Effect of Trunk Strangulation Degrees in Late Season on Return Bloom, Fruit Quality and Yield of Pummelo Trees Grown in a Plastic House

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Summary

Seven-year-old 'Tosa Buntan' pummelo (Citrus grandis (L.) Osbeck) trees on trifoliate orange rootstocks grown in a plastic house were used in this study. The trunks were strangulated using 1.6, 2.0 or 2.6 mm steel wires at a depth of wire diameter in mid-November 1991. The wire was removed 3 months later. The enlargement of the trunk girth in the treated trees, especially in the 2.6 mm treatment, was smaller than that in the control. Specific leaf weight (SLW) of the previous year’s leaves increased by treatment with 1.6 and 2.0 mm wires, but it occurred later in 2.6 mm treatment. Net photosynthetic rates (Pn) of the leaves, especially in the 2.6 mm treatment, decreased on treated trees. The numbers of inflorescences and flower buds on treated trees were much larger but shoot growth was reduced compared to control trees in 1992. Conversely, treated trees produced fewer flowers in 1993. The percentage of fruit set on treated trees ranged from 2.4 to 3.1% in 1992; no significant difference was noted among treatments. Fruits, harvested in February 1993, from the treated trees weighted less, had thinner peel, and higher contents of sucrose and citric acid in the juice than those in the control trees, but the yield and the number of fruits at harvest were, respectively, 1.4 to 1.6 times and 1.6 to 2.3 times larger in the treated trees than those obtained from control trees. The 2.6 mm treatment resulted in significant reduction in yield in 1994, whereas, the other treatments yielded as well as the control trees, the percent return bloom was significantly reduced. The wire sizes of 1.6 mm and 2.0 mm in diameter were suitable to strangulate the trunks of 7-year-old 'Tosa Buntan' pummelo trees.

Introduction

A fruit tree under mechanical stress condition, such as girdling and strangulation, is exposed to adverse effects (Cohen, 1981; Yamanishi and Nakajima, 1992; Yamanishi et al., 1994). Westwood (1978) stated that stone fruit trees should not be girdled because they do not heal well. The ability of girdles to heal is not only species dependent (Noel, 1970) but also cultivar dependent (Fernandez-Escobar et al., 1987). The 'Tosa Buntan' pummelo tree seems to be a rapidly healing cultivar among citrus varieties as evidenced by a wire ring being covered with bark callus a few months after treatment (Nakajima et al., 1992; Yamanishi et al., 1993b). Excessive trunk strangulation during the summer stunted the growth of 2-year-old pummelo trees (Yamanishi and Nakajima, 1992). Strangulating the trunks from August to November in young, actively growing non-bearing pummelo trees resulted in defoliation and production of abnormal flower buds (Nakajima et al., 1992; Yamanishi et al., 1994). However, strangulation during dormant period promoted flower bud formation (Yamanishi et al., 1993a,c; Yamanishi, 1995b) and improved fruit quality (Yamanishi et al., 1993a; Yamanishi, 1995a) without withering the tree. Consequently, the degree of strangulation should be changed according to the
tree age, tree status (bearing or non bearing), time and length of treatment. We (Nakajima et al., 1989; Nakajima and Yamanishi, 1992; Yamanishi et al., 1993a,b,c; Yamanishi, 1994) observed that a 1.6 mm diameter wire seemed to be suitable for young pummelo trees, but a suitable wire size for adult trees needs to be ascertained. Positive effects of late season trunk strangulation on fruit quality and return bloom have been reported for 4-year-old pummelo trees (Yamanishi et al., 1993a), i.e., when ≈82% of the 1.6 mm diameter wire incised into the trunk bark (≈15 cm in circ. 5 ~ 10 cm above the graft union) by pulling the wire at tension of 70 Kgf.cm with the torque wrench. In spite of the positive effect, the use of torque wrench was impractical and not recommendable for commercial use. The results gave us an insight into how deep the wire should incise into the trunk bark to be effective. Therefore, this study was carried out (1) to search for a simpler and handier method to bind the trunk with a wire to a desired degree, (2) to evaluate the wire size (1.6, 2.0 or 2.6 mm diam.), and (3) to ascertain the depth of incision which would promote flowering and fruiting in 7-year-old pummelo trees grown in a plastic house.

Materials and Methods

Seven-year-old 'Tosa Buntan' pummelo (Citrus grandis (L.) Osbeck) trees grafted on trifoliate orange (Poncirus trifoliata Raf.) rootstock grown in a plastic house (PH) were used for this study. The maximum day and minimum night temperatures in the PH were 25 °C and 5 °C, respectively, during winter. On 14 November 1991, the trunks, 5~10 cm above the graft union, were strangulated with a 1.6, 2.0 or 2.6 mm diameter steel wire, to its depth diameter and the ends fastened. The wire rings were removed 3 months later.

Sixteen trees with similar vigor and crop size (bearing less than 20 fruits per tree) were used with 4 replicates for each treatment including the control. Three secondary scaffold branches on each tree were labeled and the number of leaves and nodes of previous year's shoots (the first flush growth in the previous season) were recorded in 1992 and 1993. After harvest, the trees were pruned and treated with a compound fertilizer equivalent to 50 g N, 50 g P2O5 and 50 g K2O per tree. Fertilizer application was repeated 6 months later.

Trunk circumference 5 ~ 10 cm above the wire girdle was measured at 2- to 3-month intervals. Total shoot lengths of the first and second flush growths were measured on 28 April and 10 June 1992, respectively, on all new shoots on each labeled branch. Floral shoots were classified as leafless or leafy inflorescences, and the numbers of flower buds and open flowers in each inflorescence determined. The inflorescences and flower buds per branch were counted on 10 March 1992 and 12 March 1993, before anthesis, and subsequently at 4-day intervals in 1992. Pots (12) of 'Hyuganatsu' (Citrus tamurana Hort.) and a beehive were placed inside the PH for pollination in 1992. However, in 1993, the 'Tosa Buntan' flowers were open-pollinated. The flowers and fruitlets were counted 5 times at 10-day intervals after 50% of the flowers had opened to follow the course of fruit set. After "June" drop, fruits were not thinned. Shoots of the second and subsequent flush growths were pruned after the leaves had fully expanded.

Net photosynthetic rates (Pn) on 5 previous year's leaves from vegetative shoots were measured, using a portable porometer (Model KIP-8510, Koito Co.) 4 times at 1- and 2-month intervals beginning in mid-November; the leaf area was measured using an automatic leaf area meter (Model AAM-8, Hayashi Electric Co.). The dry weights of the leaves were then determined.

Fruits were harvested on 14 January 1992, 10 February 1993, and 12 January 1994 and the total number of fruits and yield quantified. Fruit quality analysis was determined in the fruits harvested on 10 February 1993. Sugar and organic acid contents in the filtered MeOH extract of juice from 3 medium sized fruits from each tree were determined using a high performance liquid chromatograph (Shimadzu HPLC LC-4A) (see Yamanishi, 1995a). Relative peel thickness was calculated by dividing the sum of peel thickness at both sides of an equatorial section by the transverse diameter of the fruit.

Results

The girdle on the trunks callused over after late August but hardly increased in depth until the wires were removed in mid-February. The trunk circumference, 5 ~ 10 cm above the wire girdle, especially in 2.6 mm treatment, grew less than
that of the controls (Fig. 1).

Compared with the control leaves (100%), the Pn of the previous year's leaves in the strangulated trees was 24.3% in 2.6 mm and about 54% in 1.6 and 2.0 mm on 13 December 1991; Pn were 35.8% in 2.6 mm and about 65% in 1.6 and 2.0 mm of the control on 15 January 1992 (Fig. 2).

The SLW for samples taken from strangulated trees between 14 November to 14 February was about 11.6% heavier than samples taken from the control trees, except for the 2.6 mm treatment (Fig. 3); the increase in the 2.6 mm treatment occurred one month later but finally the SLW attained almost the same level as the other 10% heavier than the control leaves.

The number and length of the bearing shoots on the treated trees were greater than those on the control in the first flush growth, in contrast to those of the vegetative shoots (Table 1). A similar trend was observed in the second flush growth. The numbers of inflorescences and flower buds were 2.0 to 2.7 times larger in the treated trees than they were in the control trees in 1992; the counts were significantly greater in the 2.6 mm treatment compared to other treatments (Table 2). The number of flower buds increased as the wire diameter was thicker in 1992. Conversely, their number decreased drastically in the treated trees, especially in the 2.6 mm treatment, in 1993; whereas their numbers in the control trees were almost constant for the two years. The number of the previous year's leaves which persisted on the trees was fewer in the 2.6 mm treatment than that in the other trees in 1992 and 1993 (Table 2).

On the treated trees, the flowers bloomed in early February about a week ahead of the control trees. Anthesis lasted from 13 March to 25 April in the treated trees, whereas it began about 10 days later in the control trees (Fig. 4). The peaks of open flowers on the treated trees, except for 1.6 mm treatment, occurred earlier and was less sharp than those of control trees.

The percentage of fruit set 50 days after anthesis ranged from 2.4 to 3.1% within a treatment;
Effect of trunk strangulation degrees in late season on shoot growth of pummelo trees grown in a plastic house.

<table>
<thead>
<tr>
<th>Wire diameter</th>
<th>Shoot number/100 node</th>
<th>Average shoot length (cm)</th>
<th>Total shoot length/100 node (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>First flush</td>
<td>Second flush</td>
<td>First flush</td>
</tr>
<tr>
<td></td>
<td>Floral</td>
<td>Vegetative</td>
<td>Total</td>
</tr>
<tr>
<td>Control</td>
<td>4.1b</td>
<td>16.2a</td>
<td>20.3a</td>
</tr>
<tr>
<td>1.6 mm</td>
<td>12.0a</td>
<td>5.7b</td>
<td>17.7ab</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>17.7a</td>
<td>11.4b</td>
<td>17.4ab</td>
</tr>
<tr>
<td>2.6 mm</td>
<td>10.1a</td>
<td>3.7b</td>
<td>13.7b</td>
</tr>
</tbody>
</table>

* Nodes of previous year’s shoots on three secondary scaffold branches.

† Investigated on 28 April 1992.

‡ Investigated on 10 June 1992.

§ Mean values within a column followed by the same letter are not significantly different (p = 0.05, Duncan’s multiple range test).

Effect of trunk strangulation degrees in late season on the numbers of inflorescences, flower buds, and leaves on pummelo trees grown in a plastic house.

<table>
<thead>
<tr>
<th>Wire diameter</th>
<th>Inflorescence number/100 node</th>
<th>Flower bud number/100 node</th>
<th>Leaf number 100 node</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Leafless</td>
<td>Leafy</td>
<td>Total</td>
</tr>
<tr>
<td>Control</td>
<td>8.1b</td>
<td>4.6b</td>
<td>12.7c</td>
</tr>
<tr>
<td>1.6 mm</td>
<td>13.3b</td>
<td>11.7a</td>
<td>25.0b</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>14.5b</td>
<td>11.7a</td>
<td>26.2b</td>
</tr>
<tr>
<td>2.6 mm</td>
<td>32.1a</td>
<td>9.7a</td>
<td>41.8a</td>
</tr>
</tbody>
</table>

† Nodes of previous year’s shoots on three secondary scaffold branches.

‡ Leaves remaining on the previous year’s shoots.

§ Mean values within a column followed by the same letter are not significantly different (p = 0.05, Duncan’s multiple range test).

Fig. 4. Flower opening period of pummelo trees as influenced by trunk strangulation degrees in late season.

No significant difference was noted among treatments (Fig. 5). The majority of flowers and fruitlets abscised within 30 days from anthesis. The percentages of sunny daylight hours during anthesis were 57 in March and 75.8 in April, 1992.

Fruits harvested in mid-February, 1993, from the treated trees were lighter and had thinner peel than those in the control trees (Table 3); they also had higher sucrose and citric acid contents than did those from the control trees (Table 4). A similar trend, except for 1.6 mm treatment, occurred with respect to fructose and glucose contents in the juice.
Yield was 1.4 to 1.6 times larger on the treated trees than that on the control trees in 1993 (Table 5). The higher the degree of strangulation, the larger was the yield but the fruits were smaller in 1993. However, in 1994, the yield in the 2.6 mm treatment dropped drastically to only 9.2% of the previous year; while it was halved in other treatments. Total yield from 3 consecutive years was the highest in the 2.0 mm treatment and the lowest in the 2.6 mm, but no significant difference was noted between treated trees and the control.

Discussion

The stage of the experimental trees corresponded to an "on" year in 1992, as all the trees used were bearing less than 20 fruits per tree in the previous year. Therefore, all strangulation degrees applied to the trunks of a vigorous pummelo tree from late autumn significantly increased the number of flower buds in 1992. This increase was chiefly due to an increase in the number of leafless inflorescences and flower buds as observed previously (Yamanishi et al., 1993c; Yamanishi, 1995b). However, the 3-month strangulation treatment during the dormant (fruit maturation) period was detrimental on flowering in the second season, especially in the 2.6 mm treatment in which only a few flower differentiated, just as young pummelo trees did in the previous experiment (Yamanishi et al., 1993c). Moreover, the relatively heavy loads on the treated trees in 1993 resulted in a significantly lower percent return bloom and, therefore, yields in 1994. Likewise, trees of 1.6 and 2.0 mm treatments yielded as well as the control trees in 1993, but significantly less differentiated flowers compared to the control one in 1994.

Strangulation applied in mid-November had no effect on the percentage fruit set in the first year because of an increased number of differentiated flowers which affected the number of setting fruits (Yamanishi et al., 1993) as observed in the present study in 1992. The low percentage in fruit set observed in the control trees in 1992 may be attributed to the large amount of leafless flowers that dropped because of the unfavorable weather and lack of pollination during anthesis. Similar factors may account for the 73% drop of leafless flowers in the control trees in 1993. Susanto and Nakajima (1990) reported that leafless flowers do not contribute to fruit set on open-pollinated pummelo trees. The excessive drop is attributed to the lack of open-pollination because leafless flowers are usually located in the interior of the canopy. Furthermore, pollinated flowers often influence the drop of non-pollinated ones by being stronger competitors for nutrients; and they produce more growth hormones during their initial growth.

In the present study, the low fruit set in the control trees in 1992 obviated the need for thinning after "June" drop. Thus, to make conditions comparable, the treated trees were, likewise, left unthinned. Shoot elongation was more extensive in control trees than it was in the treated ones in 1992, resulting in a higher leaf to fruit ratio (L/F).
Table 4. Effect of trunk strangulation degrees in late season on sugar and acid contents in juice of 'Tosa Buntan' pummelo fruits harvested on 10 February 1993.

<table>
<thead>
<tr>
<th>Wire diameter</th>
<th>Sugar content* (%)</th>
<th>Acid content* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sucrose</td>
<td>Glucose</td>
</tr>
<tr>
<td>Control</td>
<td>5.82c</td>
<td>1.65b</td>
</tr>
<tr>
<td>1.6 mm</td>
<td>6.54b</td>
<td>1.93ab</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>6.52b</td>
<td>2.26a</td>
</tr>
<tr>
<td>2.6 mm</td>
<td>7.53a</td>
<td>2.22a</td>
</tr>
</tbody>
</table>

* Determined using HPLC.

A Wakosil 5 NH2 packed column (4.6 mm i. d. × 25 cm) for sugar analysis; A Cosmosil 5 C18 packed column (4.6 mm i. d. × 25 cm) for acid analysis.

Values are the means of 12 fruits.

Table 5. Effect of trunk strangulation degrees in late season on yield of 7-year-old 'Tosa Buntan' pummelo trees grown in a plastic house.

<table>
<thead>
<tr>
<th>Wire diameter</th>
<th>Fruit number</th>
<th>Fruit weight (g)</th>
<th>Yield (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>9.8a</td>
<td>52.3c</td>
<td>60.3a</td>
</tr>
<tr>
<td>1.6 mm</td>
<td>9.8a</td>
<td>85.5b</td>
<td>44.8a</td>
</tr>
<tr>
<td>2.0 mm</td>
<td>9.3a</td>
<td>106.0a</td>
<td>52.8a</td>
</tr>
<tr>
<td>2.6 mm</td>
<td>9.5a</td>
<td>119.5a</td>
<td>7.8b</td>
</tr>
</tbody>
</table>


x Harvested on 12 January 1994, 26-month after strangulation treatment.

w Mean values within a column followed by the same letter are not significantly different (p = 0.05, Duncan's multiple range test).

in the former than in the latter. In spite of this lower L/F ratio, the yields from the treated trees were greater in 1993. Accordingly, trees like of the 2.6 mm treatment that differentiated as many as 2.5 flower per node in 1992 should be flower or fruit thinned to adjust the L/F for a stable crop. However, this ratio might be lower in strangulated trees because they accumulate assimilates above the girdle. As evidence, the fruit number in the 2.0 mm treatment was double that of the control, but the corresponding decrease in fruit weight of the former was not drastic compared to fruit weight of the latter. Dann et al. (1984) stated that girdled peach limbs supported normal-sized crops although the L/F was halved. An inverse relationship between fruit number per tree and fruit size is well-established in citrus (Fishler et al., 1983).

Leaves are the principal source of carbohydrates for dry matter production by plants. The distribution of dry matter in higher plants depends primarily on the phloem as a transport pathway for assimilates (Priestley, 1976). This pathway may be interrupted depending how deep the wire cut into the bark tissue. Thus, a change in the normal pattern of distribution inevitably occurs. In the present study, leaf dry weight per unit area increased by strangulating the trunk bark with wire sizes of 1.6, 2.0, and 2.6 mm in diameter. This change in assimilate partitioning may imply adjustment by the whole tree to changes in demands and supplies made upon it; for example, the photosynthetic activity of leaves on strangulated branches was significantly decreased. It may be that the rate of photosynthesis exceeds the demand for photosynthates so that pummelo trees,
like other species (Azcon-Bieto, 1983; Herold, 1980; Neales and Incoll, 1968), adjust their photosynthetic output by feedback inhibition.

Dann et al. (1984) stated that a diminished substrate supply appears to be a factor in determining the effects of girdling when growing organs compete strongly for assimilates. Our data support this idea because we found that strangulation suppressed the growth of trunks most severely when other competing sinks, flowers, and fruits were growing rapidly.

That changes in assimilate partitioning attributed to strangulation or girdling positively affect flowering, fruiting, and fruit quality are unquestionable. Because flower initiation and fruit growth involve phytohormones, indirectly or directly, they are influenced by strangulation. But it is not clear how they interact to control growth. No hormonal determinations were made in this study, but it is conceivable that strangulation modified their synthesis and distribution in the whole tree. Many researchers (Cutting and Lyne, 1993; Goren et al., 1971; Skene, 1972; Wallerstein et al., 1973) showed that preventing phloem transport affected endogenous hormone levels. Lower cytokinins levels have been found in the xylem sap of girdled grape vines (Skene, 1972) and peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993). Girdling also reduced gibberellic acid (GA) levels above a girdled shoot in peach (Cutting and Lyne, 1993).

Moreover, a strong linear relationship exists between the growth rate of the roots and the vegetative top of a pummelo tree, because the ratio of top to root on dry weight basis was unaffected by strangulation (Yamanishi et al., 1993b), the growths of root and shoot are postulated to be governed by some feedback signals between them (Wareing, 1978). Therefore, the root system would receive little or no photosynthates from the shoots in proportion to the wire tension applied to the trunk.

Indirect effect of strangulation, such as reduced photosynthetic availability to the roots, depends upon the degree applied in the trunk bark, which when prolonged, can cause root starvation. In this study, we tried to avoid such a side effect by applying the treatment during the inactive or dormant season. Schneider (1954) showed that the roots of citrus trees become rapidly depleted of carbohydrates following trunk girdling in the middle of the growing season; the depletion was slowest when the treatment was done at the end of the growing season.

Likewise, the detrimental direct effect of strangulation on tree growth can occur if the wire tension on trunks of 2-year-old pummelo trees exceed 50 Kg/cm during the active growth season (Yamanishi and Nakajima, 1992). The cutting into the bark tissues, constricts the outer part of the wood that may cause a partial xylem dysfunction, death, or stunted growth. However, strangulation did not interrupt the flow of the xylem in which compounds are transported from the root to the top (Schneider, 1968) when the trunks of 2-year-old pummelo trees were strangulated with wire at a tension of 30 or 40 Kg/cm degree in mid-December (Yamanishi et al., 1993b). In the present study, a 2.6 mm in diameter wire seemed to be excessive because, it apparently injured the outer part of trunk wood, and may have hindered the upward transport causing leaf abscission; but insignificant to endanger tree health. On the other hand, strangulated trees with wire sizes of 1.6 and 2.0 mm in diameter did not show any significant apparent side-effect. All girdles were completely healed after late August and all the treated trees regained their original vigor in the following year. It is likely that adult pummelo trees retain enough reserve to sustain the trees until the girdles heal. We emphasize that only trees supported by a considerable pool of photosynthetic reserves should be trunk strangulated.

The degree of strangulation may not only damage the xylelary cell, it may also change the pattern of xylogenesis. Cambial activity and cytodifferentiation that are components of xylogenesis seem to be under hormonal, primarily auxin, control (Aloni and Zimmermann, 1983; Savidge, 1990). Noel (1970) stated that auxin accumulation
above and depletion below the girdle occur until the cambium and phloem functions are restored. A basic knowledge regarding the direct and indirect effects on tree growth is essential to determine the limit of strangulating pummelo trees.

We found that strangulating pummelo trees in late autumn using wires of 1.6, 2.0, and 2.6 mm in diameter bound to the depth of wire diameter in the trunk bark increased the yield in the following year. This was attributed to an increase in the number of inflorescences, flower buds and setting fruits. Goren and Monselise (1971) reported that the enhancing effect of girdling on orange fruit yield was due to an increase in the number of fruits, rather than to an increase in the fruit size. Furthermore, strangulating in different growing seasons shows that the optimum time for strangulation to increase yield was in late season before the flower bud differentiation period (Yamanishi et al., 1993a,c). Similarly, strangulation just before anthesis increased the yield of pummelo trees (Yamanishi et al., 1993d). Hence, late season strangulation promoted flower bud differentiation, whereas preanthesis strangulation resulted in increase in fruit set.

Strangulation in mid-November does not affect fruit quality in the following year (Yamanishi et al., 1993c), but strangulation did in this study with older trees. The high sugar contents in the fruit juice of treated trees seem to be an indirect effect of strangulation, because smaller, averaged-sized fruits compared to the control were sampled. A direct and positive effect of trunk strangulation late in the season on internal quality of pummelo fruits was observed only when it was performed at least 2 months before harvest (Yamanishi, 1995a).

We conclude that 1.6 or 2.0 mm diameter wire are suitable for strangulating pummelo tree trunks.

Literature Cited


ハウスプタンの開花、果実品質ならびに収量に及ぼす後期樹幹挙約強度の影響

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要

ビニルハウス内で生育させた7年生カラタチ台‘土佐プタン’を供試し、1991年11月中旬に直径1.6、2.0および2.6mmの針金を用いて、針金の直径が完全に樹皮に吸収しように樹幹に挙約処理を行い、3か月後に針金を外した。処理樹の樹幹肥大は無処理樹に比べて劣り、2.6mmで顕著であった。挙約処理により旧葉の単位面積当たりの乾物重は増加したが、2.6mm処理ではその時期が遅れた。光合成速度は処理によって低下し、2.6mmで顕著であった。いずれの処理も1992年の花房数と花数は増加し、新梢成長は抑制されたが、1993年の開花数は2.6mmで減少した。1992年の結果率は2.4から3.1%で処理間に有意差がなかった。1993年2月に収穫した果実では、処理により果重は低下し、果皮は薄くなったが果汁のショ糖含量やクエン酸含量は高まった。1993年2月の処理樹の収量と収穫時の果実数は無処理樹に比べて、それぞれ1.4から1.6倍と1.6から2.3倍多かった。直径2.6mmの針金を用いた挙約処理では1994年の収量は著しく減少し、強い隔年結果がみられたが、1.6と2.0mmのもとでは1994年の収量は無処理樹と同様であった。このように挙約強度の違いにより、7年生の‘土佐プタン’の生育反応は異なり、樹幹挙約には直径1.6mmおよび2.0mmの針金を用いるのが適当であった。