

EFFECT OF LATE SEASON FRUIT INJURY BY THE
CITRUS RUST MITE, *PHYLLOCOPTRUTA OLEIVORA*
(PROSTIGMATA: ERIOPHYOIDEA), ON THE INTERNAL
QUALITY OF VALENCIA ORANGE¹

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ABSTRACT

Late season injury (bronzing) to mature Valencia orange by the citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), occurred from mid-October through December during 1974 and affected 30 to 45% of the fruit in experimental groves. At harvest, fruit with localized and extensive surface bronzing and peel shrinkage had a lower juice volume, higher soluble solids, higher acids, and higher concentrations of acetaldehyde and ethanol than normal fruit. Off flavors were detected only in juice extracted from fruit with extensive surface bronzing and peel shrinkage where the acetaldehyde and ethanol concentrations were highest. Dehydrated fruit harvested from a grove under severe moisture stress had lower juice volume and higher concentrations of acetaldehyde and ethanol in both normal and bronzed fruit.

Fruit surface discoloration caused by the feeding activity of the citrus rust mite, *Phyllocoptruta oleivora* (Ashmead), has been associated with the formation of lignin and probable oxidation of some substances of the cytoplasm within epidermal cells (McCoy and Albrigo 1975). Final appearance of injured areas of the fruit surface depend on the stage of fruit development at the time of initial injury. Three known visible types of fruit injury caused by citrus rust mite feeding have been reported, namely "sharkskin," "russet," and "bronzing" (Griffiths and Thompson 1957, Albrigo and McCoy 1974). For the purpose of this paper, the characteristics of bronzing will be mentioned briefly.

Fruit bronzing occurs from initial rust mite injury in late fall when little additional fruit growth takes place. Epidermal cells die, become brown, no wound periderm forms, and usually the cuticle does not develop cracks (Albrigo and McCoy 1974, McCoy and Albrigo 1975). Unlike russet oranges, which develop when fruit is still in the developmental stages, these fruit will polish since the natural cutin and wax layer is not broken up. Griffiths and Thompson (1957) suggest that the bronzing type of injury may cause localized peel shrinkage and rapid loss of moisture which results in a concentration of the juice with a correspondingly higher percentage of sugar.

As the result of a prolonged dry fall and early winter, citrus rust mite populations increased to higher than normal densities and remained high for as long as 3 months in many groves on the central ridge of Florida in 1974. Naturally, this resulted in more extensive fruit injury of the bronzing type. At the time of harvest (April-May 1975) in many groves, late season oranges (Valencia primarily) be-

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gan to exhibit considerable peel shrinkage in the injured areas having the bronzing appearance. This was particularly noticeable in groves under severe moisture stress. About this time, reports of off-flavor juice were reported by processors. This was traced to groves under moisture stress where a high percentage of the fruit had the bronzing type of citrus rust mite injury.

A high concentration of acetaldehyde and ethanol in stored citrus fruit have been associated with off-flavor juice (Chase et al. 1967, Davis et al. 1974). The purpose of this study was to determine the effect of the bronzing injury in groves with and without moisture stress on the accumulation of acetaldehyde and ethanol in fruit.

MATERIALS AND METHODS

A nonirrigated (designated Turkey Lake) and an overhead irrigated grove (designated Bay Lake), both Valencia cultivar, *Citrus sinensis* (L.) Osbeck on rough lemon rootstock, *C. jambhiri* Lush, were selected for experimentation. No chemical control measures were applied during the fall of 1974 in either grove. In the Bay Lake grove, citrus rust mite populations were monitored regularly throughout the year on fruit.

During the spring of 1975, the Turkey Lake grove received little precipitation; in fact, at the time fruit for analysis was harvested, many were dehydrated (soft) and leaves were wilted. In the Bay Lake grove, an average of 0.98 inch of free water per week was recorded during March and April. Furthermore, reports of off-flavor juice had been noted by commercial processors.

Fruit were classified according to the presence or absence of bronzing, peel shrinkage, and dehydration. The categories used for rating damage were: 1) no bronzing, no peel shrinkage, 2) soft (Turkey Lake) or firm with bronzing (Bay Lake), no peel shrinkage, 3) some bronzing and peel shrinkage, and 4) extensive bronzing and peel shrinkage. Fruit from the grove in categories 2, 3, and 4 remained firm while that from Turkey Lake was soft. No dehydrated fruit were found in the Bay Lake grove. Fruit were collected on 12-13 May, 21 May and (for the Bay Lake grove only) 4 June.

Twelve fruit of approximately the same size of each condition were selected from field samples and juiced for subsequent analysis. To test for acetaldehyde and ethanol, a 10 ml aliquot of juice was placed in 60 ml bottles, stopped with rubber septa, and warmed to 35°C for 1 h in a water bath. Then a 2 ml sample of headspace over the juice was removed by syringe and chromatographed in the manner described by Davis and Chace (1969). Juice solids were determined by refractive index and juice acid by titration with NaOH. Five laboratory workers were used to taste test juice samples.

RESULTS

Late season citrus rust mite injury (bronzing) to mature fruit began to develop during mid-October when mite populations reached an average of about 3,500 mites per fruit (29.1 mites/cm² fruit surface) in the Bay Lake grove (Fig. 1). By mid-November, about 30%

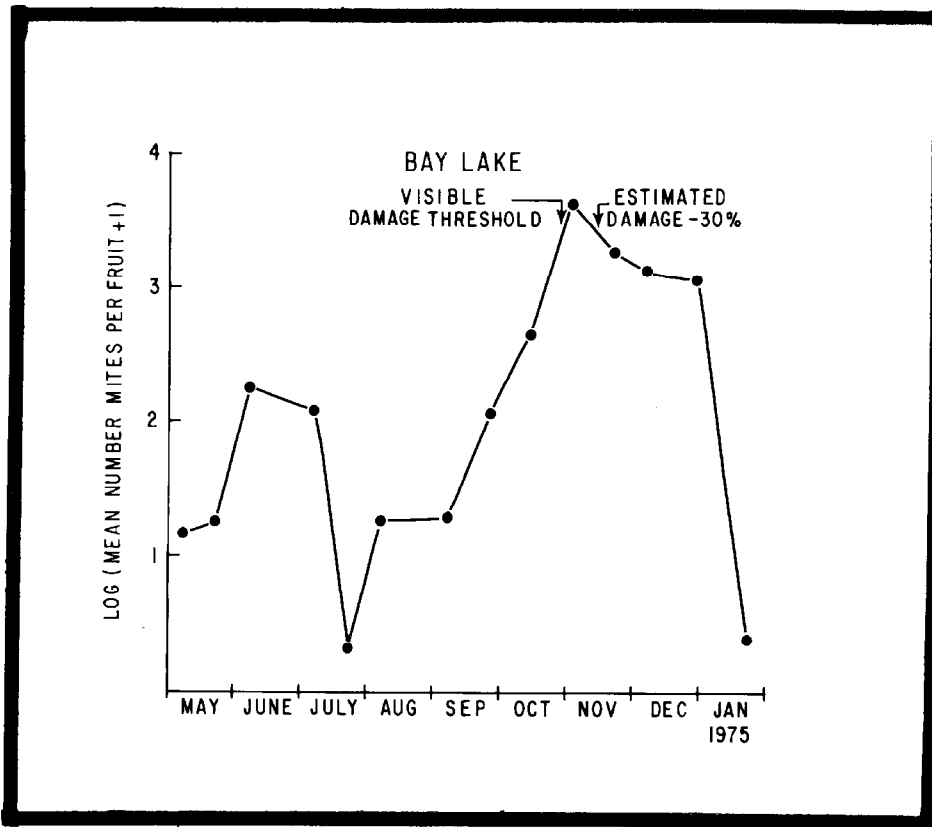


Fig. 1. Seasonal population trend for the citrus rust mite on fruit with designated time of late-season injury in the Bay Lake grove.

of the fruit (Fig. 1) showed visible injury. At the time of harvest, an estimated 45% of the fruit exhibited the bronzing type of mite injury. Although mite populations were not monitored in the Turkey Lake grove, fruit injury probably occurred during October through December too.

In the Bay Lake grove, a significant positive correlation ($r=0.98$) was found between acetaldehyde concentration and fruit condition (Fig. 2A). In the Turkey Lake grove, a high positive correlation ($r=0.93$) was also found between acetaldehyde concentration and fruit condition (Fig. 2A). The more severe the injury due to bronzing and peel shrinkage the higher the acetaldehyde concentration. The softer dehydrated fruit from the Turkey Lake grove had a higher acetaldehyde concentration than similarly rated but firm fruit from the Bay Lake grove.

A high positive correlation was also found between ethanol concentration and fruit condition for both the Bay Lake ($r=0.92$) and Turkey Lake ($r=0.94$) groves (Fig. 2B); however, category differences were not significant. Probably the lack of significance can be attributed to the low numbers of observation per fruit condition.

Again, fruit with localized and extensive surface bronzing and shrinkage had juice with the highest levels of ethanol. Fruit from the Turkey Lake grove also had more ethanol overall.

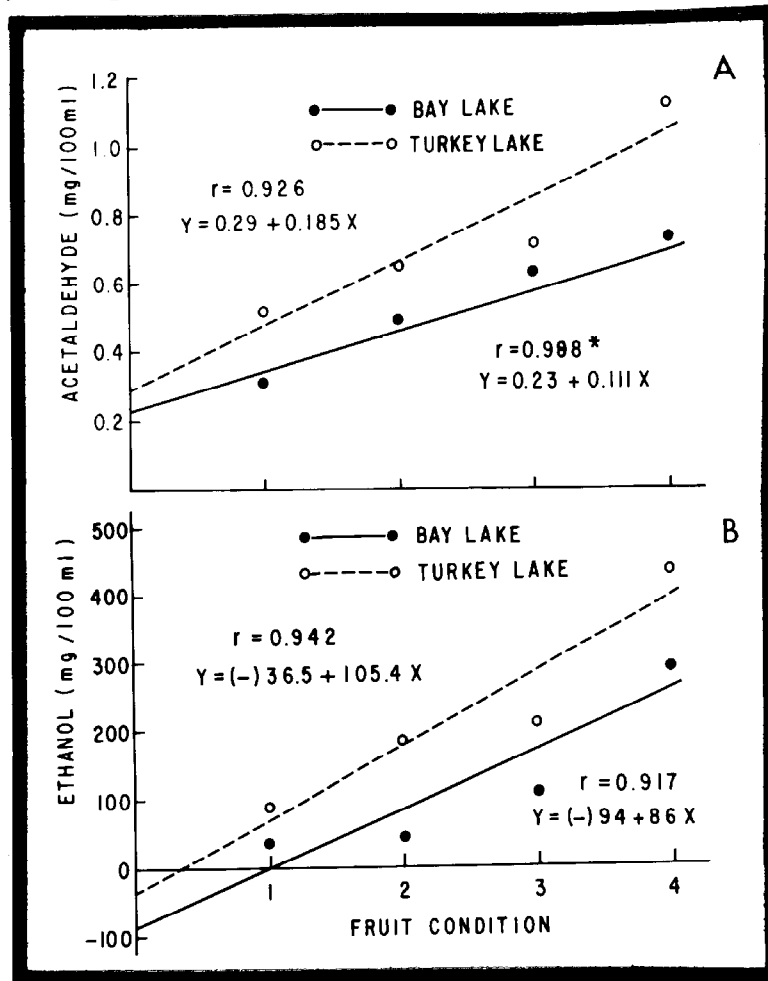


Fig. 2. Linear relationship between mean concentration of acetaldehyde, ethanol and fruit condition: 1) firm without bronzing; 2) soft without bronzing (Turkey Lake), firm with extensive bronzing, but no peel shrinkage (Bay Lake); 3) soft (Turkey Lake) or firm (Bay Lake) with localized bronzing and peel shrinkage; 4) soft (Turkey Lake) or firm (Bay Lake) with extensive bronzing and peel shrinkage (condition means calculated from values for 12 fruit from 2 samples, Turkey Lake and 3 samples, Bay Lake).

In taste tests, off flavors were detected in juice from fruit with extensive surface bronzing and shrinkage (category 4). All fruit of this type harvested from the Turkey Lake grove had off flavors, substantiating earlier grower reports, whereas only the last fruit sample (June 4) from the Bay Lake grove produced off flavors. The acetaldehyde concentration in normal tasting juice from the extensively bronzed and shrunken fruit ranged from 0.50 to 0.56 mg/100

ml, while acetaldehyde in off-flavored juice ranged from 0.91 to 1.50 mg/100 ml. Ethanol concentration in juice from normal fruit ranged from 86 to 100 mg/100 ml while ethanol in off-flavored juice ranged from 288 to 696 mg/100 ml.

In the Bay Lake grove, a significant negative correlation ($r = -0.977$) was found between juice volume and fruit condition (Fig. 3A). Fruit with localized and extensive surface bronzing and peel shrinkage contained less juice. Similarly, a negative correlation ($r = -0.819$) was also found in the Turkey Lake grove (Fig. 3B). Total juice volume for all conditions was less in the Turkey Lake grove, indicating that severe moisture stress within the grove appeared to affect juice volume. It should be pointed out that measurement of fruit size (diam) was not conducted prior to juice extraction; therefore, some variability in juice volume within treatments could have influenced results slightly.

In the Bay Lake grove, a significant positive correlation ($r = 0.99$) was found between the percent soluble solids in the juice and fruit condition (Fig. 3A). No significance was found in the Turkey Lake fruit ($r = 0.60$). Percent soluble solids were highest for all fruit in the Turkey Lake grove and this may have reduced the trend.

In both groves, a positive correlation ($r = 0.91$) ($r = 0.82$) was found between the percent acid in juice and fruit condition (Fig. 3C), extensively bronzed fruit with peel shrinkage having the highest acid levels. The percent acids were higher in all fruit of similar condition in the Turkey Lake grove.

DISCUSSION

Generally, fruit exhibiting peel shrinkage within the area of bronzing were located in regions of the tree canopy exposed to direct sunlight. Since the brownish to black appearance of fruit with extensive bronzing and peel shrinkage may decrease the ability of the fruit to reflect heat, and since injury of this type may also increase peel permeability, the possible increase in fruit temperature within these exposed areas could result in loss of moisture from both the peel and juice. As previously mentioned, rapid loss of moisture in bronzed fruit has been associated with concentration of juice (Griffiths and Thompson 1955). More recently, Ismail (1970) reported greater moisture loss from fruit with early season citrus rust mite injury (russet) compared to normal fruit. Furthermore, in situations such as in the Turkey Lake grove where severe drought conditions forced the tree to retain some water from the fruit, apparently various natural compounds, including those causing off flavors, were concentrated even more.

Since the acetaldehyde concentration in juice increases proportionally with an increase in soluble solids during normal fruit maturation (Davis 1971), one might conclude that off flavors produced in extensively bronzed fruit with peel shrinkage resulted from excessive water loss and concentration of juice, particularly when juice from fruit with extensive bronzing, but without peel shrinkage had no off flavors. However, when the ratio of acetaldehyde to soluble solids is com-

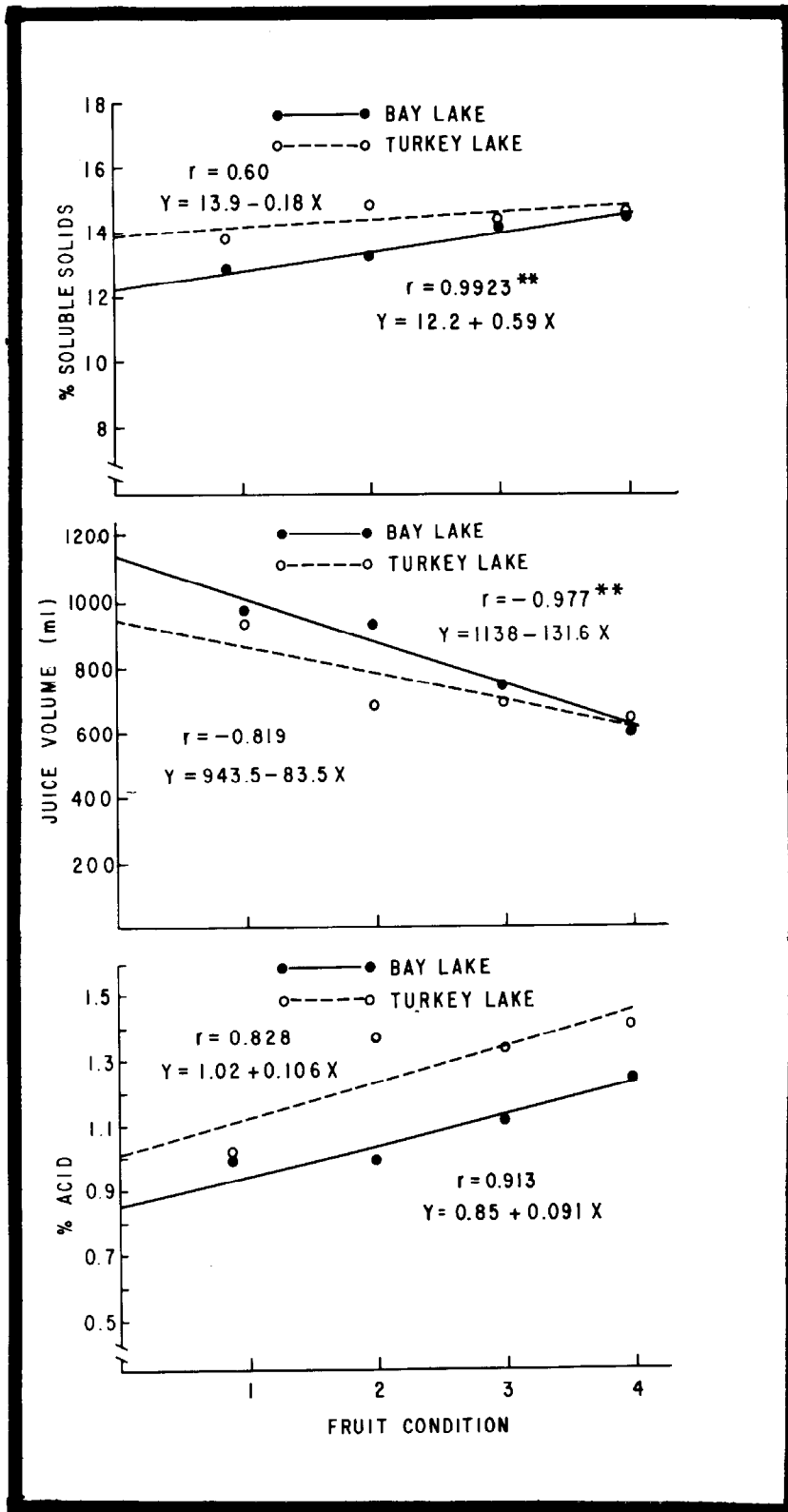


Fig. 3. Linear relationship between percent soluble solids, mean juice volume, percent acid and fruit condition: 1) firm without bronz-

pared for condition 1 (normal fruit) and 4 (off-flavor fruit), one finds that the ratio in both the Bay Lake (0.025:0.045) and Turkey Lake groves (0.037:0.077) increased by two-fold indicating some breakdown in metabolic processes which in turn resulted in a disproportionate increase in acetaldehyde concentration. This may also explain why there was a significant increase in ethanol. When sugar is converted to pyruvate in the Embden-Meyerhof scheme, probably some physiological change either initiated independently or by microbial action may inhibit normal passage into the TCA cycle, causing pyruvate to be decarboxylated to acetaldehyde and then acetaldehyde reduced to ethanol by fermentation.

From a practical standpoint, these data suggest that a low incidence of late citrus rust mite injury will not influence internal fruit quality. Also, light damage (<15 to 20% of the fruit surface) will not affect juice volume or flavor; however, if 40 to 50% of the fruit in a given grove receive extensive bronzing type injury, it should be harvested as early as possible, or irrigation should be applied regularly to prevent peel shrinkage, overall loss of moisture from the juice, and possible development of off flavors.

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