# Indicator of Freezing in Citrus Seedlings[1]

G. Yelenosky, G. Horanic, and F. Galena[2]
*U. S. Department of Agriculture, Orlando, Florida*

*Abstract.* **Studies show electrical potential (Millivoltage output) generated by citrus seedlings is useful as an indication of freezing in hardened seedlings or where freeze rates are $1^\circ$ hr$^{-1}$ or less. Needle-sharp probes of a gold-amalgam wire attached to a strip chart recorder with a variable millivolt supply were used to detect mv changes in seedlings exposed to freeze conditions in an artificial environment room. An abrupt increase of 2 to 6 mv in the mv signal indicated the onset of freezing in the seedlings as checked by the heat of crystallization measured with thermocouples, visual signs of freezing, and subsequent physical damage studies.**

The electrical potential (millivoltage output) generated by citrus seedlings shows consistent impulses that we find useful as an indication of freezing in the seedlings. As described below, electrical pressure (EP) has advantages over the temperature (T) increase in freeze detection under certain situations. EP in plants has been previously described by others (1,2) but not as an indicator of freezing.

Two, 3–cm long pieces of gold-amalgam wire were made needle sharp at one end and matched for electrical activity ($\mu$v) in glass-distilled $H_2O$. These needle-sharp probes were embedded 1 cm apart and protruded 3 mm out of the end of a plastic clip. A 36-gauge copper-constantan thermocouple was placed between the gold-wire probes. This provided a cross-check between the heat of fusion via the thermocouple and millivoltage output (mv) via the gold probes 0.5 cm on each side of the thermocouple. The plastic clip was then attached about 15 cm above soil surface on the main stem of a citrus seedling. The probes penetrated about 2 mm into the stem, whereas the thermocouple was pressed tightly against the stem.

We attached the leads from the probes to a 0 to 100 millivolt strip-chart recorder. The leads from the thermocouple were attached to a thermocouple-compensated millivolt supply. The output of the millivolt supply was connected to the second channel of the 0 to 100 millivolt recorder. The temperature and the millivolt output of the seedlings were recorded simultaneously on the same strip chart.

We used 8-month-old 'Rough' lemon (*Citrus jambhiri Lush.*) grown in a peat-vermiculite soil mix in metal containers (15 cm diam and 18 cm high) in a glasshouse. Unhardened seedlings were used directly from the glasshouse, whereas hardened-off seedlings were preconditioned for at least 4 days at $2^\circ$ C in a controlled environment room. Relative humidity was maintained at 50% ± 5%. Lights (a mixture of fluorescent and incandescent) were on daily from 7 AM to 7 PM and intensity was about 2,00 ft-c at the top of the seedlings. Freezing was done in another controlled environment room. A variety of freeze situations were used, including differences in rate of temperature decrease and differences in the hardening status of the seedlings. In all cases, conditions were allowed to stabilize for 1 hr at $1.67^\circ$ prior to any freezing.

Results indicated an EP of 35 to 100 mv immediately after the probes were inserted into the stems of the seedlings. The activity of the signal, as indicated by the size of fluctuations per unit chart movement, was greatest at temperatures above freezing and decreased as the temperature decreased. The signal leveled off to a straight line on the chart just before freezing of the seedling was indicated by the T increase via the thermocouple. With unhardened seedlings, the mv signal abruptly increased by 2 to 6 mv. The increase occurred approximately 2 sec before the T increase started (Fig. 1A). This close association with the T increase, visual signs of freezing (water-soaking and curling of leaves), and subsequent physical damage studies indicate that the abrupt increase in the mv signal is a sign of freezing in citrus seedlings. With hardened seedlings, or where the freeze rate is slow ($1^\circ$ hr$^{-1}$ or less), a thermocouple often fails to indicate freezing. Under these same conditions, however, the mv signal is consistently found (Fig. 1B).

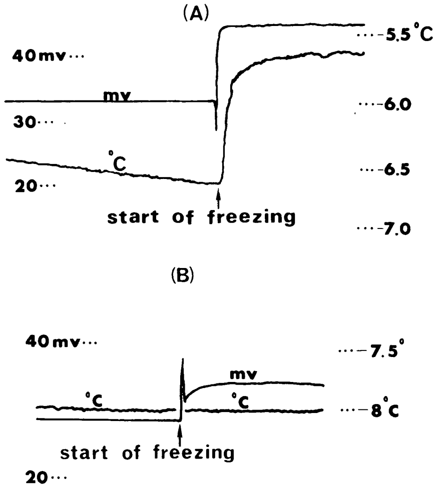

*Fig. 1. (A)* represents simultaneous measurements of freezing in the wood of unhardened citrus seedlings. ° C is the thermocouple technique (heat of fusion) and mv is the millivolt signal at the same site of measurement. Temperature was decreased at a rate of $4^\circ$ hr$^{-1}$. The chart speed was 2.54 cm min$^{-1}$.

*(B)* represents the failure of the thermocouple technique (°C) in contrast to the millivolt signal to indicate freezing in the wood of hardened off citrus seedlings at temperature decreases of $1^\circ$ hr$^{-1}$ or less.

We find the mv signal a reliable indicator of freezing and use it in conjunction with a thermocouple to indicate the onset of freezing and the temperature at which freezing started.

### Literature Cited

1. Asher, W. C. 1964. Electrical potentials related to reproduction and vigor in slash pine. *Forest Sci.* 10:116-121.
2. Sinyukhin, A. M., and I. V. Rutkovskii. 1966. An electrophysiological method of recording the vitality of woody plants. *Fiziologiya Rastenii* 13:349-357.

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[2] Plant Physiologist and Agricultural Research Technicians, respectively, Crops Research Division, Agricultural Research Service.

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# Determination of the Time of Onset of Rest in Spur and Shoot Buds of Apricot[1]

Juan Ramsay[2], George C. Martin and Dillon S. Brown
*University of California, Davis*

*Abstract.* **Apricot shoots were defoliated and spurs were decapitated and defoliated on successive dates to determine the onset of rest in specific axillary buds. While the spurs were still growing and the leaves expanding decapitation alone would induce axillary bud growth. Later, when the spurs and leaves stopped growing both decapitation and defoliation were necessary to induce axillary bud growth. Eventually when the onset of rest occurred both decapitation and defoliation would not induce bud growth. Decapitation alone was enough to induce bud growth of terminal shoots. After the onset of rest decapitation and defoliation would not induce bud growth in the terminal shoot buds.**

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[2] Present address: Nucleo Monagas, Universidad del Oriente, Jusepin, Venezuela.