CITRUS FRUIT ABSCISSION

J. K. BURNS
Citrus Research and Education Center
Lake Alfred, FL 33850

I. What is abscission?

The term 'abscission' is used to describe a distinct process that culminates in the shedding of plant parts (Sexton and Roberts 1982). Fruit, flowers, flower parts, leaves, stems, and various other vegetative structures are shed at different periods throughout the life of a plant. Plant organs can be shed by mechanical tearing or as a result of tissue death and decay, such as occurs with the shedding of roots. Abscission, however, is distinct from loss of organs by mechanical tearing or tissue death because it occurs in well-defined areas of the plant known as abscission zones. As plant organs abscise, a series of physiological and biochemical events in the abscission zone lead to cell wall breakdown in the few rows of cells on either side of the fracture line and ultimately to detachment of the organ.

II. Citrus fruit abscission

Citrus fruit abscission and its regulation have attracted the attention of Florida researchers and the citrus industry for many years (Wilson 1966; Wilson et al 1977). Mature citrus fruit require unusually large forces to remove them from the tree (break-strength), and this has been an obstacle to efficient and economical mechanical harvesting (Goren 1993; Whitney 1995). The unique anatomy and physiology of the citrus fruit abscission zone before, during and after abscission significantly affects the break-strength of the fruit.

II. A. Anatomy of citrus fruit abscission

Citrus in general has four abscission zones. Fruit have two abscission zones: the first abscission zone is located between the branch and the fruit peduncle (AZ-A) and the second is found in the fruit calyx (AZ-C). Leaves have two abscission zones: the first is located between the branch and the petiole (branch AZ), and the second is found between the petiole and the leaf blade (laminar AZ) (Figure 1).

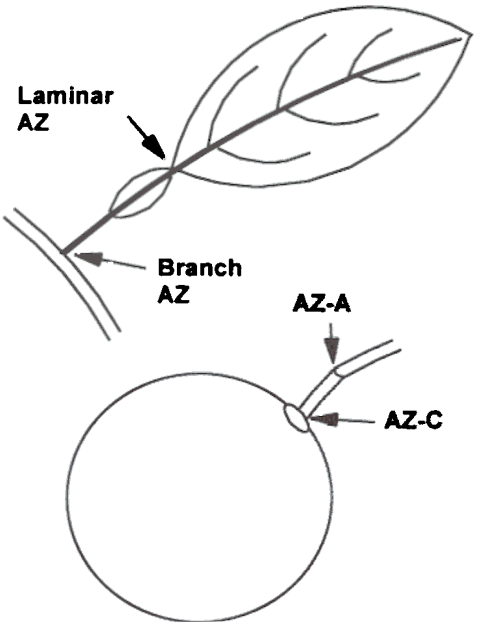

Figure 1. Citrus leaf and fruit abscission zones.

During the first 8 weeks of fruit development, fruit normally abscise at AZ-A. After this time, AZ-A loses it's ability to readily abscise. Fruit older than 8 weeks abscise only at AZ-C, however, young fruit also have the ability to abscise at AZ-C. Although older fruit do not abscise at AZ-A, microscopy studies have shown that abscission-related events are actually occurring in isolated pockets of tissue in AZ-A. However, fruit fail to abscise at this abscission zone because of extensive lignification and secondary wall formation of abscission zone cells that surround the vascular tissue and inner cortex (Goren and Huberman 1976; Greenberg et al 1975).

Cells of the AZ-C undergo numerous anatomical changes that lead to abscission. Prior to the onset of abscission, the cell layers that will be involved in the abscission process can readily be distinguished from surrounding tissues because of the presence of starch grains. Evidence of cell divisions are observed early in the abscission process and abscission zone cell walls become thickened. Cell wall thickening is a result of breakdown of the middle lamella followed by hydration of cell wall components. As abscission progresses, the primary cell wall is degraded. Eventually, a fracture develops across the abscission zone resulting in fruit separation from the peduncle (Huberman et al 1983; Iwahori and Van Steveninck 1976).

II. B. Physiology of mature citrus fruit abscission

Abscission is a natural plant process and many aspects of its physiology and regulation are unknown. However, it is well established that plant hormones are involved in control of abscission (Sexton and Roberts 1982). Ethylene accelerates abscission, and this property has been utilized to develop abscission materials for the purpose of loosening fruit of various agricultural crops for harvest. Normally auxin delays abscission, but the effect of auxin on abscission is related to the endogenous hormonal balance that changes as abscission proceeds.

Marked physiological and biochemical changes occur during abscission of mature citrus fruit. When ethylene is used to accelerate abscission, increased amounts of mRNA and protein are measured in AZ-C tissue (Kazokas 1997). We do not know the function of most of this mRNA and protein, but some mRNA and proteins are associated with the enzymes cellulase and polygalacturonase (PG)(Burns et al 1995). The activities of cellulase and PG greatly increase during

the abscission process in AZ-C (Table 1). These enzymes are thought to function in the degradation of adhesive cell wall components that link abscission zone cells together, and this increase in enzyme activities is highly correlated with reduction in fruit break-strength (Goren and Huberman 1976; Greenberg et al 1975).

Table 1. Total protein, total mRNA, cellulase and PG activities of Valencia orange calyx abscission zones (AZ-C). AZ-C were either removed from freshly harvested fruit explants or removed from explant previously treated with 5 ppm ethylene, 30°C, 95% RH.

	Total protein (mg/g FW)	Total mRNA (ng/μg total RNA)	Cellulase activity (μg reducing groups/mg FW)	PG activity (μg reducing groups/mg FW)
0 hr ethylene	2.8	182	19.7	30.5
24 hr ethylene	3.4	368	125.1	147.3

Ethylene and auxin interact during abscission of mature citrus fruit. When ethylene is first applied, there is a period of time in the AZ-C when changes in cellulase and PG activities and fruit break-strength cannot be detected. As the duration of ethylene exposure increases, enzyme activities increase (Kazokas 1997) and a reduction of fruit break-strength occurs. Auxin is found in all portions of the citrus plant, including AZ-C (Goren and Goldschmidt 1970). Its presence prevents the induction of abscission by ethylene. Continued exposure to ethylene results in 1) inhibition of auxin transport from the leaves and stem to the AZ-C, and 2) destruction of auxin in the AZ-C. Abscission can then proceed. Once abscission has commenced, however, auxin application does not inhibit abscission but in fact promotes it by accelerating endogenous ethylene production (Sexton and Roberts 1982). Gibberellins and cytokinins appear to have no effect on the abscission process of mature citrus fruit. Abscissic acid can enhance abscission, but only in situations when ethylene is also released as a result of tissue injury (Goren 1993).

II. C. Growth regulator effects

The promotive effect of ethylene on mature citrus fruit abscission has been utilized to develop abscission materials that facilitate mechanical harvesting. In general, these abscission materials release ethylene either by 1) chemical breakdown, 2) metabolism by the tissue, or 3) tissue injury. Abscission materials that release ethylene by chemical breakdown produce ethylene at a very rapid rate. The presence of fruit and other plant parts are not required. However, these chemicals were totally ineffective at promoting abscission in the field because of rapid dissipation of ethylene under field conditions . The most notable abscission material that releases ethylene as a result of tissue metabolism is ethephon, or ethrel. Ethephon is absorbed by the fruit and surrounding tissues, and metabolized to ethylene under the slightly alkaline conditions that exist in cells. Ethephon was shown to have limited utility for inducing abscission in mature citrus fruit because of its non-

specificity, its low activity at low temperatures, and its objectionable side-effects such as gumming of the trunk when applied in warm weather (Cooper et al 1968).

It is well established that the production of ethylene is a physiological consequence of wounding plant tissues (Sexton and Roberts 1982). The majority of abscission materials tested in Florida have been those that produce ethylene by tissue injury (Wilson et al 1977). ACTI-AID®, Pick-Off® and Release® are examples of abscission materials that produce ethylene by this mechanism. When applied as a spray to fruit, peel blemishes often appeared, reducing their marketability as fresh fruit. Proper timing of application and uptake were also problems with these materials. For example, the active ingredient of ACTI-AID® , cycloheximide, is a potent inhibitor of protein synthesis. When applied at times of limited uptake, such as in conditions of cold weather, the majority of active ingredient would reach the abscission zone after abscission had commenced. This actually resulted in inhibition of abscission by reducing the synthesis of cellulase and PG in the abscission zone. Non-specificity and cost were also problems with these abscission materials.

'Transfer' is a new abscission material that has potential for use on citrus destined for the processed market. In a recent report to the International Society of Citriculture (Wilcox and Taylor 1996), 'Transfer' applied at low concentrations was reported to reduce fruit break-strength over a three week post-application period. The mode of action, specificity and phytotoxicity of 'Transfer' is not known at this time, since the material remains proprietary and has not been released for experimental trials.

III. Abscission and fresh fruit quality

AZ-C is embedded in the remnants of the floral calyx or 'button' of mature citrus fruit (Wilson and Hendershott 1968). AZ-C does not traverse the button in straight cross-section, but rather begins where the tissues of the button and flavedo join and dips through a small portion of the albedo (Figure 2). Vascular tissues that carry water and sugars pass through the AZ-C. The ventral vascular traces of the central fruit core and the dorsal and lateral vascular traces that encircle the fruit must be severed at abscission. These vascular traces significantly contribute to the tensile strength and rigidity of AZ-C (Cooper et al 1968).

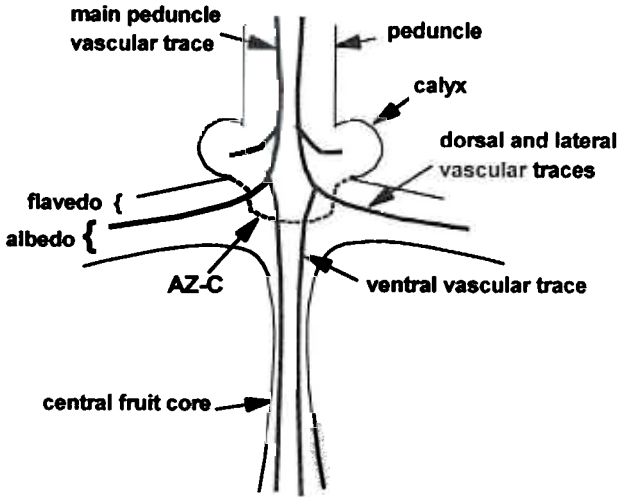

Figure 2. Longitudinal diagram of the stem-end of an orange fruit.

Plugging of mature citrus fruit results from the incomplete mechanical rupture of AZ-C during harvest. An abrupt transition of cell sizes, shapes, and types through the AZ-C creates a localized, structurally weak region (Webster 1968). When fruit are harvested, the mechanical rupture of the tissue or 'plug' will occur through the structurally weakest area of this region. If fruit are harvested before a well-formed abscission zone develops, or if susceptible thin-peeled fruit such as tangerines are not carefully harvested, a portion of the flavedo is torn away from the fruit. This can expose the albedo and segments of the fruit to

desiccation and decay. Plugged fruit will be eliminated from the fresh fruit stream in the packinghouse. In some cases, plugged fruit can account for approximately 11% of total harvested fruit (Gaffney et al 1976).

Harvested fruit are commonly degreened for marketing purposes during the early part of the season. In the degreening process fruit are treated with ethylene to cause the destruction of chlorophyll. Barmore and Brown (1985) have demonstrated that degreening enhances the susceptibility of fruit to stem-end rot caused by *Diplodia natalensis*. Although the growth and penetration of *Diplodia natalensis* through the fruit's stem-end is stimulated by ethylene treatments, recent work suggests that the enzymatic digestion of AZ-C induced by ethylene degreening treatments can ease the physical barrier to fungal penetration and therefore contribute to the development of the disease (Brown and Burns, 1995).

Abscission materials such as 'Transfer' may have potential for harvesting of fresh fruit. Tangerines would greatly benefit from a reduction in plugging due to a reduction in fruit break-strength. Fresh fruit harvesting rates could potentially increase without an increase in mechanical damage. 'Transfer' must be thoroughly tested for its effects on postharvest quality, however, before its potential for harvesting of fresh fruit can be evaluated.

IV. Literature cited

Barmore, C. R. and Brown, G. E. 1985. Influence of ethylene on increased susceptibility of oranges to *Diplodia natalensis*. Plant Dis. 69:228-230.

2 Brown, G. E. and Burns, J. K. 1995 (Abstr.). Factors affecting susceptibility of ethylene degreened oranges to Diplodia stem-end rot. Phytopathology 85:1123.

3 Burns, J. K., Nairn, C. J. and Lewandowski, D. J. 1995. Cell wall hydrolase activity and cellulase gene expression during abscission of Valencia citrus fruit and leaves. Proc. Fla. State Hort. Soc. 108:254-258.

4 Cooper, W. C., Rasmussen, G. K., Rogers, B. J., Reece, P. C. and Henry, W. H. 1968. Control of abscission in agricultural crops and its physiological basis. Plant Physiol. 34:1560-1576.

5. Gaffney, J. J., Miller, W. M. and Coppock, G. E. 1976. Citrus fruit injury as related to mechanical harvesting with limb shaker-catch frame systems. Proc. Fla. State Hort. Soc. 89:179-182.

6 Goren, R. 1993. Anatomical, physiological, and hormonal aspects of abscission in citrus. *From*: Horticultural Reviews. Vol. 15. pp.145-182. John Wiley and Sons Inc., N.Y.

7. Goren, R. and Goldschmidt, E. E. 1970. Regulative systems in the developing citrus fruit. I The hormonal balance in orange fruit tissues. Physiol. Plant. 23:937-947.

8. Goren, R. and Huberman, M. 1976. Effects of ethylene and 2,4-D on the activity of cellulase isoenzymes in abscission zones of the developing orange fruit. Physiol. Plant. 37:123-130.

9 Greenberg, J., Goren, R. and Riov, J. 1975. The role of cellulase and polygalacturonase in abscission of young and mature Shamouti orange fruits. Physiol. Plant. 34:1-7.

10. Huberman, M., Goren, R. and Zamski, E. 1983. Anatomical aspects of hormonal regulation of abscission in citrus - the shoot-peduncle abscission zone in the non-abscising stage. Physiol. Plant. 59:445-454.

Iwahori, S. and Van Steveninck, R. F. M 1976. Ultrastructural observation of lemon fruit abscission. Scientia Hort. 4:235-246.

12. Kazokas, W. 1997. Activities of cell wall hydrolases and cellulase gene expression in Valencia orange and Tahiti lime calyx abscission zones during intermittent ethylene treatments. M. S. Thesis, University of Florida.

13. Sexton, R. and Roberts, J. A 1982 Cell biology of abscission. Ann. Rev. Plant Physiol 33:133-162.

14 Webster, B. D 1968. Anatomical aspects of abscission. Plant Physiol. 43:1512-1544

15. Whitney, J. D. 1995. A review of citrus harvesting in Florida. Citrus Eng. Conf. 41:33-60

16. Wilcox, M. and J. B. Taylor. 1996. Transfer: a new abscission agent. VIIIth Congress of the International Society of Citriculture (in press).

17. Wilson, W. C. 1966. The anatomy and physiology of citrus fruit abscission induced by iodoacetic acid. Ph. D. Thesis, University of Florida.

18. Wilson, W. C. and Herndershott, C. H. 1968. Anatomical and histochemical studies of abscission of oranges. Proc. Amer. Soc. Hort. Sci. 92:202-210.

19. Wilson, W. C., Kenney, D. S. and Holm, R. E. 1977. The Florida Department of Citrus cooperative chemical screening programs for citrus. Proc. Int. Soc. Citriculture 2:692-696.