Effect of Temperature on Floral Induction and Development of Floral Organs in White Sapote (Casimiroa edulis Llave & Lex.) cv. ‘Florida’

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Abstract  The effect of the temperature on floral induction and development in white sapote cv. ‘Florida’ was investigated under field, glasshouse and growth chamber conditions to identify the effective temperature for floral induction in order to grow the crop in the warm region of Okinawa. Floral induction was observed at a mean temperature below 20°C. Under 30-15, 30-20 and 30-25°C day-night temperature regimes, however, the trees did not produce panicles within 85 days of treatment, indicating that the day temperature of 30°C might have inhibited floral induction. The emergence of panicles was obvious within 19, 23 and 30 days under the day-night temperature conditions of 25-10, 20-10 and 15-10°C, respectively. Also, the cumulative temperatures, assuming 5°C as a base temperature, were 199, 198 and 197 degree-days, respectively. Moreover, it is likely that floral differentiation occurred within a short period of time under inductive conditions which usually prevailed from November to December, depending on the years in Okinawa.

Key Words: Cultural condition, Day-night temperatures, Floral differentiation, Subtropical fruit tree

Introduction

White sapote (Casimiroa edulis Llave & Lex.) is an evergreen subtropical fruit tree that is native to the highlands of Mexico and Central America (Morton, 1987). The tree does not grow well in the hot lowlands below on elevation of 600m in the tropics (Verheij and Coronel, 1991). There are two distinct types of bearing behavior (Loebel, 1984). In the first type, fruit is produced from winter through spring flowering (Yonemoto et al., 2001), while in the second type, the trees are ever-bearing and produce flowers and fruits throughout the year. Ever-bearing cultivars carry pollen but produce small crops (Yonemoto et al., 2001). In the first type, the ovaries are larger and larger fruits are produced unlike pollen. Therefore, the first type cultivars must be interplanted with ever-bearing types (George et al., 1988; Yonemoto et al., 2001). The cv. ‘Florida’ belongs to the first type and is extremely productive (Chambers, 1984). Although ‘Florida’ is one of the most productive cultivars grown in mainland Japan, its productivity in the warm region of Okinawa has not been determined.

Floral induction in many subtropical fruit trees requires a period of cool temperatures. For example, temperatures below 25°C for avocado and below 20°C for litchi and mango are essential for flowering and this requirement cannot be replaced by water stress (Chaikiattiyos et al., 1994). The floral induction of white sapote occurs in response to low winter temperatures in mainland Japan. Panicle emergence of ‘Florida’ is usually observed in late October under greenhouse conditions and in the middle of November in open field culture in Wakayama Prefecture. Therefore, flowers and young fruits often experience frost damage in winter in open field culture (Yonemoto et al., 2004). Although attempts are being made to introduce white sapote as a new fruit tree to the warmer climatic areas of Okinawa, Japan, the temperature range and duration required for floral induction in white sapote have not been elucidated. It is important to define the temperature requirement for floral induction of white sapote for successful introduction in Okinawa.

This study was conducted to determine...
whether successful white sapote production would be possible in Okinawa and to obtain some basic information about the effect of temperature ranges and durations required for floral induction and panicle development in cv. 'Florida' white sapote, based on field experiments conducted over a period of two years in Okinawa and on growth chamber and glasshouse experiments.

Materials and Methods

Field experiments

The investigation was performed in 2002 and 2003 using 7-year-old 'Florida' white sapote trees grown in a field in Okinawa, Japan. Apical buds on summer shoots were used for microscopic observation of flower bud differentiation. The samplings were carried out on September 30, October 20 and November 20 in 2002. Three trees in each of the three orchards were used, with ten buds per tree. The buds were fixed in FAA (50% ethanol, formalin and acetic acid, 90:5:5), and cut longitudinally into 15 μm thick sections by the ordinary paraffin method and stained with Safranin O and Fast green.

The dates of panicle emergence and anthesis were monitored for each tree over a period of two years. The air temperature in the field was measured hourly with a thermo-recorder (Ondotori Jr.TR-52, T&D Corporation), and the relationship between panicle differentiation and temperature was examined.

Growth chamber and glasshouse experiments

Experiments were conducted in growth chambers (Koitotoron 3S-135A, KOITO INDUSTRIES, Ltd. Japan) and in a glasshouse at the Department of Citrus Research (Kuchinotsu), National Institute of Fruit Tree Science in Nagasaki Prefecture in 2002. Twelve three-year-old 'Florida' trees were grown in 10 liter unglazed pots in a glasshouse until July. The minimum temperature in the glasshouse was not regulated, and the side and roof windows were opened automatically at temperatures above 25 °C. The temperatures in the glasshouse were maintained between 17 and 35°C from May through July.

The 12 trees were separated into four groups. Three groups were transferred to the growth chambers on July 22, while one group remained in the same glasshouse. The temperatures in the growth chambers were maintained at 30°C for 11 hours day time, and at 25, 20 or 15°C for 13 hours (night temperatures), that is, three temperature regimes 30/25, 30/20 and 30/15°C were adopted.

In order to determine period from floral induction to the appearance of panicles, the 30-25, 30-20 and 30-15°C temperature regimes in the growth chambers were changed to 15-10, 20-10 and 25-10°C, respectively, on November 19 and thereafter. Ten lateral branches produced in June were labeled for each temperature regime and the dates after which panicles could be observed by the naked eye were recorded and the number of days to panicle emergence from November 19 was calculated. Furthermore, cumulative temperatures (degree-days at a base temperature of 5°C) from November 19 to the panicle emergence were calculated for each temperature regime. Percentage of branches bearing flowers for each temperature regime was estimated on December 20 and the number of flowers in a panicle was counted on January 10 to determine whether the trees produced a normal number of flowers.

Results and Discussion

Field experiments

The 5-day averages of the daily maximum, minimum and mean air temperatures in autumn and winter at the field site in Okinawa are shown in Figure 1. A significant reduction in the temperature occurred in early November in 2002 and in early December in 2003. The mean temperature during these periods was around 20°C. Panicle emergence was detected by the naked eye in late November in 2002 and at the end of December in 2003. Anthesis started in the middle of December in 2002 and in the middle of January in 2003 (Fig. 1). Flower bud differentiation was observed in the apical buds collected on November 20, but not in the buds collected on October 20 and September 30 in 2002 by microscopic observation (Fig. 2). These results indicate that the first sign of flower induction occurred between October 20 and November 20 in 2002, at which time the temperature decreased markedly. The maximum, mean and minimum temperatures during this period were 24.6, 19.8 and 15.9°C in 2002, and 22.2, 19.6 and 17.2°C in 2003. Therefore, these temperature conditions may be effective for the floral induction of cv. 'Florida'. It was found that anthesis started about one month after the
panicle emergence detected by the naked eye, in winter in Okinawa (Fig. 1). Considerable reduction in the temperature generally occurred in early November in Okinawa, but one month later in 2003. Thus, the beginning of anthesis was delayed by one month in 2003, which indicates that the beginning of anthesis depends on the temperature conditions in each year. Late flowering may cause delay in harvesting, i.e. harvesting in late summer, and endangers white sapote trees because of the typhoons, which usually hit Okinawa in late summer. A cultivar in which floral induction occurs at high temperatures, therefore is recommended for Okinawa.

Growth chamber and glasshouse experiments
While panicle emergence did not occur under the day-night temperature regimes of 30-15, 30-20 and 30-25°C during the 85-day period of the treatment, it did occurred on November 19 in the glasshouse without temperature regulation (Table 1). Mean temperature decreased below 20°C in late October in the glasshouse (Fig. 3), similar to the temperature range experienced in a field experiment in Okinawa. During this period, the temperature regime reached 24-15°C in the glasshouse (Fig. 3). The temperature regime of 24-15°C in the glasshouse was effective for floral induction unlike that of 30-15°C in the growth chamber (Table 1), even though under both regimes the minimum temperature was 15°C. The branches were one month old at the start of the treatment (July 22) and five months old at the end of treatment (Nov. 19). A two-months-old branch that sprouted in September differentiated flower buds in November in Okinawa (data not shown). This implies that the maximum temperature of 30°C may reduce floral induction in 'Florida'. In 'Fuerte' avocado, for example, flowers were initiated at 20°C, but not at 25 or 30°C (Buttrose and Alexander, 1978). Temperatures above 20°C reduced flowering in litchi (Menzel and Simpson, 1995). Susanto et al. (1992) suggested that day temperatures above 20°C and night temperatures above 10°C inhibited citrus flowering. Similar data have been collected for 'Washington' navel orange (Moss, 1969), 'Tahiti' lime (Southwick and Davenport, 1986), 'Okitsu Wase' and 'Miyagawa Wase' mandarin (Inoue, 1989). Chaikiattiyos et al. (1994) reported that exposure to the low day-night temperature regime of 23-18°C improved flowering in 'Sensation' mango compared to the temperature regime of 29-25°C.

In the present study, it is suggested that the maximum temperatures that limit floral induction in 'Florida' white sapote lie between 25 and 30°C. These values are slightly higher than those for citrus species, but are similar to those of avocado, litchi and mango. Therefore, it is possible to consider that 'Florida' can produce flowers in any part of the Okinawa Islands since winter temperatures were within the range in

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Fig. 1 5-day averages of daily maximum, mean and minimum air temperatures from autumn through winter 2002 and 2003 in Okinawa Prefecture.
A: Beginning of anthesis, E: First appearance of floral buds.
which flowering was induced, that is, mean and maximum temperatures were below 20°C and 30°C, respectively, in winter.

The days to panicle emergence under the 25-10, 20-10 and 15-10°C temperature regimes were 19, 23 and 30 days, respectively (Table 2). Average number of flowers produced per panicle was around 15. Hundred percent of the labeled branches produced flowers in each of the temperature regimes. This indicates that flower induction occurred normally under these temperature regimes. Since the trees were held under non-inductive conditions prior to these treatments for 85 days, it is likely that floral induction and differentiation occurred within 19 days under the favorable temperature regime of 25-10°C. These results indicate that floral induction and differentiation may occur within a short period under inductive conditions.

The cumulative temperature during the days from the beginning of the inductive period to panicle emergence for each temperature regime was the same (197 to 199 degree-days), if the base temperature was assumed to be 5°C. It was
Table 2  Effect of temperature on the time to panicle emergence and number of flowers produced for the white sapote cultivar ‘Florida’

<table>
<thead>
<tr>
<th>Day/night temperatures (°C)</th>
<th>Dates of panicle emergence</th>
<th>Days to panicle emergence</th>
<th>Cumulative temperature (degree-days)*</th>
<th>Number of flowers per floral panicle</th>
<th>Percentage of branches that produced flowers</th>
</tr>
</thead>
<tbody>
<tr>
<td>25/10</td>
<td>Dec. 8</td>
<td>19</td>
<td>199</td>
<td>14.7 ± 6.1*</td>
<td>100</td>
</tr>
<tr>
<td>20/10</td>
<td>Dec. 12</td>
<td>23</td>
<td>198</td>
<td>15.2 ± 6.6</td>
<td>100</td>
</tr>
<tr>
<td>15/10</td>
<td>Dec. 19</td>
<td>30</td>
<td>197</td>
<td>15.5 ± 6.5</td>
<td>100</td>
</tr>
</tbody>
</table>

Experiment was conducted from November 19 through December 20, 2002.

*: Cumulative temperatures (degree-days) were calculated using the base temperature (5°C) as follows: Σ (Ti-5); where, Ti is the mean temperature on day i.

**: Average ± SD (n=20)

30/25, 30/20 and 30/15°C temperature regimes for 85 days were changed to 15/10, 20/10 and 25/15°C respectively, on November 19.

considered that floral induction occurred after the change of temperature under these temperature regimes, and panicle emergence was delayed under the low temperature regime.

The cumulative temperature reached 197 degree-days for 19 days from the time at which temperatures decreased below 20°C to panicle emergence, in the glasshouse. If cumulative temperatures were zero, temperatures in the glasshouse would be 26-15°C (Fig. 3), indicating optimal conditions for flower bud induction.

In conclusion, the temperature regime of 26-15°C is considered to promote floral induction in ‘Florida’, and temperatures over 30°C may inhibit floral induction. These inductive conditions occurred usually from November through December depending on the years in Okinawa.

References


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(*: in Japanese with English summary)
シロサポテ（*Casimiroa edulis* Llave & Lex.）品種フロリダの
花成誘導と花器発育に及ぼす温度の影響

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要約 シロサポテを温暖な沖縄県で栽培するにあたり、花成誘導に有効な温度を明らかにする目的で、圃場、ガラス室と人工気象室でシロサポテ‘フロリダ’の花成誘導と花器発育に及ぼす温度の影響を調査した。‘フロリダ’の花成誘導は平均気温が20°C以下で認められた。しかし、昼夜温（昼・夜温）を30-15, 30-20, 30-25°Cで85日間処理したが花芽が着生しなかったので、昼夜温30°Cでは花成誘導が抑制されると考えられた。昼夜温25-10, 20-10, 15-10°Cでは、それぞれ19, 23, 30日後に1対の花序が出現し、この場合の5°C以上の積算温度は199, 198, 197°C日であった。好適環境下での花成誘導および花芽の分化は短時間で行われることが示唆され、沖縄における‘フロリダ’の花成誘導の好適条件は気温が低下する11月から12月に満たされ、年による変動がみられた。

キーワード 亜熱帯果樹，花芽分化，栽培条件，昼夜温（昼・夜温）