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Effects of partial ringing and heating of trunk on shoot growth and fruit quality of peach trees

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Abstract. Small-sized peach (*Prunus persica* [L.] Batsch.) trees for commercial fruit production have not been available due to the lack of suitable dwarfing rootstocks that have a wide range of compatibility among cultivars. Effects of partial girdling and trunk heating on the growth, yield, and fruit quality of peach were studied. A 4 cm wide partial ring of bark was removed at a height of 25 cm from the ground leaving a connecting strip of 5 mm. Furthermore, the de-barked spot was heated at 150°C for fifteen minutes using an electric heater. The partial girdling was effective in reducing shoot growth and improving fruit quality. The total soluble solids content of fruit in treatment trees was higher than that of control. The heating had little additive effects over partial ringing.

Keywords: Brix; Dwarfing techniques; Partial ringing; Starch content; Total sugar; Trunk heating.

Introduction

Small, compact, dwarfed, or size-controlled fruit trees seem to be the natural and obvious answer to many of the problems of commercial orchardists. They provide early fruiting, a more rapid turnover in varieties to meet changing market requirements, a lower cost of production, a higher proportion of high-grade fruit, and easier thinning, pruning, spraying, and harvesting (Tukey, 1978). The primary factor limiting the use of size-controlling rootstocks in stone fruit production is the lack of suitable rootstocks with a wide range of compatibility among cultivars (De Jong et al., 2001). This creates a need to explore alternative dwarfing techniques.

A number of workers have reported useful data on the application of various forms of girdling in fruit production. Ebell (1971) used overlapping, half – circumference – band girdles from which 25 mm wide strips of bark and phloem were removed from opposing sides of the stem of cone. Wheeler et al. (1985) compared partial – overlapping – band girdles to similar girdles applied with a pruning saw. They found both methods increased cone yield. Although stem girdling has received substantial attention, literature on the effects a combination of partial girdling and trunk heating has on shoot growth and fruit quality is limited. The interaction of bark width and shoot growth in peach has not been thoroughly investigated.

Partial ringing and trunk heating experiments were carried out to study their possible contribution to dwarfing in peach trees.

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Materials and Methods

Site

The experiment was conducted at the Ehime University Experimental Farm located in southern Japan, 33°57' N, 132° 47' E at an elevation of about 20 m above sea level. The region has a mild temperate climate characterized by hot humid summers and cold dry winters. The soil at the experimental site is sandy loam (eutric fluvisol) with a pH (H_20) of 5.7, a bulk density of a 1.08 g cm^{-3} and horizon A thickness of 0.15 m.

Plant Materials

Four-year-old peach (*Prunus persica* Batsch. var. 'Akatsuki x Banto') trees growing in an orchard at the University Farm were used in this study. On May 3, 2002, twelve trees were randomly selected and a 4 cm wide partial ring of bark removed from eight of them at a height of 25 cm above the ground to leave a 5 mm connecting strip. Four of the ringed trees were heated on the de-barked spot at 150°C for fifteen min using an electric ribbon heater (Figure 1). The growth of the trees was monitored weekly by measuring lengths of ten selected terminal shoots per tree. The growth of the 5 mm bark that was left after ringing was also monitored weekly using vernier calipers.

The fruit diameter was also evaluated weekly using vernier calipers. At harvesting, final fruit number, fruit diameter, and weight were recorded. Juice was extracted from the fruits and titratable acidity determined by acid-base titration using 0.1 N NaOH. The soluble solids content in the juice (Brix) was also measured by means of a refractometer (Atago PR-1).

After six months, bark samples were taken from above (L1) and below (L2) the connecting strip that was left after ringing. Other samples (L3 and L4) were taken from the upper and lower part of the ring away from the connecting strip, respectively (Figure 2). The samples were oven dried at 60°C for three days, ground to a fine powder using a pestle and mortar, and used for sugar and starch analysis.

Sugar Analysis

Five hundred milligram units of the ground powder was transferred into test tubes containing 20 ml of 80% ethanol and incubated in a water bath for three h. The aqueous phase was carefully pipetted into clean test tubes, and the above process was performed four times. The 80% phases were bulked and evaporated to dryness under a vacuum and taken up in 10 ml of 80% ethanol and used for sugar analysis. The final residue was dried at room temperature and used for starch analysis.

Sugar analysis was done by pipetting 20 µl each of the bulked samples into clean vials followed by freeze-drying for one h. The vials were further dried in an oven at 80°C for five min. Forty microliters each of pyridine including (1 µg ml^{-1} 1,3,5-triphenyl benzene as an internal standard), hexamethyl-disilazane (HMDS) and trimethylchlorosilane (TMCS) were added to each of the vials. The vials were capped and placed in an oven at 60°C for 30 min before injecting 1 µl from each sample into a Shimadzu 8A gas chromatograph. The peaks obtained were used to determine the sugar content in the samples after comparing with peaks obtained from sugar standards.

Starch Analysis

Fifty milligrams each of the residues was mixed with 5 ml of distilled water and put into clean centrifuge tubes. The solution was briefly heated to ensure that the tissue was thoroughly wetted before cooling the samples to room temperature. Five milliliters of amyloglucosidase solution (0.012 g ml^{-1} amyloglucosidase in 20 ml sodium acetate buffer solution) was added to each tube before incubating in a shaking water bath at 40°C for 1 h.

The samples were transferred into a boiling water bath (100°C) for five min to stop the enzyme reaction. Aliquots (0.1 ml) of both samples and glucose standards were pipetted into clean test tubes containing 4.9 ml of anthrone reagent and placed in a boiling water bath for 15 min to accelerate color development. The samples were allowed to cool to room temperature, and the absorbance of each sample recorded on a spectrophotometer (Hitachi U-2001) at 620 nm. Starch content was computed from readings of glucose standards.

Results and Discussion

The shoot length of all the trees increased gradually up to the second week. For the control trees, it then increased rapidly up to the 3rd week before rising exponentially up to the 4th week (Figure 3). Shoot length was slightly higher

Figure 1. Photograph showing an electric ribbon heater (left) that was used to heat four of the partially ringed peach trunks (R + TH). Photograph on the right shows how the ribbon heater was fitted to heat a tree trunk.

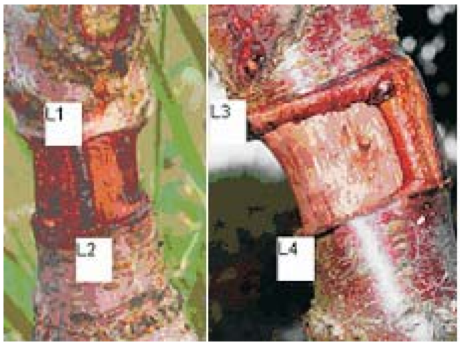

Figure 2. Photographs showing the locations from which bark samples were taken for sugar and starch analysis. Samples L1 and L2 were taken from the upper and lower parts of the strip that was left. Samples L3 and L4 were taken from the upper and lower parts of the ring, respectively, on the opposite side of the strip.

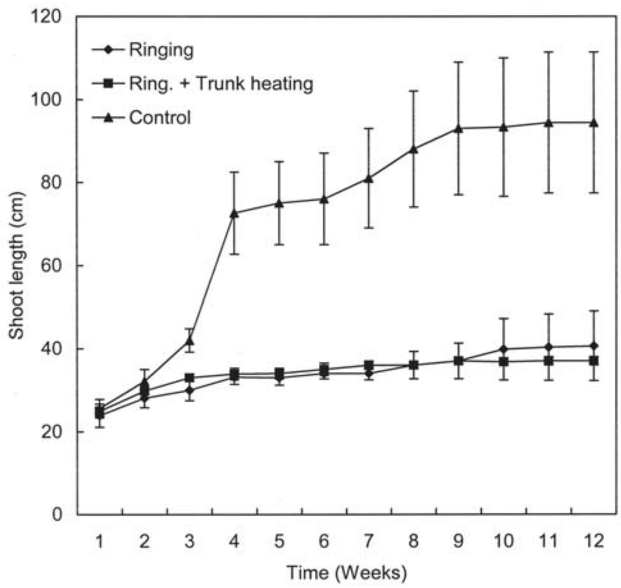

Figure 3. Effect of ringing and of ringing and trunk heating on the growth of peach. Vertical bars indicate SE (n=4).

in partial ringing than in the partial ringing and heating treatment. After the 9th week, shoot lengths in both treatments were generally the same but higher than the initial levels. This is indicative of young shoots being particularly active sinks. Since shoot growth was strongly suppressed by girdling and girdling plus trunk heating, assimilates must have been delivered to tissues engaged in rapid elongation.

The width of the bark that was left after ringing initially increased at the same rate for both the ringing and the ringing and trunk heating treatments for the first three weeks (Figure 4). Subsequently, the bark width in both treatments rapidly increased up to the 23rd week although the rate of increment was slightly higher in ringing plus trunk heating than in ringing alone. The increase in trunk circumference above the ring was greater for the trees subjected to partial ringing and trunk heating than for those subjected to ringing alone (Table 1). The increment in trunk circumference below the ring showed a similar trend but at a lower margin. Bark width growth and shoot length showed a positive correlation (Figures 5 and 6). By the end of the season, the bark had covered 40% of the tree circumference, suggesting that it might be more useful to maintain a constant bark width during the season.

Both treatments were effective in increasing the soluble solids content (Brix) of the fruits (Table 1). Brix was significantly higher in the fruit of trees subjected to partial ringing and trunk heating than in the fruit of control, showing that partial ringing has a positive effect on fruit quality. The treatments were also effective in reducing the acid content of the same fruit. The mechanism(s) inducing these fruit responses to treatment with girdling are unclear, but are likely related to decreased water content in the fruit flesh and/or changes in assimilate translocation. Peach consumers prefer fruit with high soluble solids content but low acidity. Our results thus promise to be beneficial in producing fruit of high market value.

Starch content in the bark was higher in samples taken from the upper part of the ring (L3) and the lower part of the connecting strip (L2) while the upper part of the strip (L1) and the lower part of the partial ring (L4) recorded similar amounts (Table 2). Starch content in trees subjected to partial ringing and trunk heating was highest in the upper part of the ring L3 and almost uniform in L1, L2 and L4 (Table 2). This showed that starch accumulation in L3 occurring after phloem transport was blocked by ringing. Starch content was uniform in control trees (Table 2), show-

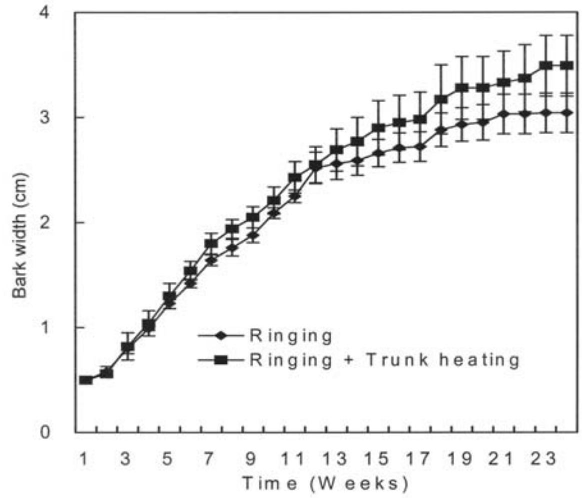

Figure 4. Bark width growth of peach after ringing and after ringing and trunk heating. Vertical bars indicate SE (n=4).

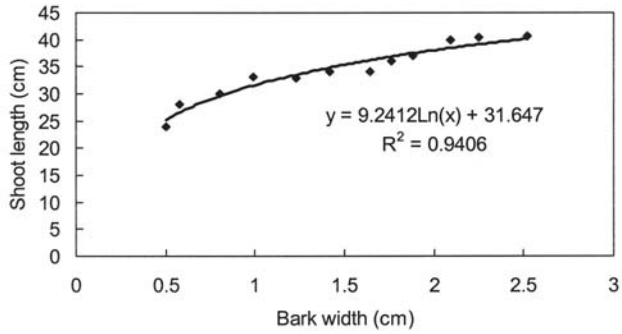

Figure 5. Relationship between bark width growth and shoot length in peach trees as influenced by partial ringing. Vertical bars indicate SE (n=4).

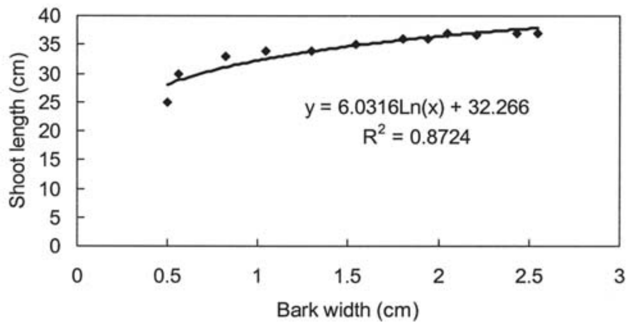

Figure 6. Relationship between bark width growth and shoot length in peach trees as influenced by partial ringing and trunk heating. Vertical bars indicate SE (n=4).

Table 1. Changes in trunk circumferences and fruit qualities of peach at harvest. Treatment trees were subjected to partial ringing leaving a 5 mm strip while others were ringed and their trunk heated with a ribbon heater (Ringing + TH).

Treatment	Initial circum. (cm)	Final circum. (cm)		A/B	Fruit weight (g)	Brix (%)	Titratable acidity (%)
		Above ring (A)	Below ring (B)				
Control	19.7±2.5[a]	22.7±1.7	22.7±3.3	1.00	130.7±10.7	10.8±0.3	0.30±0.03
Ringing	18.5±2.6	23.5±1.7	21.0±2.0	1.12	134.2±7.3	16.2±0.5	0.26±0.01
Ringing + TH	17.8±2.0	23.7±1.3	20.3±2.4	1.17	119.5±4.6	16.2±0.3	0.25±0.01

[a]Values are means ± SE (n=4).

Table 2. The starch content in the bark of ringed, ringed and trunk heated (TH) and control peach trees. Samples (L1) and (L2) were taken from the upper and lower parts of a 5 mm connecting strip that remained after partial ringing while samples L3 and L4 were taken from the upper and lower parts of the ring, respectively, away from the connecting strip.

Treatment	Starch content (%)				Ratio			
	L1	L2	L3	L4	L1/L2	L3/L4	L3/L1	L4/L2
Control	1.22±0.03[a]	1.21±0.06	1.22±0.12	1.22±0.10	1.00	1.00	1.00	1.01
Ringing	1.02±0.27	1.10±0.05	1.32±0.24	1.04±0.15	0.93	1.31	1.29	0.95
Ringing + TH	1.12±0.08	1.13±0.09	1.26±0.08	1.15±0.13	0.99	1.10	1.13	1.02

[a]Values are means ± SE (n=4).

Table 3. The sugar content in the bark of ringed (R), ringed and trunk heated (R + TH) and control (C) peach trees. Samples (L1) and (L2) were taken from the upper and lower parts of a 5 mm connecting strip that remained after partial ringing while samples L3 and L4 were taken from the upper and lower parts of the ring, respectively, away from the connecting strip.

Sugar	Treatment	Sugar content (%)				Ratio			
		L1	L2	L3	L4	L1/L2	L3/L4	L3/L1	L4/L2
Fructose	Control	0.48±0.03[a]	0.47±0.02	0.48±0.03	0.48±0.02	1.02	1.00	1.00	1.02
	Ringing	0.51±0.16	0.55±0.13	0.62±0.13	0.47±0.16	0.93	1.32	1.22	0.85
	Ringing + TH	0.50±0.09	0.49±0.06	0.48±0.11	0.48±0.09	1.02	1.55	0.96	0.98
Glucose	Control	0.48±0.03	0.48±0.02	0.48±0.03	0.49±0.02	1.00	0.98	1.00	1.02
	Ringing	0.50±0.16	0.51±0.12	0.48±0.15	0.42±0.08	0.98	1.14	0.96	0.82
	Ringing + TH	0.46±0.07	0.43±0.07	0.50±0.12	0.30±0.04	1.07	1.67	1.09	0.70
Sorbitol	Control	2.02±0.02	2.01±0.03	2.02±0.01	2.02±0.02	1.00	1.00	1.00	1.00
	Ringing	2.34±0.77	2.33±0.76	3.08±0.45	1.95±0.33	1.00	1.58	1.32	0.84
	Ringing + TH	2.40±0.21	2.39±0.13	2.83±0.40	1.48±0.14	1.00	1.91	1.18	0.62
Sucrose	Control	0.47±0.01	0.47±0.03	0.47±0.02	0.46±0.01	1.00	1.02	1.00	0.98
	Ringing	0.43±0.10	0.58±0.12	0.62±0.26	0.48±0.11	0.74	1.29	1.44	0.83
	Ringing + TH	0.45±0.11	0.49±0.05	0.62±0.06	0.42±0.03	0.92	1.48	1.38	0.86
Total	Control	3.53±0.12	3.50±0.02	3.63±0.18	3.60±0.04	1.01	1.01	1.03	1.03
	Ringing	3.77±1.18	3.97±1.09	4.65±0.97	3.47±0.65	0.95	1.34	1.23	0.87
	Ringing + TH	4.37±0.90	3.64±0.26	4.18±0.30	2.60±0.23	1.20	1.61	0.96	0.71

[a]Values are means ± SE (n=4).

ing that it was evenly distributed within the bark of peach trees. There was no significant difference between experimental and control trees in terms of fruit diameter (Figure 7), showing that ringing and trunk heating maintain the normal fruit size while improving fruit quality.

Total sugar amounts in L1 and L3 were similar in the trees subjected to partial ringing (Table 3). The total sugar content in L2 was lower while that in L4 was the lowest. This showed that sugar movement from the leaves was blocked by the ringing, causing accumulation in L3. Total sugar content in L1 and L2 for the trees that were ringed with their trunks heated was similar but lower than in L3 (Table 3) while L4 had the lowest amount. The amount in L3 was lower than in the same location in partially ringed plants. This implies that ringing might be more effective in blocking sugar movement. Total sugar amounts were uniform at all locations in the control plants (Table 3). This shows that sugar is equally distributed in the bark of peach.

The ratio L3/L4 was higher in the trees subjected to partial ringing and trunk heating than partial ringing alone, showing that the former treatment was more effective in

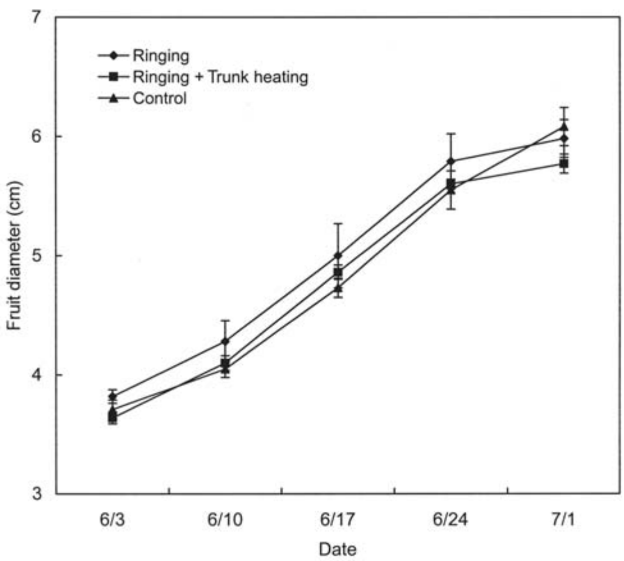

Figure 7. Fruit diameter of fruits on peach trees subjected to ringing and to ringing and trunk heating. Vertical bars indicate SE (n=4).

blocking the downward flow of photosynthates than the latter. In the case of the individual sugars, the ratio L3/L4 was highest in sorbitol, followed by glucose, fructose, and sucrose. This shows that sorbitol is the form of sugar mostly translocated from the leaves to roots in peach. Bieleski (1969) and Webb and Burley (1962) also noted that in the Rosaceae family, including peach, sorbitol is the principal photosynthate and translocating sugar. They might also imply that sorbitol is the form of sugar most adversely affected in a feedback mechanism due to carbohydrate accumulation.

The fresh matter growth of a fruit mainly depends on the balance between the input from the xylemic and phloemic flows and the fruit transpiration output. As the phloemic flow brings sugars, its flow, relative to the other flows, changes the dry matter content and the quality of the fruit (Huguet et al., 1998).

Girdling blocks the translocation of sucrose from leaves to the root zone through phloem bundles. The block causes a decrease in starch content in the root system (Schneider, 1954) and an accumulation of sucrose in the leaves (Plaut and Reinhold, 1967). Partial girdling however allowed the free flow of sucrose and starch along the 5 mm strip that was left, hence the similar amounts in L1 and L2 observed in Table 3. The blockage of flow is clearly demonstrated by the big difference in starch content between the L3 and L4.

In citrus, girdling caused a significant decrease in gibberellin level in the root system (Wallerstein et al., 1974), and since gibberellins are presumed to be synthesized partly in the roots (Kende and Sitton, 1967), the decrease may be attributed to the limited energy supply as a result of girdling. The reduced level of gibberellins may lower α-amylase activity and thus prevent the hydrolysis of starch.

In a girdling experiment with mango trees, all treatments showed lower vegetative growth in relation to control (Jose, 1997). In our experiment, the partially ringed and heated plants showed a significantly lower vegetative growth than control, but the partially ringed trees had a slightly higher overall vegetative growth than those partially ringed and heated. This seems to have affected fruit weight, which was higher in the ringed trees (Table 1). All the fruits however, were of good marketable weight.

With girdled apple trees, fruits had significantly higher soluble solids concentration and acidity, while fruit growth was not affected by treatments (Arakawa et al., 1997). In our study, fruits had significantly higher soluble solids content (Table 1) and fruit diameter (Figure 7) but a lower acidity.

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桃樹樹幹之局部環割及熱處理對枝條生長和桃子品質的影響

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小型桃樹（*Prunus persica* [L.] Batsch.）可供商用桃子生產者一直無法供應，其原因乃缺少適當之矮生砧木具廣範圍之品種接納性者。本文著眼於局部樹幹環割及熱處性對桃子生長、產量及品質的影響。在離地面 25 公分處把樹皮做 4 公分寬之環割去除，留下 0.5 公分之連接帶。更進者，在去皮處用電熱器 150°C 加熱 15 分鐘。局部環割處理有效地減少枝條之生長且改善桃子之品質。桃子之總水溶固型物含量比控制組高。但熱處理對局部環割很少加成效果。

關鍵詞：果汁固型物含量；矮化技術；局部環割；總糖量；樹幹加熱；澱粉含量。