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Dwarfing peach trees and development of fruit quality by maintaining partially ringed bark strips as an innovative process in dwarfing technology

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ABSTRACT. The effects of partial ringing (bark ringing) on size control of peach (*Prunus persica* Batsch var. 'Hikawahakuho') wild form (rootstock from seedling) trees was studied. Partial ringing was done on the trunk 4 cm long leaving a connecting strip of bark 2 mm wide (Experiment I) or 5 mm wide (Experiment II). In these experiments, treatments included an un-ringed (control), mid cut once (4 cm × 2 mm ring) and mid cut continuously with attached razor blade (Experiment I), cut once (4 cm × 5 mm ring) and cut fortnightly (Experiment II). Shoot growth was lower in the partially ringed trees than control. Bark growth resembled shoot growth. Flower bud was higher in partial ringed trees (cut once and cut fortnightly) than control. Moreover, trunk circumference was higher in the above ring and lower in the below ring of partially ringed trees. Fruit wt^{-1} was higher in partially ringed trees than in control. Soluble solid content was higher, and acid content lower, than control in partially ringed trees. The results show that 97-99% partially ringed bark strips can be effectively used to reduce peach tree size.

Keywords: Dwarfing peach; Fruit quality; Partial ringing.

INTRODUCTION

Many techniques are involved in making dwarfed fruit trees. Among them, partially ringed bark strip is an important one. Small, compact, dwarfed or size-controlled fruit trees provide easier pruning, thinning, spraying and harvesting, as well as high yields of high-grade fruit and a lower cost of production (Tukey, 1978). Tukey reported that ringing tends to increase the size and sugar content of fruit and to cause the fruit to mature a few days to a week earlier. The primary factor limiting the use of size controlling rootstocks in stone fruit production is the lack of suitable rootstocks that have wide compatibility among cultivars (De Jong et al., 2001). Jose (1997) found lower vegetative growth in all the treatments of ringing (girdling) in relation to control in mango trees. Arakawa et al. (1997) reported that trunk growth above the girdling significantly increased and that trunk growth below the girdling declined. Sitton (1949) reported that the increase in trunk girth above the girdling might be caused by an accumulation of carbohydrates. The reason for the different responses among cultivars is not known.

Arakawa et al. (1997) stated that girdling in apple significantly increased flowering the following spring. Girdling changed the fruit quality (increased SSC and reduced acid concentration) confirming the observations of previous reports by Elfving et al., 1991 and Greene and Lord, 1983. Schneider (1954) stated that girdling blocks the translocation of sucrose from leaves to the root zone through phloem bundles. The block decreases starch content in the root system and accumulation of sucrose in the leaves (Plaut and Reinhold, 1967). Onguso et al. (2004) reported that partial ringing (cut once) ([4 cm × 5 mm] of four-year-old peach trees [var. 'Akatsuki × Banto']) reduced shoot growth and developing fruit quality. Different types of partial ringing ([4 cm × 2 mm] and [4 cm × 5 mm]) using five-year-old peach trees (var. 'Hikawahakuho') were performed in these experiments. We used different varieties, tree ages, and partial ringing techniques (cut once, cut one week, cut fortnightly, and cut continuous) to study the maximum and minimum effect of treatments on the shoot growth, fruit yield, and quality in different years.

MATERIALS AND METHODS

Site

The experiment was carried out in an orchard in the Ehime University Farm located in southern Japan, 33°57 N, 132°47 E at an elevation of about 20 m above sea level.

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The site enjoys a mild temperate climate characterized by hot humid summers and cold dry winters. The soil is sandy loam with a pH of 5.7.

Plant materials

Experiment 1. Three-year-old peach (*Prunus persica* Batsch var. 'Hikawahakuho') trees, wild form (grafted from seedling stocks), were used in this experiment in May 2001. The trees were spaced at 1.0 m × 1.5 m. The bark was cut 4 cm × 2 mm (bark length × bark width). The treatments included a control, partial ringing cut one week (bark disconnected for one week) and partial ringing mid cut continuous (bark disconnected every week) as shown in Figure 1. In the treatment of partial ringing mid cut one week (bark disconnected for one week) razor blades were attached to the middle of the 2 mm bark width for one week. After one week the razor blades were removed. For the treatment of partial ringing mid cut continuous (bark disconnected every week) razor blades were attached to the middle of the 2 mm bark width for 12 weeks. Partial ringing was done by removing a partial ring 4 cm long and leaving a connecting strip 2 mm width in the trunk (main stem), 30 cm above from the soil level (Figure 1C). There were three treatments each with four replications used in the experiment. Ten shoots per tree were tagged to count new shoot length. The parameters were recorded as follows: new shoot length, total, bark width, total shoot length, and pruned shoot weight.

Experiment 2. Five-year-old peach (*Prunus persica* Batsch var. 'Hikawahakuho') trees, wild form (grafted from seedling stocks), were used in this experiment in May 2003. The trees were spaced at 1.3 m × 2.0 m in a completely randomized design. Weeding, irrigation, and insecticide were applied as required. Partial ringing was done by removing a partial ring 4 cm long and leaving a connecting strip 5 mm wide in the trunk (main stem) 30 cm above soil level (Figure 1C). The experiment had three treatments each with four replications. The treatments were control (no ringing), partial ringing (cut once), and partial ringing (cut fortnightly). Total shoot length, total bark width, pruned shoot weight, percent flower bud, and trunk circumference were measured after tree growth stopped. The experiment was continued until 2004, but the treatments were applied once in 2003.

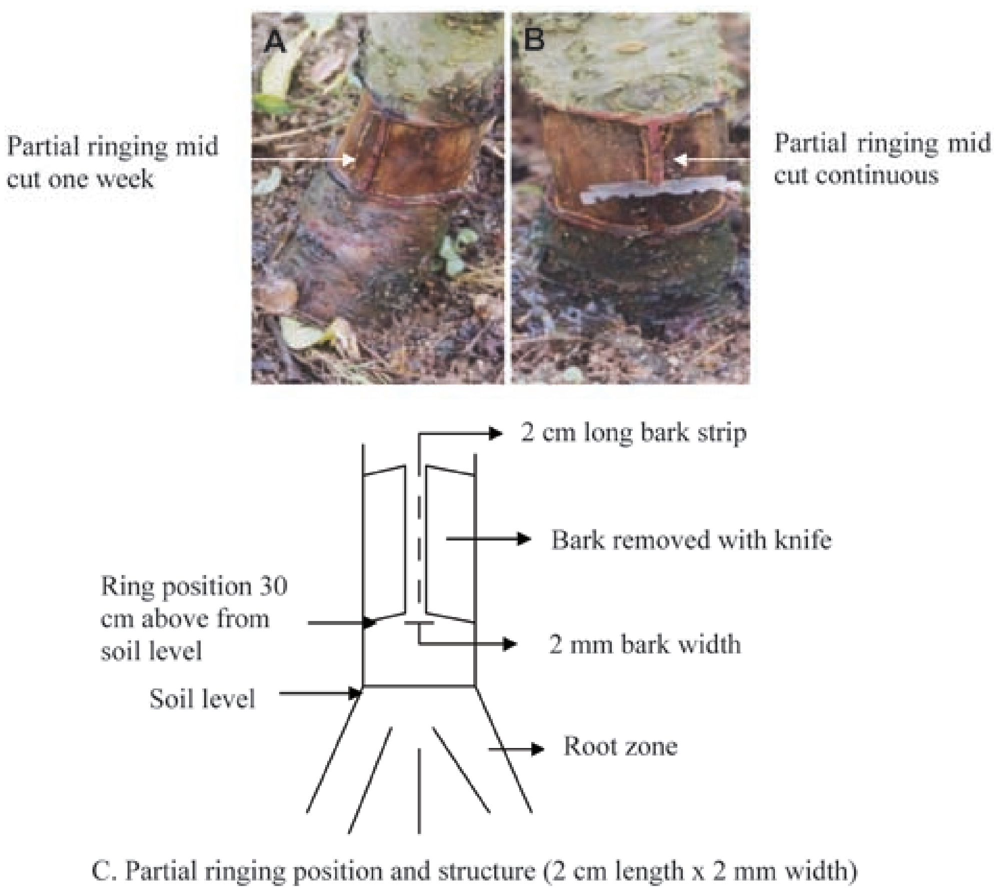

Figure 1. Photo shows the partial ringing structure in the trunk of peach tree. A = 4 cm × 2 mm partial ringing mid cut one week. Razor blade was attached in the bark strip and removed after one week; B = 4 cm × 2 mm partial ringing mid cut continuous. Bark (Phloem) was disconnected by razor blade in the middle position of bark strip; C = Drawing shows partial ringing position and structure in the trunk.

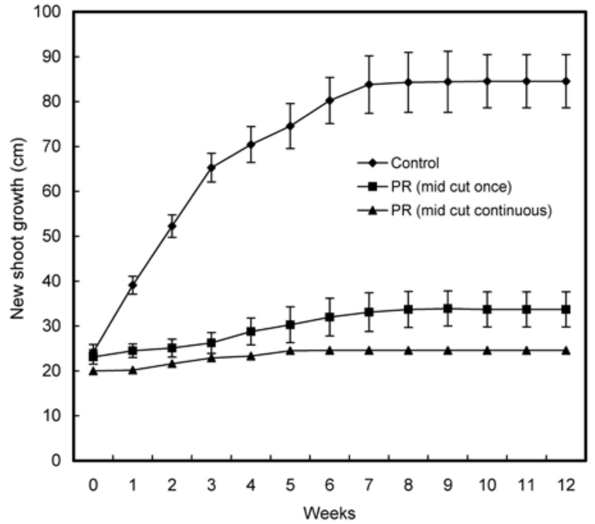

Figure 2. New shoot growth in peach tree as affected by partially ringed bark strips. Vertical bars indicate SE (n=4). PR = Partial ringing, mid cut one week and continuous mean razor blade was attached for one week to and then removed from the middle portion of bark strip. But in continuous razor blade treatment it remained for 12 weeks.

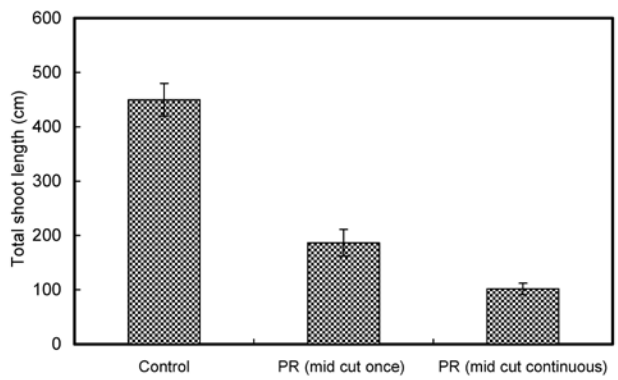

Figure 3. Total shoot length in peach tree as affected by partially ringed bark strip. Vertical bars indicate SE (n=4). PR = Partial ringing.

Fruit harvest in 2003 and 2004

Fruit was harvested in early July 2003. Fruit number per tree, and fruit weight were recorded immediately after harvest. Five fruits per tree were randomly selected and used to determine soluble solid content and titratable acidity. Soluble solid content (SSC) was measured with refractometer (Atago PR-1), and titratable acidity (TA) was determined by titration with 0.1 N NaOH with phenolphthalein as an indicator.

The experiment was continued until fruit harvesting in 2004. Only fruit data were measured. Fruit were harvested on 28 June 2004. Fruit number per tree and fruit weight were recorded immediately after harvest. Ten fruits per tree were randomly selected and used to determine soluble solid content and titratable acidity. Both were determined as mentioned above.

RESULTS

Experiment 1

The effect of partial ringing cut one week and partial ringing mid cut continuous on new shoot growth was recorded (Figure 2). Growth was lower in partial ringing mid cut one week and partial ringing mid cut continuous than in control trees. Total shoot length was measured after growth had stopped (Figure 3). The lowest shoot length was recorded in partial ringing mid cut continuous. Shoot length between control and partial ringing mid cut one week and mid cut continuous treated trees showed a large difference. Bark growth (thickness) was measured for 12 weeks (May-August) to study the relationship between bark and shoot growth (Figure 4). In partial ringing mid cut continuous bark width remained 2 mm, and all plants withered due to the razor blade barrier which prohibited the cambial re-combinations. In partial ringing mid cut one week, bark width increased after the razor blade barrier was removed. The increase began slowly and later slowed down before stopping completely. The weight of shoot removed by winter pruning was measured for all treatments (Figure 5). The lowest shoot

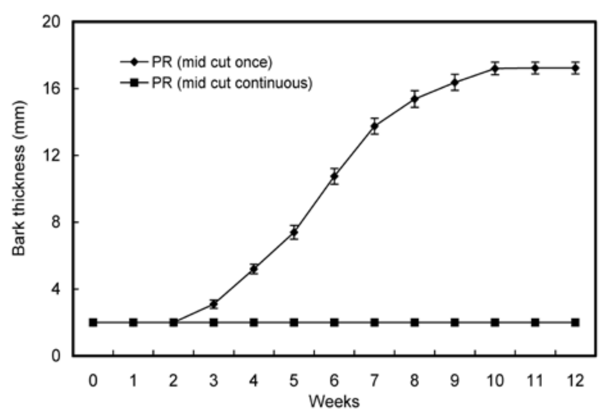

Figure 4. Bark growth (measured weekly) in peach trees as affected by partially ringed bark strip plus mid cut. Vertical bars indicate SE (n=4). PR = Partial ringing.

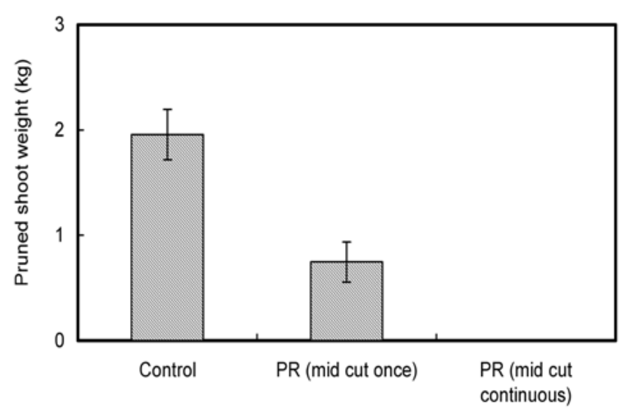

Figure 5. Effect of partially ringed bark strip on pruned shoot weight of peach tree. Vertical bars indicate SE (n=4). PR = Partial ringing.

weight was recorded in partial ringing mid cut one week treated trees. In mid cut continuously treated trees, there was no shoot weight because all shoots had withered due to disconnection of the cambial layer by razor blade. The relationship between bark thickness and shoot growth was strong as shown in Figure 6.

Experiment 2

The effect of partial ringing, cut once and cut fortnightly, of bark on shoot growth was recorded (Figure 7). The lowest shoot length was recorded in partial ringing (cut fortnightly) treated trees, and the highest was recorded in the control trees. Final bark growth (thickness) was observed to study the relationship between bark thickness and shoot growth (Figure 8). Bark growth was lower in partial ringing (cut fortnightly) compared with partial ringing (cut once). Pruned shoot weight was measured (Figure 9). It was lower in partially ringed trees than in control trees. Flower bud was counted (Figure 10). Flower bud was higher in partial ringing treatments than in control. Trunk circumference was higher in partial ringing trees than in control (Figure 11).

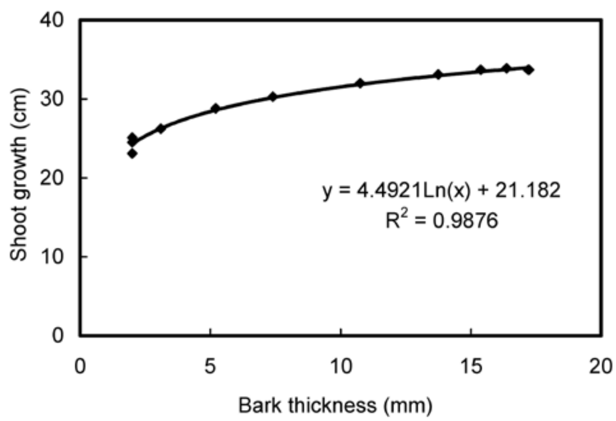

Figure 6. Correlation between bark thickness and shoot growth as affected by partially ringed bark strip. PR = Partial ringing.

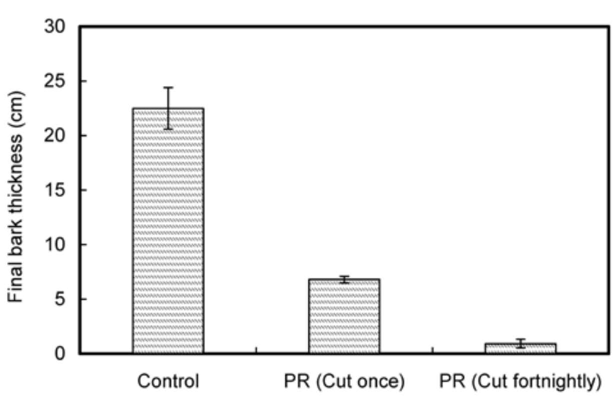

Figure 8. Effect of partial ringing on final bark thickness of peach tree. Vertical bars indicate SE (n = 4). PR = Partial ringing. Final bark width was measured after tree growth stopped

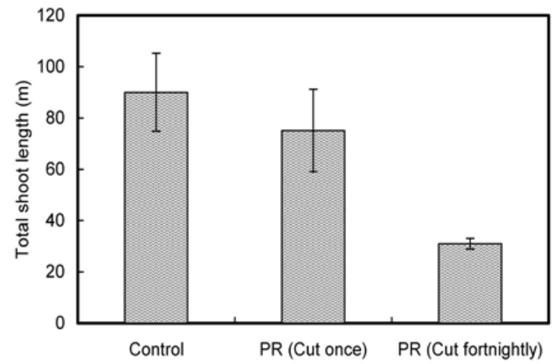

Figure 7. Effect of partial ringing on total shoot length of peach trees. Vertical bars indicate SE (n = 4). PR = Partial ringing.

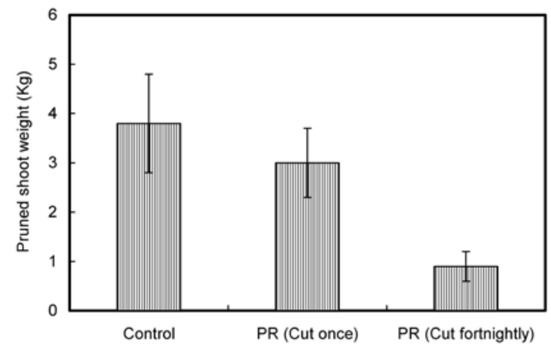

Figure 9. Effect of partial ringing on pruned shoot weight of peach trees. Vertical bars indicate SE (n = 4). PR = Partial ringing.

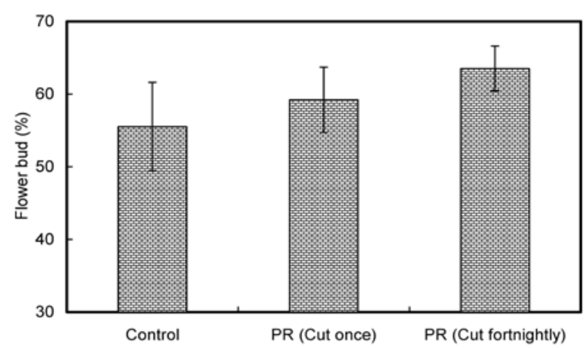

Figure 10. Effect of partial ringing on the flower bud of peach trees.Vertical bars indicate SE (n = 4). PR = Partial ringing.

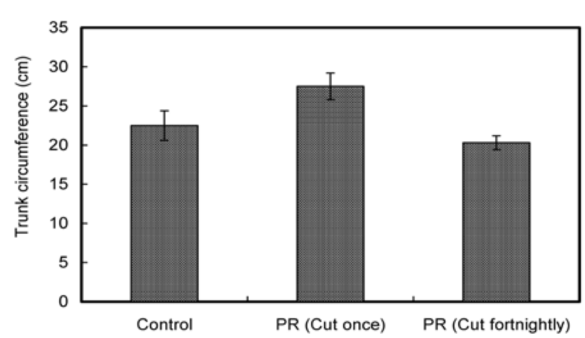

Figure 11. Effect of partial ringing on trunk circumference above from ringing. Vertical bars indicate SE (n = 4). PR = Partial ringing.

The relationship between bark thickness and shoot growth was shown in Figure 12 for different treatments. The data makes clear that when bark growth was lower, shoot growth was also lower. Conversely, when bark growth was higher, shoot growth also rose. Fruit yield was lower in partially ringed than in control trees (Table 1). However, fruit wt^{-1} was higher in partial ringing trees than in control in 2004. Soluble solid content (SSC) of harvested fruit in the following season was greater, and titratable acidity (TA) was lower in partial ringing than control trees in both 2003 and 2004 (Table 2).

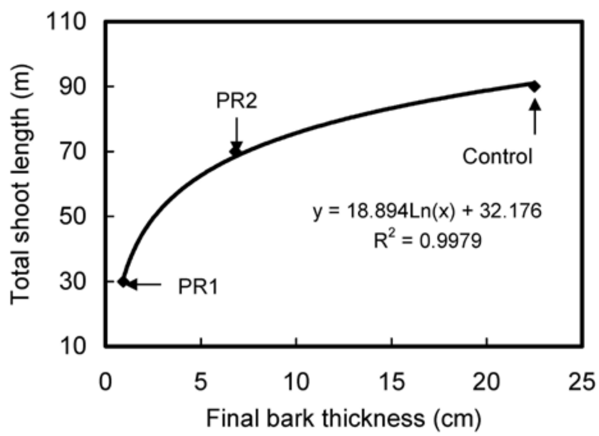

Figure 12. Relationship between shoot length and bark thickness in different treatments. PR1 = Partial ringing (cut fortnightly), PR2 = Partial ringing (cut once).

DISCUSSION

The results show that partial ringing is effective as a dwarfing component in peach trees. In the first experiment partial ringing cut once (in which bark was disconnected for one week) was found to be more effective than partial ringing mid cut continuous (in which bark was disconnected every week). When the razor blade was removed after one week, shoot and bark started to grow. In contrast, when the razor blade was attached continuously, shoot and bark stopped growing. In the second experiment, it was found that partial ringing cut once and cut fortnightly was more effective for tree dwarf and fruit quality. In the case of partial ringing (cut fortnightly), bark width (thickness) remained 5 mm for a fortnight. That is why some trees withered. Among all treatments the most effective was partial ringing (cut once). Shoot growth was lower in 5 mm partial ringing (cut fortnightly) than in partial ringing (cut once). This may be due to less suppression of food movement between shoot and root by bark ringing. Smooth carbohydrate transport from leaves to roots through the phloem was suppressed because the phloem was reduced in width by ringing. It has been reported that nutrient sap might diffuse laterally or vertically if normal phloem transport is checked by ringing cut (Tukey, 1978). Tree circumference was higher in partial ringing treatments.

Sitton (1949) reported that increases in trunk girth above the girdling might be caused by swelling of the trunk with the accumulation of carbohydrates while the reason for different responses among cultivars is not known. The percentage of flower buds was higher in

Table 1. Effects of partial ringing (PR) on fruit yield of peach trees in 2003 and 2004.

Treatment	Yield (Kg/tree)		Fruit weight (g)	
	2003	2004	2003	2004
Control	3.4 ± 0.6[a]	3.0 ± 0.3	181.4 ± 15.4	185.1 ± 10.4
PR (cut once)	3.0 ± 0.4	3.0 ± 0.5	185.1 ± 11.3	190.1 ± 2.2
PR (Cut fortnightly)	1.1 ± 0.2	1.2 ± 0.6	180.3 ± 14.5	188.0 ± 1.7

[a]Mean ± SE (n=4); PR = Parartial ringing.

Table 2. Effect of partial ringing (PR) on soluble solid content and acid content of peach fruit in 2003 and 2004.

Treatment	Soluble solids content (%)		Acid content (%)	
	2003	2004	2003	2004
Control	7.10 ± 0.42[a]	7.00 ± 0.32	0.46 ± 0.05	0.47 ± 0.06
PR (cut once)	7.60 ± 0.30	7.90 ± 0.29	0.38 ± 0.04	0.36 ± 0.05
PR (Cut fortnightly)	8.20 ± 0.28	8.40 ± 0.27	0.36 ± 0.02	0.35 ± 0.03

[a]Mean ± SE (n=4); PR = Partial ringing.

partially ringed trees than in control trees. This might be due to a deposition of sufficient carbohydrates and nutrients in the upper parts of ringing. Arakawa et al. (1997) also found that flowering the following spring in Fuji apple was significantly increased by girdling. Arakawa et al. (1997) reported that growth of the trunk above the treated area increased significantly and growth below it was reduced by girdling in apple.

Tree circumference was higher in the upper parts in the ringing treatments. Onguso et al. (2004) reported that sugars and starch were higher in the upper parts of the ring than in the lower parts. They also stated trunk circumference was higher in the upper part in the ringing treatments.

Johnson (1998) reported that photosynthates produced in the leaves are partially and completely stopped from reaching the roots by girdling. Hossain et al. (2004) found that N and Ca were higher in partially ringed trees than control. Johnson (1998) reported that 50% or more of the stem circumference made girdling the plant would probably die or hang on in a pretty unhealthy and ugly state for a while. Arakawa et al. (1997) reported that 90% girdling in apple trees might reduce growth. Our result shows that peach tree can be dwarfed by applying 97-99% girdling.

CONCLUSIONS

This study has shown that it is possible to make peach tree dwarfed from vigorous rootstock by applying bark ringing. The techniques include a new effect of 97%-99% (2 mm bark strip in Experiment I and 5 mm bark strip in Experiment II) bark ringing: the plant can survive in addtion to being dwarfed effectively. Some researchers have applied 50% and 90% ringing in other trees and varieties, and those plants have survived and been dwarfed. Some differences were highlighted, including bark ringing in peach trees (var. 'Hikawahakuho') maintained mid cut once with razor blade shock and cut fortnightly than bark ringing maintained cut once what usually done as girdling. In our result, we found that partial ringing (mid cut once) and partial ringing (cut fortnightly) were more effective than partial ringing (cut once) and control (un-ringed) in reducing tree size. No significant difference in fruit quality emerged. In addition, the spraying of growth inhibitors as a dwarfing component may cause environmental pollution. By contrast, bark ringing reduces the cost of tree spray and labor. That is why fruit tree growers can use this dwarfing technique easily to control tree sizing.

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一種新的果樹矮化過程：維持部份環割以矮化桃樹達到果實品質之掌控

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本實驗之目的在於研究部份環割（樹皮部份）對桃子大小的影響。桃 (*Prunus persica* Batsch 品種為 ‘Hikawahakuho’) 為供試材料。部份環割在樹皮上切開 4 公分長留 2 公厘（實驗 1）或 5 公厘寬之連接帶（實驗 2）。在這些實驗裡，不同之處理含：不環割（對照組），以刀片中割一次（4 公分× 5 公厘環），或以刀片連續中割（實驗 1）；在實驗 2 則為環割一次（4 公分× 5 公厘環）或每二星期割一次。經部份環割之桃樹其莖之生長較對照組為低。樹皮之生長和莖相同。經部份環割之桃樹其花芽，不論是割一次或每兩星期割一次者，比對照組多。再者，樹幹之圓周長在上環比下環粗。經環割之桃樹其可溶性固形物含量比對照組高。結果顯示 97~98% 之部份環割技術可用來減小桃樹之體積。

關鍵詞：部份環割；矮化之桃樹；果實品種。