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Importance of Heat Requirement for Bud Break and Time of Flowering in Apple

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Abstract. **Six genotypes of apple with a range in bloom date of 18 days were used to determine the contribution of the postdormant heat requirement to time of flowering. Spurs containing flower buds were collected after the chilling requirement had been satisfied but before detectable bud growth had begun, and forced at 10°, 15°, or 20°C. Bud development occurred on all samples at 20°, although at different rates which were correlated directly with field bloom date. At 10°, the genotypes fell into 2 groups. The first, consisting of the 3 earliest flowering selections, developed more slowly at 10° than at 20°. The 2nd, consisting of the 3 latest flowering selections, did not grow at all at 10°. The data suggest that late flowering in apple results from high heat and high minimum temperature requirements for bud growth, not from high chilling requirement.**

Controlling the time of flowering in deciduous fruit trees could be an important way of maintaining consistent fruit yields from season to season. Delaying flowering can avoid spring frost damage and also allow pollination and fertilization to take place when temperatures are higher, thus improving overall fruit set (4). Two factors have been proposed to account for time of flowering: 1) the length of the winter chilling requirement needed to break the rest period (1), and 2) the heat requirement in the postdormant phase needed for flower bud development (5).

Knowledge of the relative importance of the 2 components which affect bloom date would allow fruit breeders to choose parental material more effectively, develop efficient screening procedures for seedlings or germinating seeds, and predict areas of adaptation for advanced selections. Genotypes with high chilling requirements could not be grown in mild climates, but genotypes with delayed bloom due to a high heat requirement in the postdormant phase would be useful in diverse environments.

In a study of 50 pear genotypes, Spiegel-Roy and Alston (8) found a weak correlation between chilling requirement and bloom date, and a very high correlation between heat requirement after chilling and bloom date. They suggested that both components were sufficiently related to time of flowering to be used as selection criteria, but that selection for heat requirement alone would be effective. Wilson et al. (10) in a study of 533 plum seedlings of diverse genetic background found a significant correlation between high heat requirement and late development of leaf buds, but little relationship between time of bud break and the length of the dormant period was observed. In apple, Swartz and Powell (9) and Couvillon and Erez (2) suggested that late flowering genotypes have sufficiently higher chilling requirements to account for their later bloom dates. In this report, we assessed the importance of heat requirement in apple using 6 genotypes with a range in bloom date of about 18 days.

Table 1. Bloom dates of apple genotypes at Cream Ridge, N.J.

Genotype	Bloom date (1984)	Bloom date relative to RD
Red Delicious	4 May	0
226	10 May	+6
150	14 May	+10
337	17 May	+13
Camuzat	20 May	+16
Spatbluhender	22 May	+18

The following genotypes of *Malus domestica* (Borkh.) were used in this study: 'Red Delicious' (Miller Spur), 'Camuzat' (PI231939), 'Spatbluhender' (PI231942), and 3 selections from the New Jersey apple breeding program, designated 150, 226, and 337. Branches containing flower bud spurs were cut into 25 cm segments at 2-week intervals during March and April. Eight segments containing at least 4 spurs each were potted in moist vermiculite, covered with clear plastic bags, and kept at 10°, 15°, or 20°C for at least 5 weeks. Bud development was recorded 2 or 3 times/week. Days to bud break were designated as the time when at least 50% of the buds had reached the green-tipped stage of development.

The genotypes tested and their bloom dates are listed in Table 1. Bloom dates were recorded in 1984 as the date when king flowers were open and other flowers were at the balloon stage. All cultivars had completed their chilling requirements by the first sampling date as dormancy was broken in less than 25 days at 20°C (Fig. 1). There was, however, a considerable range in the time required for bud break to occur. 'Red Delicious' (RD),

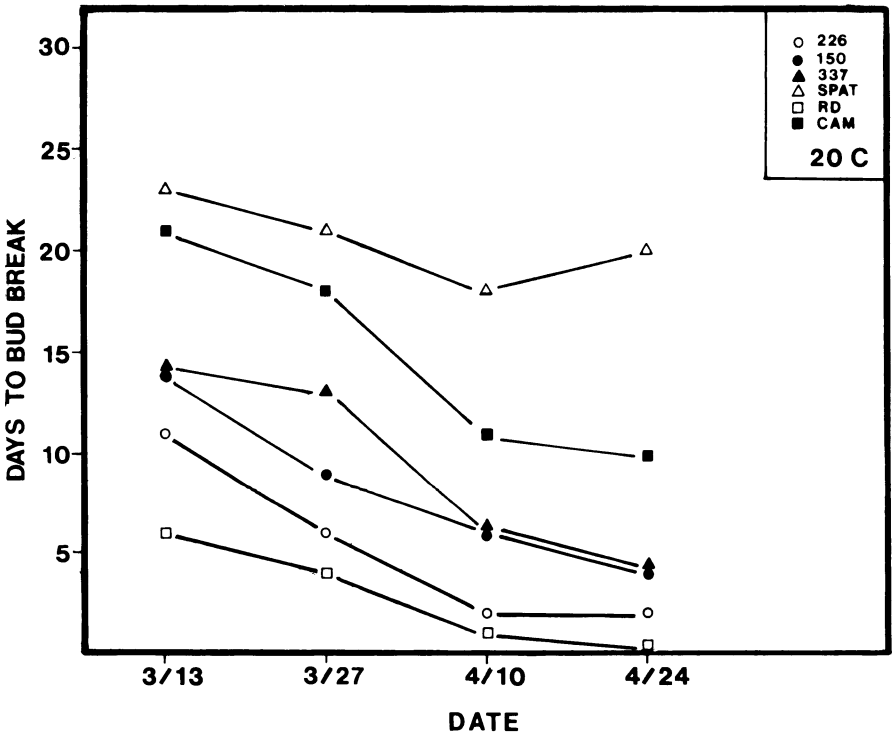

Fig. 1. The effect of 20°C treatment on the rate of flower bud development on excised twigs, from 6 apple genotypes taken from field grown trees, at several time intervals after the chilling requirement for bud break had been satisfied.

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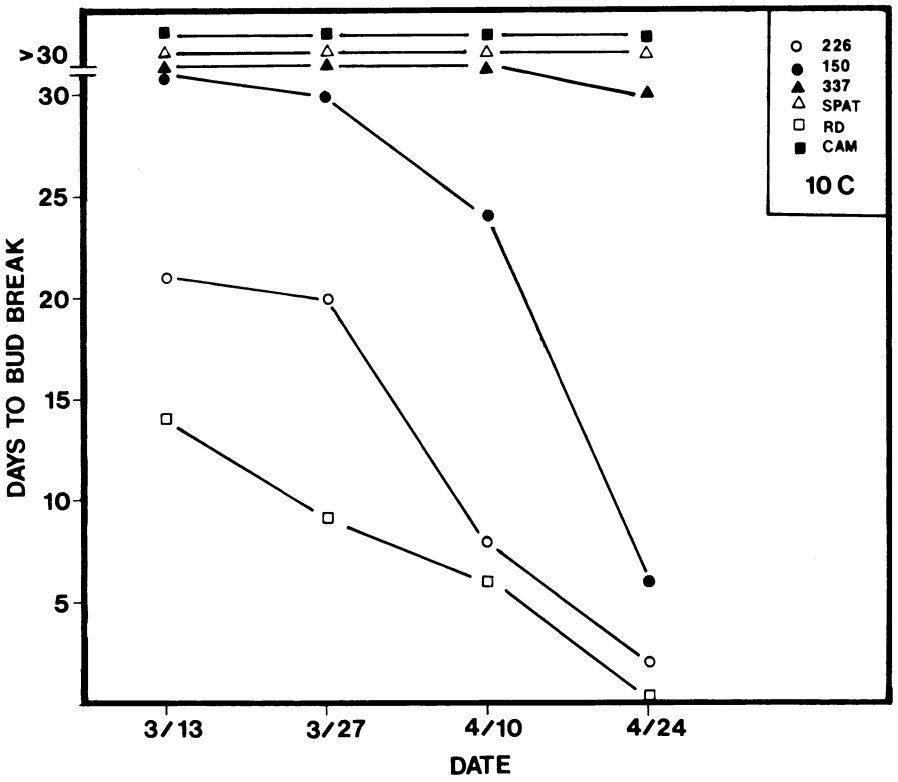

Fig. 2. The effect of 10°C treatment on the rate of flower bud development on excised twigs, from 6 apple genotypes taken from field grown trees, at several time intervals after the chilling requirement for bud break had been satisfied.

the earliest blooming cultivar, needed only 6 days at 20° before reaching the green-tipped stage, whereas the late blooming cultivars 'Camuzat' (CAM) and 'Spatbluhender' (SPAT) required more than 20 days at 20° before bud break occurred. The heat requirement, therefore, was directly related to bloom date (compare Table 1 and Fig. 1). The results with the late flowering cultivars also indicate that in the determination of rest completion, shoots should be forced for a minimum of 3–4 weeks at 20°; otherwise, chilling requirements will be overestimated (9). For the later sampling dates, each cultivar required less time for bud break, clearly as a result of accumulation of growing degree hours (GDH) in the field. In fact, RD had developed to the green-tipped stage at the time the last sample was collected.

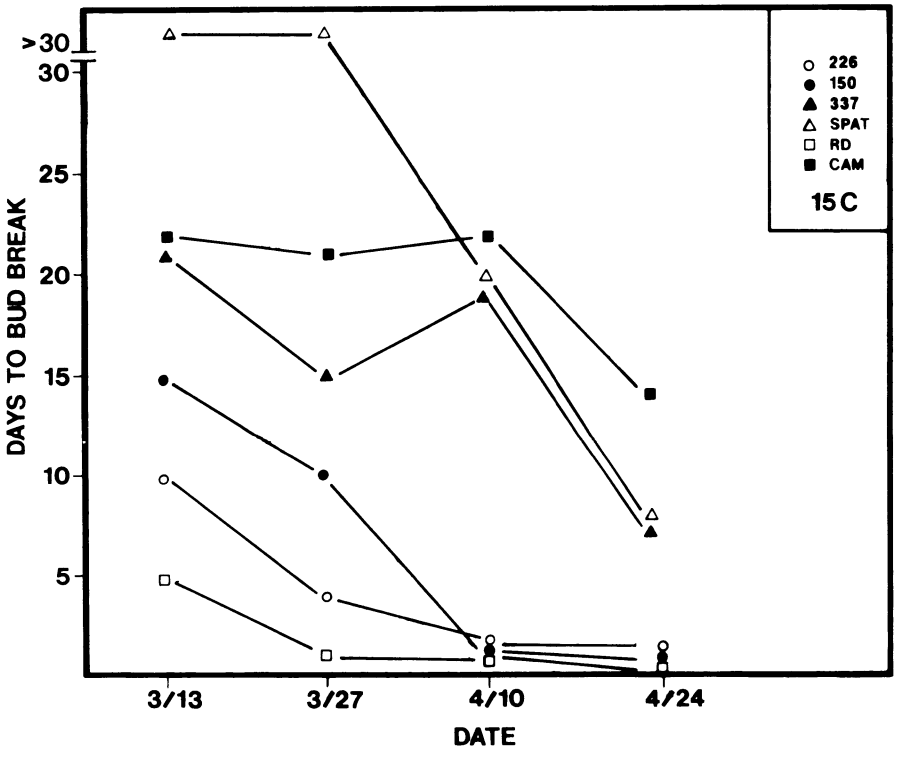

Fig. 3. The effect of 15°C treatment on the rate of flower bud development on excised twigs, from 6 apple genotypes taken from field grown trees, at several time intervals after the chilling requirement for bud break had been satisfied.

At 10°C, however, the 6 cultivars fell into 2 distinct groups (Fig. 2). The first, comprised of RD, 226, and 150, developed to the green-tipped stage, although at a slower rate than at 20°. For example, at the first sampling date, RD required 14 days at 10° before bud break occurred as compared with only 6 days at 20°. The 2nd group comprised of 337, CAM, and SPAT did not grow at all at 10°. These cultivars remained apparently "dormant" at each sampling date even after 35 days. Moreover, when the buds from the 27 Mar. collection of SPAT and CAM were kept for as long as 60 days at 10°, no bud break occurred, although after this sample was transferred to 20° bud development was rapid.

The cultivars could be divided into the same 2 groups when incubated at 15°C (Fig. 3), although the basis for separation was different. At this temperature, RD, 226, and 150 developed at about the same rate as the 20° samples, whereas CAM, SPAT, and 337 all developed more slowly at 15° than at 20°.

The results suggest that certain late blooming apple genotypes flower late because they have higher heat requirements, and higher minimum temperatures for bud expansion, rather exceptionally higher chilling requirements. Chilling requirement is believed to play, at most, only a minor role for the reasons discussed below.

RD had completed the rest period by 18 Feb. as determined by bud forcing experiments conducted at 2-week intervals during the winter. Although we do not have similar data for the other cultivars, if we conservatively place the end of the rest period at 13 Mar. (the first sampling date), the increase in chilling hour accumulation between 18 Feb. and 13 Mar. was only 240 hr (6). Moreover, calculation of GDH using a 4.5° base indicated only 40 GDH accumulated during the period 18 Feb.–13 Mar. (7). Even if RD had completed rest some 3 weeks before the late flowering cultivars, little bud development would have been possible. In addition, the number of chilling hours on 24 Apr. (the last sampling date) was only 30 less than the total accumulated for the season; yet, all genotypes developed and bloomed normally in the field. Thus, chilling requirement would have played a minimal role in determining time of flowering, regardless of genotype.

In addition to the qualitative difference in minimum temperature response, temperature optima for bud development also were different for the 2 groups. The early flowering cultivars developed at similar rates at either 15° or 20°C, whereas for the late flowering group, increasing the temperature from 15° to 20° increased rate of bud growth. These factors need to be taken into account when

developing models for GDH accumulation so that minimum and maximum temperature limits can be accurately set.

Field observations on the bloom dates of these genotypes and commercial cultivars also indicate the importance of heat requirement. The cultivars 'McIntosh', 'Red Delicious', 'Golden Delicious', and 'Rome Beauty', bloom at about 3-day intervals in areas which differ in chilling hour accumulation by several hundred hours. Several years of records in New Jersey indicate that CAM and SPAT consistently bloom about 2½ weeks after RD, yet there is no evidence of a failure to meet their chilling requirements. A similar argument led Faust et al. (3) and Overcash (5) to conclude that the sequence in which pear species and cultivars bloom is largely a function of their specific heat requirement.

Couvillon and Erez (2) suggested that postrest chilling reduces the GDH requirement for bud break, and thus dates of bud break and bloom are determined exclusively by the chilling requirement. Our experiments indicate that this is an oversimplification. More research using genotypes with known chilling requirements is needed to investigate the interrelationship between postrest chilling and GDH requirements.

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Partitioning of [^{14}C]-photosynthate in Fruiting and Deblossomed Day-neutral Strawberry Plants

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Abstract. **Deblossomed 'Tribute' strawberry (*Fragaria ×ananassa* Duch.) plants had increased [^{14}C]-photosynthates in untreated leaves 48 hr after treatment with $^{14}CO_2$. The summed quantity of radioactivity in the untreated leaves and fruit of fruiting plants approximated that in the untreated leaves of deblossomed plants. There was no effect of deblossoming on the amount of ^{14}C in the crown or roots. Autoradiographs showed that the majority of ^{14}C was in the expanding leaves. Therefore, increased leaf production rates, which often result from deblossoming strawberry plants, may be attributed to an increase in photosynthates partitioned to the expanding leaves.**

Deblossomed strawberry plants have exhibited an increased leaf production rate compared to fruiting plants (6, 8, 9, 10). Choma et al. (2) found that deblossomed 'Hecker' strawberry plants tended to have greater leaf areas than fruiting plants throughout a 6-week fruiting cycle. Dzieciol (5) found that fruiting decreased the accumulation of [^{14}C]-assimilates in the youngest leaves of strawberry plants. However, the fruiting plants used in that study were not at the same stage of development and were treated with $^{14}CO_2$ at a different time than the deblossomed plants, thereby making comparisons difficult. After treating apple leaves with ^{14}C, Hansen (7) found that ^{14}C-sorbitol was higher in leaves from shoots without fruit than in those from fruit-bearing shoots. Day-neutral strawberry plants may fruit continuously in about 6-week cycles (2), regardless of photoperiod (4). Therefore, they are an ideal model system for testing the effects of fruiting on photosynthate partitioning. The objective of this study was to compare partitioning of [^{14}C]-photosynthates in deblossomed and fruiting plants.

Day-neutral strawberry plants, cv. Tribute (3), were planted in 15-cm diameter plastic pots containing Pro-Mix and placed in an open ended plastic greenhouse on 6 June 1984. Plants were fertilized weekly with 240 ppm N from a 20N–8.7P–16.6K soluble fertilizer in the irrigation water and grown under a natural photoperiod of about 14½ hr. Uniform plants were divided into 2 treatments: 1) plants with all blossoms removed as they appeared, and 2) plants allowed to flower and fruit normally. Runners were removed from all plants as they emerged. Each treatment consisted of 10 single-plant replications in a randomized complete block design.

When the majority of primary flowers were open, one newly emerging leaf was tagged per plant. Twenty eight days later, when the majority of primary fruit were ripe, the area of the tagged leaf (then fully expanded) was

Table 1. ^{14}C partitioning in fruiting and deblossomed 'Tribute' strawberry plants 4 weeks after flowering.

	Fruiting plants			Deblossomed plants		
Plant tissue	% ^{14}C[z]	Dpm × 10^3	Dry wt (g)	% ^{14}C[z]	Dpm × 10^3	Dry wt (g)
$^{14}CO_2$ treated leaf	60 a[y,x]	557	1.2	59 a[y]	614	1.0
Untreated leaves	16 b	153	4.6	34 b	362	5.6
Crown	4 b	33	0.8	4 c	40	1.0
Roots	7 b	65	2.0	4 c	35	2.3
Fruit	13 b	120	2.0	---	---	---

[z]Percentage of total radioactivity in the plant.
[y]Data transformed by arcsine transformation for statistical analysis.
Mean separation within columns by Tukey's studentized range test ($P < 0.01$).

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