Reduction and Prevention of Chilling Injury by Pruning and Covering Treatments on Wax-apple (*Syzgium samarangense* Merr. et L.M. Perry)

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ABSTRACT

A wax-apple field was selected in Lio-Gui area during the period from January 2003 to January 2004. Night temperature in the field decreased significantly to below 15℃ after December. During December 21-31, night temperature was further dropped down to below 10℃ with the minimum of 7.4℃. It was found that development and growth of fruits and leaves were limited by low temperature, which would cause damage symptoms such as fruit abscission, chilling injury and leaves injury. The preliminary results indicated that mature and young leaves were able to maintain at a ratio of 80-90% to 10-20% after early December when plants gave first pruning in 2 days after forcing flower treatment on vigorous shoots and followed by a second pruning on inner shoots in 14 days after forcing flower treatment. At that time, the fruit pericarp had turned red. The effect to reduce chilling injury was better when the plants were pruned twice than just one time. Treatment of covering tree canopy during night time also had better chilling protection than that without canopy cover when temperature below 10℃. It showed that cold damage to matured leaves, fruits, and fruits abscission were 20%, 25%, and 10% less, respectively, when temperature decreased to 7.4℃. Results suggest that, as temperature lower down to below 8℃, adjusting plant vigor by pruning shoots two times in conjunction with forcing flower treatment and canopy covering provide the best cold protection model for wax-apple from chilling injury.

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Key words: Wax-apple, Fruit abscission, Chilling injury, Pruning, Canopy covering.

利用修剪及覆蓋處理降低與防範蓮霧之寒害

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摘要

本試驗選定高雄縣六龜鄉蓮霧園為試區，試驗期間夜溫於 93 年 12 月以後降至 15℃以下，12 月 21 日至 12 月 31 日期間夜溫下降至 10℃，最低氣溫為 7.4℃。果實及葉片因低溫而生長遲緩或受限，更造成落果、果實凍傷及葉片寒害等現象發生。經由初步結果發現，催花後第二天進行第一次徒長枝強修剪，第十四天再行第二次內部枝條修剪，樹體於 12 月 5 日後果實已達紅頭期，成熟老葉及新葉之比例為 80-90%：10-20%；歷經 7.4℃低溫後，顯示可因此減緩葉片受害及果實寒害程度。在寒害防減(護)效益評估上，催花後採二次修剪者優於一次修剪者。同時，溫度低於 10℃期間，於夜間進行樹冠覆蓋保護之效益更優於無覆蓋處理者，可減輕成熟葉片受害率 20%、果實凍傷率 25%及落果發生率 10%。因此，藉由蓮霧催花處理後採二次階段進行枝條修剪，控制抽梢調整樹體活力，並於氣溫低於 8℃時配合樹冠覆蓋處理，為本試驗中最佳的蓮霧寒害防減模式。

關鍵詞：蓮霧、落果、寒害、修剪、樹冠覆蓋。

INTRODUCTION

Wax-apple is an important competitive tropical fruit in Taiwan. The planted area was 7,795 hectares in the year of 2003. Regular flowers appear in March and fruit ripen in May under natural condition in southern Taiwan. However, blooms and sets fruit produced almost year-round after forcing flower treatment (Wang 1983).

There are four fruit seasons depending on forcing flower timing. The various fruit quality is caused by different fruit growth conditions. The optimal temperature for wax-apple is lying between 25℃ to 30 ℃ (Wang 1991). In southern Taiwan, temperature in summer may go up to 35℃, while temperature may drop down to below 8℃ in the winter season. The major wax-apple production season is in the winter, from November to February of the next year. However, low temperatures frequently occur during winter season to cause serious chilling injury (Wang 1991, 1997, Lur and Chu 1998). The critical temperature for chilling damage depends on the age and vigor of the plants.

Many experiments have been conducted to prevent wax-apple from chilling injury in the past ten years. Practices such as canopy covering during fruit development (Fu 1994), wind blowing with fan machines (Shen *et al*. 1998), field mulching (Lai 2000, 2003), and chemical spraying (Wang 1997, Lai *et al*. 2001, Huang and Wang 2003, Lai 2003) were shown effective for such purpose. The effectiveness and efficiency of different methods are also depending on climatic condition and vigor of plants.

In order to establish a safe and feasible model or method to reduce chilling injury, damages of wax-apple caused by chilling temperatures in the field under natural growing conditions were observed in Lio-Gui areas from 2000 through 2002. The results indicated that resistance to chilling injury was strongly related to plant vigor and proportionality of mature leaves during fruit-maturing stage (Huang and Wang 2003). Based on these observed phenomenon, further experiments were conducted to evaluate the effectiveness and efficiency of plant vigor adjustment by shoot pruning, after forcing flower treatment and canopy covering. Effect of the combinations of these practices to protect wax-apple from chilling injury was also investigated.

MATERIALS AND METHODS

1. PLANT MATERIALS

Twelve 16-year-old wax-apple trees were selected from a farmer's field located in Lio-Gui area in southern Taiwan. Each tree was treated with forcing flower practice on the 31st of August of 2003. Other field management practices were listed in Table 1.

2. PRUNING TREATMENTS

There were two different pruning treatments carried out in the experiment. The first pruning treatment was conducted in 2 days after forcing flower treatment to prune all the vigorous and inner shoots. The second pruning treatment was conducted in 2

Table1. Time schedule and items of field management practices during the experimental period from January 2003 to January 2004.

Items	Date	Items	Date
Trunk girdling	Jun. 21, 2003	Flowering	Oct. 16, 2003
Root pruning	Aug. 21, 2003	Growth regulator spraying*	Oct. 23, 2003 Nov. 6, 2003
Flower forcing	Aug. 31, 2003	Fruit bagging	Nov. 25, 2003
First pruning	Sep. 02, 2003	Fruit reddish beginning	Dec. 5, 2003
Second pruning	Sep. 16, 2003	Covering treatment	Dec.21~Dec.30, 2003
Young flower thinning	Sep. 26, 2003	Fruit mature and harvest	Jan. 15, 2004
Shoot thinning	Oct. 10, 2003		

* Growth regulator spraying method was adopted from Huang and Wang (2003).

days after treatment to prune all vigorous shoots. Other inner shoots were pruned in 14 days after the second pruning treatment.

3. COVERING OF PLANT CANOPY

In order to alleviate chilling injury during low temperature condition, 3 trees were chosen to cover with impermeable materials from the top of plant at 06：00 p.m. and the cover was taken off at 07：00 a.m. the next day, based on weather report by Center Weather Bureau. Another 3 trees were chosen without covering used as control. The model used in the second pruning treatment was the same as that used in the first pruning treatment.

4. INVESTIGATED ITEMS

(1) The influences of pruning method and covering treatment on fruit abscission and chilling injury of wax-apple trees, when mean air temperature lowered down to 10℃, were investigated.
(2) The proportionalities of matured and young leaves between two pruning treatments in the fruit-turning-red stage were computed.
(3) The climatic factors such as air temperature and relative humidity in the experimental field were automatically recorded by a data-logger at 15-min interval.

RESULTS AND DISCUSSION

1. TEMPERATURE IN RELATION TO PLANT VIGOR AND CHILLING INJURY

The temperature variation from the 18th of July 2003 to the 28th of January 2004 measured at Lio-Gui area is plotted in Fig. 1. It shows that field temperature at Lio-Gui area was dramatically decreased from late September until January. The mean daytime temperature was in range of 30-35℃ and the mean nighttime temperature was in range of 20-25℃ before late October. Daytime temperature decreased to below 30℃ and nighttime temperature dropped to below 20 ℃ since the late November. Before early December, day temperature was maintained at about 20℃ while night temperature was further decreased to below 10℃ after December 21, 2003. The daytime temperature maintained in range of 15-20℃ throughout fruits harvest period. The night temperature was decreased to below 8℃ between 03:00 a.m. and 07：30 a.m. during December 27-30, 2003. Changes of the relative humidity during the experimental duration were shown in Fig. 2. It indicated that relative humidity was from 80% to 98% during the night and from 40% to 60% during daytime period.

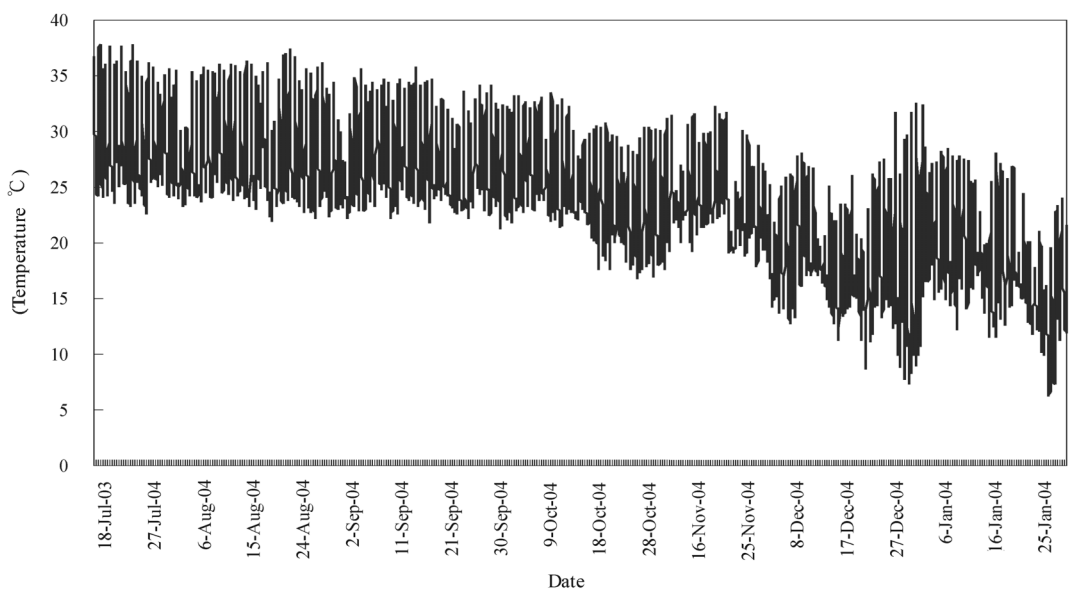

Fig. 1. The variation in temperature from July 18, 2003 to January 28, 2004 in Lio-Gui area.

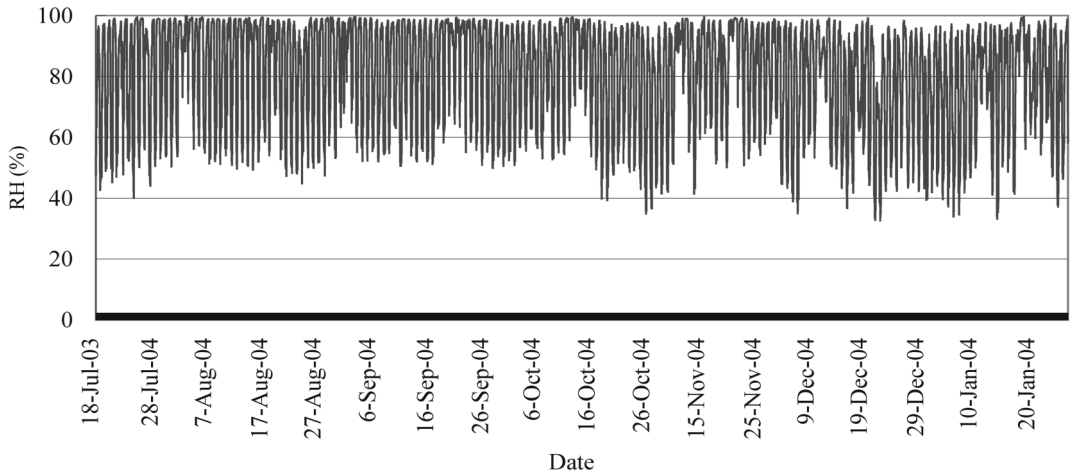

Fig. 2. The variation in relative humidity from June 18, 2003 to January 28, 2004 in Lio-Gui area.

The fruit pericarp turned to reddish and entered mid-matured stage after early December. On the 29th of December, nighttime temperature was decreased to below 10℃ from 0：45 a.m. to 07：45 a.m. with the minimum temperature dropped to 7.4 ℃ within 06:00-06:30 a.m. One week after, more chilling symptoms appeared on leaves and fruits of wax-apple trees. Also, the fruit abscission occurred and many small shrunken pittings appeared on the top of fruits' surface. Wang (1983) pointed out that temperature below 7℃ during flowering and fruit setting stages would cause chilling damages to young flower bud, young fruit, turning-red fruit, and maturing fruit. Kao (1994) indicated that the turning-red phenomenon in fruit pericarp was very sensitive to chilling effect.

In wax-apple, ages of leaves are distinguished by the time of emergence and leaf color. Young leaves emerge in less than 4 months and appear in yellow-green and yellow colors. Matured leaves emerge in greater than 4 months with green and dark-green color. The magnitude of chilling damage to leaves depends on leaf age and leaf nutrition status. Generally matured leaves are damaged more seriously than young leaves by chilling impacts, which induce damage symptoms in leaves a week later. For 6-month-old leaves, the dehydration symptom occurred in the first place. The mesophyll cells across the mid-rib of leaf suffered water deficiency in 2 days after chilling occurrence. The leaf then turned yellow and soon the abscission occurred in 7 days after chilling. For leaves emerged in less than 2 months, a lightly wilting symptom occurred, while no damage symptom was found in 2 to 4 months old leaves. When temperature decreased to 10℃, growth of leaf was inhibited.

2. INFLUENCE OF PRUNING TREATMENTS ON THE RATIO OF MATURE AND YOUNG LEAVES IN THE FRUIT-TURNING-RED STAGE

The new shoots and leaves of wax-apple trees usually sprout at 7-10 days after pruned. The efficiency of sprouting new shoots and leaves by different pruning methods was compared in this study. Results showed that rate and amount of sprouting in one-time pruning treatment was faster and larger than two-time pruning. On September 26 and October16, trees of both treatments obtained a shoot-thinning practice to control the amount of shoots remained. The secondary shoots and leaves sprouted on November 6 when the primary shoots and leaves become matured, but the rate and amount of secondary sprouting were not the same between trees of different treatments. The shoots and leaves of two-pruning trees grew faster and larger than those of one-pruning trees.

Results indicated that the ratio of mature to young leaves before fruit-turning-red stage was strongly influenced by the chilling resistance, which was manipulated by means of pruning methods. As shown by Huang and Wang (2003), the ratio of mature to young leaves was about 4:1 to 5:1 in two-pruning trees and there was no young leaves found in one-pruning trees

3. EFFECTS OF PRUNING TREATMENT ON CHILLING INJURY OF WAX-APPLE TREES

The average rates of fruit abscission, chilling injury and leaf damage were ranged from 18.3-21.9%, 24.1-35.5%, and 21.4-27.6%, respectively, in one-pruning treatment. While in the two-pruning treatment, the average rates of fruit abscission, chilling injury, and leaf damage were in range of 11.8-14.5%, 11-12.5%, and 7-9%, respectively (Table 2). Apparently, the efficiency of two-pruning treatment was better than one-pruning treatment, which had 100% matured leaves. In two-pruning trees, there was only 80-90% of matured leaves. On the other hand, The rate and amount of sprouting shoots were greater in two-pruning trees, suggesting that the second pruning enhanced chilling resistance in wax-apple trees and resulted in a reduction of chilling damages and a stimulation of young leaves.

4. EFFECT OF CANOPY-COVERING PROTECTION TREATMENT ON CHILLING INJURY OF WAX-APPLE TREES

As low temperature (below 10°C) forecast by Central Weather Bureau announced during the daytime, impermeable materials would then be used to cover tree canopy from the top at 06:00 p.m. on the same day and be lifted at 07:00 a.m. the next day (Table 3). The chilling temperatures were recorded in the range of 7.4-10.0°C and the relative humidity change from 73.6% to 99.4%. The percentages of fruit abscission, fruit injury, and leaf damage were 14.5-21.9%, 12.5-35.5% and 9-27.6%, respectively, for the trees without covering protection. When trees were cover-protected, the percentages of fruit abscission, fruit injury, and leaf damage were reduced to 11.8-18.3%, 11-24.1%, and 7-21.4%, respectively (Table 2). The results proved the effectiveness of canopy covering in reducing chilling damages to wax-apple trees.

In one-pruning treatment without canopy-covering protection, the percentages of fruit abscission, fruit injury, and leaf damage were 16.4-32.5%, 32.6-38.6%, and 20.4-35.4%, respectively. The percentages decreased to 14-26.5%, 12-30.2%, and 16.7-28.5%, respectively, in the protected trees. In two-pruning treatment without covering, the percentages of fruit abscission, fruit injury, and leaf damage were 10-18%, 10-16%, and 4-12%, respectively, while the percentages decreased slightly to 9.6-14.5%, 10-12%, and 5-10%, respectively, when protected with canopy-covering.

Table 2. The effects of pruning and canopy-covering methods in reducing the chilling injury of wax-apple trees[x].

Treatment	Symptom	Damage of fruits and leaves in different orientations				
		South	East	West	North	Mean
One-pruning without covering	Fruit abscission (%)	32.5[y]	20.4	18.5	16.4	21.9[z]
	Fruit injury (%)	32.6	34.5	36.4	38.6	35.5
	Leaf damage (%)	35.4	28.5	26.2	20.4	27.6
One-pruning with Covering	Fruit abscission (%)	26.5	18.4	14.5	14.0	18.3
	Fruit injury (%)	12.0	26.2	28.2	30.2	24.1
	Leaf damage (%)	28.5	22.1	18.5	16.7	21.4
Two-pruning without covering	Fruit abscission (%)	18.0	16.0	14.0	10.0	14.5
	Fruit injury (%)	10.0	12.0	12.0	16.0	12.5
	Leaf damage (%)	12.0	10.0	10.0	4.0	9.0
Two-pruning with covering	Fruit abscission (%)	9.6	10.8	12.5	14.5	11.8
	Fruit injury (%)	10.0	10.0	12.0	12.0	11.0
	Leaf damage (%)	10.0	8.0	5.0	5.0	7.0.

[x] Fruit abscission and leaf damage were investigated on January 6, 2004 and the degree of fruit injury was investigated on January 16, 2004.

[y] Data of each orientation were the average of 3 plants. Fruit abscission (%), fruit injury (%), and leaf damage (%) were counted from 50 fruits and 20 matured leaves marked in the early December.

[z] The mean value of the row was the average of all directions on the same treated trees.

Results showed that canopy-covering reduced the negative chilling effects significantly. Wax-apple trees were better protected when the canopy was covered with the impermeable materials. Thus, it was proved as an effective means for decreasing wax-apple chilling injury. On the nighttime during the period from December 21 to December 30, no dews were observed at the upper portion of leaf surface for trees with canopy-covering. On the other hand, quite a few dews were found in trees without covering. When temperature below 10℃, it is suspected that dews formed on the surface of leaves may be the main cause of chilling injury to wax-apple trees.

5. EFFECT OF DIFFERENT PRUNING AND PROTECTING TREATMENTS ON FRUIT QUALITY

It was found that fruits collected from this study were smaller in size and lighter in weight than other years. The reason was attributed to temperature below 10℃ occurred before the fruit-maturing stage. The average weight of single fruit was in range of 118-120 g in one-pruning trees, and 120-125 g in two-pruning trees (Table 4). As air temperature decreased to the chilling temperature regime in December, the fruit weight was lighter in all treatments. However, leaf damage was found in less degree in trees treated with two time pruning than trees treated with on time pruning.

The mean fruit weights were 120.4 g and 118.4 g for one-pruning trees with and without canopy-covering, respectively. For two-pruning trees, the mean fruit weights were 125.4 g and 120.5 g for the protected and the non-protected, respectively. The chilling condition might limit the development of fruits and increase the level of leaf damage resulting in the decreased of the amounts of carbohydrates from leaves to fruits. For those trees covered with impermeable materials during chilling period, though did not increase temperature significantly (data not shown), the reduced of leaf damage would enhance fruit filling and maintain fruit weight. No differences in fruit length, width, soluble solid, color and size of spongy tissue were found among treatments.

Results indicate that pruning and canopy covering are two effective methods in protecting wax-apple trees from chilling injury. In terms of fruit abscission, fruit injury, and leaf damage, treatment with two-pruning is better than one-pruning and practice with canopy covering is better than without covering.

Table 3. Time period to conduct chilling-protecting treatment and variations in night temperature and relative humidity during chilling.

Date	Chilling period	Temperature (℃)	Relative humidity (%)
Dec. 21, 2003	03 : 45-07 : 30 a.m.	8.63~9.96	96.9~99.4
Dec. 27, 2003	05 : 45-07 : 15 a.m.	8.79~9.74	73.6~77.0
Dec. 28, 2003	05 : 30-07 : 30 a.m.	7.66~9.89	84.0~94.0
Dec. 29, 2003	04 : 00-07 : 45 a.m.	7.36~9.60	91.6~94.6
Dec. 30, 2003	05 : 30-07 : 30 a.m.	9.06~9.60	91.6~94.6

Table 4. The effects of pruning and covering before chilling injury on quality of wax-apple fruit.

Items / Treatments	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Total S.S. (°Brix)[x]	Fruit Color	Spongy tissue[y]
One-pruning without canopy-covering	118.4±1.6	68.5±1.8	67.4±2.8	11.5±2.5	Dark red	M
One-pruning with canopy-covering	120.4±2.8	69.0±2.2	68.9±1.6	12.4±3.6	Dark red	M
Two-pruning without canopy-covering	120.5±2.5	69.6±3.2	68.6±2.4	12.5±1.8	Dark red	M
Two-pruning with canopy-covering	125.4±1.8	71.2±2.4	70.4±1.8	12.6±2.8	Dark red	M

[x] Total S.S. : Total soluble solid.

[y] The size of spongy tissue of fruit: big (B), medium (M), and small (S).

With regard to the directional effect of chilling injury to fruit abscission and leaf damage, data showed that fruits and leaves oriented in the southern and eastern directions suffered more damage than in northern and western directions. There was a developmental difference in leaves and fruits emerging sequence in wax-apple trees. Plant parts grown in the southern and eastern directions exhibited a stronger vigor and leaf growth than those grown in the northern and western directions due mainly to the longer period of sunshine. The ratio of mature to young leaves was higher in the southern and eastern directions and hence favored fruit filling and setting processes. The numbers of fruits set in these two directions were out-numbered than the other two directions and had more fruits in fully matured state. Whereas, fruit injury by chilling effects was more serious in the northern and western directions, especially in pre-matured fruits.

CONCLUSIONS

During the experimental period, air temperature decreased down to less than 10℃ from December 21 to December 30, where wax-apple trees were in the fruit pericarp turning-to-red stage. By using pruning and canopy-covering methods when temperature further dropped to below 8℃, symptoms such as fruit abscission, fruit injury, and leaf damage were significantly reduced. Pruning shoots twice gave better matured to young leaves ratio before fruit maturing stage and favored the quality of fruits. Chilling injury reduced the most in trees adjusted the matured to young leaves ratio to 80~90%:10~20% before fruit maturing stage. Covered tree canopy with impermeable materials further improved the effectiveness in reducing chilling injury. In conclusion, this study suggests that adjusting plant vigor in conjunction with forcing flower and canopy-covering treatments provide the best chilling protection to wax-apple trees, particularly when temperature drop down to below 8℃.

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