Shoot Growth and Fruit Development as Affected by Warming the Soil in Forcing Culture of ‘Tonewase’ Persimmon under Restricted Root Volume

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Summary

Effects of warmed and non-warmed soils on shoot growth and fruit development were compared by using in seven-year-old ‘Tonewase’ persimmon (Diospyros kaki L.) in forcing culture under restricted root volume condition. The warmed soil was maintained at 20°C by circulating warm water in the pipes laid in the ground from Jan.12 to Apr.15. The time of bud burst and anthesis by warming was advanced slightly, compared with plants in the non-warmed treatment. Warming the soil increased shoot growth and accelerated maturation and TSS accumulation of fruit, but the yield was reduced because of low fruit set and small fruit size.

Key Words: Diospyros kaki, fruit development, soil warming temperature.

Introduction

In Japan, cultivation under protected covers is gradually expanding for some kinds of fruit trees. When trees are grown under a greenhouse or plastic house, adequate temperature management is required to ensure productivity. As the vegetative and reproductive growth of a fruit tree is affected by interaction between aerial and root zone temperatures, both should be controlled to induce well-balanced growth. Some reports indicate that the regulation of both soil and air temperature is important for fruit production in forcing culture. Kubota et al. (1987a, 1987b) suggested that warming the soil in the heated greenhouse is an efficient method for stable grape production.

Persimmon trees have traditionally been cultivated in orchards, but the advantage of growing them under forcing culture is that the fruits mature about 3 months early. Understanding the responses of tree growth to temperature is useful for regulating environmental conditions under cover to establish and maintain stable productivity. Recently George et al. (1994) reported the effect of air temperature on the tree growth but not on soil temperature. We studied the effects of warming the soil on the shoot growth and fruit production in ‘Tonewase’ persimmon, grown in a heated plastic house.

Materials and Methods

Four, 7-year-old ‘Tonewase’ trees were planted 1 m apart within raised beds (90 cm wide × 25 cm high × 400 cm long) set 2.5 m apart in a plastic house. All trees were trained to a central leader with the lowest bearing shoot less than 2 m above ground level. The trees were draped with a transparent plastic sheet hanging from the ceiling from Jan.8 to Apr.25. The soil temperature of one bed was controlled by a water-circulating system (Model SW-1100CH, Notogawakagaku-Seikusyo, Japan) with 5 stainless pipes on the bottom of the bed. The root zone temperature was maintained at 20°C with warm water from Jan.12 to Apr.15. The soil temperature in the second bed was not controlled. The air temperature was kept above 10°C from Jan.9 to Jan.15 and above 15°C thereafter with a heater. Excess temperature during the day was alleviated with an exhaust fan and by opening up the side of the plastic house throughout the experiment. The fluctuations of air and soil temperatures in the warmed and non-warmed beds are shown in Fig.1.

Flower buds were thinned to 2 flowers per shoot in the warmed and non-warmed treatments on Mar.2 and 6, respectively. On Apr.15, fruit set was recorded on 10 randomly selected lateral branches; the crop was then thinned to establish a fruit to leaf ratio of 1:1.2. When shoot elongation stopped on May 20, the lengths of 40 randomly selected shoots were measured. On Jul.21, leaf area, fresh and dry weights were measured on the leaves collected from the middle portion of the shoots.

Fruits were harvested when fully mature and their weights and diameters were measured. Fruit skin colour at stylar end and stem end were graded with a colour chart. Flesh firmness was determined with a pressure tester (Model FT327, EFFEGI, Italy) fitted with a 7.94-mm diameter plunger. The total soluble solid (TSS) content was measured with a hand refractometer (Model N-1, Atago, Japan) after removing astringency with
carbon dioxide.

**Results and Discussion**

Kubota et al. (1987a, 1987b) reported that warming the soil temperature significantly advanced bud break and flowering of 'Muscat of Alexandria' vine under the forced condition. However, in our experiment, the treatment hastened bud burst and flowering only a few days, compared with the untreated trees (Table 1). This indicates that warming the soil temperature does not have a great effect for promoting bud break and flowering in persimmon trees grown in a root-restricted bed in a heated plastic house. The air temperature in the heated plastic house increased considerably in the daytime, which may promote the bud break and flowering, irrespective of soil temperature. Furthermore, heating the air of the plastic house resulted in a rapid increase of soil temperature in the non-warmed bed from 7°C to 12°C which we attributed to the shallow planting bed. The average soil temperature is about 15°C at which meristematic activity of root tip cells occur rapidly in Japanese persimmon (Fukui et al., 1994). High air temperature and an increase in soil temperature in the non-warmed bed may be one reason as to why promotive effect of warming the soil on bud break and flowering was not established.

Shoot length, leaf weight, and leaf area were increased by the warmed soil treatment (Table 2). These results indicate that warming the soil temperature promotes shoot elongation and leaf growth.

Fruit set was decreased by warming the soil (Table 3). In most fruit tree species the extent of shoot growth after flowering often influences the fruit set. At the higher soil temperature, promotion of shoot growth may have interfered with fruit set by weakening the sink strength of the fruit. Kubota et al. (1987a, 1987b) reported that the warmed soil treatment promoted shoot elongation,

![Air temperature and soil temperature graph](image)

**Fig. 1.** Changes in air and soil temperatures in a heated plastic house where persimmon trees were grown.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Shoot length (cm)</th>
<th>Leaf fresh weight (g)</th>
<th>Leaf area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmed</td>
<td>32.8***</td>
<td>4.16**</td>
<td>137.5***</td>
</tr>
<tr>
<td>Non-warmed</td>
<td>25.3</td>
<td>3.33</td>
<td>99.1</td>
</tr>
</tbody>
</table>

***; Significant at p=0.01, 0.001 by t-test, respectively.

**Table 1.** Effects of warmed soil on the numbers of day to sprout, beginning of flowering, full bloom and end of flowering of 'Tonewase' persimmon.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of days to sprout</th>
<th>No. of days to beginning of flowering</th>
<th>No. of days to full bloom</th>
<th>No. of days to end of flowering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmed</td>
<td>21.9 ± 0.5</td>
<td>52.1 ± 1.2</td>
<td>56.3 ± 0.6</td>
<td>58.8 ± 0.9</td>
</tr>
<tr>
<td>Non-warmed</td>
<td>24.0 ± 0.7</td>
<td>55.2 ± 0.8</td>
<td>58.8 ± 0.5</td>
<td>60.6 ± 0.3</td>
</tr>
</tbody>
</table>

Numbers of day were counted from January 8 when the heating treatment was started.

* The date when 70% of buds turned green.

* The date when 20% of flowers were open.

* The date when 80% of flowers were open.

* The date when 70% of petals turned brown.

* Mean = SD.
Table 3. Effects of warmed soil on fruit set, fruit weight and yield of 'Tonewase' persimmon.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Fruit set (%)</th>
<th>Average fruit weight (g)</th>
<th>Yield (kg/tree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warmed</td>
<td>69.6 ± 9.9</td>
<td>164.7 ± 1.5</td>
<td>12.3 ± 0.3</td>
</tr>
<tr>
<td>Non-warmed</td>
<td>88.8 ± 3.9</td>
<td>187.2 ± 3.7</td>
<td>14.0 ± 0.7</td>
</tr>
</tbody>
</table>

Mean ± SD.

but did not affect grape berry set. In their experiment the shoots were pinched to prevent shatter, which resulted in a higher fruit set on the treated vines. The effect of pinching on fruit set of Japanese persimmon trees grown under high soil temperature needs to be studied.

Harvesting began on Jul.24 in both treatments; about 87% and 68% of fruits were harvested by Aug.26 in warmed and non-warmed treatments, respectively. This indicates that warming the soil temperature accelerates the maturation of the persimmon fruit.

The weight of fruits in the warmed soil treatment was less than that of non-warmed one (Table 3), indicating that warming the soil before bud burst inhibits fruit enlargement. The yield was reduced by the soil warming treatment because fruit set and size were smaller. Thus, our results do not agree with those of Kubota et al. (1987a) who reported an increase in berry weight at warmed soil temperature. Persimmon fruit shape, skin colour, and flesh firmness differed little between treatments. TSS (17.1%) increased significantly under the soil warming treatment compared with non-warmed one (16.4%). In grapevine there was no difference in TSS of berry (Kubota et al., 1987a).

These results indicate that warming the soil temperature before bud burst has advantages and disadvantages under the forcing culture of 'Tonewase' persimmon with a restricted root volume. The advantages are that the treatment advances the harvesting time and increases total sugar content in the fruit; the disadvantages are that it results in low fruit set of smaller fruits, thus reducing yield.

Literature Cited


カキ‘刀根早生’の根域制限下での促成栽培における地中加温が新梢生長および果実発育に及ぼす影響

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摘 要

加温ハウス内において根域制限ヘッドに植栽した7年生カキ‘刀根早生’を供試し、地中加温が新梢生長と果実発育に及ぼす影響を検討した。1月12日から4月15日まで、地中に埋設したパイプに温湯を循環させて地温を20℃に維持する区と無処理区を設けた。地中加温は発芽および開花期にはわずかな影響しか及ぼさなかったが、新梢生長および果実の成熟を促進し、可溶性固形物含量を増加させた。しかし、果実の結実率と肥大生長は地中加温によって低下し、減収した。