STYLAR-END BREAKDOWN: A POST-HARVEST DISORDER OF 'TAHITI' LIME

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The 'Tahiti', or 'Persian' lime (Citrus latifolia Tan.), has increased in production in South Florida since it was first introduced from California in the late 1800s. Because of the fruit's bright green skin, large, seedless characteristics, and the tree's relative cold hardiness and disease resistance, production of 'Tahiti' lime gradually surpassed that of the traditionally grown Key lime (Citrus aurantifolia Christm.) Swingl. Stylar-end breakdown (SEB) was first recognized as a problem occurring in 'Tahiti' lime fruit in the early years of production and until recently was still considered a major problem of the industry. It occurs almost exclusively during the summer months when the weather in South Florida is typically hot and humid with frequent rains.

Losses to the lime industry due to SEB have amounted to millions of dollars; some estimates have gone as high as two million dollars annually. The problem may occur 2 hr after harvest (these fruit can be culled) or during shipment of the fruit, the source of the greatest financial losses and breakdown in market confidence in the product. These losses are primarily due to the cost of repacking boxes at the terminal markets where the disorder has been found in as much as 40% of the packed fruit.

SEB is primarily a post-harvest disorder, but it will occasionally occur, under certain conditions, on the tree. The symptoms include formation of a rapidly spreading water-soaked patch generally in the area surrounding the mammiform tip at the stylar end of the fruit (Fig. 1). The formation of this patch is associated with rapid chlorophyll breakdown, resulting in a tannish appearance in the affected area. It can spread within hours after harvest to over half of the fruit surface. On occasion, the lesion may also develop from the stem end of the fruit but seldom does it develop from this end alone. If allowed to dry, the affected area becomes grayish-brown in color, and the rind shrinks due to loss of water. SEB does not appear to be related to yellow tip, another physiological disorder typical of these fruits. Yellow tip occurs in intact fruit, developing over several weeks or months, and results in a yellow halo and water-soaked patch at the stylar end of the fruit. It, too, may form a water-soaked patch which soon dries at the stylar end. This disorder may be similar to endoxerosis which is commonly found in lemons.

For years SEB was considered a physiological rind disorder. The rapid development of symptoms in apparently healthy fruit and the inability to isolate a causal microorganism in affected fruit suggested no involvement of infectious agents. Rough handling of limes during harvest was once considered by researchers to be the cause of the problem. It was felt that shearing forces at the mammiform tip when the fruit struck the ground during harvest caused a chain reaction of cellular breakdown which rapidly spread through the albedo and flavedo. We now know that the rapidly-spreading lesion is caused by juice which has invaded the rind.

The internal symptoms of affected fruit were the key to discovering how the disorder occurs and the environmental conditions responsible for its occurrence. The most notable internal symptom of a SEB-affected fruit is the juice-soaked central axis. It can be readily observed by slicing an affected fruit lengthwise (Fig. 1). This tissue is normally white, but it becomes translucent when the intercellular spaces become filled with fluid. The juice passes from this central axis through the spongy cells at the stylar end of the fruit into the rind surrounding the mammiform tip. Depending upon the amount of juice liberated, it spreads from the stylar end towards the equator of the fruit. If sufficient juice and pressure are available to push through the relatively dense vascular tissue at the stem end of the central axis, then the juice will also invade the rind at the stem end and likewise migrate towards the equator of the fruit.

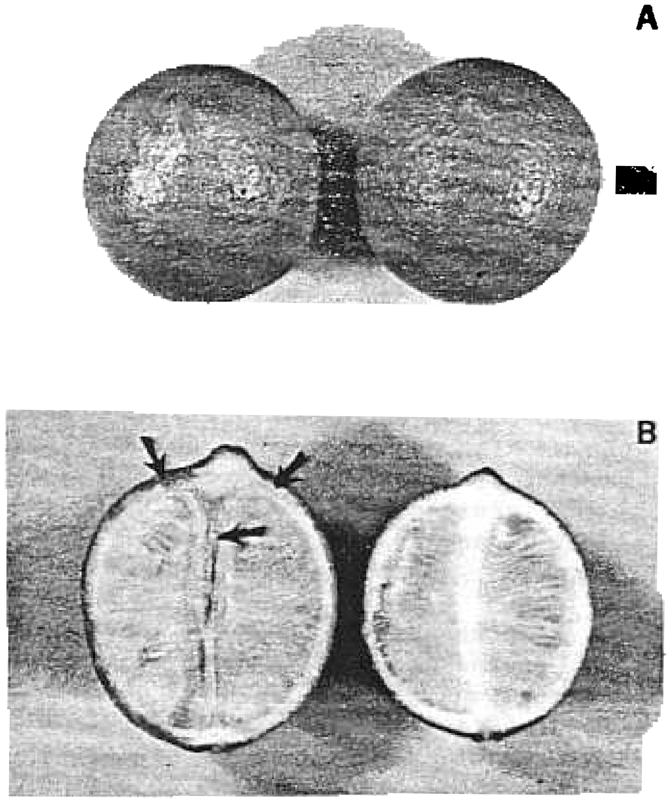

Fig. 1. A. External symptoms of stylar-end breakdown (left) showing discolored patch of rind at stylar end of fruit. Area enclosed in dotted line is tan while remainder of fruit is green. Normal fruit is shown on right. B. Internal symptoms (arrows) of stylar-end breakdown (left) compared to normal fruit on right. (From: Davenport and Campbell 1977a.)

The source of juice is from ruptured juice vesicles, the small, elongated, membranous sacs housing the juice-laden cells of citrus. The vesicles located in the periphery of the fruit seem to be the most affected. If observed under a dissecting microscope, they appear flaccid as though they had been crushed against the rind wall under the pressure of surrounding, interior vesicles. The juice then migrates to the central axis where it proceeds as described earlier. All evidence indicates that the rupture of juice vesicles and subsequent juice invasion of the rind is mediated by a pressure phenomenon. This pressure may occur as a result of rough handling such as,for example, a sharp blow to the fruit when striking the ground during harvest. This treatment was, however, found to be much less important than conditions which increase internal pressure of the fruits such as elevated temperatures or high turgor pressures. The size of the fruit also plays an important role in determining the susceptibility to breakdown due to the high pressure conditions.

High post-harvest temperature is probably the worst enemy of the lime producers as far as the incidence of SEB is concerned. The incidence of SEB in fruit after only 3 hr exposure increases exponentially from 0% at a temperature of 25°C to nearly 100% of the fruit at 50°C (Fig. 2). During the summer, the temperature of harvested fruits, sitting in field bins exposed to the sun, rises from near ambient to up to 45°C. This temperature has been known to cause SEB to occur in approximately 40% of the morning-harvested fruits. Whether SEB shows up in the rind sooner or later depends upon the intensity and length of exposure time to these elevated temperatures. The field heat is not so intense during other seasons of the year, which probably explains why the disorder is not prevalent during these times.

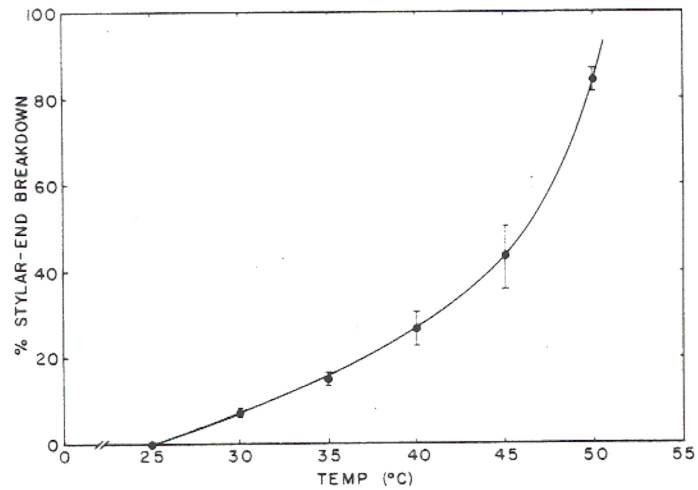

Fig. 2. Effect of temperature on the incidence of stylar-end breakdown in limes. Each datum represents the mean + SE of 50 fruit each heated for 3 hr in a water bath maintained at the temperature indicated. (From Davenport and Campbell 1977b)

Fruit turgor, the internal cellular pressure developed from water uptake into cells which gives rise to the firmness of fruits, is perhaps the most important factor governing the susceptibility of fruit to SEB. Turgor pressure can be measured indirectly by determining the rind-oil-release pressure (RORP) with the use of the Magness-Taylor pressure tester. This instrument is constructed of a rounded metal tip, 3/8 inches in diameter, attached to a rod which slides into a metal sleeve. When the rod tip is pressed against the rind of the fruit, it actuates a spring which imparts an opposing force, the amount of which is registered by a sliding ring on the sleeve. RORP is determined by pressing the tip against the fruit until sufficient force, measured in kilograms or pounds, is imparted on the fruit to cause rupture of oil glands in the flavedo. The amount of force required to cause oil release is turgor dependent, i.e., the higher the fruit turgor pressure, the less force required to cause rind-oil release.

Experiments have been conducted to test the relationship between the incidence of SEB and turgor pressure when the fruit were heated to a standard temperature (42°C) for 3 hr (Fig. 3). There was quantitatively less incidence of SEB in those fruit with reduced fruit turgor (higher RORP) than those with high turgor. Those fruit with RORP of 2.0 kg or less were the most susceptible, SEB occurring in approximately 40% of the fruit. Fruit with higher RORP up to 4.5 kg showed a proportional decrease in susceptibility. Those fruit with RORP of 4.5 kg or greater showed no incidence of the disorder when heated as described.

Fruit turgor changes dramatically through a typical summer day, ranging from less than 2 kg (high turgor) at dawn to approximately 7 kg or greater (low turgor) in the late afternoon (Fig. 4). These daily changes in fruit turgor are a result of water movement into and out of the fruit due to transpirational water loss from the tree by leaves and fruit. Thus, if fruit are harvested in the morning hours when turgor is the highest, then they are the most susceptible to SEB. Conversely, if they are harvested at a time in the afternoon after reaching a RORP of 4 kg or greater, then they are no longer susceptible to SEB, even if exposed to extremes in post-harvest temperatures. If the post-harvest temperature is controlled by keeping the fruit in the shade, then it becomes safe to harvest fruits at lower RORP values (higher fruit turgor), allowing pickers to work earlier in the day.

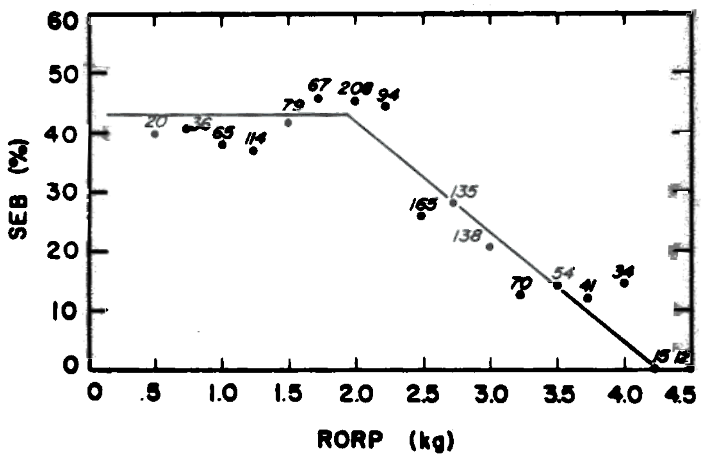

Fig. 3. Relationship of rind-oil-release pressure (RORP) to incidence of SEB in 'Tahiti' limes when heated for three hr in a 42°C constant temperature water bath. (Numbers above each datum represent the total number of fruit sampled at the indicated RORP. From: da Cunha, et al. 1978.)

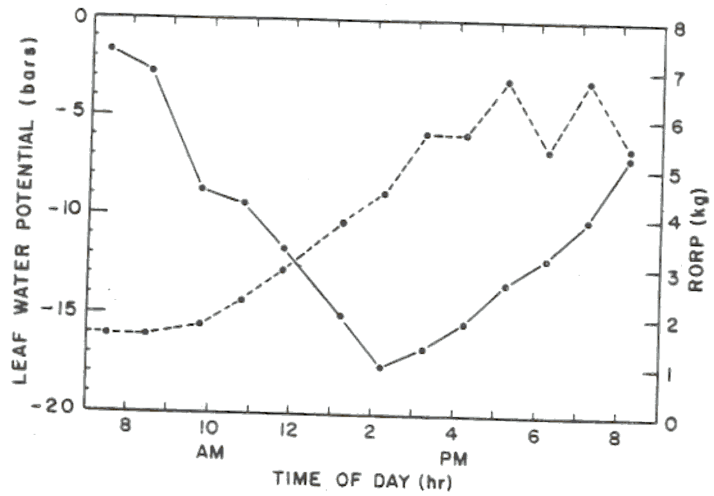

Fig. 4. Change in leaf water potential (o————o) and rind-oil-release pressure (o-----o) of fruit on a 'Tahiti' lime tree during a typical, South Florida, summer day. (Each datum is an average of two or more determinations. From: da Cunha, et al. 1978.)

The third parameter contributing to the susceptibility of lime fruit to SEB is fruit size or maturity. Fruits less than 3.5 cm in diameter have been found not to be susceptible to the 3 hr heat treatment at 42°C (Fig. 5). The susceptibility of fruit to SEB was shown to increase, however, with increase in the size of the fruit. Fruits that were 6.5 cm or greater were the most susceptible, SEB occurring in approximately 60% of the fruit subjected to the inductive temperature. Thus, large fruit are more susceptible than the small fruits to SEB. The typical size of harvested fruit depends upon the season and demand for certain sizes. Harvest sizes range from 4.0 to 7.5 cm in diameter. It becomes important to restrict harvest during the summer to those sizes which are less susceptible to SEB.

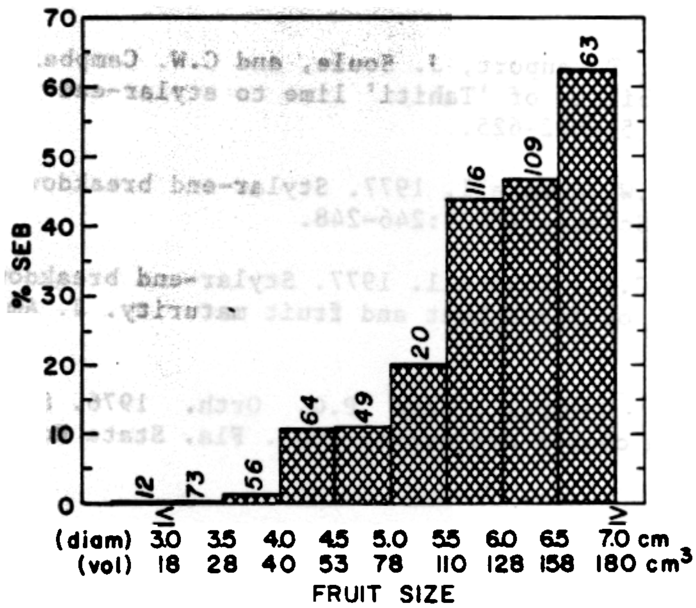

Fig. 5. Effect of fruit size on the incidence of SEB in limes heated in a water bath for 3 hr at 42°C. (Number above each datum represents sample size. From: Davenport and Campbell 1977b.)

This report has described the symptoms of SEB and factors involved in its incidence. Fruit maturity is directly correlated with susceptibility to the disorder. Furthermore, fruit temperature is directly related to the incidence of SEB. It is felt that the mechanism by which heat induces SEB is via mechanical damage through fluid expansion in the juice vesicles rather than by thermal damage to the cells. The fact that the fruit become less susceptible to SEB with decreases in fruit turgor under identical heat treatments supports this view. Although field heat plays a significant role, harvested fruits can better withstand the high temperatures to which they are subjected during summer harvests if the fruit turgor is low (RORP 4.5 kg). The fruit are not only more susceptible to heat-induced breakdown if RORP is less than 4.5 kg, they are also susceptible to breakdown in shipment and at terminal markets.

SEB in limes can be controlled during the hot, summer months by maintaining a strict picking schedule so that fruit is harvested before it becomes too large, by controlling post-harvest temperature with shading throughout the day, and by picking fruit with RORP of 4.5 kg or greater. Management of any one of these three factors will significantly reduce the incidence of SEB. Control of all three will eliminate the disorder in post-harvest fruit. One local lime producer consistently uses the Magness-Taylor pressure tester in the field to determine when limes are safe to pick. Their efforts have resulted in minimal losses to SEB during the worst times of the year with an increase in sales due to consumer confidence and a substantial decrease in product loss. They prove, that with proper management, stylar-end breakdown can be controlled.

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