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Partial ringing and liquid nitrogen effects on shoot growth and fruit quality of peach

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Abstract

Effect of partial ringing and liquid nitrogen application on the growth and fruit quality of peach was studied. Twelve five–year–old peach trees (*Prunus persica* [L.] Batsch.), cv. 'Hikawa Hakuho' grafted on wild peach rootstock were randomly selected for this experiment in April 2004. A 4 cm wide partial ring of bark was removed from eight of them at a height of 25 cm above the graft union leaving a 5 mm connecting strip. Four of the ringed trees were treated with liquid nitrogen at the ringed portions while the rest were intact trees as controls. Both partial ringing and partial ringing plus liquid nitrogen treatment led to reduced shoot length, fruit acidity, total shoot length and weight of pruned branches but increased soluble solids content. Liquid nitrogen had little additive effect on partial ringing in terms of these parameters. Both treatments had a similar effect on tree and fruit characteristics as evidenced by similar bark width recovery and fruit diameter. The use of partial ringing plus liquid nitrogen application in commercial peach orchards promises to be slightly more efficient in causing shoot length reduction while improving fruit quality.

Key words: Brix, dwarfing techniques, liquid nitrogen, partial ringing, total shoot length

Introduction

Fruit producers are always looking for ways to reduce farm operation costs while maintaining high fruit quality. The changing trends from agrochemical based production to green farming has made farmers to seek for practices that are less harmful to the environment and leave less or no chemical residue in fruit. Dwarf trees are easy to manage and early maturing. Dwarfing has been accomplished in other fruit trees like apples by using dwarfing rootstocks. The main 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 calls for the need to explore alternative dwarfing techniques. Partial ringing or an enhanced application of the technique is being proposed as a method that can be used to meet some of the current challenges in the fruit tree industry by reducing tree height.

Ringing severes phloem vascular vessels thereby preventing translocation of photosynthates from the source to sinks located below the girdle until the wound heals. Thus, ringing 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 (Krezdorn and Brown, 1970; Poll *et al.*, 1991). Ringing not only affects basipetal movement of assimilates (Schaper and Chacko, 1993) but also that of phytohormones (Cohen, 1981; Monselise, 1986).

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 in which 25 mm wide strips of bark and phloem were removed from opposing sides of the stem. Wheeler *et al.* (1985) working on Douglas fir compared partial – overlapping – band girdles to similar girdles applied with a pruning saw. They found both methods increased cone yield. Onguso *et al.* (2004) reported that partial ringing and partial ringing plus trunk heating had led to a reduction in shoot length while improving fruit quality.

Ringing imposes several effects on the plant, including direct injury and as such it elicits several responses (Cohen, 1981). Partial ringing and partial ringing plus liquid nitrogen application experiments were carried out to study their possible contribution to dwarfing in peach trees. Iwahori *et al.* (1976) in their work on improvement of fruit quality in ponkan reported earlier fruit colour and soluble solid enhancement from xylem ringing compared to phloem ringing. It is postulated that increase in total soluble solids from girdling or related effects occurs in treatments, which also reduce water movement considerably such as xylem ringing (Iwahori *et al.*, 1990) and trunk strangulation (Yamanishi, *et al.*, 1993; Yamanishi, *et al.*, 1995). Therefore, we treated ringed trees with liquid nitrogen to investigate its effect on xylem transport. Application of liquid nitrogen was to effectively kill the regenerative cambium that manufactures new phloem tissues to try and bridge the wound (Nix, 2005). The burning effect of liquid nitrogen would possibly extend to the xylem below and affect water and mineral salts transport hence exerting an effect on the sinks above the ring.

Although stem girdling has received substantial attention, there is limited literature on the combination of partial girdling and liquid nitrogen application on shoot growth and fruit quality. In the present study, the interaction of bark width and shoot growth in peach has been investigated.

Materials and methods

The experiment was conducted at the Ehime University Experimental Farm located in southern Japan, 33^{o}57’ N, 132^{o} 47’ E at an elevation of about 20 m above sea level. Twelve five–year–old peach trees (*Prunus persica* [L.] Batsch.), cv. 'Hikawa Hakuho' grafted on wild form rootstocks were used for this study starting from April 2004. A 4 cm wide partial ring of bark was removed from eight of them at a height of 25 cm above the graft union to leave a 5 mm connecting strip. Four of the ringed trees were treated with liquid nitrogen at the ringed portions using a pair of forceps and cotton wool while the rest were controls. The tree form was central leader and trees were spaced at 3 x 2.5 m in a complete randomised design. Routine cultural practices were carried out as required. The growth of the trees was monitored weekly by measuring shoot length of ten terminal shoots, and diameter of ten fruits from each tree. The growth of the 5 mm bark that was left after ringing was also monitored weekly using vernier calipers.

At harvesting, final fruit diameter, fruit number and weight were recorded. Juice was extracted from ten fruits per tree and titratable acidity was 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). These were repeated at harvesting time of the following year (2005). In February 2005 the percentage of flower buds, total shoot length and weight of pruned branches were also taken.

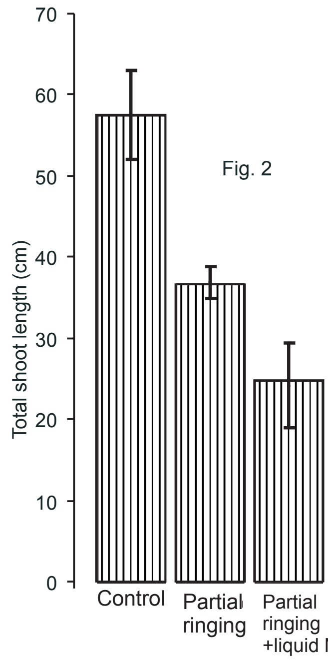
Results and discussion

The shoots of trees subjected to partial ringing plus liquid nitrogen recorded the shortest lengths (Fig. 1). They were followed by those subjected to partial ringing alone while the control had the highest shoot length throughout the study period.

The total shoot length was greatly reduced in the trees subjected to partial ringing plus liquid nitrogen (Fig. 2). Those subjected to partial ringing alone had a reduced shoot length too but to a lesser degree. This shows the cumulative effect of partial ringing and partial ringing plus liquid nitrogen on tree growth.

The weight of pruned branches from the trees subjected to partial ringing plus liquid nitrogen was greatly reduced compared to those where partial ringing alone was done and the controls (Fig. 3). This shows that application of partial ringing plus liquid nitrogen can decrease labor costs incurred for pruning and thinning.

Bark recovery steadily increased in the trees subjected to both partial ringing and partial ringing plus liquid nitrogen though it was slightly higher in partial ringing plus liquid nitrogen (Fig. 4). There was a positive correlation between shoot length and bark growth for both partial ringing and partial ringing plus liquid nitrogen (Fig. 5). This implies that an increase in bark healing



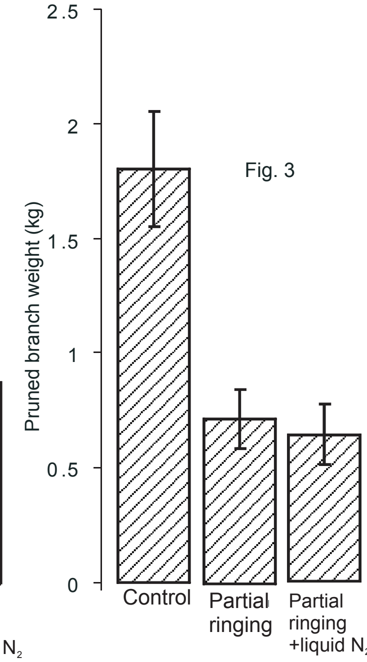


Fig. 2. The total shoot length of peach trees subjected to partial ringing and partial ringing plus liquid nitrogen application. Vertical bars represent SE.

Fig. 3. The weight of branches pruned from peach trees subjected to partial ringing and partial ringing plus liquid nitrogen application. Vertical bars represent SE.

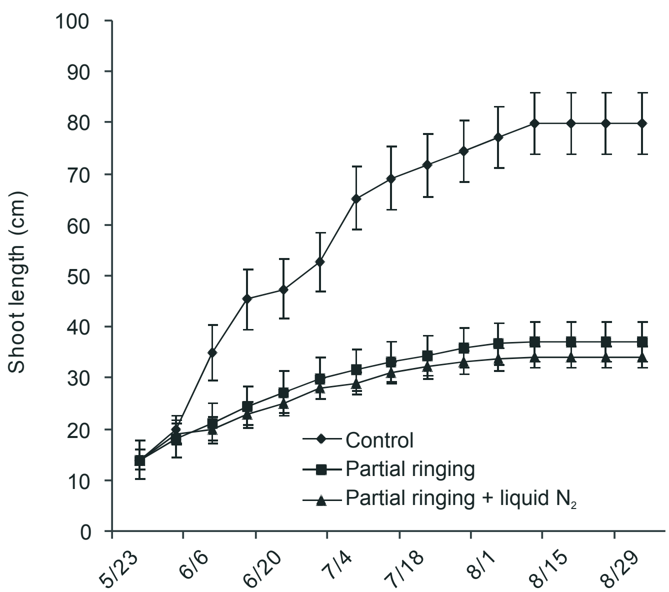


Fig. 1. The shoot length of peach trees as influenced by partial ringing and partial ringing plus liquid nitrogen application. Vertical bars represent SE.

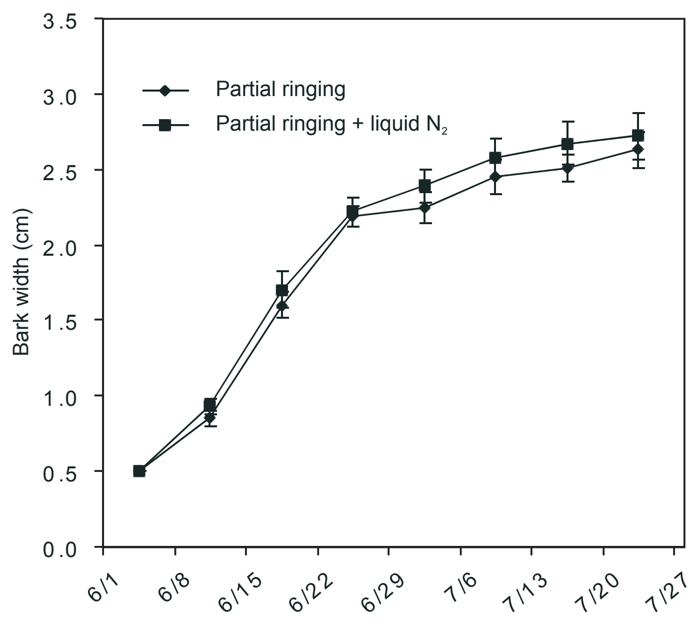


Fig. 4. The bark width of peach trees as influenced by partial ringing and partial ringing plus liquid nitrogen application. Vertical bars represent SE.

Table 1. Fruit quality at harvest in peach trees as affected by partial ringing and partial ringing plus liquid nitrogen application (2004)

Treatment	Fruit weight (g)	Fruit number/tree	Brix (%)	Acid content (%)
Control	181.6±15.5	9.1±1.6	9.46±0.13	0.35±0.08
Partial ringing	203.6± 9.2	9.3±2.1	12.25±0.27	0.26±0.03
Partial ringing +liquid nitrogen	186.6±13.9	9.3±1.4	12.63±0.25	0.29±0.02

Table 2. Fruit quality at harvest in peach trees in the following year as affected by partial ringing and partial ringing plus liquid nitrogen (2005)

Treatment	Fruit weight (g)	Fruit number/tree	Brix (%)	Acid content (%)
Control	197.0± 6.1	12.0±0.8	14.11±0.45	0.37±0.06
Partial ringing	210.8±13.2	14.0±2.4	14.23±0.58	0.26±0.01
Partial ringing +liquid nitrogen	213.2±11.1	14.3±4.3	14.29±0.18	0.24±0.01

Values are means ± standard error (n=4).

contributed to increased shoot length. Increased bark width leads to higher translocation of photosynthates as well as water and mineral salts thus leading to increased shoot length.

Fruit diameter showed a similar growth pattern for all the experimental trees (Fig. 6). This shows that both treatments maintained the normal fruit growth characteristics thus helping to assure acceptable consumer quality.

The fruit weight from ringed trees was slightly higher than that

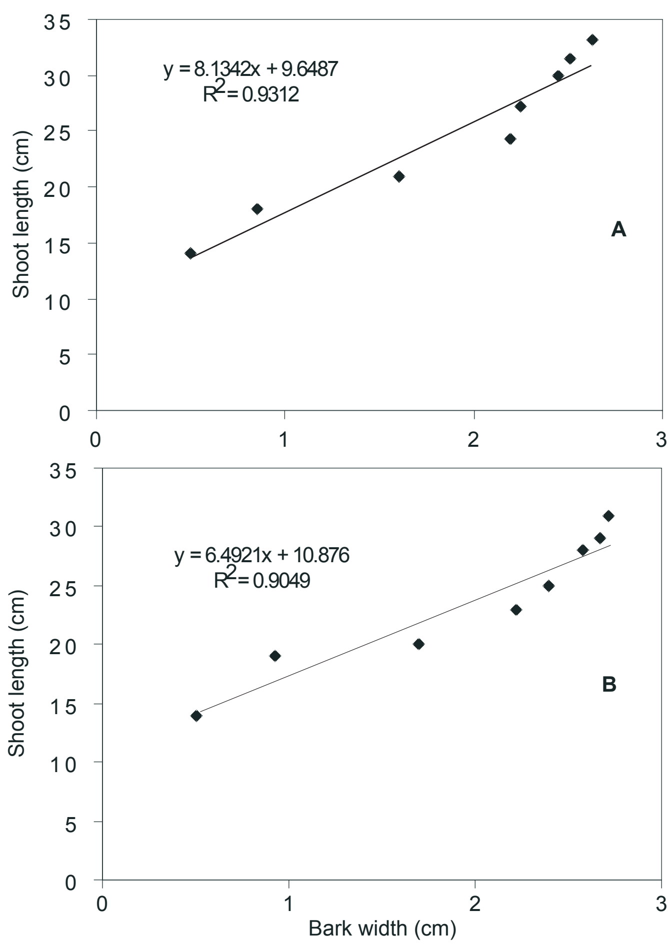


Fig. 5. The correlation between bark width regrowth and shoot length in peach trees subjected to partial ringing (A) and partial ringing plus liquid nitrogen application (B).

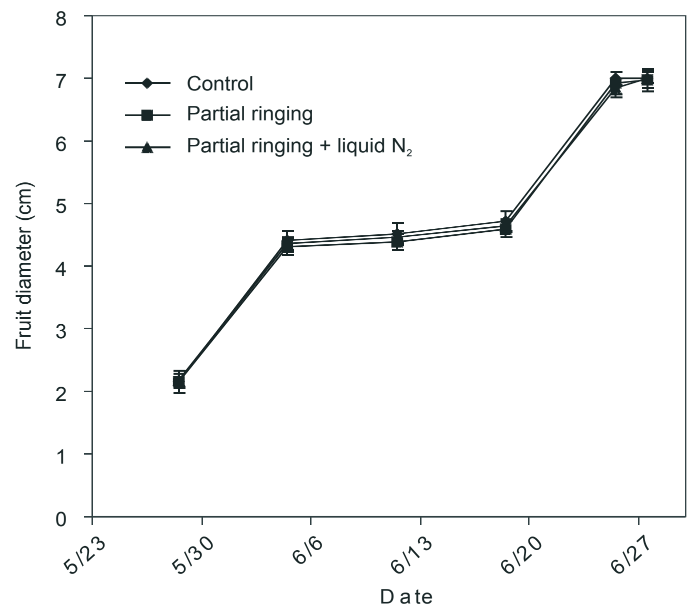


Fig. 6. The fruit diameter of peach trees as influenced by partial ringing and partial ringing plus liquid nitrogen application. Vertical bars represent SE.

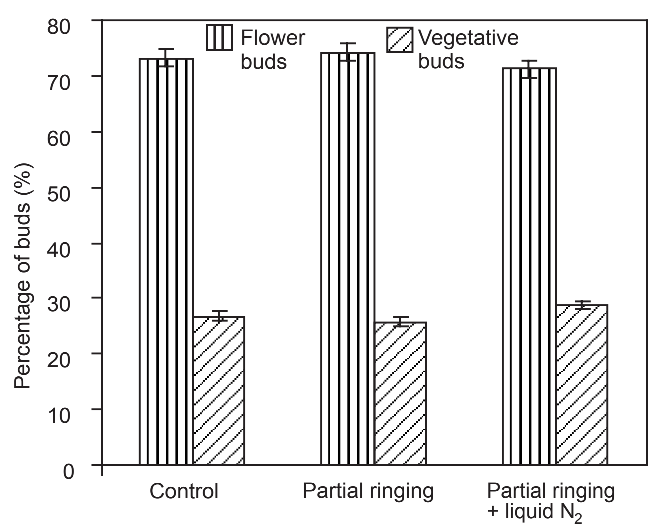


Fig. 7. The percentage of flower and vegetative buds in peach trees the following year as influenced by partial ringing and partial ringing plus liquid nitrogen. Vertical bars represent standard error.

from partial ringing plus liquid nitrogen and from control ones which had similar values in the first year (Table 1). This implies that ringing alone might be effective in improving fruit weight. In the following year, the fruit weight was generally lower in all the trees than was the case in the previous year (Table 2). This might be attributed to the prolonged drought that hit the area during the year. The partially ringed trees were more seriously affected than the partially ringed plus liquid nitrogen application and the control ones. Fruit number per tree was slightly enhanced by the treatment as all the treated trees recorded higher values than the controls in the first year (Table 1). In the following year, the same trend prevailed though the fruit number per tree was much higher with partial ringing plus liquid nitrogen application showing the highest improvement (Table 2).

The yield per tree was slightly improved by partial ringing plus liquid nitrogen compared to partial ringing alone in the first year (data not shown). In the following year, the same trend was maintained though the overall yield drastically reduced due to the drought (data not shown). Partial ringing plus liquid nitrogen application still led to highest yield. Stem girdling is known to improve fruit yield and quality (Iwahori *et al.*, 1990; Cohen, 1981; Monselise, 1986; Krajewski and Rabe, 1995; Yamanishi *et al.*, 1993; Yamanishi *et al.*,1995). 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 (Krezdorn and Brown, 1970; Poll *et al.*, 1991). The 5 mm connecting strip that was left in our treatments however, allowed some photosynthates to move to the sink below the ring hence resulting in only a slight increase in yield.

Partial ringing plus liquid nitrogen caused an increase in soluble solids content (SSC) as compared to partial ringing alone in the first year (Table 1) implying that partial ringing plus liquid nitrogen had some additive effect. The control showed a lower SSC than both partial ringing and partial ringing plus liquid nitrogen. In the following year, overall SSC was higher in all the trees with the treated trees recording better values than the control (Table 2). Fujishima *et al.* (2005) reported that girdling of 'Pione' grapevine led to a significant increase in SSC, coloring and anthocyanin content. Iwahori *et al.* (1976) in their work on improvement of fruit quality in ponkan reported early fruit colour development and soluble solid enhancement from xylem ringing compared to phloem ringing. It is postulated that increase in total soluble solids from ringing or related effects occurs in treatments which also reduce water movement in the xylem.

Both partial ringing and partial ringing plus liquid nitrogen led to reduced acidity (Table 1) though partial ringing alone caused a higher reduction in the first year. This might be due to bark width recovery as well as the diminishing effect of liquid nitrogen applied with time. The values were almost similar for the treated trees but the acid content in the fruit from the control trees slightly increased in the second year (Table 2).

There was a slight improvement in the percentage of flower buds in partially ringed trees due to the treatment (Fig. 7). The trees subjected to partial ringing plus liquid nitrogen had a slight increment in vegetative buds. This was in agreement with Arakawa *et al.* (1997) who stated that flowering in apple trees was significantly increased by girdling. Mataa *et al.* (1998) also reported a slight increment in flower number in ponkan mandarin due to ringing.

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 partial flow of sucrose and starch along the 5 mm strip that was left. Onguso *et al.* (2004) reported that partial ringing plus trunk heating had little additive effects on shoot length and fruit quality of peach compared to partial ringing alone.

Our results demonstrate that it is possible to control total shoot length by combining partial ringing and liquid nitrogen application. Further, there is the added improvement of fruit quality in terms of increased Brix and reduced acidity.

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