Uptake and Metabolism of Sucrose in Cut Roses

R. E. L. Kaltaler and Peter L. Steponkus
Cornell University, Ithaca, NY

Abstract. When placed in either the modified Cornell Solution (2% sucrose + 200 mg/1 8-hydroxyquinoline sulphate) or distilled water, levels of 14C-labelled compounds in Rosa hybrida 'Red American Beauty' flowers increased linearly. Girdling the stems decreased accumulation of 14C in the petal tissue by only 25%. Fructose and glucose were the predominant sugars in petal tissues with only minor amounts of sucrose. Addition of sucrose to the preservative solution increased the levels of glucose and fructose but had little affect on the sucrose content. The data indicate that inferences of sugar accumulation in petals cannot be made from data on xylem conductivity.

Numerous studies have been directed to vascular blockage in cut flowers by measuring water conductivity in stem segments (1, 2, 3, 5, 6) or by measuring solution uptake by the entire cut flower (3, 5). Such work has established that water flow decreases with age and serves as the basis for inferences regarding the uptake and accumulation of sugar as a component of the preservative solution (1, 4). Lester and Durkin (4) concluded that sugar uptake decreases at the same rate as water uptake. Kuc (6) found that the ability to conduct water and 14C-glucose through the stem decreased steadily during the vase life, stopping completely after 5 days. She concluded that such a block would limit the carbohydrate supply to the petals. However, Stoltz (9) reported an increase in petal sugar levels of roses maintained in preservative solutions containing sucrose. Sacalis and Durkin (7) concluded that 14C-sucrose was taken up initially in the xylem, but that exogenous additives reached the flower via the phloem.

Many individuals (4, 9) also assume that the sucrose in preservative solutions is the ultimate sugar accumulating in the petals. However, Weinstein (8) found glucose to be the major sugar constituent of petal tissue from 'Better Times' roses.

Our purpose was to ascertain whether, 1) inferences of solute uptake could be made from measurements of solvent uptake, 2) preservative solutions affect sugar accumulation in petal tissue, and 3) sucrose is the major sugar accumulating in petal tissue.

Materials and Methods
'Red American Beauty' roses were grown under standard cultural practices in Cornell University greenhouses. After harvest, stems were defoliated, recut to a length of 33 cm and, unless otherwise noted, placed in distilled water or modified Cornell solution consisting of 2% (w/v) sucrose + 200 mg/1 8-hydroxyquinoline sulfate (8-HQS). They were held in the laboratory at 23°C with a 10-hr photoperiod at 315 lux.

At the designated time 3 flowers were removed from each treatment, and the petals were frozen in liquid N2 and lyophilized. The lyophilized samples were ground to 40 mesh in a Wiley mill and stored in a vacuum desiccator. Lyophilized powders were extracted with hot 80% ethanol and centrifuged at 20,000 x g for 15 min. The residue was re-extracted 2 additional times and the supernatants were combined, centrifuged at 20,000 x g for 15 min, and concentrated under laboratory at 23°C with a 10-hr photoperiod at 315 lux.

Fig. 1. Sugar content of petal tissue of flowers maintained in distilled water or in modified Cornell solution (2% sucrose + 200 mg/1 8-HQS).

vacuum. The concentrated extract was made up to 10 ml with deionized, distilled water and used in subsequent procedures. Carbohydrate content was determined by the anthrone method (9) and expressed as glucose equivalents.

Further fractionation of the petal extract into the organic acid, amino acid, and neutral (sugar) fractions was done on Dowex 50 (H⁺) and Dowex 1 (OH⁻) columns. Following concentration, aliquots were counted in a liquid scintillation spectrometer using Bray's solution. Vials were stored for 15 hrs before counting to minimize chemi-luminescence.

The neutral effluent containing the sugars was further fractionated by gas chromatography following the procedure of Pendergrass7. The silicated sugars were chromatographed on a Varian 1840-4 dual Aerograph equipped with H2-flame ionization detectors. Stainless steel columns (12.5' x 1/8") packed with 2% QF-1 on Varaport #30 (100/120 mesh) were used. The column temperature was programmed from 105-265°C at 8°C/min for the first 2 minutes and 6°C/min for the remainder of the program. Injector and detector temperatures were both set at 225°C. Peak areas of fructose, glucose and sucrose relative to standards were used to estimate concn.

Results and Discussion

In cut roses maintained in distilled water, petal sugar levels decreased after the first day whereas sugar levels in petals of flowers maintained in the Cornell solution increased during the entire 4-day period (Fig. 1). At the end of 4 days, sugar content of petals from roses in distilled H2O was 58% of the amount in petals from roses in the modified Cornell solution. Similar observations were made by Stoltz9 working with 'Better Times' roses.

In the past6, decreased levels of petal sugars as shown in Fig. 1 were ascribed to vascular blockage. This was a logical interpretation since it is well established that water uptake and xylem conductivity decrease with age. Thus, vascular blockage was inferred to reduce both solution uptake and also impede the movement of metabolites in a preservative solution or metabolites in subtending leaves to the petals. However, a direct measurement of exogenous sugar accumulation in the petals is needed to answer this question. When uniformly labelled 14C-sucrose was added to the modified Cornell solution, 74% of the total radioactivity accumulating in the petals was in the sugar fraction, 12% in amino acids, and 3% in the organic acid fraction (Fig. 2). In petals of flowers in distilled water containing 14C-sucrose, there was a similar distribution pattern of the label into each of the fractions, but the total amount of radioactivity accumulated in the petals was only 13% of that in petals in the modified Cornell solution (Fig. 2).

Again the data would point to the fact that vascular blockage in flowers maintained in distilled water reduced the amount of 14C accumulated in the petal tissue. However, the decreased levels of 14C in petals of flowers in distilled water could have been due to smaller sugar pools as compared to those from the preservative solution. Thus, with a smaller sucrose pool, the amount of 14C-labelled compounds accumulating in the petals would be decreased because of an increased probability of the 14C-sucrose molecules being metabolized. When flowers were

![Fig. 2. Distribution of 14C-label in ethanol-soluble compounds of petal tissues of flowers maintained in distilled water or in chemical (modified Cornell solution). 14C-sucrose (3.5 mc, sp. act. 4.88 mc/mM, uniformly labelled) was added to each solution.](image1)

![Fig. 3. Accumulation of 14C in petal tissue of flowers maintained in 2% or modified Cornell solution. 14C sucrose (3.5 mc; sp. act. 4.88 mc/mM, uniformly labelled) was added to each solution.](image2)
placed in solutions of either 8-HQS + 2% sucrose or in 2% sucrose alone containing equal amounts of 14C-sucrose, the amount of 14C accumulating in the petals was identical (Fig. 3). Furthermore, previous work from this laboratory, Gilman and Steponkus (3), (using roses from the same plants as were the roses in this experiment) has shown that xylem conductivity of stems maintained in 8-HQS or 8-HQS + sucrose was the same, while xylem conductivity in sucrose or water was the same. In the presence of 8-HQS, high levels of xylem conductivity were maintained, while in sucrose or in water, xylem conductivity decreased logarithmically with time. It is interesting to note that during this previously reported logarithmic decline in xylem conductivity in the absence of 8-HQS (3), the accumulation of 14C in petals proceeded linearly in either the presence or absence of 8-HQS (Fig. 3). Thus, it can be concluded that decreases in xylem conductivity cannot always indicate a corresponding impairment in sugar accumulation in the petals.

A logical assumption is that sucrose is being taken up and transported to the petals via the phloem. To explore this possibility, harvested 'Red American Beauty' roses were both steam and mechanically girdled below the first 5-leaflet leaf and along with an equal number of non-girdled roses placed in modified Cornell solution to which 14C-sucrose had been added. Roses were removed from the solutions after 4, 8, 20, 44 and 68 hours and assayed as previously described. Levels of 14C-labelled compounds increased in petals of both girdled and ungirdled flowers (Fig. 4). However, towards termination of the experiment, the accumulation of 14C-labelled compounds took place at a reduced rate for the girdled roses than for the non-girdled roses (Fig. 4). Our results suggest that the phloem (up to the first 5-leaflet leaf) does not account for most of the sucrose uptake since girdling only reduces the ultimate levels of 14C-labelled compounds accumulated in the petals by 25%. This observation appears to be in opposition to that of Sacalis and Durkin (7) that girdling nearly completely restricted movement of 14C to the flowers. However, it should be emphasized that the 2 experimental procedures differed greatly in that Sacalis and Durkin did not defoliate the rose stems, the flowers were held in water except for pulse labelling, but more importantly the position of their girdle was above the last leaf up the stem. Thus, they conclude that 14C-sucrose was first taken up in the transpiration stream of 'Forever Yours' roses and selectively accumulated by leaves before being translocated to petals via the phloem. Such a situation could exist and allow for the 2 apparently conflicting results. That is a low girdle, as in our study, would not affect the initial uptake via the xylem, whereas a girdle above the last leaf would affect the accumulation of 14C-compounds in the petals if there was xylem to phloem transfer in the leaves. In our study, all foliage was removed and the xylem to phloem transfer could have been accomplished at an alternate site in the receptacle or the stem itself.

Fig. 4. Effect of girdling on 14C deposition in petal tissue of flowers maintained in the modified Cornell solution containing 3.5 uc of 14C-sucrose (sp. act. 4.88 mc/mM).

Fig. 5. Endogenous sugar content of petal tissue of flowers maintained in distilled water (control) or in modified Cornell solution (chemical).
The Influence of Processing and Maturity on Volatile Components in Bush Snap Beans, Phaseolus vulgaris L. 1

D. K. Toya2, W. A. Frazier3, M. E. Morgan4, and J. R. Baggett3
Oregon State University, Corvallis

Abstract. Concentration of 17 volatile components in canned, frozen, and fresh green bean pods was determined by gas-liquid chromatography. Only 1-octen-3-ol differed quantitatively with cultivar. Almost all volatile components detected in frozen pods were greatly reduced or lost as compared to those in fresh pods. In canned pods most of the "higher boiling" compounds were found to decrease while some "lower boiling" compounds increased considerably. 1-octen-3-ol, a significant component of bean flavor, increased with time after thawing of the frozen samples, while very little change was observed in the concentration of other compounds. In fresh green beans the concentration of 1-octen-3-ol was highest early in pod growth and decreased rapidly through the 21st day after anthesis and attainment of maximum marketable pod size.

MacLeod and MacLeod (7) reported the presence of 25 volatile compounds in fresh runner beans. Trans-2-butenol, cis-2-pentenol, cis-3-hexanol, and butyl isothiocyanate were identified in fresh but not in frozen runner beans while acroleins, trans-2-hexanol, and dipropyl disulfide were identified in frozen but not in fresh pods. Some 40 volatile compounds were identified in the liquor of canned snap beans by Stevens et al. (16). They concluded that cis-3-hexanol, 1-octen-3-ol, linalool, α-terpineol, pyridine, and furfural are of primary importance in the flavor of canned snap beans, particularly in the difference in flavor between cultivars. No comparisons were made between the volatile compounds in canned and fresh beans.

Identification of volatile components found in green beans has been reported, but effects of processing on these components have been essentially ignored. We report the effect of processing on volatile flavor components of green beans, in particular the compound 1-octen-3-ol, which is reported (16, 17) as being of primary importance in 'Blue Lake' snap bean flavor. The research was done in conjunction with a study of the inheritance of volatile components in crosses between bush green bean cultivars.

Materials and Methods
Bush snap beans 'Romano FM-14' (FM-14), 'Gallatin 50'

1Received for publication December 3, 1973. Technical Paper No. 3716. OR Agricultural Experiment Station. This investigation was supported in part by an Aid to Education Grant from Campbell Soup Company. The authors are indebted to L. M. Libbey for assistance in obtaining and interpretation of the mass spectra.
2Present address: Department of Vegetable Crops, Cornell University, Geneva, NY.
3Department of Horticulture.
4Department of Food Science and Technology.