Relation of Bloom Date and Blossom Temperature to Frost Injury and Fruit Set of Apricots

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The occurrence of late spring frosts during or after bloom is one of several factors affecting consistency of apricot production in south-western Ontario. Two such frosts occurred during bloom in 1966. The first frost occurred on May 4 near the peak of bloom, while the second, on May 9 to 10, occurred between full bloom and petal fall.

These frosts afforded the opportunity to study: (1) the relation of air to bud temperatures during and after the frost period, (2) influence of stage of blossom development on frost injury, (3) frost sensitivity of floral organs, (4) influence of bloom date on frost injury and fruit set, (5) relation of pistil injury to fruit set.

A continuous record of air and internal flower temperatures of apricot were maintained by use of copper-constantin thermocouples connected to a Bristol Recorder. Temperatures were monitored continuously on branches 3 to 5 feet above the ground, and recorded automatically with an accuracy of ± 1°F.

The average hourly temperatures from 7 p.m. to 9 a.m. during each frost are summarized in Table 1. Air and bud temperature remained at or below 30°F for 4 hours on May 4, but the flowers were as much as 2.7°F colder during the frost period. At sunrise, the flowers warmed up much faster than the surrounding air, and were 4.5°F warmer by 8 a.m. Conditions favored a rapid thaw since the flower temperature increased from 28.4° to 41.9°F in two hours, an increase of 13.5°F.

The second frost period, from May 9 to 10, was considerably more severe than the first. Air and bud temperatures remained at or below 30°F for 10 and 12 hours, and below 25°F for 2 and 7 hours, respectively. Again, conditions favored a rapid thaw, with flower temperatures increasing from 30.2° to 43.3°F in two hours. Blossom temperatures were warmer by 5.9°F than the surrounding air at 8 a.m. During the second frost period the sky was clear and there was little or no air movement. These conditions favored rapid radiative heat loss from the blossoms, resulting in blossom temperatures up to 4.5°F colder than surrounding air.

Apricot varieties and selections were rated within two days of each frost for injury to blossoms on branches 3 to 6 feet above the ground. In addition all trees were rated for fruit set on June 14, after the June drop had occurred. The results and rating scales used are summarized in Tables 2 and 3. Varieties and selections were grouped according to date of full bloom.

Injury from the first frost was concentrated on the petals, and to a lesser extent on the stamens and pistils. The calyx was not injured. Fully expanded petals were progressively more injured than those in the balloon and pink stages. Frost injury to the pistil was restricted to the stigma and part of the style near the stigma. The anthers and most of the filaments were injured on flowers with petal injury. Pistils and stamens of blossoms in the pink and balloon stages were not injured.

Late blooming varieties and selections escaped the first frost with very little blossom injury (Table 2): Se-

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TABLE 1. Sequence of air and bud temperatures from sunset to sunrise on May 3-4 and 9-10, 1966.

	Temperature in degrees (F)			
	May 3-4, 1966		May 9-10, 1966	
Time	Air	Blossom tissue	Air	Blossom tissue
7 p.m.	46.4	45.5	34.7	35.6
8	42.8	41.9	32.9	30.2
9	41.9	40.1	30.2	27.5
10	38.3	35.6	30.2	26.6
11	39.2	38.3	28.4	24.8
12	35.6	32.9	26.6	23.0
1 a.m.	36.5	35.6	23.9	20.3
2	33.8	32.0	23.0	18.5
3	30.2	27.5	27.5	23.9
4	30.2	28.4	26.6	23.9
5	29.3	28.4	26.6	24.8
6	30.2	28.4	26.6	25.7
7	33.8	37.4	31.1	30.2
8	37.4	41.9	33.8	39.2
9	41.9	43.7	37.4	43.3

cord, Toovey, V51073 and V51092 being particularly outstanding. Where injury occurred it was restricted to open blossoms. Medium blooming varieties sustained more than twice as much injury. Farmingdale and Haggith were the least injured of this group. Early bloomers had three times as much injury as late bloomers and were only slightly more injured than the medium bloomers. Earliril, Georgeff and V51175 had the least injury of the early bloomers. A close correlation ($r = -0.72^{**}$) was obtained between date and full bloom and total injury over all 28 varieties and selections.

The second frost was so severe that differences between early, medium and late bloomers for total blossom injury were only slight (Table 3). The least injured in each respective group were: Morden 604, NY477, Toovey and V51092. The calyx was the least injured of all floral organs, followed by the stamens, petals and pistils. Again, the correlation was close ($r = -0.62^{**}$) between date of full bloom and total frost injury.

Fruit set was greater on late bloomers than on medium or early bloomers (Table 3). The best fruit sets in each respective group were obtained with Toovey and V51092, NY477, and Alfred. Because factors other than date of full bloom and blossom injury influence fruit set, the correlation between bloom date and fruit set was not as close as the other correlations ($r = 0.54^{**}$).

Pollination and fertilization were complete for all varieties and selections by the second frost. Therefore, the degree of pistil injury was expected to have the greatest influence on fruit set of the factors studied. The correlation of pistil injury and fruit set was indeed close ($r = -0.86^{**}$) and highly significent. Varieties with the most frost resistant pistils in the early, medium and late blooming groups included: Earle Orange and Morden 604, NY477 and Haggith, Toovey and V51092, respectively.

The data on air and blossom temperatures in relation to sunshine, wind, and shade are in agreement with those obtained by other workers, for leaf surfaces (2, 3) and internal temperatures of peach and apple fruit buds (1). The fact that apricot blossoms were usually several degrees colder than the surrounding air during the night, particularly on still, clear nights, suggests that blossom temperatures are more important than air temperatures in relation to frost injury. Air temperatures of 28.4°F cause little injury to apricot blossoms (4), but temperatures of 27°F or less are very injurious (4, 5). Thus, frost forecasting and frost control usually refer to 28°F as the critical air temperature for taking frost protective measures. My data show that moderate to severe blossom injury can result from

TABLE 2. Date of full bloom and injury to apricot blossoms caused by frost on May 4, 1966[1]

Date of full bloom	Variety or Selection	Injury to floral organs[2]				Total injury (0-20)
		Calyx	Petals	Stamens	Pistil	
Apr. 28	Earliril	0	3	3	2	8
28	Lamale	0	5	4	2	11
29	Perfection	0	4	4	3	11
30	Alfred	0	5	5	3	13
30	Curtis	0	4	3	2	9
30	Earle Orange	0	5	4	3	12
30	Georgeff	0	3	3	2	8
30	Morden 604	0	5	5	3	13
30	V51175[3]	0	3	3	2	8
30	SHA 6[4]	0	5	3	3	11
30	SHA 7	0	5	4	3	12
EARLY	**Mean**	**0**	**4.3**	**3.7**	**2.5**	**10.5**
May 2	Farmingdale	0	2	2	1	5
2	Haggith	0	3	2	1	6
2	Riland	0	3	3	2	8
2	Schatti	0	3	3	2	8
2	Viceroy	0	4	3	2	9
2	V49024	0	4	4	3	11
2	V49057	0	5	5	3	13
2	V51166	0	4	4	3	11
2	S4E-28-14[5]	0	3	3	2	8
2	NY477[6]	0	3	3	2	8
3	S4E-55-9	0	4	3	2	9
MEDIUM	**Mean**	**0**	**3.5**	**3.2**	**2.1**	**8.7**
May 5	Secord	0	1	1	0	2
5	Sun Glo	0	3	2	1	6
5	Toovey	0	1	0	0	1
5	Veecot	0	3	3	2	8
5	V51073	0	2	1	0	3
6	V51092	0	1	0	0	1
LATE	**Mean**	**0**	**1.8**	**1.2**	**0.5**	**3.5**
OVERALL	**Mean**	**0**	**3.4**	**3.0**	**1.9**	**8.3**

[1]Minimum air and blossom temperatures were 29.3 and 27.5°F.

[2]Visual ratings were 0 = no injury; 1 = trace; 2 = up to 25%; 3 = up to 50%; 4 = up to 75%; 5 = up to 100% of organ injured.

[3]V-numbers from Hort. Exp. Sta., Vineland, Ont.

[4]SHA-numbers from Branch Agr. Exp. Sta., South Haven, Mich.

[5]S-numbers from Research Station, Summerland, B.C.

[6]NY477 from New York State Agr. Exp. Sta., Geneva, N.Y.

TABLE 3. Date of full bloom, blossom injury after two frosts on May 4, May 9 to 10, and fruit set[1]

Date of full bloom	Variety or Selection	Injury to floral organs				Total injury (0-20)	Fruit[2] set (0-6)
		Calyx	Petals	Stamens	Pistil		
Apr. 28	Earliril	5	5	5	5	20	0
28	Lamale	3	5	5	5	18	0
29	Perfection	5	5	5	5	20	0
30	Alfred	4	5	5	5	19	2
30	Curtis	2	5	5	5	17	0
30	Earle Orange	2	5	5	4	16	1
30	Georgeff	3	5	4	5	17	1
30	Morden 604	2	5	4	4	15	1
30	V51175	3	5	3	5	16	0
30	SHA6	4	5	4	5	18	1
30	SHA7	2	5	4	5	16	0
EARLY	**Mean**	**3.2**	**5.0**	**4.5**	**4.8**	**17.5**	**0.5**
May 2	Farmingdale	3	4	4	5	16	1
2	Haggith	2	5	4	4	15	2
2	Riland	4	5	5	5	19	0
2	Schatti	2	5	4	5	16	0
2	Viceroy	3	5	5	5	18	0
2	V49024	3	5	5	5	18	2
2	V49057	4	5	5	5	19	1
2	V51166	4	5	4	5	18	0
2	S4E-28-14	2	5	3	5	15	1
2	NY477	2	5	4	3	14	3
3	S4E-55-9	4	5	4	5	18	1
MEDIUM	**Mean**	**3**	**4.9**	**4.3**	**4.7**	**16.9**	**1.0**
May 5	Secord	4	3	3	5	15	1
5	SunGlo	3	5	5	5	18	1
5	Toovey	1	4	3	4	12	4
5	Veecot	3	5	4	5	17	1
5	V51073	4	5	3	5	17	2
6	V51092	2	3	4	3	12	4
LATE	**Mean**	**2.7**	**4.2**	**3.7**	**4.5**	**15.2**	**2.2**
OVERALL	**Mean**	**3.0**	**4.8**	**4.2**	**4.7**	**16.8**	**1.1**

[1]Minimum air and blossom temperatures of first and second frosts were 29.3 and 27.5°F. and 23.0 and 18.5°F, respectively.

[2]Values represent mean ratings were 0 = no fruit set; 1 = trace; 2 = light; 3 = light to medium; 4 = medium; 5 = medium to heavy; 6 = heavy.

air temperatures no lower than 29°F because blossom temperatures were up to 2.7°F colder.

The degree of frost injury is influenced by the duration as well as the extent of a frost (4). Again, the data show that when blossom temperatures were considered, the duration and extent of the frost (28°F or less) was up to 2 hours longer, and 4.5°F colder than the corresponding air temperatures. Better frost forecasting and control may be expected when both blossom and air temperatures are taken into consideration.

Late blooming varieties survived both frosts with less injury and more fruit set than early or medium bloomers. Full, open flowers, or blossoms at petal fall were more sensitive to injury from frost than blossoms in the pink or balloon stages. Sensitivity of floral organs to frost injury in order of increasing sensitivity were: calyx, stamens, petals and pistils following the second frost. Prosenko (4) also found pistils more frost sensitive than stamens, and petals more sensitive than sepals, but he reported the pistils and peduncles as being the most frost sensitive parts of the flower. My data indicate, on the contrary, that pistils of fully open flowers were less injured than petals or stamens by a light frost, but more sensitive than stamens to a severe frost.

Despite the severity of the second frost a medium fruit set was obtained on Toovey and V51092. The superior cropping of these varieties was probably due to a combination of late blossom season and the inherent capacity of the pistils to withstand greater cold. Similar hardiness of the pistil was shown by NY477, Haggith, Morden 604 and Earle Orange, but this effect was counteracted by the earlier blossom season. Less blossom injury and greater fruit set were obtanied in the upper third of the trees. This is probably due to the fact that blossom temperatures at this location were warmer for longer periods during the day and were also warmer during the night than blossoms in the lower parts of the trees.

Killing frosts during bloom of apricots occurred in only one year out of eight at the Harrow Research Station. During "frost" years late bloomers have sustained less injury than early bloomers. However, the frequency of consistent cropping over a 16-year period was no better for late than for early bloomers. Other varietal characteristics such as bud set, bud hardiness, frost hardiness of blossoms and ability to set fruit during conditions adverse for pollination may have a greater bearing on consistency of cropping than late blooming *per se*. In areas where frosts during bloom occur with greater frequency, late blossom season would be of particular importance.

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