

Response of Wax Apple Cultivars by Applied S-Girdling on Fruit Development and Fruit Quality

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Abstract—The study was carried out to evaluate the effect of S-girdling on fruit growth and quality of wax apple. The study was laid in Random completed block design with four replicated. Four treatments were applied as follows: S-girdling, fruit thinning plus bagging with 2,4-D sprayed, fruit thinning plus bagging and the control treatment. 2,4D was sprayed at the small bud and petal fall stage. Girdling was applied three weeks before flowering. The effect of all treatments on fruit growth was measured weekly. Number of flower, fruit set, fruit drop, fruit crack, and fruit quality were recorded. The result indicated that S-girdling, 2,4D application produced the lowest bud drop, fruit drop compared to untreated control. S-girdling improved faster fruit growth producing the best final fruit length and diameter compared to untreated control. S-girdling also markedly enhanced fruit set, fruit weight, and total soluble solid, reduced fruit crack, titratable acidity. On the other hand, it was noticed that with 2,4-D application also increased the fruit growth rate, improved physiological and biochemical characters of fruit than control treatment. It was concluded that S-girdling was recommended as the industry norm to increase fruit set, fruit quality in wax apple. 2,4D application had a distinctive and significant effect on most of the fruit quality characteristics assessed.

Keywords—S-girdling, 2,4D, wax apple, fruit growth, fruit quality.

I. INTRODUCTION

THE wax apple (*Syzygium samarangense* Merr. et Perry) is a tropical fruit tree with its origin in the Malay archipelago [34]. It is an important competitive tropical fruit in Taiwan [43] and other countries in Southeast Asia such as Thailand, Malaysia and Indonesia [50].

Girdling is widely used for fruit in grapevines [45], citrus [39], apple [5], peach [35], and other fruit tree crop, mainly to enhance flowering, fruit set, size as well as fruit quality. Girdling consists of removal of a wide strip of bark without injuring the xylem of tree trunks and major limbs, thereby blocking the downward translocation of photosynthetic and metabolites through the phloem [9]. It is known that the effects of girdling are presumably brought about by accumulation of assimilates above the girdle [39]. As a result of girdling leaf N content, C/N ratio and carbohydrate were improved. The

enhancement of carbohydrate availability has been associated with an improvement of flowering [41], fruit set and yield of citrus trees [18]. Furthermore, girdling few weeks before flowering reduced fruitlet abscission and increased leaf chlorophyll content and chlorophyll fluorescence [40].

Other agricultural practices which may increase yield and improve fruit quality are also the application of plant growth regulators, especially gibberellic acid and the synthetic auxin [8]. The auxins are known by their ability to increase the cell size [11], which enhances fruit growth in some kind of species such as citrus [1], litchi [42], and loquat [2]. Moreover, the auxins are used to control the fruit drop in citrus and to improve the quality of fruit [4].

Thinning may stimulate fruit growth by influencing cell division enhancing cell enlargement, producing more or proportionately more intercellular space, or some combination of these processes [6]. The objectives of thinning should be the elimination of the smallest fruits, improved fruit quality and annual production [15]. Fruit thinning is accomplished by hand or chemical, thinning intensity may vary not only on the method used but also on the physiological condition of the trees and cultural practices employed. Therefore, the growers will have to focus their orchard practices to satisfy these market demands in order to produce high quality fruit consistently at maximum yields [23]. Moreover, [46] proved that bagging could modify the microenvironment during fruit development, decreasing the rate of fruit drop and reducing the content of organic acid in longan fruit. Fruit bagging has been used for the production of high quality, unblemished apple [28] and Asian pear fruit [21]. Fruit bagging promotes fruit coloration [27]. Incidences of fruit cracking [13] and russet [30] can be reduced by bagging.

The use of girdling as a horticultural technique has been practiced worldwide for centuries in fruit tree crop, but there is no literature yet on girdling applied to the wax apple trees. The aim of this research was to investigate the influence of S-girdling on flower bud and fruit set, fruit drop and fruit quality. Moreover, the objective of this study was also to evaluate the effects of synthetic auxin on fruit development, size, as well as fruit quality in wax apple.

II. MATERIALS AND METHOD

A. Plant Materials and Experiment Treatments

The experiment was performed at Tropical fruit orchard, National Pingtung University of Science and Technology from March to June 2012. Four wax apple cultivars include

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Big Pink apple, Xinshi, Local and Thaiwu were chosen for the experiment. There are four blocks and each block is one cultivar. Sixteen trees were used in the experiment, sixty four the uniform branches (four branches per tree) of about the same length and diameter from twenty trees were selected for the experiment. The experiment consists of 4 treatments including control, fruit thinning plus bagging, fruit thinning plus bagging and 2,4-D, S-girdling plus fruit thinning and bagging. The experiment design was in Randomized Complete Block Design with five replicated and a single uniform branch was taken as an experiment unit. Girdling was performed using a girdling knife which simultaneously cuts and removes the bark strips. The width of the girdle was between 1.5 mm to 2 mm depending on the branch size. The cut reached the cambium and was left bare without injury to the inner layer. The girdling was carried out three weeks before flowering. 2,4-D was applied at small bud and petal fall stage on windless mornings with a truck- mounted motorized sprayed until drippoff.

B. Data Collection

For the number of bud and bud drop (%), the total number of buds was determined when the bud size was 0.8-1.0 mm. Bud dropping percentage was calculated according to the following formula:

$$\text{Bud drop (\%)} = \frac{\text{Total No. of buds at initial stage} - \text{Buds before bloom}}{\text{Total No. of buds at initial stage}} \times 100$$

For the determination percentage of fruit setting from tagged branches on the experimental tree, the percentage of fruit setting was calculated using the following formula:

$$\text{Fruit set (\%)} = \frac{\text{Total No. of fruitlets}}{\text{Total No. of flowers}} \times 100$$

Fruit dropping percentage was calculated at 35 days after anthesis using the following formula:

$$\text{Fruit drop (\%)} = \frac{\text{Total No. of fruitlets} - \text{No. of fruits in 35 days after anthesis}}{\text{Total No. of fruitlets}} \times 100$$

Fruit growth (length and wide) were measured weekly with vernier calipers. At harvesting, flesh thickness was determined with the help of Vernier caliper. Average fruit weight was determined by weighing and number of fruit crack, fruit injury per cluster was determined by counted.

Total soluble solid (TSS) were measured by using a hand refractometer (ATAGO Co. LTD., Tokyo, Japan) juice was squeezed from the fresh-cut wax apple and the result was expressed as oBrix. Titratable acidity (TA) was determined using the method described by [7]. The results were expressed as percentage of citric acid.

C. Statistical Analysis

The data obtained from the study were analyzed using SAS 9.1 statistical software for each cultivar separately. The least significant difference was calculated following a significance F-test (at $p \leq 0.05$)

III. RESULTS

A. Number of Bud and Bud Drop

The response of wax apple cultivars by applied S-girdling and 2,4-D spray on the mean number of bud is show in Table I. For 'Big pink apple' cultivar, maximum (51.75) number of bud was achieved in S-girdling treated, followed by combining fruit thinning plus bagging with 2,4-D application, and fruit thinning plus bagging. The minimum number of bud (41.0) was observed in untreated control. However, the highest number of bud (47.75) was seen at the fruit thinning plus bagging in combination with the 2,4-D application, followed by S-girdling treatment, while the lowest value of 33.0 bud numbers was found in untreated control. This results was achieved in 'Xinshi' cultivars with the significantly difference at ($p \leq 0.05$) (Table I). In the case of 'Local' cultivar, S-girdling plus fruit thinning and bagging produced the highest number of bud 58.75, followed by fruit thinning plus bagging with 2,4-D application, fruit thinning plus bagging with value of 52.0 and 50.75 bud number, respectively. The untreated control gave the lowest (48.75) number of bud, even though treatment effects were not significant (Table I). Similar trend was observation concerning bud number in 'Thaiwu' cultivar. In term, S-girdling plus fruit thinning and bagging exhibited the highest (62.75) bud number, followed by fruit thinning plus bagging in combination with 2,4-D application, fruit thinning plus bagging, whereas the lowest bud number (52.25) was recorded in untreated control as shown in Table I.

The data presented in Table I showed that, there were significant differences among treatments concerning bud drop for all wax apple cultivars, except 'Xinshi' cultivar. In the case of 'Big pink apple', the highest bud drop (55.73%) recorded in untreated control, while the least percentage of bud drop was found in S-girdling plus fruit thinning and bagging with value of 32.85%, followed by fruit thinning plus bagging in combination with 2,4-D application. However, the lowest value of bud drop (27.68%) was obtained at fruit thinning plus bagging with 2,4-D application, followed by S-girdling plus fruit thinning and bagging, whereas the control treatment gave the highest value 45.09% bud drop, which was found in 'Xinshi' cultivar (Table I). In the same table data showed that the minimum bud drop of 25.99% was recorded in S-girdling plus fruit thinning and bagging, followed by combining fruit thinning plus bagging with application 2,4-D with 27.61%, whereas the highest bud drop of 44.58% was found in case of control. This result was achieved in 'Local' cultivar (Table I). For 'Thaiwu' cultivar, application of S-girdling plus fruit thinning and bagging had the lowest bud drop with value of 35.31%, followed by fruit thinning plus bagging with 2,4D

application, fruit thinning plus bagging with 39.09% and 43.37%, respectively, whereas the control treatment gave the

maximum (55.07%) bud drop, with the significant difference at ($P \leq 0.05$) (Table I).

TABLE I
EFFECT OF S-GIRDLING ON NUMBER OF BUD, BUD DROP, FRUIT SET AND FRUIT DROP OF WAX APPLE¹

Treatment	Number of bud	Bud drop (%)	Fruit set (%)	Fruit drop (%)
Big Pink apple				
Control	41.00a	55.73a	35.23b	54.93a
Fruit thinning+bagging	42.25a	49.98ab	46.96b	44.30ab
Fruit thinning+bagging+2,4-D	45.50a	38.46bc	61.31a	34.21bc
S-girdling+fruit thinning+bagging	51.75a	32.85c	68.90a	26.80c
Xinshi				
Control	33.00b	45.09a	37.47c	64.05a
Fruit thinning+bagging	37.25ab	33.55 a	47.79bc	61.69a
Fruit thinning+bagging+2,4-D	47.75a	27.68 a	54.48ab	40.61b
S-girdling+fruit thinning+bagging	43.00ab	32.95 a	63.17a	41.95b
Local				
Control	48.75a	44.58a	38.47b	60.54a
Fruit thinning+bagging	50.75a	40.33ab	41.56b	53.99ab
Fruit thinning+bagging+2,4-D	52.00a	27.61bc	74.64a	32.71b
S-girdling+fruit thinning+bagging	58.75a	25.99c	71.35a	29.89b
Thaiwu				
Control	52.25a	55.07a	39.53c	56.74a
Fruit thinning+bagging	54.00a	43.37b	49.39bc	45.37ab
Fruit thinning+bagging+2,4-D	58.75a	39.09b	61.83ab	35.47b
Sgirdling+fruit thinning+bagging	62.75a	35.31b	72.12a	37.82b

¹ Mean in each column followed by the same letters are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

B. Fruit Set and Fruit Drop

As observed in Table I, S-girdling plus fruit thinning and bagging showed the highest fruit set with values of 68.90% in case of 'Big pink apple', followed by 'Thaiwu' and 'Xinshi' cultivar with a fruit set of 72.12% and 63.17%, respectively, whereas the untreated control gave the lowest fruit set with values of 35.23%; 37.47% and 39.53%, respectively. It was also clear from the data in Table I that fruit thinning plus bagging in combination with 2,4-D application also gave the higher fruit set as compared to untreated control with significant difference at $p \leq 0.05$. However, the maximum fruit set (74.64%) was observed with combining fruit thinning plus bagging with application 2,4-D, followed by S-girdling plus fruit thinning and bagging, while the minimum (38.47%) fruit set was recorded in untreated control, which was found in case of 'Local' cultivar (Table I).

The data presented in Table I indicated that S-girdling plus fruit thinning and bagging exhibited the least percentage of fruit drop with values of (26.80%) and (29.89%), whereas the control treatment showed the maximum (54.93% and 60.54%) fruit drop, followed by combining fruit thinning plus bagging with application 2,4-D, which was found in the case of 'Big pink apple' and 'Local' cultivar, respectively. In the same table data showed that, application of 2,4-D plus fruit thinning and bagging had the minimum fruit drop with values of (35.47%) in 'Thaiwu' and (40.61%) in 'Xinshi' cultivar, followed by S-girdling plus fruit thinning and bagging, while the maximum fruit drop (56.74% and 64.05%, respectively) was found in untreated control (Table I)

C. Fruit Growth (Length and Diameter)

The results indicated that fruit thinning plus bagging, fruit thinning plus bagging in combination with 2,4-D application, and S-girdling plus fruit thinning and bagging had the significant effect on fruit growth rate, with regard to fruit length and diameter (Figs. 1 and 2). At the 7th week of observation, S-girdling plus fruit thinning and bagging produced the maximum fruit length growth rate with values of 7.47 cm, followed by combining fruit thinning plus bagging with application 2,4-D, fruit thinning and bagging, whereas the control showed the minimum fruit length with values of 6.89 cm, which was found in the case of 'Big pink apple'. The same was observed in 'Thaiwu' cultivar, the highest fruit growth length (5.45 cm) was recorded in S-girdling plus fruit thinning and bagging, while the lowest values of 4.61 cm fruit growth length was found in untreated control. However, fruit thinning plus bagging in combination with the 2,4-D application exhibited the highest fruit length growth with values of 3.52 cm in 'Local' and 4.55 cm in 'Xinshi' cultivar, whereas the lowest values 2.94 cm and 3.69 cm fruit growth length was found in untreated control, respectively.

In the case of fruit diameter, S-girdling plus fruit thinning and bagging showed the highest fruit growth diameter with values of 4.02 cm in 'Xinshi', 6.33 cm in 'Thaiwu' and 7.04 cm in 'Big pink apple' cultivar, whereas the control treatment gave the lowest values of 3.89 cm, 5.45 cm, and 6.45 cm fruit growth diameter, respectively. However, the maximum 4.61 cm fruit growth diameter was found in combining fruit thinning plus bagging with application 2,4-D, while the

untreated control had the minimum fruit growth diameter with values of 3.69 cm. This result was achieved in 'Local' cultivar.

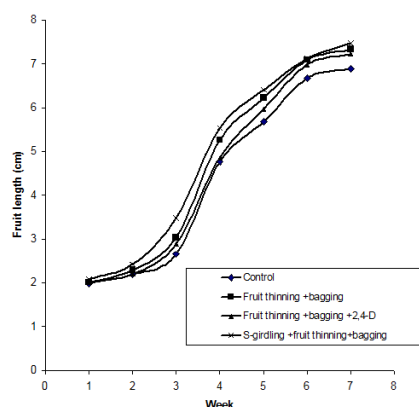


Fig. 1 (a) Effect of S-girdling on fruit growth (length/week) in Big pink apple cultivar

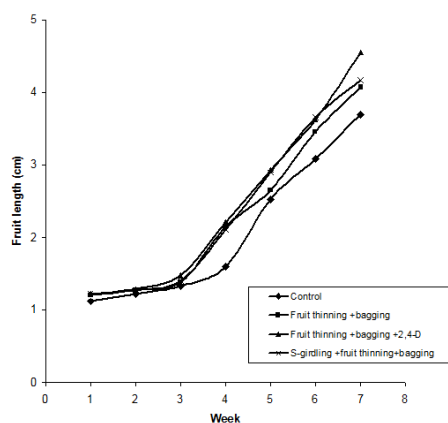


Fig. 1 (b) Effect of S-girdling on fruit growth (length/week) in Xinshi cultivar

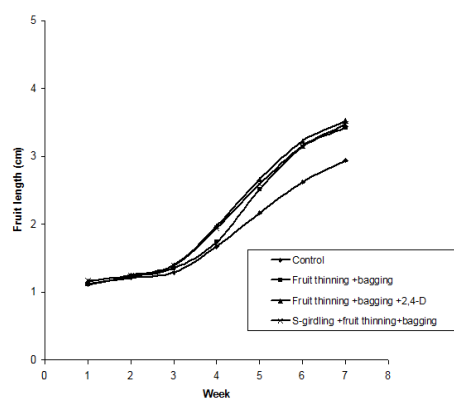


Fig. 1 (c) Effect of S-girdling on fruit growth (length/week) in Local cultivar

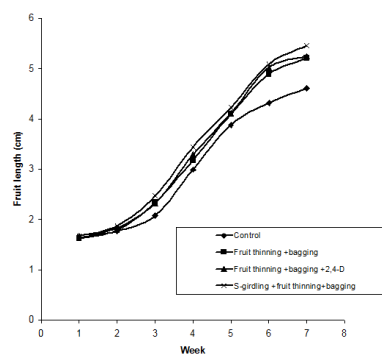


Fig. 1 (d) Effect of S-girdling on fruit growth (length/week) in Thaiwu cultivar

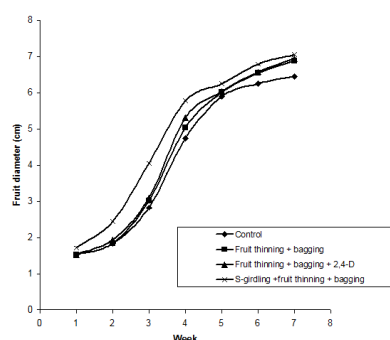


Fig. 2 (a) Effect of S-girdling on fruit growth (diameter/week) in Big pink apple cultivar

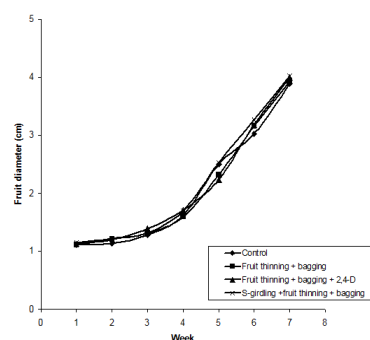


Fig. 2 (b) Effect of S-girdling on fruit growth (diameter/week) in Xinshi cultivar

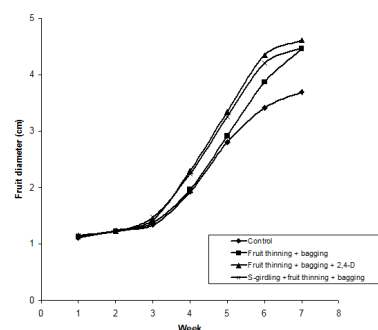


Fig. 2 (c) Effect of S-girdling on fruit growth (diameter/week) in Local cultivar

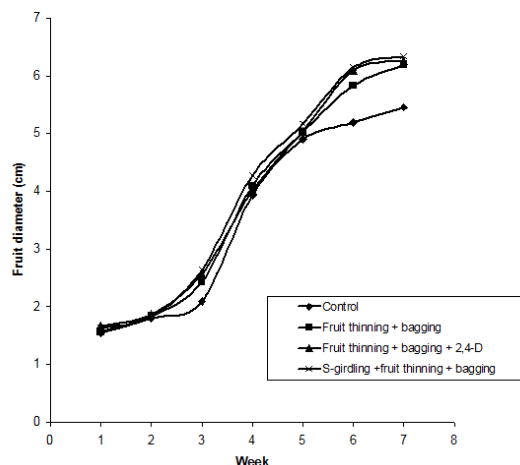


Fig. 2 (d) Effect of S-girdling on fruit growth (diameter/week) in Thaiwu cultivar

D.Effect of S-Girdling on Fruit Quality Parameters

Fruit weight

As shown in Table II, application of S-girdling plus fruit thinning and bagging produced the highest fruit weight with values of 85.58g in 'Thaiwu' and 155.28g in 'Big pink apple' cultivar, followed by fruit thinning plus bagging with 2,4-D application, and fruit thinning plus bagging, whereas the lowest fruit weight with values of 58.46g and 125.09g was recorded in untreated control, respectively. However, maximum fruit weight 36.21g in 'Local' and 42.91g in 'Xinshi' were observed in case of combining fruit thinning plus bagging with application 2,4-D, followed by S-girdling plus fruit thinning and bagging, while the control treatment exhibited the minimum fruit weight with values of 30.52g and 25.82g, respectively as shown in Table II.

TABLE II
EFFECT OF S-GIRDLING ON FRUIT CHARACTER OF WAX APPLE¹

Treatment	Fruit weight (g)	Flesh thickness (mm)	Fruit crack/cluster	Fruit injury/cluster	TSS (oBrix)	TA (%)
Big Pink apple						
Control	125.09c	15.76b	0.93a	1.06a	6.78b	0.71a
Fruit thinning+bagging	146.62ab	16.78ab	0.66ab	0.33b	7.75ab	0.61ab
Fruit thinning+bagging+2,4-D	136.23b	16.21b	0.53b	0.40b	6.99b	0.52b
S-girdling+fruit thinning+bagging	155.28a	18.42a	0.40b	0.46b	8.68a	0.60b
Xinshi						
Control	25.82c	12.42b	0.73a	2.66a	10.50c	0.77a
Fruit thinning+bagging	34.76b	13.31b	0.33b	0.40b	11.19bc	0.55b
Fruit thinning+bagging+2,4-D	42.91a	15.92a	0.53ab	0.20b	12.80a	0.57b
S-girdling+fruit thinning+bagging	35.20b	15.04a	0.26b	0.53b	11.78ab	0.50b
Local						
Control	22.15c	11.99b	0.06a	1.93a	5.41b	0.98a
Fruit thinning+bagging	35.28a	14.48a	0.00a	0.46b	9.34a	0.80b
Fruit thinning+bagging+2,4-D	36.21a	14.61a	0.00a	0.93b	9.68a	0.71b
S-girdling+fruit thinning+bagging	32.36b	13.65a	0.00a	0.66b	9.55a	0.78b
Thaiwu						
Control	58.46b	13.17c	0.53a	1.06a	5.87b	0.87a
Fruit thinning+bagging	81.41a	14.87bc	0.33a	0.26b	7.72a	0.71ab
Fruit thinning+bagging+2,4-D	82.78a	15.30b	0.20a	0.46b	7.93a	0.55b
S-girdling+fruit thinning+bagging	85.58a	17.67a	0.20a	0.20b	8.14a	0.61b

¹ Mean in each column followed by the same letters are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

Flesh Thickness

As can be seen in Table II, application of S-girdling plus fruit thinning and bagging gave the highest values of 18.42 mm, followed by fruit thinning plus bagging, fruit thinning plus bagging with 2,4-D application, whereas the control treatment produced the lowest value of 15.76 mm. This results was achieved in 'Big pink apple' with significant different at $p \leq 0.05$. For 'Thaiwu' cultivar, S-girdling plus fruit thinning and bagging also gave the maximum flesh thickness (17.67mm), followed by fruit thinning plus bagging in combination with 2,4-D application, fruit thinning plus bagging, while the minimum (13.17 mm) flesh thickness was found in untreated control (Table II). However, fruit thinning plus bagging in combination with the 2,4-D application had the

highest flesh thickness with value of 14.61mm in 'Local' and 15.92mm in 'Xinshi' cultivar, followed by S-girdling plus fruit thinning and bagging, fruit thinning plus bagging, while the minimum of flesh thickness 11.99mm and 12.42mm, respectively was recorded in untreated control (Table II).

Fruit Crack

As shown in Table II, S-girdling plus fruit thinning and bagging produced the minimum (0.40 fruit crack), followed by fruit thinning plus bagging with 2,4-D application, whereas the control treatment showed the maximum (0.93 fruit crack), which was found in 'Big pink apple' with significant different at $p \leq 0.05$. For 'Xinshi' cultivar, the lowest fruit crack (0.26) was found in S-girdling plus fruit thinning and bagging,

followed by fruit thinning plus bagging, fruit thinning plus bagging in combination with the 2,4-D application with values of 0.33 and 0.53 fruit crack, respectively. The highest value of 0.73 fruit crack was found in untreated control (Table II). In the case of 'Local' and 'Thawu' cultivar, the lowest fruit crack was found in fruit thinning plus bagging, fruit thinning plus bagging in combination 2,4-D application, and S-Girdling plus fruit thinning and bagging, whereas the highest values of 0.06 and 0.53 fruit crack, respectively was recorded in untreated control, even though treatment effects were not significant (Table II).

Fruit Injury

The results summary in Table II indicated that there was a significant difference on the fruit injury among treatments. In the case of 'Big pink apple' and 'Local' cultivar, fruit thinning plus bagging produced the lowest values of 0.33 and 0.46 fruit injury, while the highest values of 1.06 and 1.93 fruit injury was recorded from the untreated control, respectively. However, the minimum (0.20) fruit injury was obtained in combining fruit thinning plus bagging with application 2,4-D, followed by fruit thinning plus bagging, S-girdling plus fruit thinning and bagging, whereas the control treatment had the maximum 2.66 fruit injury, which was found in 'Xinshi' cultivar (Table II). For 'Thaiwu' cultivar, the lowest fruit injury with value of 2.20 was found in S-girdling plus fruit thinning and bagging, followed by fruit thinning plus bagging, fruit thinning plus bagging in combination with 2,4-D application. The control treatment gave the highest value of 1.06 fruit injury as shown in Table II.

Total Soluble Solids and Titratable Acidity (TA)

As can be seen in Table II, S-girdling plus fruit thinning and bagging produced the highest values of 8.68oBrix, followed by fruit thinning plus bagging, fruit thinning plus bagging with 2,4-D application, whereas the untreated control gave the lowest value of 6.78oBrix. For 'Thaiwu' cultivar, the highest values of 8.14oBrix was also obtained in S-girdling plus fruit thinning and bagging, followed by fruit thinning plus bagging in combination with the 2,4-D application, fruit thinning plus bagging, while the lowest values of 5.87oBrix was recorded in untreated control. However, fruit thinning plus bagging with 2,4-D application exhibited the maximum TSS with values of 9.68oBrix in 'Local' and 12.80oBrix in 'Xinshi' cultivar, whereas the untreated control produced the lowest values of 5.41oBrix and 10.50oBrix, respectively (Table II).

The result of Table II indicated that there was significant different TA among treatments. For 'Xinshi' cultivar, application of S-girdling plus fruit thinning and bagging had the lowest values of 0.50%, followed by fruit thinning plus bagging, fruit thinning plus bagging with 2,4-D application, while the control treatment show the maximum TA with values of 0.77%. However, fruit thinning plus bagging in combination with 2,4-D application gave the minimum TA with values of 0.52% in 'Big pink apple', 0.55% in 'Thaiwu' and 0.71% in 'Local' cultivar, whereas the highest values of 0.71% TA,

0.87%TA and 0.98% TA was found in untreated control, respectively (Table II)

IV. DISCUSSION

Data in Table I showed the effect of S-girdling and 2,4-D, fruit thinning plus bagging on bud number. As for 'Xinshi' cultivar, it is clear that application of 2,4-D plus fruit thinning and bagging significantly increased number of bud as compared to untreated control. However, application of S-girdling plus fruit thinning and bagging slightly increased bud number in comparison with untreated control, which was found in the case of 'Big pink apple', 'Local' and 'Thaiwu' cultivar, although this effect was not significant. This result is in accordance with the finding reported by [38]. Moreover, [37] indicated that branch girdling, which interrupts the phloem pathway and hence disrupts the transport of carbohydrates in and out of the branch, has been utilized experimentally for control bud drop as well as increase the fruit set in apple. Thus, the data presented in Table I showed that there was significant reduced bud drop in S-girdling plus fruit thinning and bagging than the untreated control. This result was obtained in the case of 'Big pink apple', 'Local' and 'Thaiwu' cultivar (Table I). However, application of 2,4-D plus fruit thinning and bagging showed markedly decreasing bud drop as compared to untreated control, which was found in 'Xinshi' cultivar (Table I). In contrast, for all wax apple cultivars fruit thinning plus bagging treated had no beneficial effect on bud dropping compared with the untreated control (Table I).

Reference [17] demonstrated that fruit-set seems to be quantitatively correlated with carbohydrate availability. The enhancement of carbohydrate availability has been associated with an improvement of fruit set and yield of citrus trees [18]. As observed in Table I, the percentage of fruit set from S-girdling was significantly response in increasing as compared to untreated control in 'Big pink apple', 'Xinshi' and 'Thaiwu' cultivars. It considers that S-girdling can improve carbohydrate availability and thus increase fruit set and thus, the increased carbohydrate supply caused by girdling correlated with the transient reduction in fruitlet abscission. These results are in conformity with those of [16], [18]. On the other hand, fruit thinning plus bagging with 2,4-D application also clearly enhanced percentage of fruit set for these wax apple cultivars (Table I). Moreover, in compared with the control treatment the highest response in improving fruit set percentage was found by fruit thinning plus bagging in combination with 2,4-D application, which was achieved in 'Local' cultivar (Table I). However, no significant difference between the untreated control and fruit thinning plus bagging was observed. Thus, fruit set on all wax apple cultivars was not altered by fruit thinning and bagging, these effects were observed in all wax apple cultivars in this study (Table I).

Plant growth regulators (PGR's) are known to have a great influence on fruit drop and fruit retention in fruit trees [29]. The compound 2,4- dichlorophenoxyacetic acid (2,4-D) is

regarded as one of the most effective ones in preventing fruit drop in citrus [10]. Therefore, the results presented in this study showed that in comparison with the control treatment the least percentage of fruit drop was obtained by fruit thinning plus bagging with 2,4-D application, which was recorded in 'Xinshi' and 'Thaiwu' cultivar (Table I), while there was no significantly response in reducing fruit drop between control treatment and fruit thinning plus bagging for all wax apple cultivar in this study (Table I). This is in accordance with the finding reported by [12] who indicated that 2,4-D has been shown to increase the total number of fruits, the fruit weight per plant by reducing pre-harvest fruit drop in orange. Moreover, it is known that girdling produces many growth alterations including a decline in fruit abscission [47]. The increased carbohydrate supply caused by girdling correlated with the transient reduction in fruitlet abscission that was observed. Similar findings were reported previously in 'Ponkan' mandarin by [31]. Moreover, [24] reported that girdling resulted in low fruit abscission rates, through the increase of carbon availability for the fruitlets above the girdle of citrus. Thus, the results presented in this study showed that application of S-girdling plus fruit thinning and bagging greatly response in reducing fruit drop as compared to untreated control in the case of 'Big pink apple' and 'Local' cultivar. It seems that S-girdling is suitable to reduce fruit drop. Furthermore, delayed abscission and increased fruit-set caused by girdling were associated with an increase in carbohydrate availability, which is in agreement with reported by [33], [17]. Therefore, from the data in present study it can be suggest that S-girdling plus fruit thinning and bagging, fruit thinning plus bagging with 2,4-D application delayed abscission, but resulted in greater fruit-set, and thus wax apple cultivars have been shown to respond well to application of S-girdling plus fruit thinning and bagging, fruit thinning plus bagging with 2,4-D sprayed in controlling fruit retention, fruit dropping.

All treatments promoted fruit growth as reflected by faster increase in fruit length and diameter compared to untreated control. Reference [32] reported that girdling alone or with potassium spray increase the fruit size and fruit weight in Balady mandarin orange. The increase in fruit size demonstrated here in response to girdling application at the three weeks before flowering may indicate their ability to stimulate carbohydrate translocation to the fruit in combination with their effect on increasing cell wall elasticity. Therefore, from this results it can be seen that S-girdling treatment showed greatly response in accelerating fruit growth rate length, followed by fruit thinning plus bagging with 2,4-D application, fruit thinning and bagging as compared to untreated control, which was found in 'Big pink apple' and 'Thaiwu' cultivar (Figs. 1 (a) and (d)). On the other hand, fruit thinning plus bagging with 2,4-D application also showed markedly response in enhancing fruit growth length compared to control treatment. This is achieved in the case of 'Xinshi' and 'Local' cultivar (Figs. 1 (b) and (c)). For the fruit

diameter, similarly trend was investigated during fruit growth rate. Fig. 2 (c) showed that fruit diameter growth rate was greatly enhanced by applied 2,4-D plus fruit thinning and bagging. Moreover, S-girdling treatment also gave the faster fruit growth diameter rate as compared to untreated control, which was obtained in 'Big pink apple', 'Xinshi' and 'Thaiwu' cultivar (Figs. 2 (a), (b), (d)). This is in accordance with the finding reported by [19] who indicated that girdling increased in photosynthetas above the girdle available for fruit growth.

A number of workers have reported useful data on the application of various forms of girdling in fruit production. [14] used overlapping, half - circumference - band girdles in which 25 mm wide strips of bark and phloem were removed from opposing sides of the stem. Reference [48] working on Douglas fir compared partial - overlapping - band girdles to similar girdles applied with a pruning saw. They found both methods increased cone yield. According to [26] scoring one type of girdling significantly increased the fruit weight in persimmon. Therefore, our results showed that, S-girdling plus fruit thinning and bagging greatly in improving fruit weight as compared to untreated control, which was achieved in 'Thaiwu' cultivar (Table II). This implies that S-girdling might be effective in improving fruit weight. The same has been reported by [3] who found that either scoring or girdling will suffice for the goal of increasing fruit set and yield and to induce early production in loquat. On the other hand, application of 2,4-D plus fruit thinning and bagging greatly response in increasing weight of fruit, followed by S-girdling treatment, fruit thinning and bagging as compared with the control, which was recorded in 'Xinshi' and 'Local' cultivar (Table II). However, for 'Big pink apple', fruit weight was markedly enhanced by applied S-girdling treatment than the untreated control (Table II).

Fruit cracking is caused by a number of reasons. Drought, hot temperature, heavy rain and high humidity have been reported to induce fruit cracking in litchi and longan [22]. As previous in Table II, application of S-girdling plus fruit thinning and bagging showed markedly reduced fruit crack as compared to untreated control in 'Big pink apple' and 'Xinshi' cultivar, whereas for 'Thaiwu' cultivar no significant difference fruit crack between control treatment with among treatment (Table II). Moreover, no fruit crack was found in the case of 'Local' cultivar. This difference might be due to difference response of wax apple cultivars. On the other hand, fruit thinning plus bagging with 2,4-D application also showed clearly response in decreasing fruit crack in 'Big pink apple' cultivar, whereas no significant reduced fruit crack was found in 'Xinshi' cultivar as compared to untreated control. Moreover, for all wax apple cultivar fruit injury was markedly reduced among treatment as compared to untreated control (Table II). Similar finding had been reported by [13].

TSS is an important quality factor attribute for many fresh fruits during ripening. Reference [20] found that soluble solids content was higher and acid content was lower in partially ringed peach trees than in control trees. Girdling severes

phloem vascular vessels thereby preventing translocation of photosynthates from the source to sinks located below the girdle until the wound heals. Thus, girdling has an indirect effect of reducing sink size and increasing the amount of photosynthates available to fruits and other active meristems above the girdled region. Thus, from the data present in this study, S-girdling treatment showed significantly response in increasing TSS compared to untreated control. This result was achieved in 'Big pink apple' and 'Thaiwu' cultivar (Table II). It seems that fruits from the girdle branch yielded the higher amount total sugars which may be due to carbohydrate availability and starch content high in upper part of girdle. These results are in agreement with [36] who stated that girdling has been reported to induce a significant increase of total soluble solids in 'Mihowase' satsumas. Moreover, application of 2,4-D and some other growth regulators increased the sugar content in various mandarin and sweet orange cultivars [49]. Therefore, in this study application of fruit thinning plus bagging with 2,4-D showed markedly enhanced TSS in comparison with the control treatment, which was recorded in the case 'Xinshi' and 'Local' cultivar (Table II). This is in accordance with the finding reported by [25] started that synthetic auxin application during anthesis was found to increase the amount of sugar content in tomato. Furthermore, in comparison with the control treatment fruit thinning plus bagging also showed clearly response increasing the TSS in 'Local' and 'Thaiwu' cultivar, whereas no significant response in enhancing the TSS was found in 'Big pink apple' and 'Xinshi' cultivar (Table II).

Finally, for the TA acid as previous in Table II, no significant response in reducing TA between fruit thinning plus bagging with the control treatment was found in 'Big pink apple' and 'Thaiwu' cultivar, whereas TA was markedly reduced was achieved in 'Xinshi' and 'Local' cultivar. Moreover, [35] reported that partial ringing and partial ringing plus trunk heating had led to a reduction in shoot length while improving fruit quality. Therefore, our result showed that S-girdling plus fruit thinning and bagging greatly response in decreasing TA as compared to untreated control, which was obtained in 'Xinshi' cultivar (Table II). On the other hand, for 'Big pink apple', 'Local' and 'Thaiwu' cultivar fruit thinning plus bagging with 2,4-D application showed markedly response in reducing TA than the control treatment (Table II). The reduction in titratable acidity observed with the application of 2,4-D, can probably be attributed to the conversion of the organic acids to sugar during fruit ripening. Similar results were reported by [44] who started that the acidity of tomato fruits was reduced when the plant was sprayed with GA3 and 2,4-D.

V. CONCLUSIONS

From the present study we can concluded that S-girdling treatment response well in improving in bud number, reducing bud drop as well as enhancing fruit set in 'Big pink apple', 'Local' and 'Thaiwu' cultivar. For the application of 2,4-D

plus fruit thinning and bagging had the greatest effect on reducing bud drop, increasing fruit set in 'Xinshi' cultivar. Moreover, S-girdling treatment was the best response in reducing fruit drop in 'Big pink apple' and 'Local' cultivar. For 'Xinshi' and 'Thaiwu' cultivar fruit thinning plus bagging with 2,4-D application had the most effect on fruit drop. The results also suggested that girdling enhanced faster fruit growth and improved significantly the quality characteristics of the fruits, increase the total soluble solid as a result of increased carbohydrate concentration, reduce fruit crack, fruit injury as well as acidity in 'Big pink apple' and 'Thaiwu' cultivar. On the other hand fruit thinning plus bagging with 2,4-D application also gave the best response in improving fruit quality as well as fruit character in 'Xinshi' and 'Local' cultivar. Therefore, we can be concluded that girdling could be a valuable tool in improving wax apple fruit quality, based on both physical and biochemical quality characteristics. On the other hand fruit thinning plus bagging with 2,4D application, fruit thinning plus bagging could be also strategies to regulate the growth and development of wax apple.

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REFERENCES

- [1] M. Agusti, M. El-Otmani, M. Juan, and V. Almela, "Effect of 3,5,6-trichloro-2-pyridyloxyacetic acid on clementine early fruitlet development and on fruit size at maturity," *Journal of Horticultural Science*, 1995,70,pp.955-962.
- [2] M. Agusti, N. Gariglio, A. Castillo, M. Juan, V. Almela, A. Martinez-Fuentes, and C. Mesejo, "Effect of the synthetic auxin 2,4-DP on fruit development of loquat," *Plant Growth Regulators*, 2003,41,pp.129-132.
- [3] M. Agusti, N. Gariglio, M. Juan, V. Almela, C. Mesejo, and A. Marti nez-Fuentes, "Effect of branch scoring on fruit development in loquat," *Journal of Horticultural Science and Biotechnology*, 2005,80,pp.370-374.
- [4] I. Almeida, I.M. Leite, J.D. Rodrigues, and E.O. Ono, "Application of plant growth regulators at pre-harvest for fruit development of 'PERA' oranges," *Brazilian Archive of Biology and Technology*, 2004, 47(4), pp.658-662.
- [5] O. Arakawa, A. Kanetsuka, K. Kanno, and Y. Shiozaki, "Effects of five methods of bark inversion and girdling on the tree growth and fruit quality of 'Megumi' apple," *Journal of Japanese Society Horticultural Science* 1998,67,pp.721-727 (in Japanese with English abstract).
- [6] O. Bergh, "Effect of time of hand -thinning on apple fruit size," *South African Journal of Plant and Soil*, 1990,7,pp.1-10.
- [7] D.R. Bhattarai, and D. M. Gautam, "Effect of harvesting method and calcium on post harvest physiology of tomato," *Nepal Agriculture Research Journal*, 2006,7,pp.37-41.
- [8] C. T. Chao, and C. J. Lovatt, "Foliar-applied 3,5,6-trichloro-2-pyridoxylacetic acid (3,5,6-TPA) increases yield of commercially valuable large-size fruit of 'Fina Sodea' clementine mandarin," *Acta Horticulturae* 2010,884,pp.433-440.
- [9] Y.L. Chun, W. David, and E.G. Eliezer, "Girdling affects carbohydrate-related gene expression in leaves, bark and roots of alternate-bearing citrus trees," *Annals of Botany*, 2003,92,pp.137-143.
- [10] C.W.Jr. Coggins, and C.J. Lovatt, "Pest management guidelines," Citrus UC Publication 3441, University of California, Riverside, California, 2004.
- [11] P.J. Davis, "The plant hormones: their nature, occurrence and functions. In: P.J. Davis. (Ed.), *Plant Hormones*, Kluwer Academic Publishers, Dordrecht, the Netherlands, 2004, pp. 1-15.

- [12] F.S. Davies, and G. Zalman, "Gibberellic acid, fruit freezing, and post-freeze quality of Hamlin oranges," *Horticulture Technology*, 2006, 16, pp.301-305.
- [13] Q. Ding, M.Y. Han, and Y.M. Tian, "Effect of bagging on nectarine fruit quality and fruit cracking," *Journal of Northwest Sci-Tech University of Agriculture and Forestry*, 2004, 32 (9), pp.81-83 (in Chinese with an English abstract)
- [14] L. F. Ebell, "Girdling: its effect on carbohydrate status and reproductive bud on cone development of Douglas fir," *Canadian Journal of Botany* 1971, 49, pp.453-466
- [15] C. Forshey, and D. C. G.-Elfvig, "The relationship between vegetative growth and fruiting in apple trees," *Hort. Rev.* 1989, 11, pp.229-287
- [16] A.Garcia-Luis, F. Fornes, A. Sanz, and J.L. Guardiola, "The regulation of flowering and fruit set in Citrus: relationship with carbohydrate levels," *Israel Journal of Botany*, 1988, 37, pp.189-201
- [17] E.E.Goldschmidt, N. Aschenazi, Y. Herzano, A.A. Schaffer, and S.P. Monselise, "A role for carbohydrate levels in the control of flowering in citrus," *Scientia Horticulturae*, 1985, 26, pp. 159-166.
- [18] R.Goren, M. Huberman, and J. Riov, "Girdling: physiological and horticultural aspects," *Horticultural Reviews (American Society Horticultural Science)*, 2003, 30, pp.1-36.
- [19] R. Goren, M. Huberman, and E.E. Goldschmidt, "Girdling: physiological and horticultural aspects," *Horticultural Reviews*, 2004, 30, pp.1-36
- [20] A. B. M. S. Hossain, F. Mizutani, J. M. Onguso, and A. R. El-Shereif, "Dwarfing peach trees and development of fruit quality by maintaining partially ringed bark strips as an innovative process in dwarfing technology," *Botanical Studies*, 2006, 47, pp.251- 57.
- [21] C.H. Huang, M.L. Chai, Z.M. Pan, B. Yu, Z.M. Jiang, J.L. Hu, and Y.W. Teng, "Effects of bagging on fruit skin features and quality of Cuiguan pear cultivar," *Journal of Fruit Science* 2007, 24, pp.747-751 (in Chinese).
- [22] X.M. Huang, "Fruit disorders. In: Menzel, C., G.K. Waite, (Eds.). *Litchi and Longan-Botany, Production and Uses*," CABI Pub., Wallingford, Oxford, UK, 2005, pp.41-152.
- [23] H.Link, "Significance of flower and fruit thinning on fruit quality," *Plant Growth Regulation*, 2000, 31, pp. 17-26
- [24] D.J.Iglesias, F.R. Tadeo, E. Primo-Millo, and M. Talon, "Fruit set dependence on carbohydrate availability in citrus trees," *Tree Physiology* 2003, 23, pp.99-204
- [25] M.Iqbal, M. Q. Khan, U. D. Jalal, K. Rehman, and M. Munir, "effect of foliar application of NAA on fruit drop, yield and physico-chemical characteristics of guava (*Psidium guajava* L.) Red flesh cultivar," *Journal of Agricultural Research*, 2009, 47(3), pp.259-269.
- [26] M.C.Juan, A. Mesejo, C. Mart'nez-Fuentes, and M. Agusti, "Branch scoring encourages fruit development and climacteric in persimmon," *Scientia Horticulturae*, 2009, 122, pp.497-500
- [27] H.J. Jia, A. Araki, and G. Okamoto, "Influence of fruit bagging on aroma volatiles and skin coloration of 'Hakuho' peach (*Prunus persica* Batsch)," *Postharvest Biology and Technology*, 2005, 35, pp.61-68.
- [28] H.Kitagawa, K. Manabe, and E.B. Esguerra, "Bagging of fruit on the tree to control disease," *Acta Horticulturae*, 1992, 321, pp.870-875.
- [29] K.Lahey, R. Yuan, J.K. Burns, P.P. Ueng, L.W. Timmer, and K. Chung, "Induction of phytohormones and differential gene expression in citrus flowers infected by fungus *Colletotrichum acutatum*," *Molecular Plant Microbe-Interactions* 2004, 17(12), pp. 1394-1401.
- [30] E.M. Li, D.C. Shi, Y.H. Xu, F. Chen, and H. Zhai, "Changing characteristics of temperature and humidity in different type bags for bagging apple and their effects on fruit appearance quality," *Chinese Journal of Applied Ecology*, 2008, 19, pp.208-212 (in Chinese with an English abstract).
- [31] M.Mataa, S. Tominaga, and I. Kozaki, "The effect of time of girdling on carbohydrate contents and fruiting in 'Ponkan' mandarin (*Citrus reticulata* Blanco)," *Scientia Horticulturae*, 1998, 73, pp. 203-211.
- [32] E.A.M. Mostafa, and M.M.S. Saleh, "Response of Balady Mandarin trees to girdling and potassium sprays under sandy soil conditions," *Research Journal of Agriculture Biological Science*, 2006, 2, pp.137-141
- [33] S.P.Monselise, R. Goren, and Y.I. Wallerstein, "Girdling effects on orange fruit set and young fruit abscission," *HortScience*, 1972, 7, pp.514-515.
- [34] H.Y.Nakasone, and R.E. Paull, "Tropical Fruits," CAB International, New York, 1998
- [35] J.M.Onguso, F. Mizutani, and A.B.M.S. Hossain, "Effects of partial ringing and heating of trunk on shoot growth and fruit quality of peach trees," *Botanical Bulletin Academia Sinica*, 2004, 45, pp.301-306.
- [36] Y.H. Peng, and E. Rabe, "Effect of summer trunk girdling on fruit quality, maturation, yield, fruit size and tree performance in 'Mihowase' satsumas," *Journal Horticultural Science* 1996, 71, pp. 581-589.
- [37] C.A. Priestly, "Some effects of ringing branches on the distribution of dry matter in young apple trees," *Journal of Experimental Botany*, 1976, 27: 1313-1324.
- [38] F.Rivas, H.Arbiza, and A. Gravina, "Caracterización del comportamiento reproductivo de la mandarina 'Nova' en el sur del Uruguay," *Agrociencia*, 2004, 8, pp.79-88
- [39] F.Rivas, Y. Erner, E. Alos, M. Luan, V. Almela, and M.Agusti, "Girdling increases carbohydrate availability and fruit-set in citrus cultivars irrespective of parthenocarpic ability," *Journal Horticultural Science Biotechnology*, 2006, 81, pp.289-295.
- [40] F.Rivas, F. Fernando, and M. Agusti, "Girdling induces oxidative damage and triggers enzymatic and non-enzymatic antioxidant defences in Citrus leaves," *Environmental Experimental Botany*, 2008, 64, pp.256-263
- [41] L.H.Shao, L. Deng, and L.Y. Qing, "Effects of floral promotion or inhibition treatments on flowering of citrus trees and protein fraction in buds," *J. Trop. Subtrop. Bot.* 1998, 6, pp.124-130
- [42] R.A.Stern, D. Stern, M. Harpaz, and S. Gazit, "Applications of 2,4,5-TP, 3,5,6-TPA and combinations thereof increases lychee fruit size and yield," *HortScience*, 2000, 35, pp.661-664.
- [43] Z.H.Shu, D.N. Wang, and T.F. Sheen, "Wax apple as a potential economic crop for the world. In: Vijayasegaran, S., Pauziah, M., Mohamed, M.S., Ahmad Tarmizi, S. (Eds.), *Proceedings of the International Conference Tropical Fruits*, vol. I. Malaysian Agr. Res. Dev. Inst., Serdang, Selangor, Malaysia, 1996, pp. 69-73.
- [44] B. R. Thakur, R. K. Singh, and P. Nelson, "Quality attributes of processed tomato products: a review," *Food Reviews International*, 1996, 12(3), pp.375-401.
- [45] T.Yamane, and K. Shibayama, "Effects of trunk girdling and crop load levels on fruit quality and root elongation in 'Aki Queen' grapevines," *Journal of Japanese Society Horticultural Science*, 2006, 75, pp.439-444.
- [46] W.H. Yang, X.C. Zhu, J.H. Bu, G.B. Hu, H.C. Wang, and X.M. Huang, "Effects of bagging on fruit development and quality in cross-winter off-season longan," *Scientia Horticulturae*, 2009, 120, pp.194-200.
- [47] O.K. Yamanishi, "Trunk strangulation and winter heating effects on fruit size, internal quality and maturation of 'Tosa Buntan' pummelo grown in a plastic house," *J Hort Sci*, 1995, 70, pp.65-74
- [48] N.C. Wheeler, C.T. Masters, S.C. Cade, S.D. Ross, J.W. Keeley, and L.Y. Hsin, "Girdling: an effective and practical treatment for enhancing seed yields in Douglas fir seed orchards," *Canadian Journal of Forest Research*, 1985, 15, pp.505-510.
- [49] C.F. Wang, Y.You, F.Chen, X.S.Lu, J.Wang, and J.S. Wang, "Adjusting effect of brassinolide and GA3 on the orange growth," *Acta Agronomica*, 2004, 26, pp.759-762.
- [50] S.Vara-Ubol, E. Chambers, V. Kongpensook, C. Oupadissakoon, R. Yenket, and A. Retiveau, "Determination of the sensory characteristics of rose apples cultivated in Thailand," *Journal of Food Science*, 2006, 71, pp. 547-552.