GLC analyses of extracts from dormant and non-dormant cranberry seeds indicated that considerably more ABA was present in the dormant seed extract (Fig. 1).

Numerous studies have shown that exogenously applied ABA is a potent inhibitor of seed germination (10, 12, 13). In other studies ABA was found to be naturally present at a high level in dormant seeds and at a much lower level when the same seeds were no longer dormant. For example, Sondheimer et al. (14) determined that high levels of ABA are present in ash seeds prior to stratification and low levels following stratification. In the present study considerably more ABA was found in dormant as compared to non-dormant cranberry seeds. Apparently cranberry seeds immediately following harvest have a high level of ABA, a circumstance that prevents their germination. When exposed to sufficient light ABA concn drops to a non-inhibitory level and germination takes place.

Devlin and Karczmarczyk (7) have shown that exogenously applied GA enhances dark germination of scarified cranberry seeds. The influence of GA in the barley endosperm assay and in the growth of dwarf maize or dwarf peas can be counteracted by exogenously applied ABA (1, 3, 4). The two compounds may be mutually antagonistic. For example, Sondheimer and Galson (13) found that GA antagonizes the inhibitory effect of ABA on the germination of excised ash embryos. Similar results have been obtained with the sprouting of potato buds and with the elongation of genetically tall corn leaf sections (8). Thus it seems entirely possible that the GA enhanced dark germination of cranberry seeds found by Devlin and Karczmarczyk (7) could be due to the applied GA counteracting the inhibitory influence of endogenous ABA.

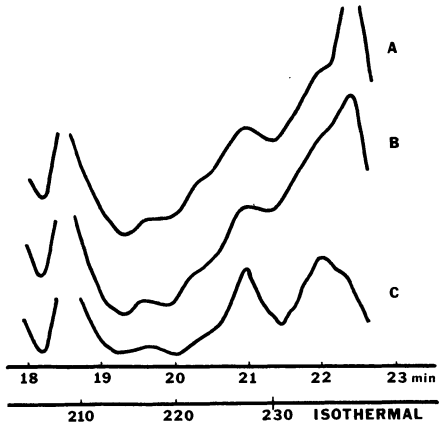

Fig. 1. Gas-chromatographic traces of silylated (TMS) extracts of dormant and non-dormant cranberry seeds. Peaks at the extreme right indicate the presence of ABA. A = Extract of dormant seeds fortified with ABA; B = Extract of dormant seeds; C = Extract of non-dormant seeds.

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Frost Tolerance in Strawberry Cultivars[1]

Donald K. Ourecky and Jack E. Reich[2]
Department of Pomology and Viticulture, New York State Agricultural Experiment Station, Geneva, NY 14456

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Abstract. **A range of 3°C was observed in flower frost tolerance in 21 cultivars of strawberry (*Fragaria* × *ananassa.* Duch.). Fruits were more susceptible to damage than flowers or buds. 'Gala' and 'Robinson' were among the least tolerant cultivars while 'Earlidawn' and 'Catskill' were the most tolerant to flower injury. Origin of cultivar had no relationship to flower frost tolerance.**

In cold climates, frost damage and winter injury are important to the production and maintenance of a strawberry planting. Frost damage is of primary concern during the spring as growers take advantage of cultural methods to produce an early crop. Overhead irrigation can be used to protect plantings; however, many growers do not have an adequate system nor can the minimum temp be predicted accurately. Most studies have been conducted on crown and root hardiness, but no correlation exists between spring flower or bud hardiness and crown or root hardiness (2, 7). This study was conducted to determine the amount of variability among present cultivars in flower frost tolerance. Such information might enable recommendations to be made to growers on tolerant cultivars and enable the breeder to initiate a breeding program for frost tolerance.

Flowers, fruits and flower buds are killed or damaged in several ways: 1) complete killing of the whole primordium, 2) variable damage within the flower truss, 3) damage to flower parts or 4) injury to part of the vascular tissue of the peduncle (3). Factors which influence hardiness include physiological condition of the plant, stage of truss development, duration and rate of temp drop, and cultivar (1, 2, 8).

Bazzocchi (1) investigated spring frost resistance of 105 strawberry cultivars, and found that the percentage of killed flowers was related to the place of origin of the cultivar, the more northerly cultivars being more tolerant. Flowers protected by leaves were more resistant while flowering date was of little importance. Stancevic (10) reported significant differences in survival among 12 European strawberry cultivars after a late spring frost of −3°C.

[1]Received for publication January 16, 1976.
[2]Associate Professor and Experimentalist, respectively.

Havis (8) found that 'Blakemore', 'Catskill', 'Fairfax' and 'Dunlap' all could withstand −1.6°C but differed in the susceptibility of the flower parts to damage.

A selection of *Fragaria virginiana* Duch. showed no flower injury at −5°C while the variety 'Sheldon' showed only 10% (4). Another possible source of hardiness is *Fragaria ovalis* Duch. from Cheyenne (5, 6, 9). Darrow and Scott (4) found that selections having frost resistance when crossed with 'Midway' transmitted a high degree of frost resistance to seedlings.

Dormant plants of 21 cultivars were secured from a nursery, potted, and grown in a greenhouse at 15–18°C. At bloom, tags were applied to each fruit, flower, or bud, indicating stage of development. A specially designed low temp chamber was used with a rate of change of 3°C/hr. Potted plants were covered with plastic bags to circumvent the slight fluctuation in chamber temp resulting from an automatic defrost cycle. Twelve thermocouples from a 24 point recorder were attached at random to fruits, flowers and buds to monitor the temp cycle. Five plants of each cultivar were removed at each test temp and placed in a room at 8°. The plants were scored within 3–4 hr and again a week later to allow time for the small flower buds to develop. Scoring was based on the amount of dark, damaged, or water soaked tissue. Several runs were made using the earliest flowering cultivars first. 'Sparkle' was used as check cultivar in each run.

Cultivars were classified into hardiness groups based on the temp required to cause a maximum of 10% injury to the flowers (Table 1). Results indicated that present commercial cultivars vary as much as 3°C in their frost tolerance. Additional flower hardiness may be present in species and clones not tested. Of the cultivars tested, 'Gala', 'Jerseybelle', and 'Robinson' were the most susceptible; 'Earlidawn', 'Redchief', 'Catskill', 'Darrow', 'Fletcher', and 'Redglow' were the most tolerant.

In comparing the relative hardiness of fruits, flowers and buds, 'Sparkle' and 'Guardian' fruits showed less tolerance at −4.5°C than the other 4 cultivars (Table 1). The large and small buds of 'Fletcher' were extremely frost tolerant. Most cultivars exhibited some tolerance, but temps of −6.5° or below caused severe damage. At −5.5° nearly 50% of the flowers and a small portion of the buds of 'Redchief' and 'Catskill' were killed, but at −6.5° severe injury occurred to both flowers and buds. Fruits were more susceptible to low temp injury than flowers or buds (Table 2).

These data indicate that some frost tolerance does exist in present commercial cultivars. Stage of truss development during low temp periods will determine the amount of injury occurring in a particular cultivar. Late ripening cultivars, e.g. 'Sparkle', are not necessarily more hardy than early ripening clones, but the small buds protected in the crowns are less susceptible to injury compared to cultivars with flowers or developing fruit.

Contrary to Bazzocchi's (1) observations, no leaf protection was observed in the cold chamber, probably because most American cultivars produce flower trusses which are even with or above the leaf canopy.

Preliminary data (not shown) indicate some differences between field and greenhouse grown plants, but the relationship between cultivars remains. The duration and rate of temp change has a slight effect but again the relationship between cultivars remains.

No relationship was observed between origin of cultivars and frost tolerance in contrast with Bazzocchi's (1) report.

Table 1. Classification of strawberry cultivars in relation to flower frost tolerance by minimum temp resulting in 10% injury or less to open flowers.

Cultivar	% injury at 5.5°C	Classification (°C)
Gala	100.0 a[z]	
Jerseybelle	100.0 a	−2.5
Robinson	83.4 ab	
Fulton	75.0 b	−3.0
Sparkle	74.6 bc	
Holiday	70.4 bc	−3.5
Redcoat	67.2 bc	
Raritan	61.2 c	
Guardian	60.0 c	−4.0
Sunrise	59.3 cd	
Midland	57.8 cd	
Surecrop	55.4 d	
Garnet	44.7 de	−4.5
Marlate	44.1 de	
Pocahontas	44.0 e	
Redchief	44.0 e	
Catskill	44.0 e	
Darrow	39.0 e	−5.0
Fletcher	39.0 e	
Redglow	38.5 e	
Earlidawn	25.5 f	−5.5

[z]Mean separation by Duncan's multiple range test, 5% level.

Table 2. Response of fruits, flowers and buds of 6 strawberry cultivars to freezing temp.

Cultivar	Plant part	% organ kill −4.5°C	−5.5°	−6.5°
Sparkle	Fruit	100.0	75.0	100.0
	Flower	12.0	85.2	85.7
	Buds (>5mm)	0.0	38.2	36.8
	Buds (<5mm)	0.0	0.0	2.5
Redchief	Fruit	0.0	75.0	100.0
	Flower	0.0	52.4	88.8
	Buds (>5mm)	0.0	0.0	66.6
	Buds (<5mm)	0.0	0.0	26.4
Fletcher	Fruit	0.0	100.0	100.0
	Flower	0.0	40.0	60.0
	Buds	0.0	0.0	0.0
	Buds	0.0	0.0	0.0
Guardian	Fruit	100.0	75.0	100.0
	Flower	13.8	52.2	55.0
	Buds (>5mm)	9.0	14.2	50.0
	Buds (<5mm)	0.0	0.0	4.8
Catskill	Fruit	0.0	100.0	100.0
	Flower	0.0	54.5	100.0
	Buds (>5mm)	0.0	14.3	71.4
	Buds (<5mm)	0.0	0.0	11.5
Earlidawn	Fruit	0.0	28.5	100.0
	Flower	0.0	25.5	50.0
	Buds (>5mm)	0.0	0.0	30.0
	Buds (<5mm)	0.0	0.0	7.7

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