

PEEL INJURY AND RIND COLOR OF 'PERSIAN' LIMES AS AFFECTED BY HARVESTING AND HANDLING METHODS¹

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ABSTRACT

Stylar-end breakdown of 'Persian' limes was shown to be a physiological disease initiated mostly by rough handling. Susceptibility to this form of damage was 5 times as high in fruit picked in the morning as it was in fruit picked in the afternoon. A delay of 24 hours between picking and rough handling did not decrease susceptibility to stylar-end breakdown. Susceptibility to oleocellosis was inversely related to rind oil release pressure (RORP), this form of damage being greatest in the morning, least at noon, and tending to increase again as RORP values declined in the afternoon. Rough handling was associated with increases in respiration rate and rapid disappearance of the desirable dark green peel color. Both this color change as a result of rough handling and susceptibility to oleocellosis were decreased by a 24-hour delay between picking and handling. Storage temperatures below 50° F caused chilling injury as indicated by surface pitting and abnormally high respiration rate on removal to higher temperatures.

INTRODUCTION

'Persian' lime, *Citrus aurantifolia* (Christm.) Swing., is a summer crop in Florida with a short harvesting period and a storage life of 6 to 8 weeks at best (1). Thus, when outbreaks of peel injury occur, the chance for market recovery is poor, with consequent disproportionately high financial losses.

A major problem with 'Persian' limes in Florida is stylar-end breakdown in which tissue around the apex of the fruit becomes brown and translucent. The lesion thereafter progresses

successively down the sides of the fruit. The etiology of this injury is obscure, although at times it reaches disastrous proportions during the months of May to September when the weather is warm and rainy. Other problems in the marketing of fresh limes are oleocellosis, caused by mechanical injury to the epidermal oil cells, and fading of the desirable dark green color.

REVIEW OF LITERATURE

Oleocellosis.—Mustard (10) reported that Florida limes picked while wet from rain or dew were susceptible to oleocellosis. Eaks (7) in California showed that oleocellosis in limes could be minimized by careful picking under moist soil conditions. Three picking treatments, clip-picked, snapped gently, and snapped roughly were used. Turrell, *et al.* (14) found a similar relationship between cool, damp weather and prevalence of oleocellosis on grapefruit in California. Cahoon, *et al.* (3) employed the Magness-Taylor pressure tester to predict when a citrus fruit is susceptible to rind oil spotting. Oberbacher (12) corroborated the results of Cahoon, *et al.* in an experiment with Florida lemons.

Stylar-end breakdown.—A preliminary report by Salama, *et al.* (13) related stylar-end breakdown to rough handling.

Color.—Manley and Godwin (9) stressed the importance of marketing bright, dark green limes. Various chemicals have been tested to maintain this green color during storage. Gibberellic acid and sorbic acid (2) and 2, 4-D (8) have been tried as dips. Gibberellic acid was found by Salama, *et al.* in Florida (13) to be the most effective post-harvest chemical treatment. Coggins, *et al.* (5) tried it rather extensively in California. No report has been found of the use of kinetin, a well-known agent for maintaining green color, on citrus fruits.

MATERIALS AND METHODS

The present study was of 4 pickings in Highlands County, at the southern end of the Cen-

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tral Ridge citrus district, and 1 picking from the major lime producing area at the extreme south of Dade County.

Climatic factors.—Certain microclimatic conditions at a grove located in Goulds, Florida were recorded. Light intensity was measured by a light meter in terms of foot-candles; temperature and relative humidity by a Brown hygrothermograph; and wind velocity by an Alnor "Velometer" using the "no jet" scale.

RORP studies.—Variations in rind oil release pressure (RORP) of fruits with time of day, location of fruit on the tree, position in the field box, fruit size, and environmental factors were determined using two Magness-Taylor pressure testers (0 to 10 and 3 to 30 pound ranges) with a rounded $\frac{3}{8}$ -inch tip. Fruits with fairly smooth rind and about 55 grams in weight were used.

Handling techniques.—Observations were made at 3 picking times during the day, morning, noon, and afternoon, and 24 hours after picking to see how handling practices at these times would affect color, respiration rate, stylar-end breakdown, and oleocellosis. Three picking

methods were used. "Very carefully handled fruit" was clipped and handled using a picker's glove padded with $\frac{1}{2}$ -inch thick polyurethane foam. Each fruit was placed gently on a sheet of polyurethane foam to prevent contact with the container. "Normally handled fruit" was clipped and handled in the commercial manner. "Roughly handled fruit" was clip-picked and was pressed 6 times at 10 pounds pressure using the mechanical thumb attachment to the pressure tester, and the stylar-end was hit 3 times on hard corrugated fiberboard. Each lot of 10 to 35 fruits was placed in a ventilated polyethylene bag during transportation from the grove to the packinghouse. Five replications were made about 2 weeks apart.

Determinations.—Fruit color was determined as absorbance at $675 m\mu$ on a B & L Spectronic 20 (12). Respiratory activity was measured on individual fruit with a Beckman IR-nondispersion CO_2 analyzer. Analyses were recorded on a Sargent recorder in microamperes. Data are reported as mg CO_2 per kg fresh weight per hour (15). Stylar-end breakdown, oleocellosis, and decay were recorded as percentage of affected fruit.

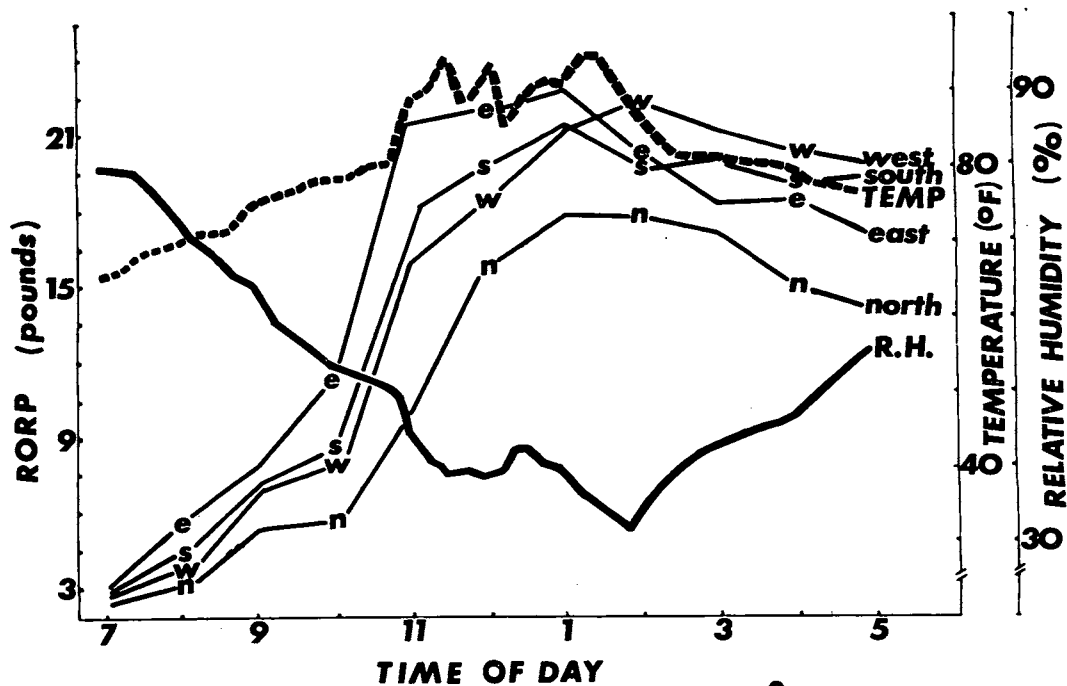


Fig. 1.—Diurnal variations in rind oil release pressure (RORP) of limes as affected by microclimate (temperature = temp and relative humidity = R.H.) and position on the tree.

Holding temperatures.—Prompt and delayed refrigeration and several subsequent holding temperatures were compared with regard to color, respiration, oleocellosis, and stylar-end breakdown. The lots subjected to immediate refrigeration were placed in "Vexar" (polyethylene net) bags, wrapped with polyurethane foam sheets, and put in insulated ice chests immediately after picking. Holding temperatures included 32°, 40°, 50°, 60°, and 70° F.

Observations for oleocellosis were made after 1 week, respiratory activity after 3 weeks, and color and stylar-end breakdown after 4 weeks of storage.

Prestorage treatments.—Combinations of kinetin dips and waxing treatments were used. For the kinetin treatments, concentrations of 0, 1, 10, and 100 ppm were used. In each case, fruit was dipped twice and air dried after each dip. Water-emulsion citrus wax was applied as a hand dip and thickness of wax coating varied

by using 4 treatments: not waxed, dipped once, dipped twice, and dipped 3 times. The limes were air dried between dips. Blanched (white to yellow) areas on each fruit were marked. Subsequent color readings were taken only on the originally green portions. Data were plotted as logarithmic values of kinetin concentrations.

RESULTS

Climatic influences.—Temperature and relative humidity affected RORP values more than did light intensity. An increase in temperature, with a corresponding decrease in relative humidity, raised the RORP (Figure 1). In the morning, RORP was higher for fruits on the east side of the tree. Fruit from the north side exhibited the lowest value throughout the day. RORP values declined in the afternoon after reaching a peak at noon as temperature decreased and relative humidity increased (Figure 1).

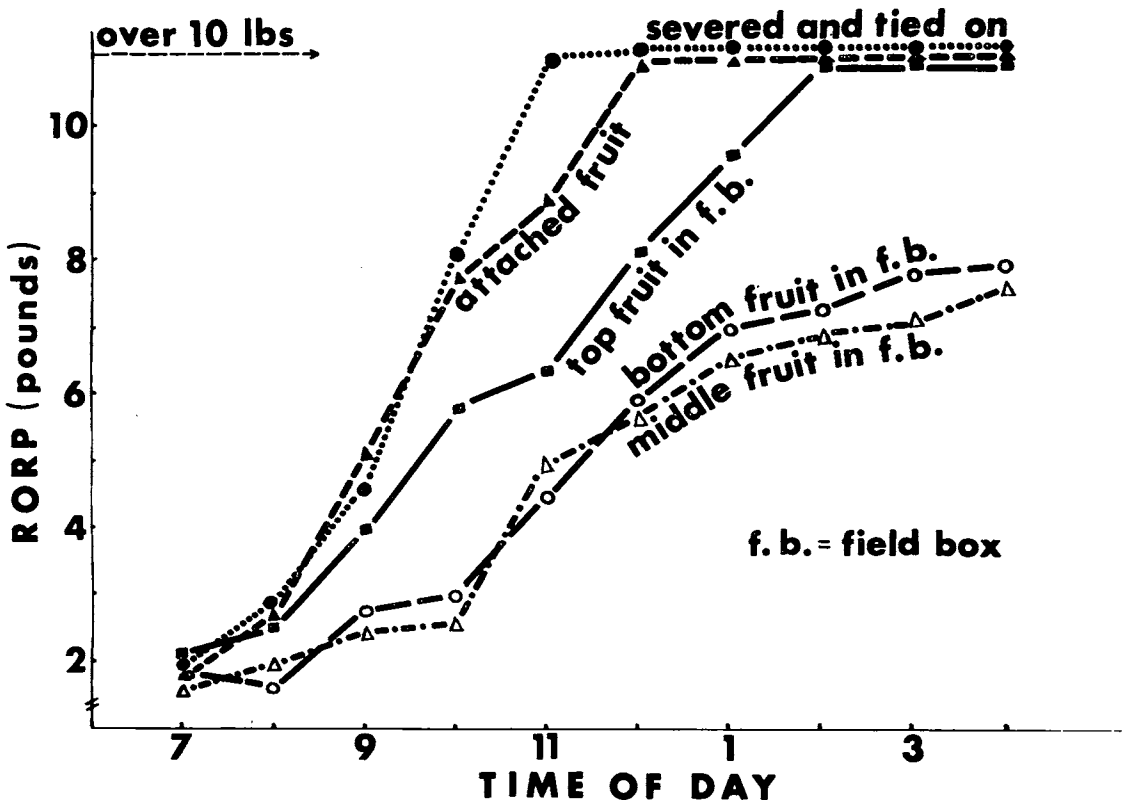


Fig. 2.—Hourly variation in rind oil release pressure (RORP) from the trees to the field box.

It was further observed that a light rain could also lower the RORP. Wind velocity up to 3.4 miles per hour had no effect. Light intensity *per se* did not influence RORP values markedly.

Nonclimatic influences contributing to low RORP values were also investigated. As shown in Figure 2, conditions in the tree itself could delay the increase in value at a particular time of day. At 10:00 a.m., fruits severed from the tree and hung at the same position in the tree had higher RORP values than adjacent attached fruits. Fruits in the top of a field box had higher values than fruit in the middle or the bottom of the box. RORP values from the latter 2 locations did not differ materially from each other (Figure 2).

RORP values were, however, related to fruit size. The curve of RORP plotted against diameter (Figure 3) was sigmoidal, with a critical range at about 2 inches.

Harvesting practices affected peel injury and rind color (Table 1.) The incidence of oleocellosis was most severe on fruit picked in the morning and was further increased by rough handling at this time. Styler-end breakdown was not observed in normally handled fruit. However, immediate rough handling produced more than 5 times the amount of styler-end breakdown in the morning picked limes as compared with those picked in the afternoon. Immediate rough handling increased respiration rate of the fruit regardless of picking time. Rough hand-

ling also hastened yellowing, especially in the fruit picked in the morning.

That these controlled tests simulated commercial conditions was indicated by a single experiment in which single field box samples were taken from successive stages in a commercial harvesting operation (Table 2). Each handling resulted in an appreciable increase in the percentages of both oleocellosis and styler-end rot that developed when these samples were held for observation.

Holding temperatures influenced color and respiratory activity subsequent to holding, but not styler-end breakdown and oleocellosis. The lower the temperature, the longer the desirable green color was preserved. Respiratory activity increased with holding temperatures of 50° F or below, indicating metabolic injury (Table 1). No benefit was apparent from prompt refrigeration.

Prestorage dips.—The treatments of 10 ppm of kinetin plus 2 wax applications was optimum in delaying the green to yellow color change (Figure 4).

DISCUSSION

Diurnal and other variations in microclimate affected RORP values and hence, susceptibility to oleocellosis (Table 3). RORP could exceed 10 pounds before noon on a sunny day (July 13), may not reach 10 pounds until afternoon on a cloudy day (May 11), fluctuate during the day (May 25), or become invariably low in a heavy rain (June 9). Of the climatic factors studied, temperature and relative humidity were critical. When RORP values are low, midday is the best time to pick. Risk of oleocellosis increases as RORP value decreases in late afternoon, but susceptibility to styler-end breakdown continues to decrease throughout the day.

During conditions which cause low RORP, extreme care should be taken in picking the north side of the tree. Ideally, it is advisable to start picking only on the east side of the trees at about 10:30 a.m., pick the north sides at noon, and then transfer to the west side early in the afternoon.

Styler-end breakdown is apparently a physiological disease aggravated by rough handling practices. Susceptibility to this disorder is very high in the morning, decreases steadily through the day, and appears to be independent of position on the tree or of the microclimate factors

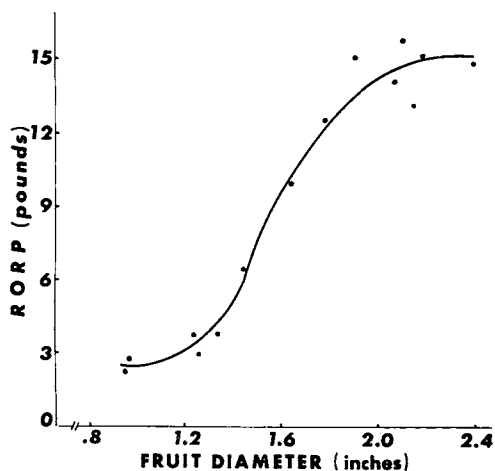


Fig. 3.—Relationship between size of fruit and rind oil release pressure (RORP).

Table 1.--Effect of handling methods and holding temperature on color, respiratory activity, stylar-end breakdown, and oleocellosis.

	Color* values after 4 weeks Absorbance at 675 m μ	Respiratory activity** mg CO ₂ /kg/hr	% stylar-end breakdown after 4 weeks	% oleocel- losis after 1 week
Handling practices (Held at 50° F)				
Very careful handling	97	8.0	0	5.9
Normal handling	95	8.4	0	8.6
Immediate rough handling	72	10.3	22.5	60.9
Rough handling after 24 hours	87	8.5	25.4	27.7
Immediate rough vs. normal handling (Held at 50° F)				
Normal	97	7.6	0	22.8
Morning picking				
Rough	64	9.1	61.0	88.5
Normal	90	8.4	0	8.6
Noon picking				
Rough	78	10.3	22.5	60.9
Normal	87	9.5	0	10.2
Afternoon picking				
Rough	83	8.4	11.9	36.6
Holding temperature (Normally handled)				
32° F	105	31.6	5.7	8.0
40° F	92	17.2	1.5	10.2
50° F	87	9.5	0	10.2
60° F	79	7.4	0	12.0
70° F	71	7.4	0	10.9

*High absorbance values indicate dark green. Low values, pale green or yellow.

**At 60° F, subsequent to 3 weeks storage at indicated temperatures. Increases in respiration rate indicate internal injury.

studied. cursory observation in the grove, however, shows that fruit may exhibit stylar-end breakdown when it is mature and beginning to lose its green color, as Camp (4) and Conover (6) reported.

Low holding temperatures of 32° or 40° F prevented fading of the desirable green color but promoted undesirable chilling injuries, mainly pitting. Higher temperatures of 50°, 60°, or 70° F caused progressively faster yellowing but

Table 2.--Percentages of oleocellosis and stylar-end rot in samples from a commercial harvesting operation held at 50° F for 3 weeks (single test, no replication).

Sampling point	% oleocellosis	% stylar-end breakdown
From field boxes	18.3	1.0
After dumping field boxes into pallet boxes	25.2	6.4
On arrival at packinghouse	29.6	6.3
After dumping	35.5	9.3

Table 3.--Diurnal variation in rind oil release pressure (RORP) of fruits picked at approximately biweekly intervals.

Picking dates	Morning	Noon	Afternoon
May 11, 1966	5.3	7.7	9.0
May 25, 1966	3.1	9.2	6.4
June 9, 1966	1.8	3.2	3.0
June 22, 1966	2.0	10.0	10.0
July 13, 1966	2.9	20.5	16.8

no pitting. Another report will deal with exploratory studies on control of surface pitting at chilling temperatures. Meanwhile, a storage temperature of 50° F as recommended by ASHRAE (1), plus possibly a chemical to delay the color change, is indicated. Green color can be maintained by applying 10 ppm kinetin solution in combination with a double wax application. Its efficiency, cost, and legal status merit further investigation.

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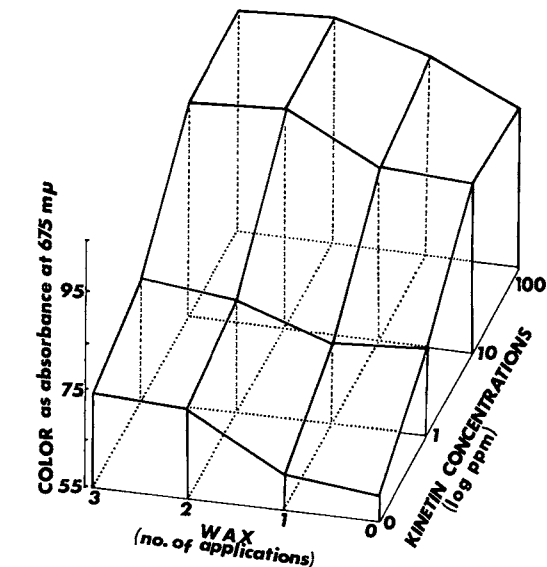


Fig. 4.—Effects of various levels and combinations of water-emulsion wax and kinetin on yellowing of 'Persian' limes held at 50° F.

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