GALA SPLITTING

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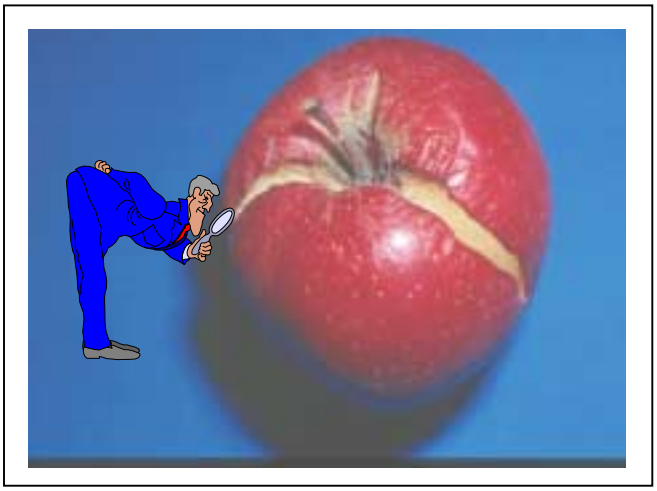
INTRODUCTION

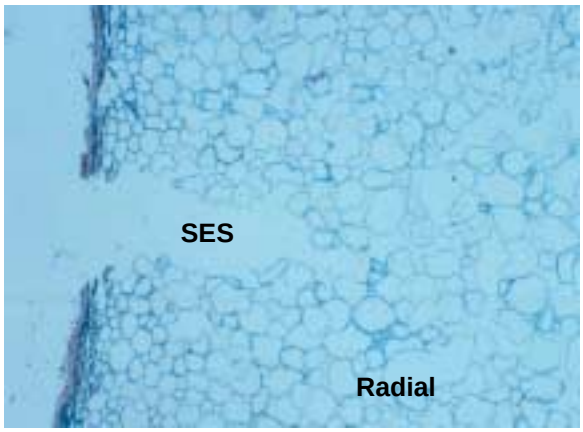
Stem-end splitting (SES) of 'Gala' apples occurs in all of the apple-producing regions in Washington, as well as in other parts of the world. Stem-end splitting frequently can be severe enough to result in significant cullage and financial loss to many Washington apple growers.

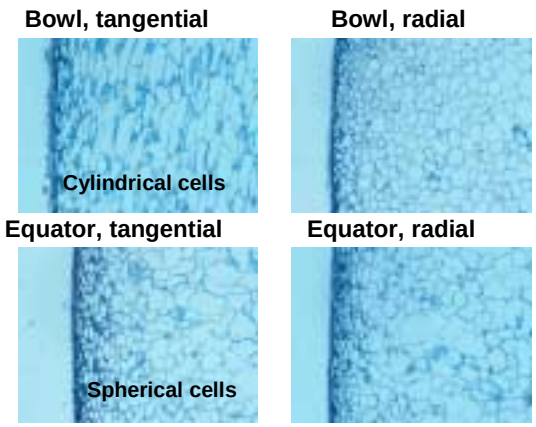


Stem-end splitting is usually maturity related (Andrews et al., 1999), so the risk of it occurring increases when fruits are left on the trees until satisfactory color grade is reached or when insufficient labor is available for a timely harvest. In terms of internal maturity, the flesh (i.e., cortical) tissue that forms the stem bowl is more mature than tissue near the equator. Because of this differential maturity, we believe that the cell walls of flesh near the stem bowl weaken sooner than cell walls in other parts of the fruit. Our microscopic studies of SES indicate that splitting is due to separation of the wall between cells (probably of the pectin-rich middle lamella), and not cell breakage. The shape and arrangement of cells in the stem bowl also favor this separation. By indirect evidence, we believe that the internal forces within the stem bowl region are greater than at the equator of the fruit, and that these forces increase with advancing maturity. Therefore, we hypothesize that it is the combined effect of increasing internal forces on the weakening, easily separated, cell walls of the flesh in the stem bowl which promotes splitting in this part of the fruit.

STRUCTURAL CHARACTERISTICS

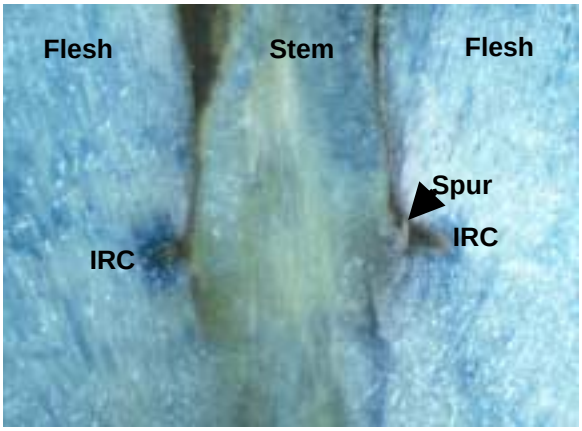
We believe that there are specific structural characteristics of the stem bowl flesh of 'Gala' apples which make them more susceptible to splitting than flesh in other parts of the fruit, or of other cultivars. When 'Gala' apples are sectioned radially and longitudinally and each orientation's cut surface is examined through a light microscope, it is apparent that flesh cells in the stem bowl are elongated and cylindrically shaped, and they are oriented more or less vertically with respect to the central axis of the fruit. Cells near the equator, and probably in other parts of the fruit, are roughly spherical in shape. The cylindrical, vertically oriented cells in the stem bowl could make them more prone to separation between the cells (Vincent, 1990). There may be other structural features that we have not identified which also may contribute to an increased likelihood of splitting in the stem bowl, such as the rigidity/flexibility of the epidermis and hypodermis (i.e., skin).





INTERNAL RING CRACKING

We have identified two categories of splitting. The most common category is not associated in 'Gala' with internal ring cracking (IRC), a radial crack found internally at the base of the stem, while the second category may be associated with IRC (Opara, 1996a, b). It appears that IRC is caused by a hardened "spur" near the base of the stem, which presses against adjacent tissue with sufficient force to shear and tear the elongated cells which characterize this part of the fruit's flesh. The percentage of splitting in each category appears to vary among cultivars, years, and orchards. Over four years of evaluation we have observed only about 20% of split 'Gala' fruit with IRC. Although we have not evaluated 'Fuji' apples as thoroughly, the percentage of split 'Fuji' apples with IRC may be higher than for 'Gala'.



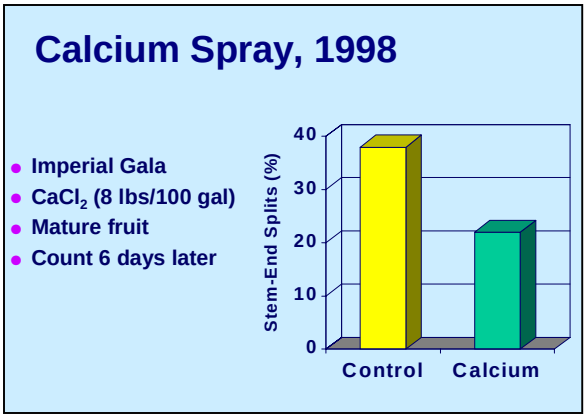
PREDICTING SPLITTING

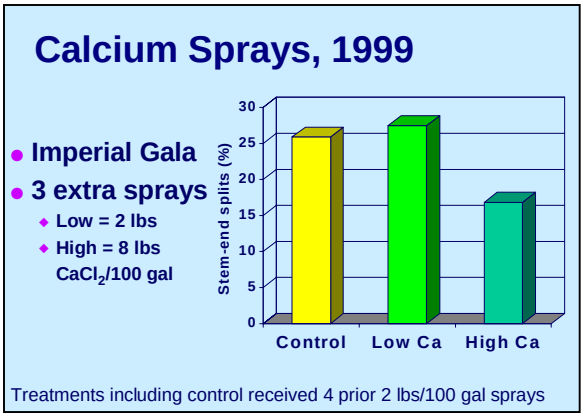
Artificial SES can be induced by making a shallow, vertical incision with a scalpel through the skin in the stem bowl. If internal forces are sufficient within the bowl, this incision will widen after about 48 hours, mimicking a fresh split. A similar incision at the equator of the fruit does not widen appreciably due to internal forces, but it does widen slightly because of dehydration. When the width of the incision at the equator is subtracted from the width of the stem bowl

incision, there is an increase in widening of the stem bowl incision as fruit approach harvest maturity. Although we have not yet used this test for comparisons across orchards, strains of 'Gala', or treatments, it may be a useful test for predicting susceptibility to splitting.

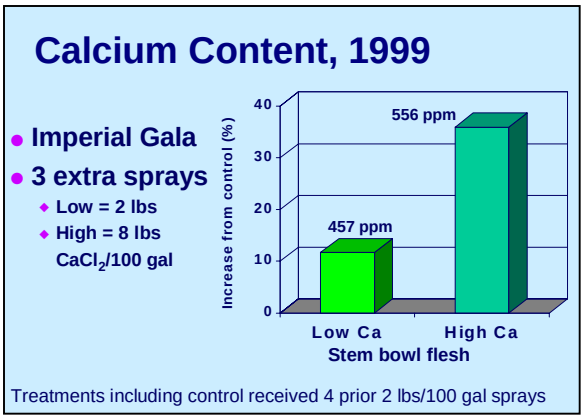
CALCIUM

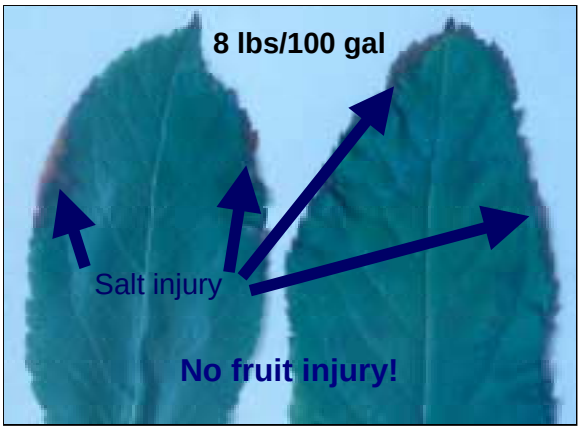
In 1998, we applied calcium chloride (Moraleaf® Calcium) at an 8 lb/A rate to 'Imperial Gala' trees just prior to harvest. This treatment reduced splitting at harvest to 22%, from 38% for the control. In our 1999 trial, we applied three weekly pre-harvest sprays of calcium chloride at either 2 or 8 lb/A rate. Both treatments, including the control, received four mid-season calcium sprays at 2 lb/A. At harvest, both the control and low rate pre-harvest calcium treatment had 26-27% splitting, while the high rate calcium treatment had less than 17% splitting.



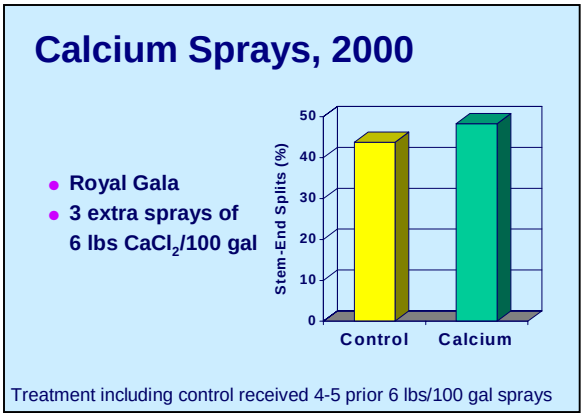


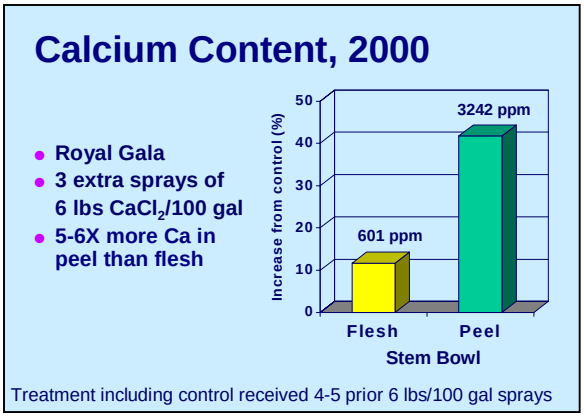
Compared to the control, the low and high rate calcium treatments had 12 and 36% greater calcium content in stem-bowl flesh, respectively. The high rate also caused salt injury to the leaf margins, but no fruit marking was observed.





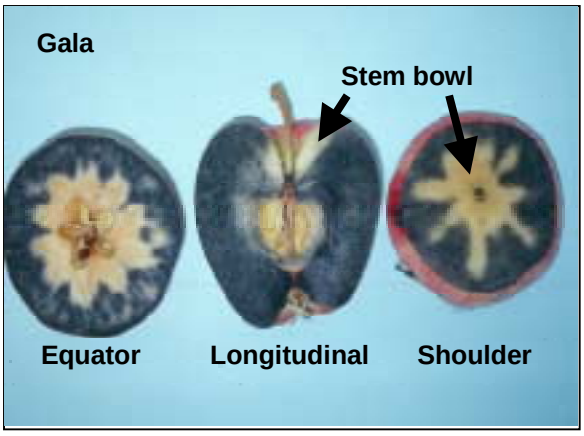
In 2000, we applied three weekly pre-harvest sprays of calcium chloride at 6 lb/A rate to 'Royal Gala' trees, following a standard five application, 6 lb/A calcium chloride program. However, splitting exceeded 40% for both the control and treatment, and the increase in calcium content of the stem bowl flesh was only 12% higher for the calcium treatment. Peel from the stem bowl had 5-6X higher calcium content than the flesh. Therefore, the cuticle, epidermis and hypodermis tissues may be barriers to increasing flesh calcium concentrations by late season applications.

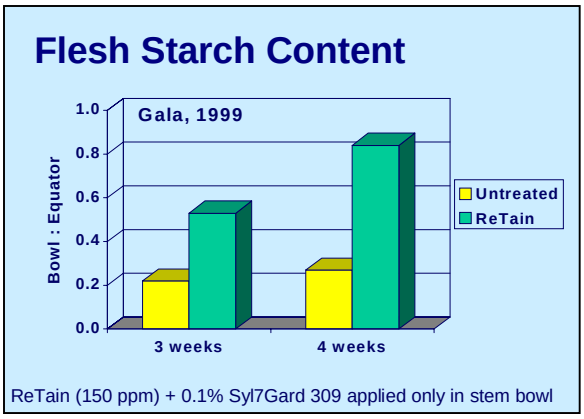




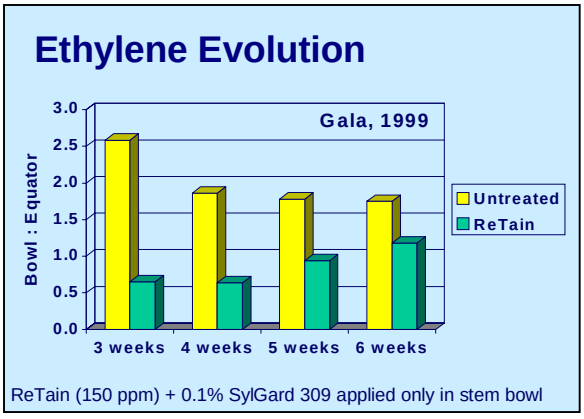
FRUIT MATURITY

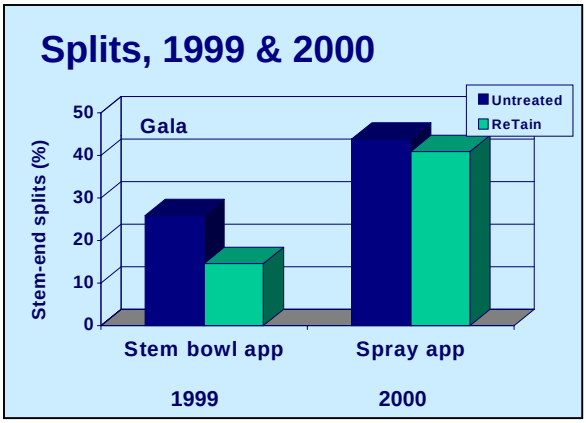
As fruit approach harvest maturity, a starch-iodine test performed on longitudinally cut 'Gala' apples shows clearing of starch from flesh in the stem bowl prior to flesh at the equator. This indicates that stem-bowl flesh is one of the most physiologically mature parts of the fruit. We assume that hydrolysis of cell wall components is associated with this earlier maturation of the stem bowl, thus weakening them at the same time that internal forces in the stem bowl are increasing. In untreated Gala apples, the measured starch content of stem bowl flesh was only 20% of that at the equator, while ethylene evolution was 2-2.5X higher in stem bowl flesh than equator flesh.





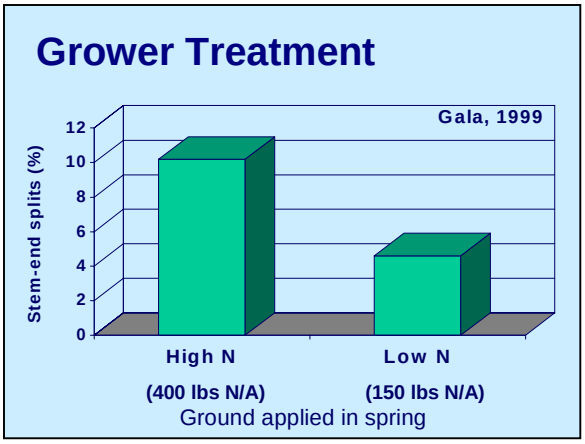
When 150 ppm ReTain™ (a.i.=aminovinyl glycine) was applied only into the stem bowl of 'Imperial Gala' apples four weeks before harvest in 1999, starch degradation and ethylene evolution in stem bowl flesh relative to equator flesh decreased. Stem bowl flesh had 60% of the starch content and 60-70% of the ethylene evolution of equator flesh. Splitting in the ReTain treatment was reduced to 14%, from 26% in the untreated fruit. In 2000, a spray application of 150 ppm ReTain with 0.05% SylGard 309 did not reduce splitting in 'Royal Gala', with both treatment and control above 40% splitting. Modifying maturity patterns specifically in the stem bowl may not be possible with standard spray applications.





GROWER TREATMENTS

We have also evaluated grower treatments to reduce splitting, including reduced irrigation and nitrogen applications. Despite an insufficient sample size, reduction in splitting was observed by reduced irrigation in one grower's non-replicated trial. Evaluation of a larger sample size indicated that reduced spring nitrogen application (150 vs. 400 lbs N/acre), reduced splitting of 'Royal Gala' apples from 10 to 5% in 1999.



FUTURE RESEARCH

Stem-end splitting is a complex physiological disorder, which likely will require multiple approaches to reduce its incidence in 'Gala' orchards. Reducing the rate of weakening of cell walls and decreasing internal forces within the stem bowl are two approaches that in combination may reduce splitting. Research efforts should include treatments that increase calcium content, delay the ripening climacteric, and reduce internal forces specifically within the stem bowl. These treatments could include: 1) post-bloom and pre-harvest calcium sprays (CAUTION: use a formulation that does not cause fruit marking); 2) ethylene inhibitors; 3) fruit growth and development bio-regulators, e.g. cytokinins, gibberellins, and gibberellin inhibitors; and 4) irrigation and nitrogen management, and other cultural practices. Obviously, some apple cultivars are not as susceptible to splitting as others. Differences in fruit growth and cell shape and orientation between susceptible and non-susceptible varieties may serve as selection criteria among 'Gala' strains and in breeding programs to reduce this cultivar's genetic susceptibility to splitting. In the meantime, it would be useful to have a technique to predict the probability that a specific lot of fruit would, or would not, have high levels of splitting before sorting and storage. An incision test or longitudinally oriented starch index may be the best candidates for this approach. Currently, however, growing strains of 'Gala' that permit earlier harvest to meet grade is the best way to avoid maturity related splitting.

REFERENCES

Andrews, P.K., Collier, M.L., Fahy, D., and Evans, R.B. 1999. Gala stem-end splitting and internal ring cracking. Good Fruit Grower 50 (11): 20-23 (June).

Opara, L.U. 1996a. What is stem-end splitting in apples? Good Fruit Grower 47 (16): 57-59 (Nov.).

Opara, L.U. 1996b. Some characteristics of internal ring-cracking in apples. Fruit Varieties J. 50 (4): 260-264.

Vincent, J.E.V. 1990. Fracture properties of plants. Advances in Botanical Research 17: 235-287.

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