

Effect of forcing at different times on bud burst, flowering and fruit development of low-chill peach cultivar 'Premier'

Sutasinee Maneethon¹, Kenji Beppu^{1*}, Naoko Kozai¹, Ryosuke Mochioka² and Ikuo Kataoka¹

¹Faculty of Agriculture, Kagawa University, Miki, Kagawa, Japan 761-0795; ²University Farm, Faculty of Agriculture, Kagawa University, Sanuki, Kagawa, Japan 769-2304; *Corresponding author: Email: beppuk@ag.kagawa-u.ac.jp

Abstract

Response of low-chill peach cultivar 'Premier' to early forcing culture was studied. Three-year-old trees were forced in a glasshouse from 15 November, 1 and 15 December and 1 and 15 January. Symptoms of insufficient chilling were detected when forcing was started from 15 November and 1 December. Bud break was delayed and sporadic. The flower and leaf buds forced from 15 December and 1 and 15 January rapidly burst within 15 days after the onset of the treatments. The final burst rate exceeded 70%. Generally, flowering started 10-15 days after flower bud burst. The size of the flowers from the trees forced from 15 November and 15 January was smaller than that recorded at other forcing times. Earliest harvest started under forcing from 15 December and 1 January. These results suggested that by using this low-chill cultivar, forcing could be initiated from mid-December, more than one month earlier than for high-chill cultivars, with complete dormancy release, in this region.

Key words: *Prunus persica* Batsch cv. 'Premier', low-chill peach, forcing culture, bud break, flower characteristics, fruit growth

Introduction

Peach (*Prunus persica* Batsch) is one of the most popular summer fruits in Japan. Its cultivated area spread over 10,300 ha with a production of 174,000 t in 2005 (The Ministry of Agriculture, Forestry and Fisheries of Japan, 2005). Although peaches are mainly produced under natural conditions, forcing culture in plastic greenhouses has been attempted recently. In 1999, the area of plastic houses where peach is grown covered 89.3 ha and the production amounted to 1,386 t (The Ministry of Agriculture, Forestry and Fisheries of Japan, 2000). The objective of forcing culture is mainly to obtain a high market price of the products at an earlier date and to improve the fruit quality by avoiding unfavorable climatic conditions, such as frost damage during flowering and excessive seasonal rainfall before harvest as well as damage by pests and diseases (Gemma *et al.*, 1990; Yoshida, 1994).

Under forcing conditions, the growers usually start covering and heating in late January and harvest fruits from late May to early June in case of early cultivars, which is one month earlier than for the fruits grown under natural conditions. However, it is difficult to further advance harvest because Japanese cultivars require more than 900 chilling hours (CH) below 7 °C for the release of endodormancy and resumption of growth. Therefore, it would be desirable to subject low-chill peach cultivars to earlier forcing culture. The characteristics of low-chill cultivars could be valuable for early-season production because the environmental conditions of a low-chilling zone are similar to those of forcing culture. So far, however, the performance of low-chill peach cultivars under forcing conditions has not been elucidated. Moreover, it is essential to determine when the forcing should be started for this type of cultivation, in order to avoid a less bud break, abnormal bloom and delayed foliation (Gemma *et al.*, 1990).

In the present study, bud burst and flowering, flower morphology, fruit development and the characteristics of the low-chill peach cultivar 'Premier' forced at different times were observed to utilize low-chill peach cultivars under forced culture.

Materials and methods

Plant materials: 'Premier' (150 CH) peach (*Prunus persica* Batsch.) trees propagated by cuttings were used. Three-year-old trees planted in 7 L pots, filled with granite soil and bark compost (2/1 parts v/v) were grown under field conditions in the experimental field of Kagawa University prior to the forcing treatment.

Forcing dates: On 15 November, 1, 15 December, 2004 and 1, 15 January, 2005, the trees were placed in a glasshouse where the lowest temperature was kept at above 17 °C using a petroleum heater. Three trees were used per treatment.

Bud burst and flowering: The rates of flower and leaf bud burst, and flowering were observed every 5 days until 120 days after the start of heating. Flower and leaf buds were considered to have burst when the green calyx and tip of leaf appeared, respectively.

Flower morphology and pollen germinability: Five flowers per tree were collected at anthesis, and the weight of the flower, length of the pistil and ovary, length and width of the petal were measured. From these flowers, pollen grains were collected to estimate the germination rate on a medium containing 15% sucrose and 1% agar at 25 °C.

Fruit development and characteristics: After fruit-set, the fruits were thinned, leaving approximately 5-8 fruits per tree, except for the forcing from 15 November and 1 December. The fruit longitudinal and transverse diameters (cheek and suture) were

measured every week from 2-3 weeks after fruit-set to harvest. When the fruits matured, they were collected, and their weight, longitudinal and transverse diameters (suture and cheek) and total soluble solid (TSS) content in the juice were measured. The date of harvest was also recorded.

Temperature conditions: Temperature in the experimental field from October, 2004 to January, 2005 was monitored using a thermo-recorder (Model RT-11, TABAI ESPEC) placed in a ventilated case in the field. Then, chilling hour (CH) accumulation below 7.2 °C was calculated. Chilling units (CU) were also calculated according to the model suggested by Richardson *et al.* (1974). In the Richardson CU model, one unit is assigned for the range between 2.5 and 9.1 °C, 0.5 unit for the range between 1.5 and 2.4 °C and 9.2 and 12.4 °C, no unit for temperatures below 1.4 °C and for the range between 12.5 and 15.9 °C, and a 0.5 unit is subtracted for the range between 16 and 18 °C, and one unit above 18 °C.

Statistical analysis: Trees were arranged using a completely randomized design (CRD) in a controlled greenhouse. Data were analyzed statistically by analysis of variance (ANOVA) using Statistix 3.5 (NH Analytical Software, Roseville, MN, USA), and the means were separated by LSD test at $P < 0.05$.

Results

Cumulative chilling hours and units recorded at the forcing dates are shown in Table 1. Accumulation began in early November. In mid-November, the accumulation of CU and CH was small and it increased rapidly from early December.

Table 1. Comparison of calculated Richardson chilling units (CU) and cumulative recorded chilling hours (CH) < 7.2 °C in experimental field of Kagawa University

Date	Bgllnt mtr	Bgllnt gnt q
15 November 2004	65	2
1 December 2004	028.4	8
15 December 2004	202-/	086
1 January, 2005	5/ 6-1	315
15 January, 2005	347-2	6/ 1

Bud burst and flowering: The pattern of flower bud burst was similar to that of leaf bud burst (Fig 1 a and c). The flower and leaf buds of 'Premier' forced from 1 and 15 January rapidly burst within 10 days after the onset of forcing. The final burst rate exceeded 80%. In the trees forced from 15 December the flower and leaf buds started to burst after 15 days, with a final rate of about 70%. In contrast, under the forcing conditions from 1 December flower buds started bursting after 30 days of forcing with a final rate of 42%. Flower buds burst slightly earlier than leaf buds. However, final leaf bud burst rate reached 48%. The duration of the period from the first bud burst to the final one under this forcing condition was much longer than that under the above three forcing conditions. Under the earliest forcing condition, flower buds started to burst 85 days after forcing, with a final burst rate of 20%. Only 1% of the leaf buds were found to burst at 120 days. Generally, flowering in all the treatments started 10-15 days after the flower bud burst (Figs. 1 a and b).

Flower morphology and pollen germinability: The morphological characteristics of the flowers at anthesis are shown

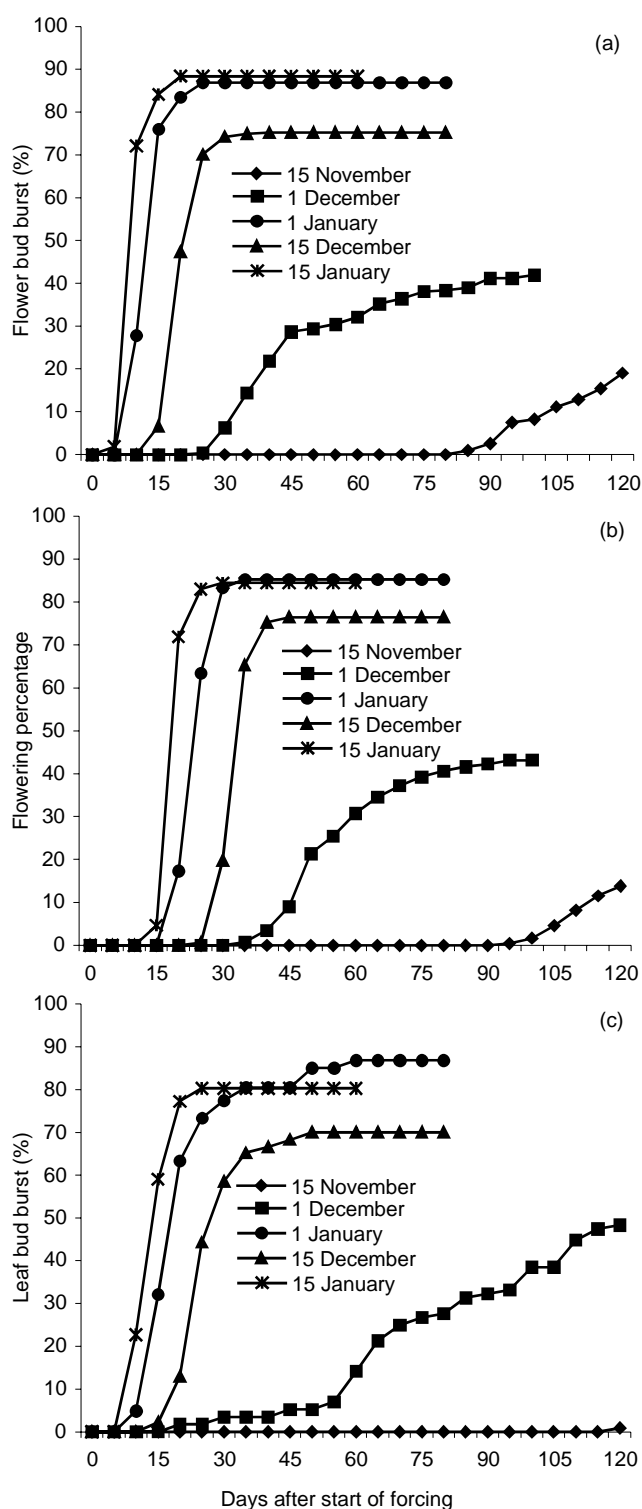


Fig 1. Effect of forcing at different times on the percentage of flower bud burst (a), flowering (b) and leaf bud burst (c) of 'Premier'.

in Table 2. Generally, the size of the flowers of the trees forced from 15 November was smaller than that of at the other forcing times, especially, the values of the weight, pistil length and petal size were lower. Moreover, the values of the flower weight and ovary length under forcing from 15 January were also lower than those of other forcing times. There was no significant difference in the percentage of pollen germination.

Fruit development and characteristics: Seasonal changes in the fruit diameter and length from 2-3 weeks after fruit-set to harvest are shown in Fig. 2. In all the forcing treatments, the

Table 2. Effect of forcing at different times on morphological characteristics of the flower organs and the percentage of pollen germination of 'Premier'

Onset of forcing	Weight (g)	Ovary length (mm)	Pistil length (mm)	Petal		Pollen germination (%)
				Width (mm)	Length (mm)	
15 November, 2004	163.7±6.4b ^c	3.37±0.05ab	15.13±0.29b	10.13±0.61b	13.97±0.72b	49±10
1 December, 2004	189.3±9.8ab	3.45±0.26a	16.80±0.80a	12.33±0.67a	16.43±0.35a	63±11
15 December, 2004	190.0±7.0ab	3.73±0.17a	16.47±0.38ab	12.53±0.38a	16.73±0.44a	64±8
1 January, 2005	200.0±8.1a	3.67±0.13a	17.87±0.29a	13.20±0.16a	17.80±0.47a	72±5
15 January, 2005	171.3±14.5b	2.91±0.12b	16.51±0.49ab	12.30±0.52a	17.27±0.52a	62±3

Values are indicated as means and analyzed by ANOVA. NS denotes non-significance.

Different letters denote significant difference at $P < 0.05$ (LSD).

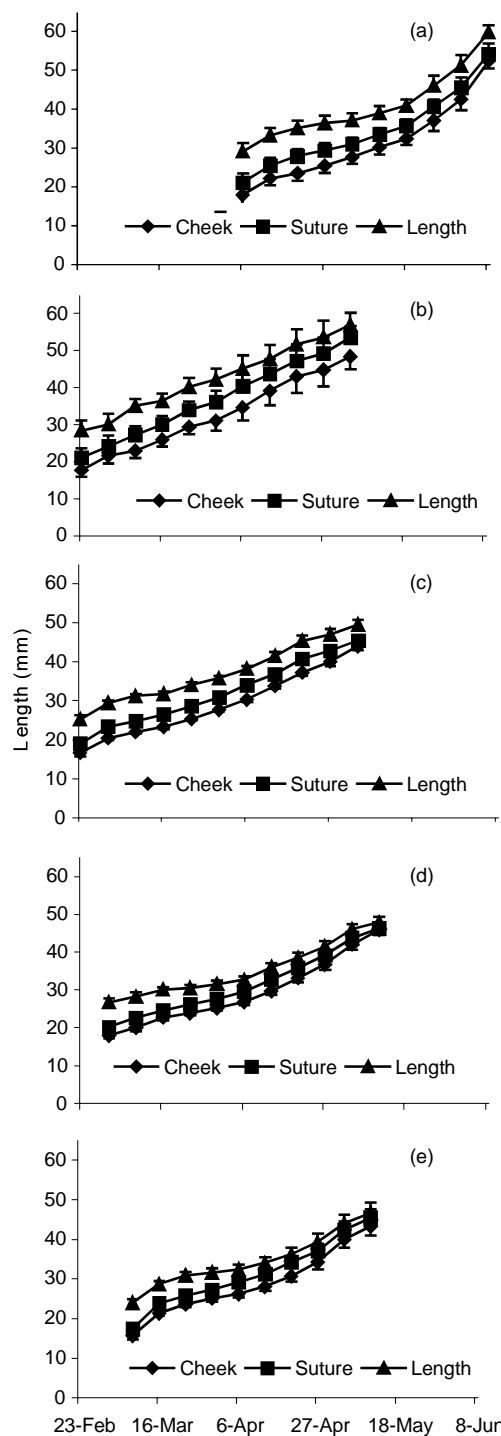


Fig 2. Effect of forcing at different times on seasonal changes in the fruit diameter (cheek and suture) and length of 'Premier' forced from 15 November (a), 1, 15 December 2004 (b and c) and 1, 15 January, 2005 (d and e).

fruits exhibited a double sigmoidal growth pattern. The fruit growth rate that had increased rapidly until 5 weeks after fruit-set (Stage 1) decreased from 5 to 8 weeks after fruit-set (Stage 2). After the short slow growth period, rapid growth resumed until harvest (Stage 3). This cultivar showed a short period of fruit development from fruit-set to maturation (about 12-13 weeks), which was even shorter in the trees forced from 15 November and 15 January.

Harvest period of the trees forced from 15 November was late in spite of the earliest forcing time. Under forcing from 1 and 15 December harvest started in early May, which was about ten days earlier than in the later forcing treatments (Table 3).

Fruit number per tree was much lower under forcing from 15 November and 1 December compared to the other treatments. Under these forcing conditions, although the fruit size was larger than that recorded under the other forcing conditions, variability was large, as indicated by the standard error. In these large fruits, the styler tip was prominent. The percentage of total soluble solids (TSS) ranged from 11.2 to 12.7, with no significant differences among the treatments.

Discussion

Erez (2000) reported that incomplete dormancy release affected the tree behavior in three main aspects: delayed bud break, low level of bud break and lack of uniformity of leafing and bloom. In the present experiment, under forcing conditions from 15 November and 1 December similar symptoms of insufficient chilling were observed. The values of natural CH accumulation on 15 November 2004 and 1 December 2005 were 3 and 79, respectively (Table 1), which were much lower than the reported CH values for dormancy release in 'Premier' (The State of Queensland, Department of Primary Industries, 1998). On the other hand, when 'Premier' was forced from 15 December (197 CH), and 1 and 15 January an early and high level of bud break occurred. Therefore, by using this low-chill cultivar, heating could be started from mid-December, more than one month earlier than for high-chill cultivars, with complete dormancy release, in this region.

Lack of chilling also results in defective fruit-set because the flowers are poorly developed (Giesberger, 1972; Wienberger, 1950). Peach anthers fail to dehisce, pollen production is low, and the styles and stigma fail to develop (Wienberger, 1950). In the present study, although pollen germination was not significantly different when forcing was performed at different times, the values of the flower weight and pistil and petal size in the trees forced from 15 November were lower than those at other forcing times. Moreover, with 702 CH chilling, the values of the flower

Table 3. Effect of forcing at different times on the fruit characteristics of 'Premier'

Onset of forcing	Fruit number tree ⁻¹	Fruit weight (g)	Fruit size (mm)			TSS	Harvest date
			Cheek	Suture	Length		
15 November, 2004	1.7	95.14±17.68 ^a	57.25±2.61a	57.28±4.17a	60.22±2.32a	12.6±0.7	Mid-June
1 December, 2004	2.0	85.90±16.33ab	51.85±3.30ab	54.72±3.34ab	58.40±3.03a	11.4±2.1	Early May- mid-June
15 December, 2004	6.0	52.49±1.97b	47.50±0.55b	48.87±0.48b	50.50±1.60b	10.7±0.4	Early-late May
1 January, 2005	5.6	56.16±2.93b	48.03±0.74b	48.66±0.85b	51.01±1.35b	12.3±0.3	Mid-late May
15 January, 2005	4.3	55.94±4.34b	48.85±0.72b	48.87±1.03b	49.38±1.32b	11.4±0.5	Mid May- early June

Values are indicated as means and analyzed by ANOVA. NS denotes non-significance. Different letters denote significant difference at $P < 0.05$ (LSD).

weight and ovary length were lower than in the case of the flowers subjected to 426 CH chilling. Citadin *et al.* (2001) suggested that in the low-chill cultivars, the buds might experience physiological injury, when they were exposed to excessive chilling.

Harvest was earliest when forcing took place from 1 and 15 December. However, under the former condition, the harvest period was much longer than under the latter one, probably due to sporadic bud burst. In the case of forcing from 15 January harvest was delayed by only 10 days, compared to forcing from 15 December although forcing started 1 month later, presumably due to the short periods of bud burst and fruit development. This early fruit maturation observed under forcing from 15 January might be related to temperature of the glasshouse during fruit growth, which was higher under forcing from 15 January (20.3 °C) than under forcing from 15 December (19.7 °C). Exposure to high temperature may result in early maturation, thus reducing the growth period (Dennis, 2000). This suggests that by increasing the temperature in the glasshouse during fruit growth, earlier harvest would become possible.

The fruits of the trees forced from 15 November and 1 December were larger than those in the other treatments, probably due to the small number of fruits because of the low rate of flower bud burst. Fruit weight under these forcing conditions ranged from 51-129 and 42-148 g, respectively (data not shown). Maggs (1975) reported that limited chilling led to prolonged flowering, which in turn resulted in the lack of uniformity of the fruit size. Additionally, by forcing on 15 November and 1 December the stylar tip become prominent. George *et al.* (1990) attributed prominent sutures and tips in peaches grown in the subtropical region of Australia to insufficient chilling.

In conclusion, it was demonstrated that subjecting low-chill peach cultivars to forcing culture enabled to advance the flowering time, compared to Japanese high-chill cultivars. In addition, it was suggested that forcing could be started in mid-December with complete dormancy release, in this region, when this cultivar is used. However, the fruit development and characteristics of low-chill peach cultivars under forcing conditions should be evaluated under more practical growth conditions.

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