EFFECT OF GIRDLING AND GIBBERELLIC ACID APPLICATION ON YIELD AND FRUITS QUALITY CHARACTERISTICS OF BALADY MANDARIN

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The present study was carried out during two successive of 2016 and 2017 on 10 years old Balady mandarin (*Citrus reticulate* Blanco) trees budded on sour orange rootstock (*Citrus aurantium* L. Osbeck) and spaced 3.5×3.5 meters apart. Trees have been treated with girdling and gibberellic acid and were grown in sandy soil under drip irrigation system in a private orchard at Al-kamal region- Ismalia Governorate, Egypt, in July and December. The aim of this work was to study the effect of girdling and gibberellic acid on the vegetative growth, yield and fruit quality. The chosen trees girdled with 2 mm, 4 mm width and gibberellic acid was sprayed (at 50 and 100 ppm) alone or in combination with girdling in each season. Results showed that, girdling 4 mm+100 ppm gibberellic acid have given the best enhanced vegetative growth parameters in terms of leaf area, carbohydrate and chlorophyll contents in the leaves of Balady mandarin trees in both seasons. Moreover, treatment of girdling 4 mm in December and girdling 4 mm+50 ppm GA_3 gave the best fruit length, diameter as compared to control treatment. Yield and fruit quality of the chosen trees were significantly increased by all treatments as compared to control in both seasons.

Keywords: girdling, gibberellic acid, Balady mandarin, fruit quality

INTRODUCTION

In Egypt, citrus is a backbone of fruit crop cultivation. However, Balady mandarin fruits occupy the third rank after Navel orange and Valencia orange fruits. Mandarin (*Citrus reticulate* Blanco) is a promising export fruit crop in Egypt. Citrus trees representing the most important fruit crop in Egypt, occupy around 395730 feddans producing about 3730685 ton fruits. Mandarin trees occupy 101342 feddans and produce around 885365 tons, as reported by the annual statistics of Ministry of Agriculture in 2015.

Balady Mandarin (*Citrus reticulata* Blanco), is one of the popular citrus cultivars due to the beautiful shape, easy to peel, and rich in vitamin-C

with fair amounts of vitamins A and B and other antioxidant compounds. Besides, they are rich sources of minerals (calcium, phosphorus and iron). The juice is very refreshing, delicious and soothing (Ahmed et al., 2007).

Different types of girdling particularly for branches and limbs can increase the number of flowers, set fruitlets, fruit yield as well as leaf photosynthetic pigments, endogenous hormones content and retained fruit/ branch of Washington Navel orange (*Citrus sinensis* L. Osbeck) trees. In addition, an intensified fertilization program must be accompanied to promote leaf / fruit ratio and the fruit physical and chemical properties as reported by Ibrahim et al. (2016). On the other hand, Rivas et al. (2007) reported that girdling trunk few weeks before flowering of mandarin trees, failed to induce any differences in the total chlorophyll concentration between control and girdled trees. Girdling effect has been related to the accumulation of photo assimilates in the canopy as a result of the interruption of the downward transport of soluble sugars, resulting in increasing in fruit set in citrus. Girdling applications are important and have been used worldwide for centuries in citrus and other fruit tree crops. Girdling treatment led to an increase in the fruit yield, fruit set and fruit size of the Robinson mandarin (Mostafa and Saleh, 2006 and Yilmaz et al., 2018).

Girdling consists of the removal of a strip of bark from the trunk or major limbs of a fruit tree, which blocks the downward translocation of photosynthates and metabolites through the phloem, thus reducing fruit drop and enhancing fruit growth and yield (Mostafa and Saleh, 2006; Raveh, 2013 and Zhao et al., 2013).

Girdling applications at different times are used to increase the yield of some citrus varieties, such as Robinson, Nova, Dancy, Osceola, Klemantin, Minneola, Orlando and Ortanique, which are self-sterile. The fruit set process is complex because photosynthetic activity and thus, the production of photosynthetic compounds, can be altered by sink demand. Girdling effect is related to the accumulation of photoassimilates in the canopy as a result of the interruption of the downward transport of soluble sugars resulting in the increase in fruit set in citrus (Rivas et al., 2007). In addition, girdling treatments increased yield by 125% in mandarins (Rivas et al., 2006). Mahouachi et al. (2012) found that girdling increases gibberellic acid concentration when performed on branches of Satsuma mandarin at anthesis. Also, many times girdling and gibberellic acid sprays are used together shortly after anthesis as they have a synergistic effect on increasing berry size (Brar et al., 2008).

Plant growth regulators as foliar applications are the most powerful tools used for manipulating tree growth, flowering, yield and fruit quality traits (Ashraf et al., 2013). The use of girdling and gibberellic acid (GA_3) has become a wide spread practice in the citrus producing countries of the world to improve fruit quality Moreover, GA_3 has increased the yield of fruit in Balady mandarin (El-Sese, 2005). Preharvest application of growth regulators

like GA_3 along with mechanical treatments like girdling reduced weight loss (%), decay (%), shattering (%), total spoilage (%) and acidity (%) while it increased berry colour, TSS and TSS/acid ratio compared to control after 45 days of storage at 0°C, RH 90-95% (Abd El-Rahman, 2007 and Saini et al., 2011). GA_3 applied to clusters and or trunk girdling increased berry weight and vine yields significantly over the control (Harrell and Williams, 1987). Girdling and GA_3 sprays are used together shortly after anthesis as they have a synergistic effect on increasing berry size (Brar et al., 2008 and Harrell and Williams, 1987). Girdling in combination with an application of GA_3 indicates that GA_3 may possibly mitigate the depressing effect of girdling on stomatal conductance, and subsequently whole vine water use (Williams and Ayars, 2005). In addition, preharvest GA_3 applications were found to be improved growth parameters of Washington Navel orange trees (Hanafy et al., 2012). An important and distinctive link in the technology of growing table grapes is the application of growth regulators or girdling (Crupi et al., 2016). Mandarin fruit set may also be improved by cultural practices like branch girdling, either alone or in combination with other practices.

One of the practices that can be used to increase production and fruit set is the girdling, whose function is to promote accumulation of carbohydrates in the aerial parts of plants (Rivas et al., 2006). Thus, the objective of this study was to evaluate the effects of girdling and application of GA_3 on yield and fruits quality characteristics of Balady mandarin trees.

MATERIALS AND METHODS

1. Plant Material and Site Experience

The present study was carried out during 2016 and 2017 seasons on 10 years old Balady mandarin (*Citrus reticulate* Blanco) trees budded on sour orange rootstock (*Citrus aurantium* L. Osbeck) and spaced 3.5×3.5 meters apart. Trees were grown in sandy soil under drip irrigation system in private orchard at Al-kamal region, Ismalia Governorate, Egypt.

This study was carried out to explore possibilities of inducing fruitfulness through the use of girdling operations and GA_3. Girdling was carried out before blossoming (late December) and on July with about 2 mm and 4 mm width around trunk using a knife without injuring the wood layers. Gibberellic acid was sprayed at 50 and100 ppm twice in July and December.

2. Experiment Design and the Treatments

Factorial design - Time of treatment was the main factor and the sub main factor was the following treatments:

1- Control (untreated)
2- Girdling (2 mm)
3- Girdling (4 mm)
4- 50 ppm GA_3

5- 100 ppm GA_3
6- Girdling (2 mm) + 50 ppm GA_3
7- Girdling (2 mm) +100 ppm GA_3
8- Girdling (4 mm) + 50 ppm GA_3
9- Girdling (4 mm) +100 ppm GA_3

The following parameters were recorded for both seasons:

a- Vegetative growth parameters

1- Leaf area (cm^2): Twenty mature leaves replicated three times were abscised in December, then leaf area (cm^2) was calculated at the end of each season by using cl-202 area meter.
2- Leaf carbohydrate was extracted and determined according to the method described by Malik and Singh (1980).
3- Leaf chlorophyll was recorded by using chlorophyll meter (Minolta, SPAD 502).
4- Leaf nutrient content: In September of each season leaf samples were taken randomly from non-fruiting and non-flashing terminal shoots, washed with tap water then with distilled water, dried at 70°C until constant weight, ground and finally digested. The digested solution was used to determine N, P, K percentage in leaves, which estimated by standard procedure according to Wilde et al. (1985).

b- Fruit quality parameters

The following parameters were considered: At harvest time (first week of January), the yield expressed in weight (kg) and number of fruits per tree. Ten fruits were randomly collected from all sides of the trees under treatments for measuring the physical and chemical characterization: fruit dimensions [fruit length and diameter (cm)], peel thickness (mm), fruit weight (g), total soluble solids percentage (TSS) using a hand refractometer, total titratable acidity as mg citric acid/100 ml of juice by titration against 0.1 normal sodium hydroxide in the presence of phenolphthalein as an indicator, TSS /acid ratio, ascorbic acid content (mg /100 ml of juice) by titration against 2,6-dichlorophenol indophenol (mg/100 ml) and total sugars (%) as described in the method of A.O.A.C. (1985).

RESULTS AND DISCUSSION

1. Effects of Girdling and GA_3 on Leaf Area, Carbohydrate and Chlorophyll Contents in the Leaves

Table (1) indicates that during 2016 and 2017 seasons, all treatments increased leaf area. The highest significant values of leaf area were produced by 100 ppm GA_3, girdling 2 mm+100 ppm GA_3 and girdling 4 mm+100 ppm GA_3 in both seasons. Concerning leaf area, no significant differences appeared during summer and autumn in both seasons. On the other hand, there were significant differences by using some combination of treatments, the use of

girdling 2 mm+100 ppm GA_3 in autumn of the first season followed by girdling 4 mm+100 ppm GA_3 in Autum of the second season. Sharma and Ananda (2004) found that, applications of GA_3 at 10-40 ppm and GA_3 at 10 ppm + benzyladenine (BA) at 5 ppm resulted in a significantly high increase in vegetative growth of apples over the control. Also, it was reported that girdling application increased leaf area (Bahlool et al., 2000 and Said et al., 2003). In addition, Yilmaz et al. (2018) indicated that girdling significantly increased total chlorophyll compared to untreated trees.

Results in table (1) clearly indicate that the maximum recorded carbohydrates content in leaves was 12.24 and 12.89% in 2016 and 2017, respectively, using 50 ppm GA_3 in the second season and girdling 4 mm+100 ppm GA_3 during both seasons, compared with all treatments. No significant differences in the total carbohydrates was observed between summer and autumn treatments in both seasons. Hence, combined application of different treatments gave the highest carbohydrates content with girdling 4 mm+100 ppm GA_3 in autumn in the first season and girdling 4 mm+100 ppm GA_3 in both seasons. Girdling increased the carbohydrate concentration in *Vitis vinifera* L. (Roper and Williams, 1989). On the other hand, Vemmos et al. (2012) found that girdling increased carbohydrates, particularly starch in pistachio shoots. Also, Jordan et al. (2001) reported that starch level increased in leaves and shoots of girdled peach trees. Finally, Chun et al. (2003) on 'Anna' apple found that girdling increased the accumulation of carbohydrate content in the upper part of girdle.

Regarding chlorophyll content in the leaves, it is observed that significant differences were among the treatments, since the highest value was obtained with girdling 4 mm+100 ppm GA_3 during the two studied seasons. On the other hand, there were significant differences in summer treatments, which gave the highest values for the two seasons. However, the highest value was obtained with autumn treatments in the second season. Regarding the combination between treatments, the highest significant value was obtained with girdling 4 mm+100 ppm GA_3 in the two seasons when compared with any other treatments. For treatments in combination, the data of both seasons

Table (1). Effect of girdling and GA_3 foliar spray on leaf area, carbohydrate and chlorophyll of Balady mandarin in the 2016 and 2017 seasons.

Treatment	Leaf area (cm^2)			Carbohydrate			Chlorophyll		
	Summer	Autumn	Mean	Summer	Autumn	Mean	Summer	Autumn	Mean
				Season 2016					
Control	7.53 i	7.26 i	7.40 D	7.19 j	7.52 j	7.36 G	58.51 gh	57.27 h	57.89 F
Girdling 2 mm	10.73 fgh	10.28 h	10.51 C	8.83 f-i	8.43 i	8.63 F	60.02 efg	60.01 efg	60.01 E
Girdling 4 mm	10.87 e-h	11.13 b-h	11.00 BC	9.25 e-h	9.36 d-h	9.31 E	69.63 ab	68.54 b	69.08 B
50 ppm GA_3	11.03 d-h	11.40 a-g	11.22 BC	8.70 ghi	8.63 hi	8.67 F	60.11 efg	58.90 fg	59.51 E
100 ppm GA_3	12.03 a-d	12.23 ab	12.13 A	10.17 d	10.17 d	10.17 C	60.40 def	59.21 fg	59.80 E
Girdling 2 mm+50 ppm GA_3	10.63 gh	11.10 c-h	10.87 BC	9.52 def	9.46 d-g	9.49 DE	60.37 def	59.59 fh	59.98 E
Girdling 2 mm+100 ppm GA_3	11.83 a-f	12.30 a	12.07 A	9.83 de	9.89 de	9.86 CD	61.83 d	61.44 de	61.64 D
Girdling 4 mm+50 ppm GA_3	11.13 b-h	11.80 a-f	11.47 AB	11.41 bc	11.23 c	11.32 B	65.43 c	65.22 c	65.32 C
Girdling 4 mm+100 ppm GA_3	11.87 a-e	12.17 abc	12.02 A	12.03 ab	12.45 a	12.24 A	70.57 a	70.38 a	70.47 A
Mean	10.85 A	11.07 A		9.66 A	9.68 A		62.99 A	62.28 B	
				Season 2017					
Control	8.46 g	8.83 g	8.64 E	7.47 h	7.63 h	7.55 G	58.78 fg	59.57 efg	59.18 E
Girdling 2 mm	10.90 f	11.07 ef	10.98 D	9.26 efg	8.76 g	9.01 F	60.20 efg	60.14 efg	60.17 E
Girdling 4 mm	11.77 cde	11.70 cde	11.73 C	9.72 c-f	9.39 d-g	9.55 DE	70.17 ab	68.51 b	69.34 B
50 ppm GA_3	11.57 def	11.77 cde	11.67 C	9.21 fg	9.22 fg	9.22 EF	59.77 efg	58.47 g	59.12 E
100 ppm GA_3	12.40 abc	12.13 a-d	12.27 AB	11.35 b	10.10 c	10.73 B	60.58 d-g	59.02 fg	59.80 E
Girdling 2 mm+50 ppm GA_3	11.60 def	11.23 ef	11.42 CD	9.94 cd	9.38 d-g	9.66 D	61.01 def	58.67 g	59.84 E
Girdling 2mm+100 ppm GA_3	11.60 def	11.50 def	11.55 C	10.28 c	9.87 cde	10.08 C	62.63 d	61.79 de	62.21 D
Girdling 4 mm+50 ppm GA_3	11.80 cde	11.87 b-e	11.83 BC	12.52 a	12.52 a	12.52 A	66.07 c	66.38 c	66.23 C
Girdling 4 mm+100 ppm GA_3	12.57 ab	12.63 a	12.60 A	13.05 a	12.73 a	12.89 A	71.86 a	71.23 a	71.55 A
Mean	11.41 A	11.41 A		10.31 A	9.96 A		63.45 A	62.64 A	

showed that the highest value was obtained with girdling 4 mm and girdling 4 mm+100 pp GA_3. Additionally, results obtained in the first season showed that the highest value was in summer. While, in the second season, there was no significant effect, when compared with the control. In addition, Mostafa and Saleh (2006) indicated that girdling induced increase in total chlorophyll significantly, compared to control. In addition, several authors have proposed that total leaf carbohydrate content and starch increased as a result of girdling (Rivas et al., 2008). It may be due to the accumulation of chlorophyll content and increased photosynthesis in the girdled branch. Chlorophyll fluorescence has become one of the most powerful and widely used techniques available to plant physiologists and ecophysiologists. In addition, Yilmaz et al. (2018) indicated that girdling significantly increased total chlorophyll.

2. Ffects of Girdling and GA_3 on Nitrogen, Phosphorus and Potassium Contents in the Leaves

As shown in table (2), leaf nitrogen content reached its maximum levels at summer and autumn 2017 and 2018 seasons. However, treatment girdling 4 mm+100 ppm GA_3 gave the best leaf nitrogen content followed by 100 ppm GA_3 in both seasons during this study, compared to all treatments.

Interaction data showed that, leaf nitrogen (%) was the highest value in case of leaves of trees that have treated with girdling 4 mm+100 ppm GA_3 in summer in the first and second seasons and only in autumn in the second season, respectively.

The data presented in table (2) show that the highest significant leaf phosphorus (%) was recorded with girdling 4 mm+100 ppm GA_3 in the first season and girdling 4 mm+50 ppm GA_3 in the second season. In addition, significant increases in leaf phosphorus were recorded by summer treatment in both seasons and autumn in the second season only. Regarding the interaction, the highest values of leaf phosphorus content were obtained with girdling 4 mm+50 ppm GA_3 in summer in both seasons and in autumn in the second season. In addition, control was the lowest leaf phosphorus content.

Results in table (2) show that leaf potassium (%) was significantly influenced by different treatments; girdling 2 mm+50 ppm GA_3 in the first season and girdling 2 mm+100 ppm GA_3 in the second season. Data also indicated that, trees at autumn gave the highest significant values in the first season. Meanwhile, no significant values were observed in both summer and autumn in the second season, compared with all treatments.

The obtained data revealed that girdling 2 mm+50 ppm GA_3 in the first season and girdling 2 mm+100 ppm GA_3 in the second season reflect significant increases in leaf potassium content of leaves, compared with all treatments. In the other side, it was found that girdling improved N and K content in leaves. According to Rivas et al. (2006), the productivity of Fortune and Clausellina mandarins can be improved by girdling. Cimó et al. (2013)

Table (2). Effect of girdling and GA_3 foliar spray on nitrogen, phosphorus and potassium of Balady mandarin in the 2016 and 2017 seasons.

Treatment	Nitrogen %			Phosphorus %			Potassium %		
	Summer	Autumn	Mean	Summer	Autumn	Mean	Summer	Autumn	Mean
Season 2016									
Control	2.27 h	2.25 i	2.26 F	0.32 i	0.32 i	0.32 E	1.24 k	1.25 jk	1.25 F
Girdling 2 mm	2.33 g	2.32 g	2.32 E	0.35 h	0.36 g	0.36 D	1.30 j	1.36 i	1.33 E
Girdling 4 mm	2.41 f	2.41 f	2.41 D	0.38 fg	0.38 g	0.38 C	1.38 i	1.44 gh	1.41 D
50 ppm GA_3	2.44 de	2.42 ef	2.43 C	0.40 def	0.39 efg	0.40 B	1.40 hi	1.47 fg	1.43 D
100 ppm GA_3	2.47 c	2.47 c	2.47 B	0.41 cde	0.40 def	0.40 B	1.50 ef	1.60 cd	1.55 BC
Girdling 2 mm+50 ppm GA_3	2.41 f	2.42 f	2.41 D	0.35 h	0.40 def	0.37C	1.60 cd	1.75 a	1.68 A
Girdling 2 mm+100 ppm GA_3	2.44 de	2.45 d	2.44C	0.42 abc	0.29 j	0.35 D	1.50 ef	1.66 b	1.58 B
Girdling 4 mm+50 ppm GA_3	2.41f	2.42f	2.41 D	0.44 a	0.42 bcd	0.43 A	1.51 ef	1.62 bc	1.57 B
Girdling 4 mm+100 ppm GA_3	2.51a	2.50 b	2.51A	0.43 ab	0.41 cde	0.42 A	1.49 fg	1.55 de	1.52 C
Mean	2.41 A	2.41A		0.39 A	0.37 B		1.45 B	1.52 A	
Season 2017									
Control	2.29 h	2.29 h	2.29 G	0.33 g	0.34 fg	0.34 F	1.23 k	1.26 k	1.25 G
Girdling 2 mm	2.38 g	2.36 g	2.37 F	0.36 f	0.36 f	0.36 E	1.32 j	1.33 j	1.33 F
Girdling 4 mm	2.42 ef	2.43 def	2.43 C	0.38 de	0.38 e	0.38 D	1.44 hi	1.39 i	1.42 E
50 ppm GA_3	2.46 c	2.46 c	2.46 C	0.40 cd	0.39 cde	0.39 C	1.45 gh	1.50 fg	1.48 D
100 ppm GA_3	2.49 b	2.48 b	2.49 B	0.40 bc	0.40 bc	0.40 C	1.56 de	1.59 cd	1.57 C
Girdling 2 mm+50 ppm GA_3	2.38 g	2.37 g	2.38 F	0.35 fg	0.40 bc	0.38 D	1.52 ef	1.56 de	1.54 C
Girdling 2 mm+100 ppm GA_3	2.44 cd	2.44 de	2.44 D	0.42 ab	0.30 h	0.36 E	1.68 b	1.74 a	1.71 A
Girdling 4 mm+50 ppm GA_3	2.41 f	2.42 ef	2.42 E	0.43 a	0.43 a	0.43 A	1.58 cd	1.68 b	1.63 B
Girdling 4 mm+100 ppm GA_3	2.53 a	2.52 a	2.53 A	0.42 ab	0.42 ab	0.42 B	1.62 c	1.68 b	1.65 B
Mean	2.42 A	2.42 A		0.39 A	0.38 A		1.49 A	1.53 A	

reported that girdling treatments decreased N, P, K, Ca and Mg concentrations in the leaves of citrus and reduced the levels of all measured micronutrients.

3. Effects of Girdling and GA_3 on Fruit Size and Thickness on Balady Mandarin

It is clear from table (3) that fruit size (length and diameter) has shown that there was a significant increase in in fruit length, diameter and thickness of fruit. Effects of trunk girdling and gibberellic acid on the fruit length was maximum giving fruit length of 6.48 cm, recorded in plants treated with girdling 4 mm alone in the first season. While, girdling 4 mm+100 ppm GA_3 recorded the highest values (5.87 cm) of fruit length in the second season. However, the data cleared that in both seasons, no significant differences between summer and autumn was shown in the first season but in the second season, the the highest value (5.46) was observed in autumn. Regarding interactions on fruit length, data revealed that girdling 4 mm or girdling 4 mm+100 ppm GA_3 gave the highest values (6.43, 6.53 and 5.80, 5.93 in summer and autumn in the first and second seasons, respectively). Sousa et al. (2005) found that, girdling increased fruit length of pear trees.

The results in table (3) show that the highest fruit diameter was significantly affected by girdling 2 mm+100 ppm GA_3, followed by 50 ppm GA_3 in the first season and girdling 4 mm in the second season, compared to control. Also, the data indicated that no significant differences were observed between summer and autumn treatments on fruit diameter in the second season. The treatments in the first autumn gave the best value for increasing fruit diameter.

The interaction on fruit diameter was significant, where, as the application of girdling 2 mm+50 ppm GA_3 and 100 ppm GA_3 in autumn of both seasons, respectively. The increase in fruit size might be pertained to the fact that gibberellins indirectly affected the level of auxin that ultimately caused cell elongation by enlargement of vacuoles and loosening of cell wall after increasing its palatability. Also, girdling grapevines increases carbohydrate concentration above girdle and resulted in larger berries as the transport of sugars from leaves to the root system (Roper and Williams, 1989). The increase in fruit size by girdling also reported Davie et al (1995) in avocado, Sousa et al (2008) in 'Rocha' pear, Reginato and Mesa (2011) in 'Castlebrite' apricot and Murakami (2012) in 'Rainbow Red' kiwifruit. Khandaker et al (2011) found that girdling branches of wax jambu (*Syzygium samarangense*) produced the highest fruit length and diameter.

Data the table (3) clear that in both seasons, the highest peel thickness was obtained by the control treatments (0.36 - 0.37), while, the lowest was obtained by girdling 4 mm+100 ppm GA_3 (0.25 - 0.24) in both seasons. On the other hand, no significant differences were observed between summer and autumn treatments in both seasons. Regarding interaction effects, the obtained data revealed that girdling 4 mm+100 ppm GA_3 gave the lowest significant

Table (3). Effect of girdling and GA_3 foliar spray on fruit length, fruit diameter and Peel thickness of Balady mandarin in the 2016 and 2017 seasons.

Treatment	Fruit length (cm)			Fruit diameter (cm)			Peel thickness (mm)		
	Summer	Autumn	Mean	Summer	Autumn	Mean	Summer	Autumn	Mean
Season 2016									
Control	4.93 d	4.97 cd	4.95 C	6.53 c	6.73 bc	6.63 C	0.37 a	0.34 b	0.36A
Girdling 2 mm	5.33 bc	5.10 bcd	5.22 B	6.83 bc	6.73 bc	6.78 BC	0.31 cd	0.31 cd	0.39 BC
Girdling 4 mm	6.43 a	6.53 a	6.48 A	6.97 abc	7.07 abc	7.02 AB	0.29 ef	0.32 c	0.30C
50 ppm GA_3	5.23 bcd	5.23 bcd	5.23 B	6.90 bc	6.83 bc	6.87 BC	0.32 c	0.31 c	0.32 B
100 ppm GA_3	5.33 bc	5.47 b	5.40 B	6.90 bc	7.07 abc	6.98 ABC	0.26 gh	0.28 fg	0.27 E
Girdling 2 mm+50 ppm GA_3	5.17 bcd	5.17 bcd	5.17 BC	6.87 bc	6.83 bc	6.850 BC	0.28 ef	0.30 de	0.29 D
Girdling 2mm+100 ppm GA_3	5.27 bcd	5.03 cd	5.15 BC	7.03 abc	7.43 a	7.23 A	0.29 ef	0.28 ef	0.29 D
Girdling 4 mm+50 ppm GA_3	5.33 bc	5.33 bc	5.33 B	6.83 bc	7.13 ab	6.98 ABC	0.26 ghi	0.25 hi	0.26 EF
Girdling 4 mm+100 ppm GA_3	5.07 cd	5.27 bcd	5.17 BC	6.67 bc	7.00 abc	6.83 BC	0.24 i	0.28 ghi	0.25 F
Mean	5.34 A	5.34 A		6.84 B	6.98 A		0.30 A	0. 30 A	
Season 2017									
Control	5.00 f	5.17 ef	5.08 D	6.90 ab	6.97 ab	6.93 BC	0.377 a	0.36 a	0.37 A
Girdling 2 mm	5.27 def	5.30 def	5.28 CD	6.93 ab	6.97 ab	6.95 ABC	0. 30 de	0.31 cd	0.30 C
Girdling 4 mm	5.40 cde	5.47 cde	5.433 C	7.23 ab	7.33 a	7.28 A	0.30de	0.30 de	0.29 C
50 ppm GA_3	5.17 ef	5.30 def	5.23 CD	6.93 ab	6.90 ab	6.92 C	0.33 b	0.320 bc	0.33 B
100 ppm GA_3	5.60 bcd	5.70 abc	5.65 B	7.23 ab	7.30 a	7.27 AB	0.27 fgh	0.283 ef	0.28 DE
Girdling 2 mm+50 ppm GA_3	5.40 cde	5.50 b-e	5.45 BC	7.07 ab	7.23 ab	7.15 ABC	0.29 de	0.31 cd	0.30 C
Girdling 2 mm+100 ppm GA_3	5.20 ef	5.33 def	5.27 CD	6.87 ab	7.10 ab	6.98 ABC	0.28 efg	0.28 efg	0.28 D
Girdling 4 mm+50 ppm GA_3	5.30 def	5.43 cde	5.37 C	7.03 ab	7.00 ab	7.02 ABC	0.26 gh	0.27 fgh	0.27 E
Girdling 4 mm+100 ppm GA_3	5.80 ab	5.93 a	5.87 A	6.77 b	6.93 ab	6.85 C	0.24i i	0.25 h	0.24 F
Mean	5.35 B	5.46 A		7.00 A	7.02 A		0.30 A	0.30 A	

values (0.24 - 0.24) in both seasons. The same has been reported by Elotmani et al. (1993), who found an increase of peel weight in absolute value but not relatively to whole fruit weight after auxin treatment. Fruits harvested from trees treated with girdling were significantly larger than fruits from control trees, which indicated that the application of girdling increased fruit size (Mostafa and Saleh, 2006 and Rivas et al., 2007). The increasing effect of gibberellic acid combined with girdling on weight and size of bunches and berries agree with several authors (Roper and Williams, 1989). It was observed a synergic action between crop set and gibberellic acid, enhancing effects on berry size. Also, Ogˇuzhan et al. (2015) found that vines had girdled to accomplish for enhancing yield as well as cluster weight, cluster length and width of Red Globe grapevine.

4. Effects of Girdling and GA_3 on Number of Fruits, Fruit Weight and Yield on Balady Mandarin

Data in table (4) indicated that there was a significant difference between the treatments and the control. It could be observed that the maximum value of number of fruit/tree was related to the treatment of girdling 4 mm+100 ppm GA_3 as compared with control during both seasons. Treatments in summer have given the maximum values of number of fruits/tree in both seasons. On the other hand, the results indicated that using combination between girdling and application of GA_3, the maximum value with girdling 4 mm+100 ppm GA_3 was in summer during the two seasons. Girdling generally has a positive effect on fruit size if not accompanied by an increase in fruit number (Goren et al., 2003). Similarly, Mohamed (2011) found that spraying Washington Navel orange with GA_3 at concentration of 10 ppm at 3 times (beginning of flowering, full bloomming and after fruit set), gave the maximum fruit retention percentage and yield/ tree. Girdling is a practice used in order to control the excessive vegetation and thereby improving the crop yield due to increase of fruit set and fruit size (Raffo et al., 2011). The increase in fruit yield with the girdling also reported by Chanana and Gill (2008) in grapes, and Huang et al. (2012) in 'Nuomici' and 'Guiwei' cultivars of litchi. According to Rivas et al. (2006), the productivity of Fortune and Clausellina mandarins can be improved by girdling. Similarly, trunk girdling has been shown to increase fruit set in many crops, including apple [*Malus domestica* Borkh.] (Hoying and Robinson, 1992), kiwifruit [*Actinidia chinensis* Planch.] (Boyd and Barnett, 2011) and Fuyu persimmon [*Diospyros kaki* L.] (Choi et al., 2010).

Significantly maximum fruit weight (145.0-149.5 g) was obtained with girdling 4 mm+100 ppm GA_3 treatment. While, minimum fruit weight was 132.7 - 135.7 g of control treatment. Both treatments of autumn significantly increased the fruit weight. The highest values of fruit weight was recorded in the second autumn treatment in both seasons, whereas the lowest

Table (4). Effect of girdling and GA_3 foliar spray on number of fruits, fruit weight and yield/tree of Balady mandarin in the 2016 and 2017 seasons.

Treatment	Fruit No.			Fruit weight (g)			Yield (kg)		
	Summer	Autumn	Mean	Summer	Autumn	Mean	Summer	Autumn	Mean
				Season 2016					
Control	345.0 ghi	330.0 i	337.5 F	131.7 j	133.7 i	132.7 E	46.23 kl	43.43 l	44.83 F
Girdling 2 mm	383.3 def	370.0 e-h	376.7 DE	137.3 h	139.0 fgh	138.2 D	53.27 fgh	51.73 ghi	52.50 D
Girdling 4 mm	395.0 de	393.3 de	394.2 CD	139.3 efg	140.7 def	140.0 C	55.53 def	54.80 efg	55.17 C
50 ppm GA_3	350.0 ghi	343.3 hi	346.7 F	138.3 gh	139.7 efg	139.0 CD	48.90 ijk	47.50 jk	48.20 E
100 ppm GA_3	410.0 cd	393.3 de	401.7 C	142.3 bcd	143.0 bc	142.7 B	58.63 cd	55.07 efg	56.85 C
Girdling 2 mm+50 ppm GA_3	372.7 efg	360.0 fgh	366.3 E	139.7 efg	140.0 efg	139.8 C	52.17 f-i	50.27 hij	51.22 D
Girdling 2 mm+100 ppm GA_3	398.3 de	383.7 def	391.0 CD	141.3 cde	144.3 ab	142.8 B	57.47 de	54.20 efg	55.83 C
Girdling 4 mm+50 ppm GA_3	442.3 b	435.0 bc	438.7 B	141.0 c-f	142.7 bcd	141.8 B	63.13 b	61.30 bc	62.22 B
Girdling 4 mm+100 ppm GA_3	479.3 a	470.0 a	474.7 A	144.0 b	146.0 a	145.0 A	69.93 a	67.67 a	68.80 A
Mean	397.3 A	386.5 B		139.4 B	141.0 A		56.14 A	54.00 B	
				Season 2017					
Control	343.3 hi	325.0 i	334.2 G	135.7 i	135.7 i	135.7 F	46.57 jk	44.07k	45.32 G
Girdling 2 mm	383.0 efg	380.0 fg	381.5 EF	138.3 h	140.0 gh	139.2 E	53.37 fg	52.57 fgh	52.97 E
Girdling 4 mm	428.3 cd	423.3 d	425.8 C	141.3 fg	143.0 ef	142.2 D	60.23 d	59.87 d	60.05 C
50 ppm GA_3	350.0 hi	346.7 hi	348.3 G	138.3 h	141.3 fg	139.8 E	48.90 hij	48.30 ij	48.60 F
100 ppm GA_3	413.3 d	410.0 de	411.7 CD	142.7 ef	143.7 de	143.2 CD	59.13 de	58.20 de	58.67 CD
Girdling 2 mm+50 ppm GA_3	377.7 fg	365.0 gh	371.3 F	142.7 ef	142.7 ef	142.7 D	52.87 fg	51.20 ghi	52.03 E
Girdling 2 mm+50 ppm GA_3	405.0 def	385.0 efg	395.0 DE	144.0 de	148.3 b	146.2 B	58.47 de	55.43 ef	56.95 D
Girdling 4 mm+100 ppm GA_3	465.3 b	453.3 bc	459.3 B	143.0 ef	145.3 cd	144.2 C	67.73 bc	64.80 c	66.27 B
Girdling 4 mm+100 ppm GA_3	493.3 a	480.0 ab	486.7A	146.7 bc	152.3 a	149.5 A	75.10 a	70.43 b	72.77A
Mean	406.6 A	396.5 B		141.4 B	143.6 A		58.04 A	56.10 B	

amount was obtained during the first girdling. It might be due to the fact that growth regulators as GA_3 show indirect effect through auxin stimulation, which lead to the increase in fruit weight as reported in the study conducted by Wo et al. (2001) on 'Fujiminori' grapes. Thus, the results of the present study could agree with the finding of Mostafa and Saleh (2006), who reported that girdling alone or with potassium spray increases the fruit size and fruit weight in Balady mandarin orange. Fruit weight is an important quality parameter of fruit production. Bark ringing or girdling significantly increases the fruit weight as well as yield (Hossain et al., 2007).

Table (4) reveals that the best results were obtained with girdling 4 mm+100 ppm GA_3, which gave the maximum yield of mandarin trees (68.80 -72.77 kg/tree). On the other hand, treatments with girdling 4 mm+100 ppm GA_3 have given the maximum yield in summer (56.14-58.04 kg/tree) and autumn (67.67-70.43 kg/tree) in the two seasons. On the other hand, the fruit yield per tree with girdling 4 mm+100 ppm GA_3 gave the maximum values in the first (69.93-67.67 kg/tree) and second (75.10-70.43 kg/tree) seasons, respectively. In this respect, girdling application increased yield by about 25-37% as reported by Dawood et al. (2001). On the other hand, Rivas et al. (2006) found increase in fruit retention percentage and yield of most of citrus species by girdling. Girdling can improve carbohydrate availability to fruits and as consequently lead to an increase in fruit-set and yield as well as number of fruits (Goren et al., 2003). On the other hand, Abu-Zahra (2010) reported that GA_3 and GA_3 + girdling was effectively influenced the yield of grapevine for the commercial production of Thompson seedless grapes.

5. Effects of Girdling and GA_3 on Juice Chemicals Constitute of Balady Mandarin Fruits

Results in table (5) concerning the soluble solids content in the fruit juice, treatments significantly increased this parameter especially with girdling 4 mm + 100 ppm GA_3, which increased of the TSS% as compared with the other treatments in both seasons. Also, there was no significant differences between summer and autumn as compared with control during the two seasons. Meanwhile, using girdling 4 mm +100 ppm GA_3 has given the highest significantl values in both seasons. On the other hand, the control gave the lowest values in the two seasons. The results obtained in the present investigation are also supported by the findings of Mishra et al. (2003) and Nawaz et al. (2008) in Kinnow mandarin. The results obtained in the present study agree with those described in a previous report by Rather et al. (2011), who reported that girdling and growth regulator application are attractive practices to improve berry ripening and berry quality in grape cv. Perlette. The increase in TSS in the present study is in line with the findings of Huang et al. (2012) in 'Nuomici' and 'Guiwei' litchi. Kaur et al. (2008) also reported

Table (5). Effect of girdling and GA_3 foliar spray on T.S.S%, acid and T.S.S/ acid ratio of Balady mandarin in the 2016 and 2017 seasons.

Treatment	T.S.S. %			Acid			T.S.S/ acid ratio		
	Summer	Autumn	Mean	Summer	Autumn	Mean	Summer	Autumn	Mean
				Season 2016					
Control	10.73 g	9.58 h	10.16 E	1.44 b	1.47 a	1.45 A	7.473 h	6.532 i	7.003 G
Girdling 2 mm	11.20 fg	10.70 g	10.95 D	1.36 c	1.36 c	1.37 B	8.257 fg	7.852 gh	8.054 F
Girdling 4 mm	12.37 bc	11.53 def	11.95 C	1.24 f	1.26 e	1.25 D	10.010 c	9.148 de	9.580 D
50 ppm GA_3	12.10 cde	11.46 efg	11.78 C	1.26 e	1.28 d	1.27 C	9.607 cd	8.952 e	9.279 D
100 ppm GA_3	13.07 ab	12.20 cde	12.64 B	1.17 hi	1.20 g	1.19 E	11.130 b	10.170 c	10.65 B
Girdling 2 mm+50 ppm GA_3	11.93 c-f	11.90 c-f	11.92 C	1.35 c	1.37 c	1.37 B	8.818 ef	8.687 ef	8.752 E
Girdling 2 mm+100 ppm GA_3	11.90 c-f	12.13 cde	12.02 C	1.18 hi	1.19 gh	1.19 E	10.090 c	10.200 c	10.14 C
Girdling 4 mm+50 ppm GA_3	12.30 cd	12.20 cde	12.25 BC	1.27 de	1.28 de	1.28 C	9.658 cd	9.555 cd	9.607 D
Girdling 4 mm+100 ppm GA_3	13.50 a	13.33 a	13.42 A	1.14 j	1.17 i	1.16 C	11.800 a	11.400 ab	11.60 A
Mean	12.12 A	11.67 A		1.27 B	1.29 A		9.650 A	9.166 B	
				Season 2017					
Control	10.60 kl	10.08 l	10.34 F	1.42 b	1.46 a	1.44 A	7.448 k	6.907 l	7.178 F
Girdling 2 mm	11.27 ij	10.92 jk	11.09 E	1.34 d	1.35 d	1.34 C	8.408 ij	8.107 j	8.257 E
Girdling 4 mm	12.10 d-h	11.63 hi	11.86 D	1.22 g	1.24 f	1.23 E	9.889 fg	9.354 h	9.622 C
50 ppm GA_3	12.37 c-f	11.95 e-h	12.16 CD	1.22 g	1.26 f	1.24 E	10.150 ef	9.509 gh	9.827 C
100 ppm GA_3	13.00 bc	12.31 d-g	12.65 B	1.21 g	1.21 g	1.21 F	10.770 cd	10.150 ef	10.460 B
Girdling 2 mm+50 ppm GA_3	11.77 f-i	11.70 ghi	11.73 D	1.36 d	1.38 c	1.37 B	8.674 i	8.478 ij	8.576 D
Girdling 2 mm+100 ppm GA_3	13.03 b	12.63 bcd	12.83 B	1.19 h	1.21 g	1.20 G	10.980 c	10.470 de	10.730 B
Girdling 4 mm+50 ppm GA_3	12.63 bcd	12.43 b-e	12.53 BC	1.31 e	1.30 e	1.30 D	9.641 gh	9.588 gh	9.615 C
Girdling 4 mm+100 ppm GA_3	14.23 a	13.77 a	14.00 A	1.15 j	1.16 i	1.16 H	12.410 a	11.840 b	12.120 A
Mean	12.33 A	11.94 A		1.27 B	1.29 A		9.819 A	9.377 A	

similar findings with the application of GA_3 + girdling in 'Perlette' grapes and Nawaz et al. (2008) in Kinnow.

For in the fruit juice acidity percentage, results in table (5) reveal that, the averages values of total acidity (%) gave the highest values in the trees treated as control in 2016 and 2017 seasons, respectively. Regarding to acidity percentage, it recorded the highest significantly value of different treatments in autumn during both seasons.

Regarding interaction, data demonstrate that, total acidity (%) was the highest with control treatments in two seasons. In addition, the data of the girdling 4 mm+100 ppm GA_3 showed the lowest significant values for acidity percentage. However, different results were obtained when CPPU was used affecting the chemical composition of the fruit **(**Harrel and Williams., 1987 and Leão et al., 2000). Acidity was also found to decreased with the girdling by Fujishima et al. (2005) in 'Pione' grapes, Huang et al. (2012) in 'Nuomici' and 'Guiwei' cultivars of litchi. Kaur et al. (2008) also observed similar trend of reduction of acidity with the use of GA_3 and girdling.

Regarding TSS/acid ratio, results showed significant differences between treatments in both seasons, since the maximum TSS: acid ratio (11.60-12.12) was observed under treatment of girdling 4 mm + 100 ppm GA_3 in the two studied seasons as compared to control (7.003-7.178). Also, maximum TSS: acid ratio in this respect was obtained when trees were treated in summer and summer and autumn in the first and second seasons, respectively (9.65- 9.82 and 9.38). On the other hand, the results indicated that using the combination between girdling and GA_3 application has given the maximum TSS: acid ratio (11.80 - 12.41) by using girdling 4 mm+100 ppm GA^3 in summer for the first and second seasons, respectively. These results support the earlier findings of Singh et al. (2002) in 'Royal Delicious' apple and Wu and Lin (2003) in loquat in response to the application of growth regulators. Crupi et al. (2016) mentioned that girdling was able to improve the soluble solids content over titrable acidity (SSC /TA), a ratio strictly related to the quality perception by the consumer.

The data given in table (6) show that the highest values of vitamin C was obtained when trees were treated with girdling 4 mm + 100 ppm GA_3 in the two studied seasons. Also, the lowest values of vitamin C were obtained when trees were treated with girdling 2 mm and 50 ppm GA_3 in the first and second seasons, respectively, compared with control. Also, no significant differences were recorded between summer and autumn during the two seasons. On the other hand, the highest vitamin C value was obtained by using the combination of girdling 4 mm + 100 ppm GA_3, girdling 2 mm +100 ppm GA_3 and girdling 4 mm in the first and second seasons, respectively. The results obtained in the present investigation are also supported by the findings of Sharma et al. (2003), Kachave and Bhosale (2009) in Kagzi lime and Nawaz et al. (2008) in Kinnow mandarin. Zhao et al. (2013) stated that vitamin C content in apple in-creased with girdling.

Table (6). Effect of girdling and GA_3 foliar spray on vitamin C and total sugars (%) of Balady mandarin in the 2016 and 2017 seasons.

Treatment	Vitamin C			Total sugars (%)		
	Summer	Autumn	Mean	Summer	Autumn	Mean
Season 2016						
Control	49.83 cd	50.50 c	50.17 C	6.66 g	6.65 g	6.66 E
Girdling 2 mm	40.47 i	39.83 i	40.15 H	7.77 e	7.73 ef	7.75 D
Girdling 4 mm	59.43 b	59.27 b	59.35 B	8.25 d	8.15 d	8.20 DC
50 ppm GA_3	44.00 h	44.00 h	44.00 G	7.56 ef	7.56 ef	7.56 D
100 ppm GA_3	48.33 de	48.57 de	48.45 D	8.40 d	8.36 d	8.38 B
Girdling 2 mm+50 ppm GA_3	45.60 gh	45.20 gh	45.40 F	8.10 d	8.17 d	8.14 C
Girdling 2 mm+100 ppm GA_3	59.87 ab	59.50 ab	59.68 B	9.29 b	9.11 bc	9.20 A
Girdling 4 mm + 100 ppm GA_3	46.47 fg	49.43 ef	46.95 E	7.43 f	7.67 ef	7.55 D
Girdling 4 mm + 100 ppm GA_3	60.63 ab	61.13 a	60.88 A	9.78 a	8.87 c	9.38 A
Mean	50.51 A	50.60 A		8.14 A	8.03 A	
Season 2017						
Control	49.63 d	48.63 d	49.13 D	7.09 h	6.75 i	6.92 G
Girdling 2 mm	49.57 d	47.67 d	48.62 D	7.95 ef	7.93 ef	7.94 E
Girdling 4 mm	60.23 a	59.53 ab	59.88 B	8.46 cd	8.30 d	8.38 CD
50 ppm GA_3	43.67 e	43.63 e	43.65 E	7.90 f	7.89 f	7.90 E
100 ppm GA_3	54.60 c	54.83 c	54.72 C	8.61 c	8.28 d	8.44 C
Girdling 2 mm+50 ppm GA_3	47.93 d	47.93 d	47.93 D	8.20 de	8.27 d	8.24 D
Girdling 2 mm+100 ppm GA_3	57.10 bc	56.17 c	54.63 C	9.43 b	9.35 b	9.39 B
Girdling 4 mm+50 ppm GA_3	48.00 d	47.13 d	47.57 D	7.50 g	7.57 g	7.54 F
Girdling 4 mm+100 ppm GA_3	62.13 a	62.50 a	62.32 A	10.70 a	9.36 b	10.03 A
Mean	52.54 A	52.00 A		8.43 A	8.19 B	

Data represented in table (6) show the initial increase in total sugars with girdling and increased application of GA_3 in both seasons, compared with control. Maximum total sugars was recorded with girdling 4 mm + 100 ppm GA_3 in the two seasons. On the contrary, the control trees produced significantly the minimum total sugars in the two tested seasons. The highest value of total sugars was obtained with girdling 4 mm + 100 ppm GA_3 in summer in the two seasons. Roussos and Anastassios (2011) reported that sucrose, glucose and fructose concentrations were the highest in fruits from girdled scaffold of mandarin trees. The results agree with Abd El- Wahab (2006), Abd El-Razek et al. (2010), Abu-Zahra (2010) and Abu-Zahra and Salmeh (2012), who found that trunk girdling increased total sugar and enhanced berry colorations. Verreynne et al. (2001) reported that girdling enhanced total soluble solids and total sugar content in Marisol' Clementine's. Fruits from the girdle branch yielded the higher amount of total sugars which may be due to carbohydrate availability and the high starch content in the upper part of girdle**.** The present study is in accordance with the findings of Wahdan et al. (2011) on 'Succary Abaid'mango in response to GA_3 and NAA application. The increase in total sugars content of fruits by girdling was also noted by Chanana et al. (2006) in 'Florda Prince'cultivar of peach. Kaur et al. (2008), also noticed the increase in reducing sugars of 'Perlette' grapes with GA_3 application and girdling.

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تأثير التحليق والجبرلين على المحصول وخصائص جودة ثمار اليوسفي البلدي

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أجريت هذه التجربة خلال موسمين متتاليين ٢٠١٦، ٢٠١٧ على أشجار اليوسفي البلدي عمر١٠سنوات المطعومة على أصل النارنج التي تروى بالتنقيط بمياه ترعة الإسماعيلية بمزرعة الكمـال، محافظـة الإسماعيلية، جمهورية مصر العربية .وكان الهدف دراسة تأثير التحليق والجبرلين على المحصول وصفات جودة ثمار أشجار اليوسفي البلدي من خلال معاملات التحليق ورش حمض الجبرليك. واشتملت التجربة على عاملين؛ الأول يشمل مواعيد الرش والثاني يشمل معاملات الرش والتحليق على النحو التالي :١- الكنترول (بدون معاملة)، ٢- التحليق بسمك ٢ مم، ٣- التحليق بسمك ٤ مم ، ٤- رش بحمض الجبرليك بتركيز ٥٠ جزء فى المليون، ٥ -رش حمض الجبرليك بتركيز ١٠٠ جزء في المليون، ٦ -التحليق بسمك ٢ مم + رش بحمض الجبرليك بتركيز ٥٠ جزء في المليون، ٧ -التحليق بسمك ٢ مم + رش بحمض الجبرليك بتركيز ١٠٠ جزء في المليون، ٨- التحليق بسمك ٤ مم + رش بحمض الجبرليك بتركيز ٥٠ جزء في المليون و٩- التحليق بسمك ٤ مم رش بحمض الجبرليك بتركيز ١٠٠ جزء في المليون. والعامل الثاني مواعيد المعاملات وتم إجراء المعاملات مرتين؛ في الأولى في شهر يوليو والثانية فى شهر ديسمبر. وقد أظهرت معاملة التحليق بسمك ٤ مم + رش حمض الجبرليك بتركيز ١٠٠ جزء في المليون. أفضل النتائج وأعلى القيم في محتوى الأوراق من الكلوروفيل والكربوهيدرات والنتروجين والبوتاسيوم والفسفور في حين أظهرت معاملة التحليق بسمك ٤ مم فقط والتحليق بسمك ٤ مم + الرش بحمض الجبرليك بتركيز ٥٠ جزء في المليون أعلى محصول للشجرة ووزن الثمرة وطول الثمرة وأقل القيم لسمك القشرة عن أشجار الكنترول .