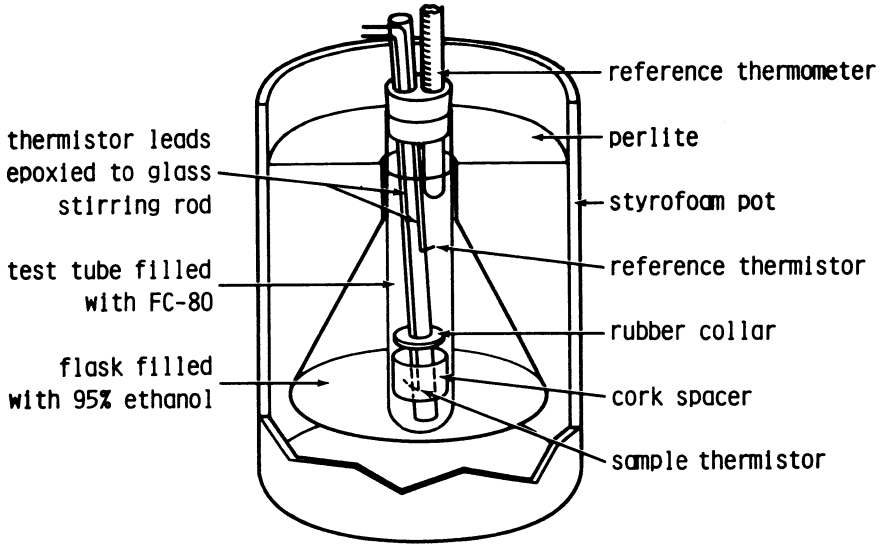

Fig. 2. Diagram showing the construction of a freezing unit of SAEDTAS.

thermistor was surrounded by a cork spacer which was covered by a rubber collar. A small amount of the cork was removed to make space for the thermistor and the bud to be tested. Five buds have been accommodated at one time by removing more of the cork. It should be possible to test larger buds as well, as long as they will fit into the cork near the thermistor.

Operation of SAEDTAS was test by using *Forsythia* 'Sunrise' flower buds that were taken from hardwood cuttings obtained from container-grown shrubs being overwintered in storage at 4–6°C. After removal from the shrubs, hardwood cuttings were placed immediately in polyethylene bags and stored in darkness at 4° until buds could be excised just before testing. SAEDTAS freezing units also were stored at 4°. When a freezing test was to be made, flower buds were excised at random from hardwood cuttings with at least 2 mm of flower bud pedicel attached (7) and positioned individually in contact with the sample thermistor. Freezing units then were placed in a cryostat, which had been cooled to −30°C. Subsequent cooling curves were recorded with Microsen 1300S-XMK recorders.

SAEDTAS freezing curves of single 'Sunrise' *Forsythia* flower buds exhibited a broad exotherm from −8 to −10°C and a second sharp exotherm near −23 (Fig. 3). This second sharp exotherm is associated with a dramatic loss of tissue viability as verified by a refined triphenyl tetrazolium chloride reduction assay (9) and direct measurements of flower bud respiration after cooling using a differential respirometer (unreported data). This pattern of freezing curve kinetics is similar to that of acclimated peach flower buds (1) and is thought to represent the following general sequence: supercooling, intercellular freezing (first exotherm) deep supercooling, intracellular freezing (second exotherm), death (10).

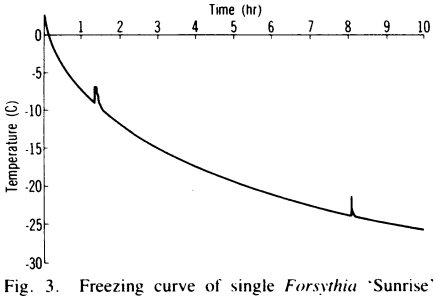

Fig. 3. Freezing curve of single *Forsythia* 'Sunrise' flower bud as recorded by SAEDTAS showing the first broad exotherm from −8 to −10°C and a second sharp exotherm near −23°.

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Evaluation of Apricot Flower Bud Hardiness Using a Computer-assisted Method of Thermal Analysis[1]

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Additional index words. Prunus armeniaca, freezing resistance, winter hardiness

Abstract. **A method for large scale evaluation of flower bud hardiness in apricots using a thermal analysis system interfaced to a computer is described. The technique measures the heat released during the lethal freezing of supercooled water within the bud primordia. Nine thermoelectric junctions wired in series were used to monitor the temperature of 10 individual buds. Bud temperature was scanned every 30 seconds and the data recorded on magnetic tape. The data were subsequently transferred to a minicomputer which analyzed and stored data and produced graphics. Computer assisted thermal analysis can accommodate a large number of samples and simplifies handling and storage of data. This technique has applications as a research tool, for determining critical bud temperatures and in screening selections from a breeding program.**

The dormant flower buds of several important horticultural crops supercool and thereby avoid freezing injury (1, 2, 4). Thermal analysis studies have demonstrated the occurrence of a low temperature exotherm resulting from the freezing of supercooled water. Quamme (4) demonstrated that the temperature at which this exotherm was initiated was closely correlated with the temperature of freezing injury in several species of *Prunus*. Thermal analysis has been employed primarily in research on the nature of freezing in-

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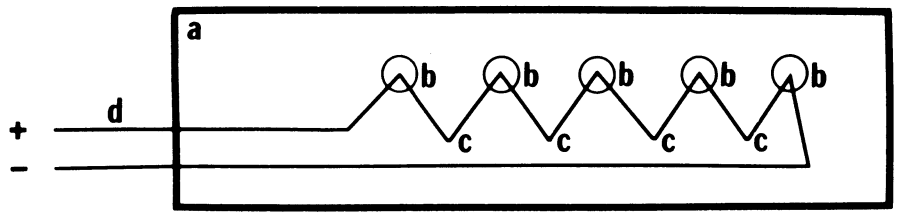

Fig. 1. Apparatus used for simultaneous thermal analysis of ten flower buds. Nine thermoelectric junctions were wired in series and mounted on a piece of poster board (a). The positive thermoelectric junctions (b) were mounted over holes in the poster board. Buds were mounted on each side of the poster board so that two buds made contact with each of the five positive thermoelectric junctions. Negative thermoelectric junctions (c). Thermocouple extension wires (d).

jury, however, a few attempts have been made to use it as a screening technique for winter hardiness. Quamme and coworkers (5) used the technique to compare the bud hardiness of peach cultivars, and Proebsting and Sakai (3) used thermal analysis for determining critical bud temperatures. Although thermal analysis is a sensitive method for determining the lethal temperature of buds, the technique is generally not employed in breeding programs since it is both time consuming and difficult to process large numbers of samples. We describe a thermal analysis system which is interfaced to a computer. With this configuration large numbers of samples can be processed, stored, and analyzed. Incorporating these features makes thermal analysis a useful screening technique.

Twigs from trees of apricot (*Prunus armeniaca* L.) were harvested on February 26, put in plastic bags, and placed in insulated containers partially filled with crushed ice for transportation back to the laboratory. All manipulations of the buds were performed outside the laboratory building to prevent the buds from warming and deacclimating. Flower buds were excised from the twigs along with a small portion of twig tissue. An apparatus with 9 thermoelectric junctions in series was used to monitor the temperature of 10 individual buds (Fig. 1). The thermoelectric junctions were constructed of 36 guage copper and constantan wires soldered together and mounted on a 4 × 14 cm piece of poster board. Five 0.6 cm holes were punched in the poster board so that the 5 thermoelectric junctions producing the positive signal were accessible from each side of the poster board. Using this configuration, 10 individual buds could make contact with the 5 positive junctions and be measured simultaneously. Buds were taped to the poster board with 3 × 20 mm strips of masking tape so that each bud made contact with a thermoelectric junction. The temperature measuring apparatus and attached buds were placed in a thermos bottle equilibrated to −2°C and the thermos bottle was transferred to a −60° freezer. The contents of the thermos bottles cooled at about 5°C/hr. Thermocouple extension wire was 24 gauge copper and constantan wire. The output from the 9 thermoelectric junctions wired in series was equal to the sum of the output of the 5 positive junctions minus the sum of the output of the 4 negative junctions. Therefore, the output represented the ambient temperature plus any differences in temperature between the positive junctions, which were in contact with the flower buds, and the negative junctions. The heat released during the freezing of water in each bud was detected by the adjacent thermoelectric junction and appeared as an exotherm on a time-temperature plot. A data logger (CR5 Digital Scanner, Campbell Scientific, Logan, Utah) scanned bud temperature every 30 sec and recorded the data on cassette tape. The data were subsequently transferred to a mini-computer (Macsym II, Analog Devices, Norwood, MA) which analyzed and stored data and produced graphics.

Thermal analysis of dormant apricot flower buds demonstrated the occurrence of 2 distinct exothermic events when the temperature was lowered from 0° to −25°C. the first exotherm was initiated at approximately −5°. This broad exotherm appeared to result from the freezing of water in the bud scales (1, 4). The second exotherm was generally initiated between −15° and −25° and resulted from the sudden freezing of supercooled water within the primordia tissue. The freezing of supercooled water within the bud primordia was lethal (4). Therefore, thermal analysis provided an excellent method for determining the lethal low temperature for individual buds.

Although thermal analysis offered several advantages for screening selections for cold hardiness, the utility of the technique was limited by the number of buds which could be analyzed concurrently. One method used to increase the techniques effectiveness was to employ thermoelectric junctions wired in series. Quamme and coworkers (5) used 9 thermoelectric junctions in series to analyze 5 flower buds per channel. We have modified this configuration to enable us to monitor 10 buds per channel. Also, mounting the thermocouple junctions on poster board provided structural support to the fine thermocouple wires and a base to which the bud could be attached and brought into contact with the thermocouple junctions.

The utility of thermal analysis as a screening procedure was also enhanced by increasing the number of selections which could be tested concurrently. A data logger interfaced to a computer was used to collect bud temperature data. This data logger had the capacity to monitor 50 channels concurrently. By interfacing the data logger with a computer, the large volume of data points compiled could be stored, and analyzed. With these modifications, thermal analysis can be performed on far more samples than could be done using a multipoint recorder. When the size and shape of exotherms are of interest, the computer can produce plots of bud temperature vs. time or differential plots of bud temperature vs. reference temperature.

Fig. 2 represents a typical plot of the output obtained when 10 buds were analyzed using thermoelectric junctions in series. Each of the deflections occurring between −18 and −22°C corresponded to an exotherm produced by the crystallization of supercooled water within a bud. Large deflections were probably the result of simultaneous freezing of more than one bud. With this data, the mean and the range of lethal bud temperatures were determined for a given set of buds. Using this system, the bud hardiness of 10 apricot selections was evaluated (Table 1). A range of hardiness was observed, V51095 was the least hardy, and the OK 10114 selection was the hardiest. The remaining selections showed very little difference in bud hardiness at this time.

The described modifications enhance the

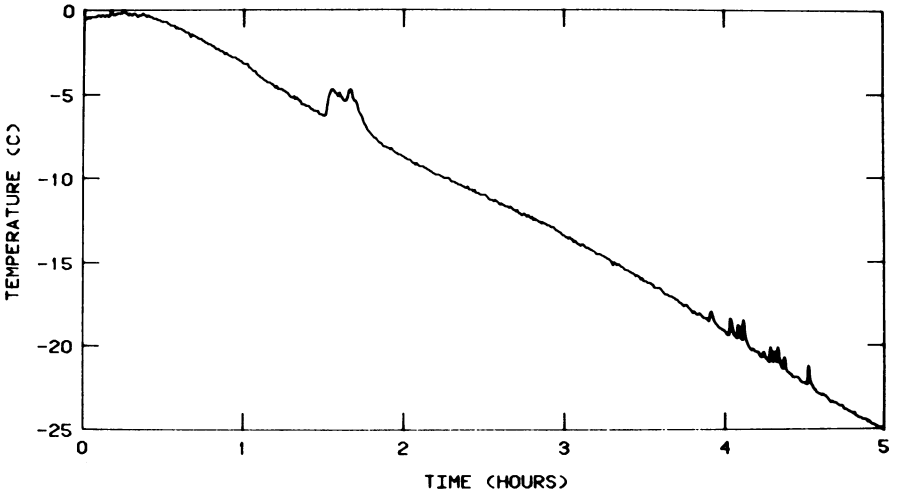

Fig. 2. Thermal analysis of 10 apricot flower buds harvested from selection F69-52. Plot of bud temperature versus time was obtained using 9 thermoelectric junctions in series. Deflections in time-temperature plot are exotherms produced by the freezing of individual buds.

Table 1. Bud hardiness of apricot selections as determined by thermal analysis.

Selections	Temp of exotherm initiation (°C) Mean	Range
V 51095	−17.2a[1]	−9.0 to −21.0
B 66130	−18.7ab	−16.3 to −23.0
Vivagold	−19.4b	−16.7 to −21.3
F69-85	−19.9b	−18.3 to −22.1
B 66209	−20.0b	−18.0 to −22.0
NJA-1	−20.1b	−18.3 to −22.0
F69-52	−20.1b	−18.0 to −22.0
S4E-55	−20.2b	−15.0 to −22.6
P7-70	−20.4b	−17.3 to −22.0
OK 10114	−23.0c	−22.3 to −24.0

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

utility of thermal analysis for routine screening of bud cold hardiness in stone fruits. The technique has applications as a research tool, in screening selections from a breeding program and in determining critical bud temperatures.

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Movement of Granular Simazine by Wind Erosion[1]

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Additional index words. herbicide, pesticide, *Prunus persica*

Abstract. **An early spring wind storm 8 days after application of granular simazine [2-chloro-4,6-bis (ethylamino)-*s*-triazine] to sandy loam soil reduced the amount of simazine in the treated area to 57% of that applied. The herbicide was deposited up to 2½ m downwind of the area of application at concentrations phytotoxic to susceptible crops. These results and observations made in other years suggest that herbicide loss by wind erosion may be more significant than loss by water erosion.**

Simazine is a selective herbicide for broadleaf and grass weed control in field crops, orchards, vineyards, woody nursery stock and non-cropped areas. In southwestern Ontario the granular formulation is recommended for weed control in established fruit trees (4) and its extension to newly-planted orchards is being considered. Simazine is herbicidally active through the root with limited foliar activity. Many vegetable crops are very sensitive to simazine and movement of herbicide by wind or water from the point of application to these crops is a concern.

The movement of herbicides by water is well documented (1, 2, 6, 8) but few reports are concerned with wind transport. Herbicide injury to susceptible crops downwind of areas treated with volatile chemicals has been reported (9). In many parts of Canada and especially in southwestern Ontario strong winds in the spring cause considerable soil movement. Herbicide injury has been observed on susceptible weeds and crops in experiments downwind of herbicide applied to Fox sandy loam soil following high winds but the extent of herbicide loss has not been quantified. The present study was conducted to quantify the extent of granular simazine movement by wind.

The study area was part of a larger experiment on efficacy of selected herbicides for weed control in transplanted peach (*Prunus persica* (L.) Batsch) which consisted of 16 treatments in plots 2 × 6 m. Treatments were in a completely randomized block design with blocks oriented with the longitudinal axis in a N-S direction. Two of the blocks were located adjacent to each other in the north half and 2 adjacent in the south half of the field. The area was situated downslope of an open area east of the experimental area on Fox sandy loam which contained 1% organic matter. The southwesterly corner of 1 replicate was situated in a depression. Three peach trees had previously been planted in each treatment.

One treatment in each replicate received 4 kg a.i./ha granular simazine applied with a hand applicator on April 26, 1978. The simazine treatments were sampled at application time and again on May 5, the day after a strong north-east wind. Soil samples were collected downwind of the simazine treated area at the distances indicated in Table 1.

Simazine was extracted from 50 g of soil by shaking the sample for 2 hr with 100 ml methanol. Samples were filtered under suction and the extracts reduced to dryness at 40°C on a flash evaporator. The residue was dissolved in ethyl acetate for analysis by gas chromatography. The 0.5 m × 3 mm i.d. glass column was packed with 5% OV-17 on 60–80 mesh Gas Chrom Q. Injector, column and detector temperatures were 180, 180, and 230°C, respectively. Air, hydrogen and carrier (He) gas flow rates were 200, 6 and 30 ml/min respectively. Simazine was detected on a N thermionic sensitive detector.

In this study, wind erosion was not maximized because of the location of the treatments in the field, the wind direction and topography of the land. Hence, the results do not reflect the maximum movement of herbicide which could be expected had the treatments been located further upslope and the wind perpendicular to the treated area. The average wind speed on May 4, the day of the storm, was 21 km/hr with gusts to 59 km/hr. No precipitation fell from April 26 to May 3. On May 4 and 5, 11 mm of precipitation fell.

The initial amount of simazine applied to the soil average 4.4 ± 0.8 kg/ha. After the wind storm the amount of simazine which remained in the treated area averaged 2.5 ± 0.3 kg/ha with the rest deposited up to 2½ m downwind of the treatments (Table 1). The loss of simazine from the treatments was attributed to wind removal since volatile losses of simazine added to soil as the wettable powder are negligible (3). Simazine availability from the granule is less than from the wettable powder formulation (5). Air temperature averaged 8°C and soil moisture content dropped from 12 to 7% (w/w) over the week before the wind storm, thus, biological and chemical degradation of simazine in the soil would be insignificant (7).

About 43% of the simazine was removed from the treated area by wind erosion. This is considerable greater than soil losses by water erosion which range from 0–5% of that applied (8). The simazine wad deposited 2½ m downwind of the treatments at quantities sufficiently high to be phytotoxic to susceptible crops or to impair the quality of adjacent irrigation ponds or water ways. In past years we have observed herbicide transport by wind erosion of wettable power or emulsifiable concentrate formulations of other herbicides,

Table 1. Movement of granular simazine downwind of a treated area.[z]

Distance downwind from treatment (m)	Simazine amount (kg/ha) Range	Mean ± SE
0.00	1.0–4.6	2.5 ± 0.3
0.25	0.2–1.6	1.0 ± 0.8
0.50	0.4–3.7	1.9 ± 1.7
0.75	0.1–0.7	0.4 ± 0.3
1.00	0.2–0.8	0.5 ± 0.3
1.50	0.1–0.4	0.3 ± 0.2
2.00	<0.1–0.6	0.2 ± 0.3
2.50	<0.1–0.2	<0.1 ± 0.1

[z]Initial amount 4.4 kg/ha, applied April 26, sampled May 5, 1978. Average of 3 replicates.

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