PEEL MORPHOLOGY AND FRUIT BLEMISHES

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A primary factor in fresh citrus fruit production is final external quality. In fresh fruit sales, the consumer's perception of what citrus should look like is as important as fruit taste. For citrus, poor color and blemishes are important problems under tropical and humid subtropical growing conditions. In Florida, average packout is only around 60%.

Control of natural peel development and prevention of blemishes is important in several ways to citrus production for fresh and even processed market fruit. As the fruit grows and matures, the epidermal layer and its cuticle develop into a natural barrier to control water loss, gas exchange, and penetration by pathogens. Various stress factors can cause damage which interacts with fruit growth and this results in the various blemishes observed at harvest.

Development and Structure of the Citrus Peel

The citrus peel consists of the white albedo which contains the primary vascular system of the fruit, the colored outer flavedo which contains oil glands, and the epidermal layer which contains stomatal guard cells and is covered by the cuticle. Albedo and flavedo development have been reviewed earlier in this short course. Critical consideration in development of these two tissues to physiological behavior of the fruit is the large amount of air space in the albedo and the small amount of air space in the flavedo.

Our main discussion will concern epidermal and cuticle development and its importance to fruit development and function. The outer epidermal layer is primarily responsible for production of the cuticle. At bloom, the epidermal cells are elongated radially, contain mostly cytoplasm with small vacuoles, and do not have a cuticle covering. Early development (4-6 weeks) is by cell division, but unlike the rest of the fruit, some epidermal cell areas continue to divide until fruit expansion is completed. During expansion, epidermal cells become vacuolated and slightly elongated tangentially. At the time the fruit is approximately 1 inch in diameter (8-12 weeks after bloom), the fruit begins to develop a continuous cuticle. The materials for cuticle development are rapidly deposited as amorphous materials through the outer cell wall matrix. The cutin materials are cross-linked to form a matrix layer with waxes embedded in it and other waxes accumulated on the cutin matrix (fruit surface). The waxes accumulate faster than expansion growth increases surface area. These waxes become the effective barrier against water loss from the fruit during development and after harvest.

The amount of wax deposited on the surface of various cultivars differs, with mandarin types having less wax and late maturing cultivars tending to have more wax (Table 1). Mandarin types have much higher rates of water loss, reflecting their thinner wax layers. Mandarin types' short shelf-life may be partly due to the poorly developed cuticle. The amount of wax is not the only factor determining rate of water loss from the fruit. The chemical composition of the waxes also influences the rate of water loss. 'Pineapple' and 'Valencia' oranges from different grove sources have an overlapping range of wax concentrations, but the weight loss after harvest from these fruit reflect a difference in wax chemistry (Fig. 1). Another

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influence of chemical composition is the form the wax layer takes on the fruit surface. Citrus wax occurs in flat platelets. As the wax becomes hard and brittle during fruit development, the waxes break up into platelets. The wax layer becomes less effective as a water loss barrier as the continuous layer breaks up.

Table Total and soft epicuticular wax accumulation by different types of mature citrus fruits.

Variety	Location	Total wax		Soft wax	
		Average	Range	Average	% of total
		$\mu g/cm^2$	$\mu g/cm^2$	$\mu g/cm^2$	
Calamondin	Central Florida	37 a	(32-53)	24	65.0
Dancy tangerine	Central Florida	48 a	(40-53)	16	33.3
Orlando tangelo	Central Florida	57 a	(53-59)	14	24.6
Hamlin orange	Central Florida	79 b	(61-92)	34	43.0
Pineapple orange	Coastal Florida	83 bc	(69-95)	34	41.0
Pineapple orange	Central Florida	100 cd	(74-114)	40	40.0
Grapefruit	Coastal Florida	116 de	(107-125)	56	48.3
Grapefruit	Central Florida	117 de	(103-131)	62	53.0
Valencia orange	Central Florida	122 e	(92-154)	41	33.6
Valencia orange	Central California	178 f	(174-186)	66	36.9

$hsd_{0.05}$ for total wax = 20.2.

The wax and weight loss data in Figure 1 also reflect site to site variation in fruit wax deposition. Cultural practices and environment play a role in determining rates and amount of waxes deposited on fruit. Temperature optimums exist for wax production for each cultivar. Mandarin types have a lower temperature optimum than 'Valencia' or grapefruit for wax production. Moderately low humidity stimulates wax production compared to high humidity. Most cultural practices: nutrients, water, etc. have not been tested for their influence on wax production. Fungicide sprays of benomyl or difolatan were found to increase wax production from the control level (75 $\mu g/cm^2$) to 91 to 100 $\mu g/cm^2$. The control fruit had a 20-day postharvest weight loss of 8% while the treated fruit ranged from 6.6 to 5.4% weight loss (67 to 82% of controls). This one year test did not differentiate how the fungicides produced this effect but does indicate that wax production may be influenced by sprays and other cultural practices. Refinement of fruit production and handling practices to obtain maximum quality should include controlling wax production for weight loss control.

The cuticle, primarily chemically cross-linked cutin matrix, becomes an effective barrier against penetration by several microorganisms. This does not occur, however, until the fruit is 2 to 3 months old. The cuticle and outer epidermal wall is not sufficiently thick nor impermeable enough to prevent insect feeding or uptake of some phytotoxic spray chemicals. The stomatal pores also act as a site for penetration of organisms and chemicals into the fruit. Many of these pores become plugged with wax but many remain functional. Because the flavedo cells are tightly packed below the stomatal guard cells, penetration through the guard cells usually leads to limited damage within the fruit but often results in unsightly blemishes. Stomatal plugging is highly variable over the fruit, does not

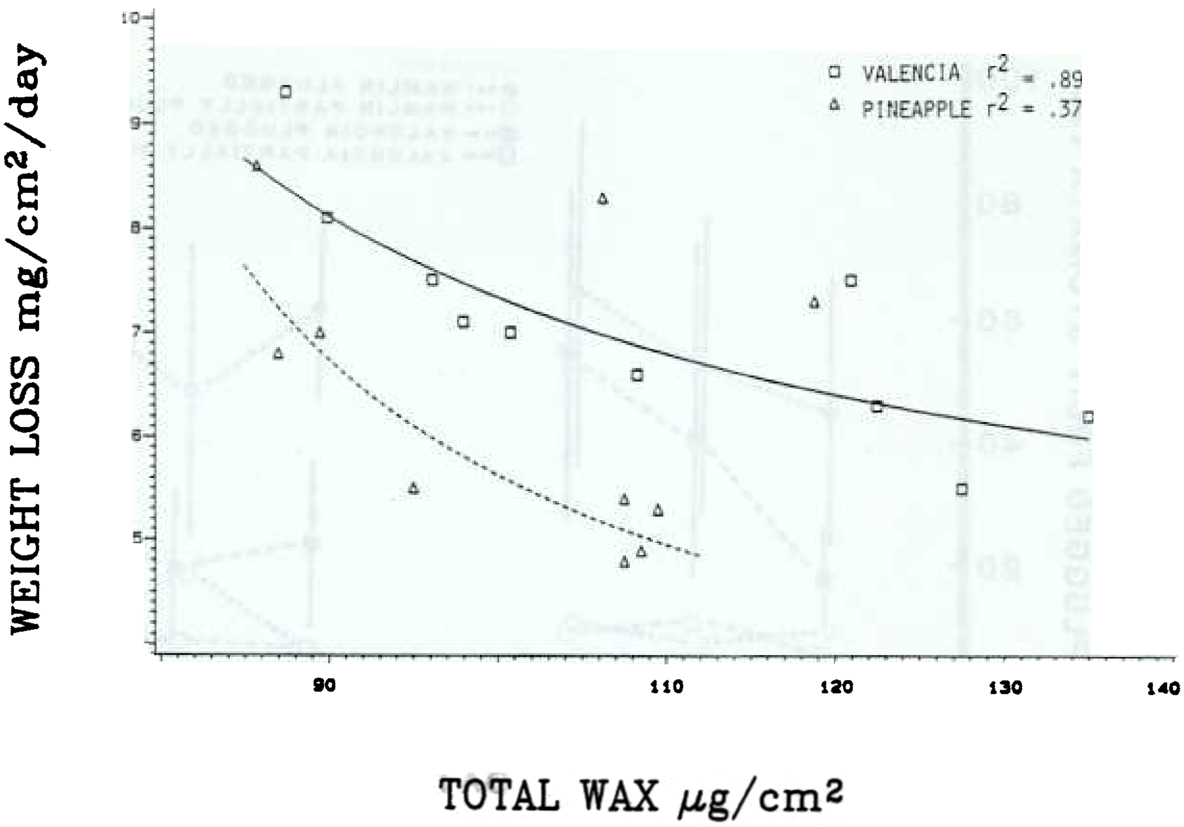

Fig. 1. Regression and correlation for weight loss of field-run 'Pineapple' and 'Valencia' oranges against total surface wax at harvest. Correlation coefficient significant at 5% level.

follow a seasonable pattern, and may result in drastic differences in gas exchange from one area of the fruit to another.

The first step toward improving pack-out is to have a better understanding of the causes of the various kinds of fruit blemishes and of the measures required for their prevention. Blemishes can be caused by climatic factors, insect and mite injury, pathogens, spray burns, and nutritional maladies. Over 60 separate disorders are known. Although the majority of these disorders seldom occur, many commonly occur and cause reduction in fresh fruit pack-out each year. Common blemishes include wind scar, hail damage, green color, citrus rust mite injury, scale spots, melanose, scab, greasy spot, spray burns, and splitting. Most injuries only influence fruit appearance but severe rust mite injury can cause off-flavor development in processed 'Valencias' if harvested late in the season. Plant bug injury can severely downgrade processed grapefruit sections.

Over a number of years, certain key criteria have been found useful to determine the probable cause of a blemish. Most important is the appearance of the blemish. Many blemishes have characteristic damage patterns, color, roughness, etc. that can be used for diagnostic purposes. The time of injury can often be determined from the appearance of the blemish at harvest. Oftentimes, this is the first time the grower or packer notices the disorder.

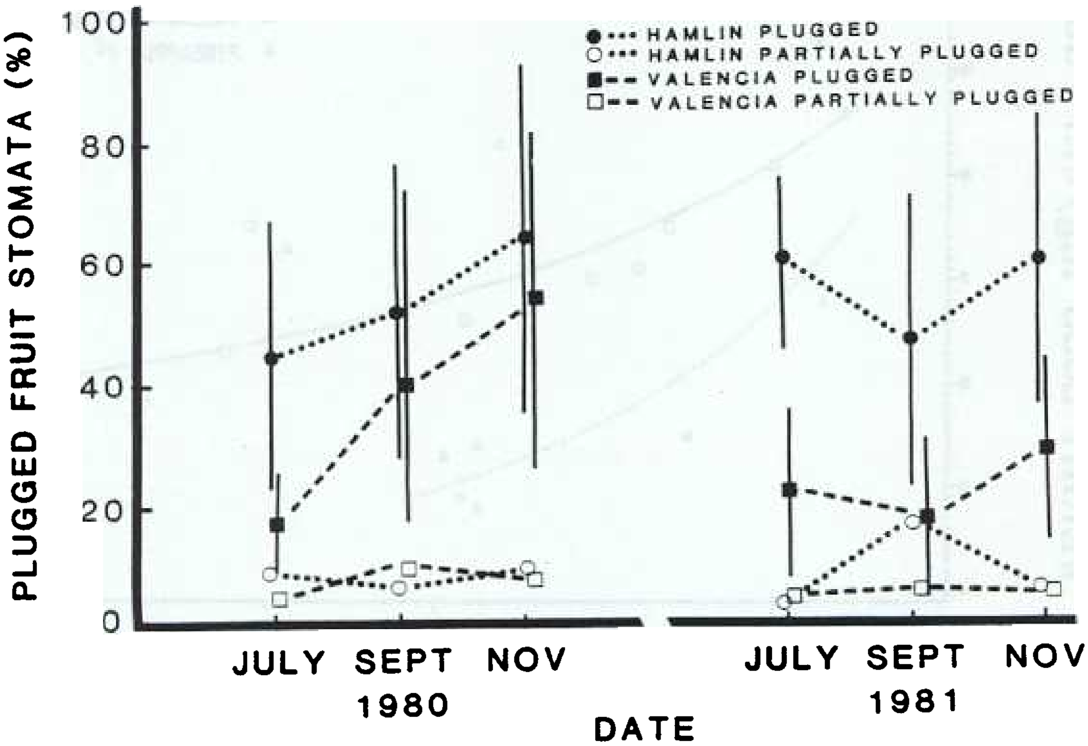

Fig. 2. Average plugging and standard deviations of percent plugging of fruit stomates of 'Hamlin' and 'Valencia' oranges on three sampling dates in 2 years

Many surface injuries to citrus fruits are emphasized by the development of a wound periderm that forms after injury. Sometimes, as the fruit continues to grow, the dead tissue above the periderm bleaches and breaks into patches. With very early injury, the wound tissue is completely sloughed off before fruit maturity, whether injuries are shallow, such as those caused by rust mite, or deeper injuries such as hail damage. Therefore, the degree of bleaching, patching, and sloughing is a guide to how early the injury occurred.

The depth of the injury is also important. Either hail or chewing insects will cause deep wounds. Citrus rust mite, spray burns, and wind scar result in very shallow injury. When injured areas are raised rather than depressed, it is usually an indication of a fungal pathogen; i.e., scab and melanose. However, not all pathogen-associated blemishes are raised. For example, greasy spot does not cause raised lesions. Early Alternaria induced lesions on tangerines are initially raised but later develop into pockmarks due to the loss of corky tissue.

The cause of a blemish can be indicated by the abnormal color of the rind. Blemishes which are dark to light brown involve peel necrosis and occur late in the fruit development period. Some disorders result in rind areas greener than normal as in delayed color break, scale spots, green stink bug feeding, greasy spot, and regreening. This usually means that chlorophyll synthesis was stimulated by a toxin or gibberellin synthesis or that chlorophyll breakdown was inhibited.

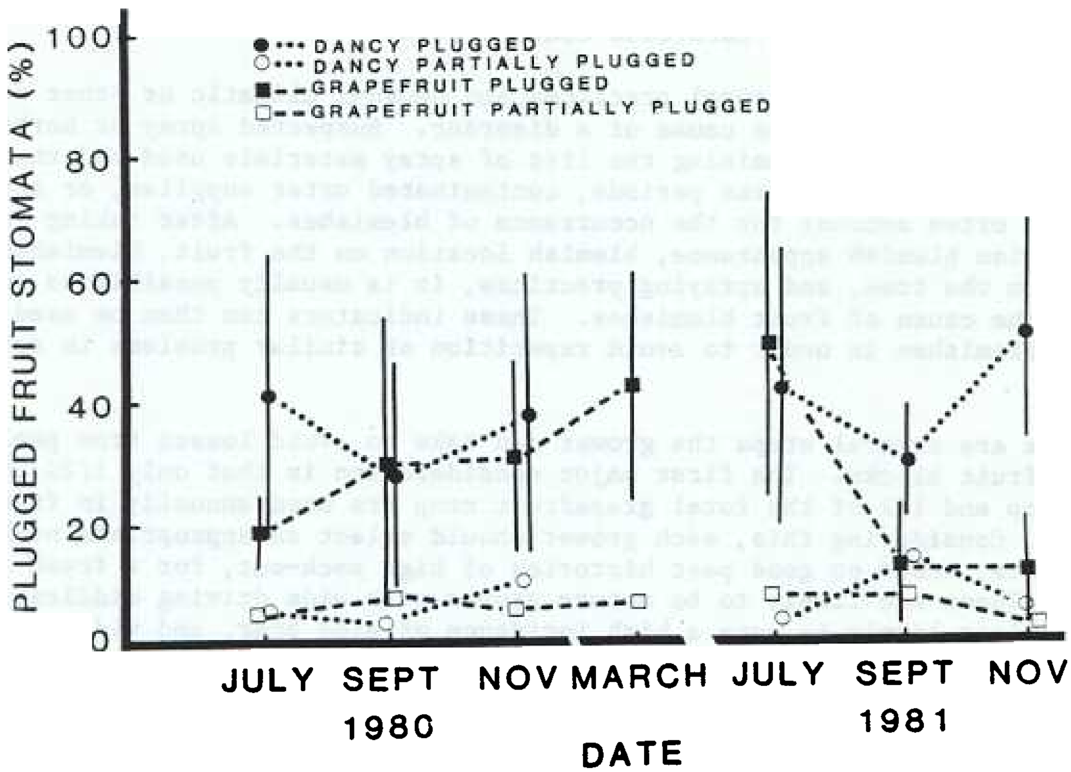

Fig. 3. Average plugging and standard deviations of percent plugging of fruit stomates of 'Dancy' tangerines and 'Marsh' grapefruit on three or four sampling dates in 2 years.

The cause of a blemish can also be indicated by its specific location on the fruit. For example, greasy spot (pink pitting) occurs only between the oil glands because it destroys only a limited number of cells beneath the stomates. Conversely, rust mite usually causes injury over the entire surface; however, on grapefruit, late rust mite injury also can be located mostly between the oil glands. When this happens, it may be difficult to decide whether the blemish was caused by rust mites or greasy spot. Observation of one or more small punctures near the center of a blemish area, especially when there is necrosis, is good evidence of insect feeding or thorn damage.

Evidence for the cause of injuries on the fruit can be found in the position of the injury on the fruit as it hangs on the tree. Spray burns from concentrate spray are usually on the exposed surface. The bottom of the fruit will show spray burns if dilute sprays were used and the drip concentrated the spray material. By maturity, the damaged areas may not be positioned the same as when the spray was applied. In the spring, the stylar end of the fruit tends to be uppermost and, hence, more exposed. As the fruit enlarges and drops down, the stylar end becomes the bottom of the fruit. The exposed part of the fruit in the spring later becomes turned toward the inside of the tree as it drops down from increasing weight during development. Certain disorders characteristically occur on the stem or stylar ends of the fruit (stem-end breakdown, lime stylar-end breakdown, grapefruit blossom-end clearing) and should not be confused with spray burns. Location in the canopy of the affected fruit also can provide valuable information in determining the causes of blemishes. If the affected fruit are predominately on the sun-exposed side of the tree, damage may be from spray burns associated with climatic stress or damage caused by climatic stress alone. Damage to fruit located only at the top or inside of the tree canopy may indicate poor spray coverage, and damage only on bottom fruit may indicate fertilizer or herbicide contact burn.

Information about cultural practices and unusual climatic or other occurrences can help in determining the cause of a disorder. Suspected spray or herbicide burns are often confirmed by examining the list of spray materials used and their time of application. Climatic stress periods, contaminated water supplies, or spraying errors can often account for the occurrence of blemishes. After taking into consideration blemish appearance, blemish location on the fruit, blemished fruit location on the tree, and spraying practices, it is usually possible to successfully identify the cause of fruit blemishes. These indicators can then be used to identify blemishes in order to avoid repetition of similar problems in subsequent crops.

There are several steps the grower can take to avoid losses from peel blemishes in fresh fruit blocks. The first major consideration is that only 1/20 of the orange crop and 1/2 of the total grapefruit crop are used annually in fresh fruit channels. Considering this, each grower should select an appropriate number of grove blocks, based on good past histories of high pack-out, for a fresh fruit program. These are likely to be mature groves with wide driving middles. Large trees are less likely to have a high incidence of wind scar, and wide middles will minimize damage to lower fruit from equipment. Hedged rows across prevailing wind directions will usually result in lower wind scar damage. Cultivating across the grove, traveling tight cross rows, is a practice that leads to heavy damage to lower fruit. All blocks selected for fresh fruit should receive a moderate fertilizer program to avoid green color, rough peel, and accentuation of blemish problems. This type of program will not adversely affect yields. A well-managed irrigation program will avoid prolonged dry or wet periods which also contribute to many peel disorders.

Of vital importance in minimizing blemish losses after blocks are selected is adequate pest monitoring and spray scheduling. Blocks should be examined frequently for insects and mites that can cause blemishes. Even citrus rust mite can be adequately controlled on the basis of a careful and frequent monitoring program which will avoid unnecessary sprays. Of particular importance is the timing of fungicide sprays in fresh fruit blocks. This can be accomplished even with a large number of grove blocks and minimum amount of spray equipment if the fresh fruit blocks are predetermined and given priority. Processing fruit blocks can be sprayed at the beginning and end of the time period considered adequate for control.

Other scheduling and spray procedures that can improve pack-out include using appropriate equipment to provide adequate coverage. Slower spray speeds and dilute sprayers should be used in fresh fruit groves when equipment options are available. Spray material sequences that will lead to pest upsets should be avoided. A recurring example of pest upsets is the increased incidence of armored scale blemishes in many groves where growers have gone back to a heavy sulfur program. This is especially likely if two or more sulfur dusts or sprays are used in sequence.

Finally, the choice of spray materials is of importance in minimizing blemish incidence. Some combinations and individual compounds are very risky in a fresh fruit program. A sulfur application too close to an oil spray is very likely to cause a burn. Another commonly used spray combination that often results in spray burns is ethion and oil. When this combination is applied as a concentrate spray on a 95°F (35°C) summer day, spray burn can occur. Generally, oil tends to increase the phytotoxic potential of any compound because it increases the penetration of chemicals through the stomatal pores and plant cuticle. Difolatan burns are often associated with oil use. Mixing untested combinations of materials in the spray tank and applying these mixtures as concentrate sprays involves serious risks that growers should not take on potential fresh fruit blocks. When chelated nutritionals are mixed with other materials, particularly as concentrate sprays, and applied to young fruit during the post bloom period, spray burns are likely to occur.

The grower should be aware of the fact that grove practices and climatic conditions prior to harvest influence the ability of the fruit to withstand rough handling during or after harvest. Uniform and adequate soil moisture is particularly important in order to avoid several stress-related blemishes. The grower can also reduce handling losses, particularly on mandarins, by applying ethrel preharvest to reduce plugging and improve color of early harvested fruit. The ethrel may also reduce decay due to less degreening time being required. Maintenance of good fertility is important also since low N and K fertility can lead to increased fruit plugging at harvest.

Blemishes are a major concern if good appearing fruit are to be produced under warm, humid tropical and subtropical conditions. Some peel development characteristics have been reviewed. The barrier effects of the cuticle against penetration by foreign organisms and toxic chemicals, and prevention of excessive water loss by the waxes in and on the cuticle, are important in limiting the fruit injuries that do occur. There is need to further improve blemish prevention in citrus production. Many blemishes can be prevented by grower caution and sound practices. The grower should consult current spray guides for control recommendations for recognized insect and disease problems. Better practices on fewer acres will save money and increase profits. Spraying fewer acres for fresh market also reduces the use of cosmetic sprays intended primarily to control agents causing fruit surface blemishes thereby reducing the pesticide impact on the environment.

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