.00 | 250.30 | 252.40 | 253.30 | 241.60 | **249.3 a** |
| **Mean harvest** | **236.3 ab** | **237.6 ab** | **239.1 a** | **240.0 a** | **229.4b** | |

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

**Juice weight percentage:** Results in **(Table 2)** showed a significant increase in the percentage of juice weight in the fruits in all treatments especially when spraying trees with 2, 4 – D at 20 ppm (53.4 and 56.2%) compared to the control treatment (50.3 and 50%) during the two seasons (2021 and 2022), respectively, while the other treatments gave the intermediate values in this regard. The results also indicated that, the juice weight (%) increased with the increase in the harvest period on the tree until mid-February (fourth harvest) and then decreased sharply in mid-March (fifth harvest). The maximum juice weight (55.4, 61.0%) was in the fourth harvest, while the minimum juice weight (42.1, 41.0%) was in the fifth harvest in the first and second seasons, respectively. These results were consistent with what was found by (Sandhu, 1992) in Kinnow mandarin and (Ladaniya, 1997) in Nagpur mandarin where they indicated that, the fruits treated with gibberellic acid remained firm and the untreated fruits were over ripe in their condition. Similar observations were made by Abd El-Rahman and Mohamed (2017) when extending the storage period of Balady mandarin fruits on the trees until mid-March.

**Table (2). Juice weight (%) as affected by some treatments on the storage of Washington navel orange on trees.**

| Treatments (T) | Juice weight (%) | | | | | |
|---|---|---|---|---|---|---|
| | 1st harvest | 2nd harvest | 3rd harvest | 4th harvest | 5th harvest | Mean (T) |
| | | | Season, 2021 | | | |
| **Control (untreated)** | 48.60 | 54.30 | 55.10 | 55.50 | 37.80 | **50.3 b** |
| **$GA_3$ at 10 ppm** | 51.20 | 52.00 | 53.40 | 56.30 | 42.60 | **51.1 ab** |
| **$GA_3$ at 20 ppm** | 49.60 | 50.20 | 52.30 | 53.60 | 43.90 | **49.9 c** |
| **2, 4-D at10 ppm** | 52.00 | 53.70 | 54.60 | 55.20 | 39.40 | **51.0 ab** |
| **2, 4-D at 20 ppm** | 53.30 | 54.00 | 56.40 | 56.50 | 46.70 | **53.4 a** |
| **Mean harvest** | **50.9 d** | **52.8 c** | **54.4 b** | **55.4 a** | **42.1 e** | |
| | | | Season, 2022 | | | |
| **Control (untreated)** | 50.00 | 53.00 | 55.40 | 57.60 | 34.00 | **50.0 d** |
| **$GA_3$ at 10 ppm** | 53.00 | 56.70 | 58.00 | 60.00 | 39.00 | **53.3 c** |
| **$GA_3$ at 20 ppm** | 54.00 | 56.80 | 58.00 | 62.00 | 41.60 | **54.5 b** |
| **2, 4-D at10 ppm** | 54.80 | 57.00 | 59.00 | 62.40 | 44.70 | **55.6 ab** |
| **2, 4-D at 20 ppm** | 56.00 | 57.30 | 59.00 | 63.00 | 45.80 | **56.2 a** |
| **Mean harvest** | **53.6 d** | **56.2 c** | **57.9 b** | **61.0 a** | **41.0 e** | |

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

**Peel thickness (mm):** The results shown in **(Table 3)** showed the peel thickness of Washington navel orange fruits under the effect of foliar spraying with some growth regulators and extending the storage period on trees. The data for both seasons indicated that, Gibberellic acid ($GA_3$) and Isopropyl Ester (2, 4-D) treatments increased the peel thickness of the fruits compared to the control treatment especially the trees treated with 2, 4-D at a concentration of 20 ppm, which had thicker fruits (6.28, 6.26 mm) while thinner fruits were obtained in the control treatment (5.3, 5.52 mm) during the 2021 and 2022 seasons, respectively. On the other hand, with regard to the harvest periods the data indicated that, the peel thickness of the fruits decreased as the storage period on the trees increased and the lowest peel thickness was in the last harvest (the fifth harvest). These results are consistent with Abd El-Rahman and Mohamed (2017) who reported that, the application of 2, 4-D at a concentration of 15 ppm led to an increase in the thickness of the fruit peels when storing Balady mandarin fruits on trees. Also, in this concern, Dinar et al. (1977) observed that, both $GA_3$ and 2, 4-D increased the thickness of Marsh grapefruit peels.

**Table (3). Peel thickness (mm) as affected by some treatments on the storage of Washington navel orange on trees.**

| Treatments (T) | Peel thickness (mm) | | | | | |
|---|---|---|---|---|---|---|
| | 1st harvest | 2nd harvest | 3rd harvest | 4th harvest | 5th harvest | Mean (T) |
| | | | Season, 2021 | | | |
| **Control (untreated)** | 5.70 | 5.50 | 5.30 | 5.10 | 4.90 | **5.3 d** |
| **$GA_3$ at 10 ppm** | 6.30 | 6.10 | 5.90 | 5.80 | 5.70 | **5.96 c** |
| **$GA_3$ at 20 ppm** | 6.40 | 6.30 | 6.10 | 5.90 | 5.80 | **6.10 b** |
| **2, 4-D at10 ppm** | 6.50 | 6.40 | 6.30 | 5.90 | 5.70 | **6.16ab** |
| **2, 4-D at 20 ppm** | 6.60 | 6.50 | 6.40 | 6.10 | 5.80 | **6.28 a** |
| **Mean harvest** | **6.3 a** | **6.16ab** | **6.0b** | **5.76c** | **5.58 d** | |
| | | | Season, 2022 | | | |
| **Control (untreated)** | 5.90 | 5.70 | 5.60 | 5.50 | 4.90 | **5.52 d** |
| **$GA_3$ at 10 ppm** | 6.20 | 6.10 | 5.90 | 5.80 | 5.60 | **5.92 c** |
| **$GA_3$ at 20 ppm** | 6.50 | 6.30 | 6.20 | 6.10 | 5.90 | **6.20 b** |
| **2, 4-D at10 ppm** | 6.60 | 6.50 | 6.30 | 6.20 | 5.80 | **6.28 a** |
| **2, 4-D at 20 ppm** | 6.60 | 6.40 | 6.30 | 6.10 | 5.90 | **6.26a** |
| **Mean harvest** | **6.36a** | **6.20b** | **6.06 c** | **5.94d** | **5.62e** | |

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

**Peel firmness (mm):** The peel firmness or puncture resistance of the peel is one of the factors that determine the quality of the fruits. The results presented in **(Table 4)** showed that, all treatments increased the peel puncture resistance and gibberellic acid at 10 ppm was superior in achieving the highest averages (10.55, 10.33 mm) followed by 2, 4-D treatment at a concentration of 20 ppm (10.31, 10.28 mm) while the lowest averages (8.95, 9.04 mm) was obtained by the control treatment during the two seasons (2021 and 2022) respectively, while other treatments recorded intermediate values in this regard. On the other hand, it can be observed that, the peel puncture resistance decreased with increasing harvest period. Firmness was found to decrease with advancing ripening in mid-March (fifth harvest). This may be due to loosening of the cell wall of the fruit. Propectin, which acts as a cement to bind cellulose and hemicellulose, is converted to soluble pectin. As a result, it reduces the binding strength of the cell wall during ripening (Rana, 2006). These results are in agreement with the findings of Abd El-Rahman and Mohamed (2017) who mentioned that, prolonging storage season of Balady mandarin fruits on trees and fruits treated with gibberellic acid and 2,4-D were more resistant to peel puncture. The role of gibberellic acid is not only limited to regulating the peel color but also in delaying the overall peel aging process (Baez-Sanudo et al., 1992). The same trends were observed in plums by Kaur et al. (2008). Also, Gibberellic acid + 2, 4-D maintained peel puncture resistance when applied at pre-harvest stage (El-Otmani et al., 1990) on Clementine mandarin and orange .

**Table (4). Peel firmness (mm) as affected by some treatments on the storage of Washington navel orange on trees.**

| Treatments (T) | Peel firmness (mm) | | | | | |
|---|---|---|---|---|---|---|
| | 1st harvest | 2nd harvest | 3rd harvest | 4th harvest | 5th harvest | Mean (T) |
| | | | Season, 2021 | | | |
| **Control (untreated)** | 9.98 | 9.96 | 8.59 | 8.50 | 7.74 | **8.95 e** |
| **$GA_3$ at 10 ppm** | 11.48 | 11.41 | 10.57 | 10.48 | 8.81 | **10.55 a** |
| **$GA_3$ at 20 ppm** | 10.67 | 10.33 | 9.59 | 8.74 | 7.86 | **9.44 c** |
| **2, 4-D at10 ppm** | 10.44 | 10.38 | 8.89 | 8.73 | 7.78 | **9.24d** |
| **2, 4-D at 20 ppm** | 11.35 | 11.23 | 10.53 | 9.59 | 8.86 | **10.31b** |
| **Mean harvest** | **10.78 a** | **10.66 b** | **9.63 c** | **9.21d** | **8.21e** | |
| | | | Season, 2022 | | | |
| **Control (untreated)** | 9.89 | 9.80 | 8.89 | 8.77 | 7.87 | **9.04 e** |
| **$GA_3$ at 10 ppm** | 11.66 | 11.43 | 10.56 | 9.43 | 8.56 | **10.33 a** |
| **$GA_3$ at 20 ppm** | 10.87 | 10.01 | 9.67 | 8.66 | 7.88 | **9.42 d** |
| **2, 4-D at10 ppm** | 10.77 | 10.60 | 9.82 | 8.90 | 7.73 | **9.56 c** |
| **2, 4-D at 20 ppm** | 11.31 | 11.12 | 10.78 | 9.31 | 8.89 | **10.28 b** |
| **Mean harvest** | **10.90 a** | **10.59b** | **9.94 c** | **9.01d** | **8.19e** | |

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

**TSS/acid ratio:** The total soluble solids/ acidity ratio is an important characteristic of fruits destined for local consumption or export. It is noted from **(Table 5)** that, TSS/acid increases with the increase of the harvest period until the fifth harvest (mid-March). On the other hand, the control treatment can reach the over-ripening date by increasing the TSS/acid in the fruits (14.29, 14.85), while the tested 2,4-D and $GA_3$ treatments delay the over-ripening date and the lowest values were obtained at 20 ppm of $GA_3$ (13.36, 13.64) in the first and second seasons (2021 and 2022), respectively. These results are in the same line with those obtained by Abd El-Rahman and Mohamed (2017) who reported that, the application of 2, 4-D at 15 ppm led to decrease the TSS/Acid of fruits when prolonging the storage of Balady mandarins on the tree until early March. Also, these results are consistent with the previous findings of (Mohamed and Mohamed, 2015) on navel orange, who reported that, TSS/ acid ratio of fruits increased with advancing the harvest dates.

**Table (5). TSS/acid ratio as affected by some treatments on the storage of Washington navel orange on trees.**

| Treatments (T) | TSS/acid ratio | | | | | |
|---|---|---|---|---|---|---|
| | 1st harvest | 2nd harvest | 3rd harvest | 4th harvest | 5th harvest | Mean (T) |
| | | | Season, 2021 | | | |
| **Control (untreated)** | 13.22 | 13.66 | 13.98 | 14.93 | 15.66 | **14.29 a** |
| **$GA_3$ at 10 ppm** | 12.56 | 13.44 | 13.93 | 14.45 | 14.84 | **13.84 b** |
| **$GA_3$ at 20 ppm** | 12.33 | 12.67 | 13.56 | 13.78 | 14.45 | **13.36 d** |
| **2, 4-D at10 ppm** | 12.61 | 12.73 | 13.66 | 14.32 | 14.66 | **13.60 c** |
| **2, 4-D at 20 ppm** | 12.41 | 12.92 | 13.66 | 13.78 | 14.72 | **13.50 c** |
| **Mean harvest** | **12.63 e** | **13.08 d** | **13.76 c** | **14.25 b** | **14.87 a** | |
| | | | Season, 2022 | | | |
| **Control (untreated)** | 14.34 | 14.52 | 14.71 | 14.88 | 15.78 | **14.85 a** |
| **$GA_3$ at 10 ppm** | 13.54 | 13.62 | 13.68 | 14.27 | 15.32 | **14.09 c** |
| **$GA_3$ at 20 ppm** | 12.11 | 13.45 | 13.56 | 14.33 | 14.73 | **13.64 d** |
| **2, 4-D at10 ppm** | 13.43 | 13.56 | 13.74 | 14.91 | 15.00 | **14.13 b** |
| **2, 4-D at 20 ppm** | 13.50 | 13.67 | 13.82 | 14.75 | 14.66 | **14.08 c** |
| **Mean harvest** | **13.38 e** | **13.76 d** | **13.90 c** | **14.63b** | **15.10 a** | |

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

**Vitamin C:** Fruits with high vitamin C content are considered to have high nutritional value. The data in **(Table 6)** showed that vitamin C content decreased with increasing storage period of fruits on the tree in all treatments. However, the decrease was more marked in untreated fruits (control treatment). On the other hand, maximum vitamin C content was obtained with $GA_3$ at 20 ppm (40.71, 39.10 mg/100 ml) versus control (33.65, 35.8 mg/100 ml) in the first and second seasons (2021 and 2022), respectively. Also, the variations in V.C fluctuated during the two seasons. These results were in agreement with the findings of Sindhu and Sighrot (1993) who reported that, maximum ascorbic acid content in fruits treated with $GA_3$. The decrease in ascorbic acid could be due to enzymatic loss of ascorbic acid as it is converted to 2-3-dioxy-L-gluconic acid (Mapson, 1970). Few studies have indicated that $GA_3$ applications were effective (El-Zeftawi, 1980 a, b). The differences between the research results are due to the variable factors of growth regulators according to the citrus species and the time of application especially $GA_3$ (Cogins, 1981). Furthermore, Chundawat and Randhawa (1973) reported that, vitamin C content increased with spraying of 2, 4-D in Duncan grapefruit cultivar. Also, Abd El-Rahman and Mohamed (2017) mentioned that, the application of $GA_3$ at 20ppm increased fruit vitamin C content when extending the storage of Balady mandarins on the tree until early March.

**Table (6). Vitamin C (mg/100 ml) as affected by some treatments on the storage of Washington navel orange on trees.**

| Treatments (T) | Vitamin C (mg/100 ml) | | | | | |
|---|---|---|---|---|---|---|
| | 1st harvest | 2nd harvest | 3rd harvest | 4th harvest | 5th harvest | Mean (T) |
| | | | Season, 2021 | | | |
| **Control (untreated)** | 35.21 | 35.10 | 34.67 | 33.44 | 29.81 | **33.65 e** |
| **$GA_3$ at 10 ppm** | 36.33 | 36.20 | 35.41 | 34.11 | 30.77 | **34.56 d** |
| **$GA_3$ at 20 ppm** | 45.88 | 44.72 | 39.33 | 38.61 | 35.00 | **40.71 a** |
| **2, 4-D at10 ppm** | 38.72 | 38.51 | 37.63 | 37.02 | 33.44 | **37.06 c** |
| **2, 4-D at 20 ppm** | 43.45 | 40.31 | 38.22 | 37.44 | 36.21 | **39.13 b** |
| **Mean harvest** | **39.92 a** | **38.97 b** | **37.05 c** | **36.12 d** | **33.05 e** | |
| | | | Season, 2022 | | | |
| **Control (untreated)** | 38.44 | 37.61 | 36.55 | 35.81 | 30.44 | **35.8 d** |
| **$GA_3$ at 10 ppm** | 40.73 | 38.65 | 37.40 | 36.33 | 33.88 | **37.4 cd** |
| **$GA_3$ at 20 ppm** | 46. 82 | 43.32 | 39.66 | 39.22 | 34.36 | **39.1a** |
| **2, 4-D at10 ppm** | 39.84 | 39.53 | 38.71 | 37.33 | 36.09 | **38.3 b** |
| **2, 4-D at 20 ppm** | 39.44 | 38.27 | 37.43 | 37.10 | 36.88 | **37.8 c** |
| **Mean harvest** | **39.6 a** | **39.5 a** | **38.0 b** | **37.2 c** | **34.3 d** | |

Mean separation within columns by Duncan's multiple range test, 5% level. Values that don't share the same letter are significantly different.

**Leafy inflorescence density (No./m$^2$):** In citrus trees the density of leaf inflorescences is considered one of the important things to increase the fruit set and the final yield. **Fig. (3)** shows that, prolonging storage season of navel orange fruits on the trees did not affect the density of leaf inflorescences, as there were no significant differences during the three years 2021, 2022 and 2023. In this concern, (Krajewski and Rabe, 1995) mentioned that, fruit set is higher and the eventual fruit size is larger for fruits arising from leafy inflorescences in citrus trees. Also, Erner and Shomer (1996) stated that, the matter is not limited to the fact that the leafy inflorescences increase the supply of light-absorbing materials to the developing ovaries, but rather the flowers on the leafy inflorescences are also a stronger source of absorption than the flowers on the leafless inflorescences.

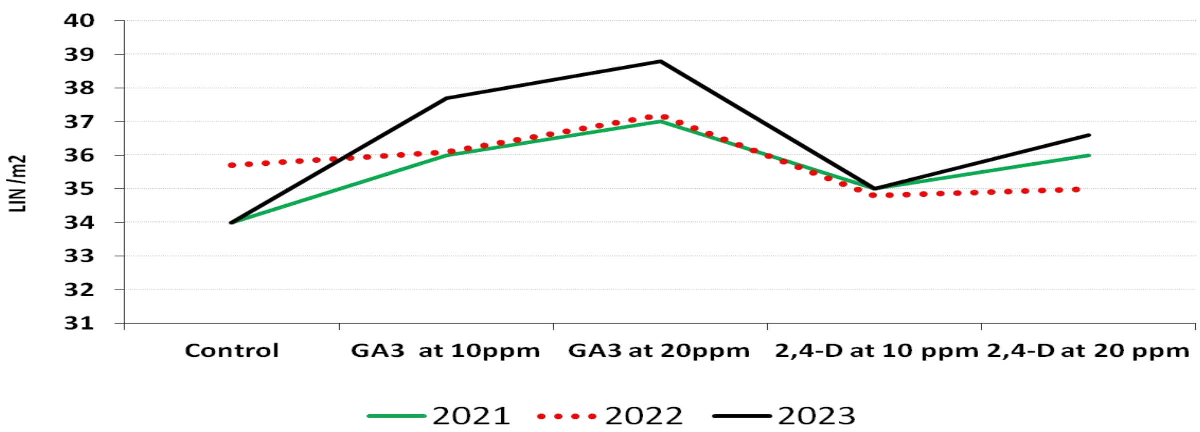



**Fig (3). Leafy inflorescence (LIN) density (No./m$^2$) as affected by some treatments on the storage of Washington navel orange on trees** .

**Anatomical study:** The anatomical studies clearly showed that no cell division was noted during abscission layer formation. The longitudinal section of the fixed fruit is shown in **(Fig. 4 A)** as a result of Isopropyl Ester (2, 4-D) application, and the longitudinal section of the abscission fruit is shown in **(Fig. 4B and C).** It was observed that the abscission zone (AZ) contains small, compact cells without extracellular spaces and swollen cell walls; the separation layer was approximately of 8–10 cells wide. No cell division was found at or near the abscission zone. This results confirmed with mentioned by (Zanchin et al., 1995)who revered that, abscission zone undergoes significant anatomical changes over time, such as increased cell wall thickness, changes in cell shape, and the occurrence of plasmolysis in the final stage and the formation of intercellular cracks, leading to fruit abscission .In this regard, Sexton and Roberts (1982) and (Roberts et al., 2000) indicated that, the cells participating in the abscission process were identified by a rapid decrease in cell integrity as an abscission layer. Weis et al. (1991) also indicated that, plasmolysis occurs as a natural phenomenon during abscission in olive trees.

A B C

**Fig. (4). (A) Longitudinal section of fixed fruit, (B and C) longitudinal section of abscission fruit, arrow refer to abscission zone (AZ).**

**Feasibility study:** The economics of citrus fruits varies depending on the final use of the fruit and the point at which the fruit is valued from orchard to consumer. For the grower, any fruit that can be sold at a good and reasonable price is economically viable. Therefore, when the local market is saturated with navel orange, storing the fruit on the tree for a certain period while maintaining its quality as much as possible increases the farmer's profitability.

**CONCLUSION**:

The extension of the harvest period of navel orange fruits on trees can be successfully achieved without affecting the quality of fruits. The best quality can be achieved until mid-February by foliar spraying at the beginning of the fruit color break (mid-September) with Isopropyl Ester (2, 4-D) at a concentration of 20 ppm.

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## الملخص العربى

## تأثير الرش الورقي ببعض منظمات النمو على إطالة موسم تخزين ثمار البرتقال أبو سره على الأشجار وتقليل تساقط ما قبل الحصاد

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نظراً لبعض التقلبات المفاجئة في أسعار ثمار البرتقال أبو سره سواء في السوق المحلية أو التصدير فقد يضطر المنتج إلى تخزين الثمار على الأشجار لتجنب إنخفاض الأسعار الذي يسبب خسائر اقتصادية وقد يدفعه ذلك إلى الإمتناع عن التوسع في زراعة الموالح. أُجريت هذه الدراسة لموسمين (2021 و2022) لدراسة تأثير الرش الورقي ببعض منظمات النمو وهي حمض الجبرليك ($GA_3$) واسترالايزوبروبيل (2, 4-D) عند كسر لون الثمار في منتصف شهر سبتمبر على إطالة موسم تخزين ثمار البرتقال أبو سره على الأشجار وتقليل تساقط ما قبل الحصاد. أشارت النتائج المتحصل عليها إلى أن استرالايزوبروبيل (2,4-d) بتركيز 20 جزء في المليون كان أفضل معاملة لتقليل النسبه المئوية لمعدل تساقط الثمار وتحقيق أعلى قيم معنويه لوزن الثمار والنسبة المئوية لوزن العصير ونسبة المواد الصلبة الذائبة الكلية/الحموضه وجعل قشرة الثمار أكثر سمكاً. كما أدى حمض الجبرلين بتركيز 20 جزء في المليون إلى زيادة صلابة القشرة ومحتوى الثمار من فيتامين( سى). أيضا تخزين الثمار على الأشجار حتى منتصف فبراير (الحصاد الرابع) كان أفضل فترة للحفاظ على جودة الثمار. ومن ناحية أخرى، لم يؤثر تخزين الثمار على الأشجار على كثافة النورات الورقية التي تُعتبر من الأمور الهامه لزيادة عقد الثمار والمحصول النهائي. أظهرت الدراسة التشريحية بوضوح عدم ملاحظة أي انقسام خلوي أثناء تكوين طبقة الانفصال.

ويمكن التوصية بإطالة فترة تخزين ثمار البرتقال ابو سره على الأشجار مع الحفاظ على جودة الثمار حتى منتصف فبراير، وذلك برش الأشجار بـإستر الأيزوبروبيل (2, 4-D) 20 جزء في المليون لتحقيق عائد اقتصادي مُربح للمزارع