STRESS FACTORS AFFECTING EXTERNAL AND INTERNAL QUALITY OF CITRUS FRUIT

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A number of stresses can affect either internal or external quality of citrus fruit. These stresses can be categorized into general types of causal agents that include climatic and water relations (Table 1), insects and pathogens (Table 2) and phytotoxic pesticides or growth regulators and nutritional stresses (Table 3). About 70 individual problems are recognized, but many rarely occur.

CLIMATIC AND WATER RELATIONS

Of the climatic stresses causing fruit quality reduction, wind scar, poor color (delayed color break or regreening) and section drying are the most common in Florida. Section drying develops with over maturity in mandarin and grapefruit cultivars most years. Freeze damage related section drying occurs about 1 in every 3 to 5 years, particularly in central Florida.

Wind is a problem to citrus production in many areas of the world including Australia, South Africa, California and Florida. Both tree damage and fruit damage can occur. Florida packinghouses commonly eliminate 15 to 30% of the fruit because of wind scar. Citrus fruits are readily bruised and surface cells are killed by the midrib or edges of older leaves rubbing on the tender young fruit 0 to 8 weeks after petal fall. Less severe damage can occur from 9 to 12 weeks after petal fall and normally little damage occurs after 12 weeks. The bruised area darkens and, subsequently, a wound periderm is formed under the damaged area. The periderm expands as the fruit grows. With earlier scarring (0 to 8 weeks post bloom), the initially damaged tissue is completely sloughed off leaving a smooth silvery or brownish blemish.

Windbreaks can be beneficial. For windbreaks to give successful citrus fruit protection, the spring winds should have a primary direction and windbreaks should be placed perpendicular to this primary wind direction. Winds of 10 mph in the tree or 15 to 20 mph (24 to 32 kph), weather reported, unobstructed wind speed probably cause some fruit damage. Windbreaks should reduce wind speeds below damaging levels. Citrus hedgerows, if perpendicular to primary spring winds, provide significant protection from wind scarring.

Poor color development is caused by lack of sufficient cool weather in the fall to induce chlorophyll breakdown and orange pigment development. Warm, wet weather in the spring will cause 'Valencia' oranges to regreen on the stem end. Rootstocks, nutrition and irrigation influence color development in the fall (see other sections of these proceedings).

Section drying is a severe problem in mandarin and grapefruit cultivars. The problem most often manifests itself as hardened juice vesicles (granulation) in mandarins and collapsed juice vesicles in grapefruit. Granulation occurs sometimes in oranges, particularly 'Valencia.' The problem is more severe after the fruit reaches maturity and becomes senescent. Some mandarin cultivars, particularly on rootstocks other than 'Cleopatra' mandarin, develop granulation before they are mature. Severity of section drying varies from year to year and grove to grove suggesting that climatic factors and cultural practices may influence this disorder, but no specific climatic factor influence has been determined.

A problem accompanying vesicle collapse in grapefruit is seed germination. The seed germination appears to be the result of warm spring temperatures and the moisture released by the collapsed juice vesicles.

Table 1. List of citrus fruit quality lowering injuries caused by climatic stress and/or handling.

Causal category	Injury name	Cause	Season first appears
Climatic induced	Wind scar	Winds > 10 mph	Early spring
	Thorn punctures	Wind & thorns	Summer on
	Hail damage	Hail	Anytime
	Creasing	?	Early summer
	Splitting	?	Fall
	Sun scald	Sun radiation	Summer-fall
	Freeze injury	Cold temp.	Winter
	Poor color or delayed color break	Chlorophyll retention, warm temp.	Fall
	Regreening	Warm temp. stimulate chlorophyll synthesis	Spring
	Granulation & drying	?	Nearly mature fruit
Water relations	Pineapple pitting	Water deficits	Fall
	Diluted soluble solids	Excess moisture	Late summer, fall
Unknown	Pitting of grapefruit & oranges	?	Mature fruit
	Rumple of lemon	?	Color break
Mechanical	Harvester damage	Mechanical harvesting	Spring
	Equipment damage	Cultivation, spraying equip.	Anytime
Handling	Zebra skin	Water excess & rough handling	Harvest
	Oleocellosis	Water excess & Rough handling	Harvest
	Stem end rind breakdown	Dessication	Postharvest
	Plugging	Rough picking	Harvest

Table 2. List of citrus fruit quality lowering injuries caused by insects or pathogens.

Causal category	Injury name	Cause	Season first appears
Insects (chewing mouthparts)	Crickets	Hapithus agitator	Early spring
	Grasshoppers	Schistocerca americana	Spring
	Katydids	Microcentrum rhombuifolum	Spring
	Thrips	Anaphothrips orchidii	Spring
	Leaf miners	Mining insects	Spring-summer
	Pink scavenger worm	Pyroderces rileyi	Anytime
	Orange dog	Papilio cresphontes	Summer
Insects & mites (piercing mouthparts or ovipositor)	Citrus rust mite	Phyllocoptruta oleivora	Late spring to Late fall
	Scale spots	Armored scales	Summer on
	Plant bugs	Leptoglossus sp.	Summer on
	Green stink bug spots	Nezara viridula	Summer on
	Mealy bugs	Pseudococcus citri	Spring, early summer
	Broad mite	Hemitarsonemus latus	Spring
	Texas citrus mite	Eutetranychus banksi	Spring
	Fruit flies	Mediterranean, Caribbean oviposit in mature fruit	Mature fruit
	Leprosis	Brevipalpus australis & virus, false spider mite	Summer
	Coffee bean weevil	Araecerus fasciculatus oviposit in mature fruit	Mature fruit
Fungal induced	Melanose	Diaporthe citri	Spring
	Scab	Elsinoe fawcetti	Spring
	Alternaria brown spot	Alternaria citri	Spring
	Greasy spot (pink pitting)	Mycosphaerella citri	Summer
	Flyspeck	Leptothyrium pomi	Summer
	Lime anthracnose	Gloeosporium limetticola	Spring
	Sooty blotch	Gloeodes pomigena	Summer
	Alternaria black rot	Alternaria citri	Fall
	Brown rot	Phytophthora citrophthora parasitica	Mature fruit
Other pathogens	Algal disease	Cephaleuros virescens	Mature fruit
	Bacterial canker	Xanthomonas citri	Spring

Table 3. List of citrus fruit quality lowering injuries caused by toxic chemicals or nutritional stresses.

Causal category	Injury name	Cause	Season first appears
Phytotoxic materials			
Nutritional	Boron toxicity	Application	Spring
	Chelate burn	Nutrient sprays	Spring-summer
	Granular fertilizer burn	Spreader use with dew still on fruit	Anytime
Pesticides	Copper toxicity	Sprays	Spring-summer
	Difolatan	Sprays	Anytime
	Copper-oil	Sprays	Spring-summer
	Copper-lime-sulfur (historical)	Sprays	Summer
	Oil blotch	Sprays	Summer or fall
	Sulfur	Sprays	Spring-summer
	Sulfur-oil	Sprays	Spring-summer
	Oil + ethion, trithion, zineb or chelates	Sprays	Spring-summer
	Trithion	Sprays	After August
	Dinitro (historical)	Sprays	No longer used
Growth regulators	GA burn	Gibberellin k+ sprays	Fall
	Arsenic toxicity	Sprays	Spring
	2,4-D	Direct sprays	Fall-winter
Herbicides	Paraquat	Direct sprays	Summer
	2,4-D	Sprays	Summer
Nutritional	Copper deficiency	Low copper	Spring
	Boron deficiency	Low boron	Spring
	High N--green fruit	High fertility	Fall
	Splitting--low K	Low K	Fall

Water relations are probably related to several disorders common to citrus. Excessive moisture in the late summer and fall leads to dilution of soluble solids and acids resulting in large insipid fruit. Cycles of severe drought on shallow or low moisture capacity sandy soils appear to contribute to peel necrosis problems such as 'Pineapple' pitting.

Water relations can play an important role in fruit condition. Several harvesting and handling problems are the result of poor handling practices under unfavorable moisture conditions. Mandarin cultivars, if subjected to rough handling when turgid from excess moisture, can develop injury to the raised peel areas over the juice segments. This gives a longitudinal striped appearance to the fruit referred to as 'Zebra Skin.' Blossom-end-clearing in grapefruit and stylar end breakdown of limes are similar problems. All citrus is subject to oleocellosis if it is too turgid when harvested and abraded by sand grains. The firm peel will not give and the sharp edges of sand grains or other objects rupture oil glands. The toxic oils kill or injure surrounding cells. The problem is most noticeable if degreening is required since the peel oils prevent degreening of the injured areas. Harvesting fruit wet accentuates this problem. The fruit peel is usually turgid and sand is more likely to adhere to the fruit surface. Dought stressed peel and dessicating conditions after harvest often lead to breakdown of an area near the stem end (stem-end rind breakdown). Field stress and late harvest of 'Valencia' oranges or grapefruit can result in a dark, wrinkled appearance of the stem-end peel (aging).

INSECTS AND PATHOGENS

Although many insects can attack citrus fruit, few are of economic importance. Citrus rust mite damage is the most prevalent and is covered in another section of these proceedings. Scale insects may be the second most common insect problem on citrus fruit. The scale insect's armor often remains after washing and downgrades the fresh fruit. Some scale feeding results in fruit areas that will not degreen early in the season. Plant bugs can cause fruit injuries also. Mowing or disking before harvest forces the adults from their host weeds to the fruit. Plant bug feeding can allow secondary infections by fungal organisms and feeding injury leaves brown spots on sectionized grapefruit. Coffee bean weevil can occasionally be a problem but mostly on over-mature fruit. Caribbean fruit fly and Fuller Rose beetle cause little damage but interfere with marketing because of quarantine restrictions.

Melanose, scab, Alternaria brown spot, pink pitting and sooty blotch are the most common fungal induced blemishes on fruit. As blemishes, none of these problems are of concern to processing fruit quality, although the pink pitting causing organism, Mycosphaerella citri, causes greasy spot on leaves and this disorder can seriously depress yields the following year due to leaf drop. Melanose affects most cultivars. Melanose is usually severe in older or freeze damaged trees with more dead wood. The melanose causal agent (Diaporthe citri) colonizes dead wood. Lesions develop on young fruit (1st 3 months post bloom) after rain or irrigation washes spores onto the fruit if the fruit remains wet for 18 or more hours. One of two copper sprays postbloom are used to control melanose. Sooty blotch is the result of the buildup of a dead fungal mycelia mat with adhering debris on the fruit surface during the fruit's growth. The fungal organism, Gloeodes pomigena, firmly attaches the mat to the cuticle. Summer oils help to loosen this mat and a summer copper spray controls Gloeodes. Often, particularly on grapefruit, this mat is not completely removed by packinghouse wash lines.

Alternaria brown spot, scab and pink pitting are blemishes that occur on a few specific cultivars for each fungus and are serious problems on the cultivars affected. Alternaria citri attacks 'Dancy' tangerines and 'Minneola' and 'Orlando' tangelos. Scab can be serious on 'Temple' and 'Orlando' tangelo and moderate on

grapefruit and 'Murcott.' Pink pitting can be a serious rind blemish problem on grapefruit. Copper or copper-oil sprays at appropriate times are recommended for control of these disorders.

Bacterial canker (A and B strains) is a potentially serious rind blemish problem, particularly on grapefruit and limes. It is not presently a problem in commercial citrus in Florida.

PESTICIDES, GROWTH REGULATORS AND NUTRIENTS

Nutritional levels greatly affect both internal and external fruit quality and are covered elsewhere in these proceedings. Blemishes due to nutritionals are not very common, but chelated metal sprays can cause burns if sprayed as concentrate, particularly with oil (Table 3). Growth regulators can cause burn or spotting problems when applied at higher than recommended rates. This is rarely seen in Florida. Many pesticides are phytotoxic and cause burns to fruit if applied at higher than the recommended rates or under adverse, stressful weather conditions.

Some combinations and individual compounds are very risky in a fresh fruit program (Table 3). A sulfur application during a hot period or 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 95°F (35°C) plus summer days, 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. 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.

PRODUCTION, HARVESTING AND HANDLING MANAGEMENT

Most packinghouses average 40% eliminations and some lots of fruit brought to packinghouses in the past have run 70 to 80% eliminations. Most of the blemishes which cause elimination occur prior to harvest. Fruit with a high pack-out potential is basic to a successful fresh fruit operation. This has become more important in recent years because of increasing production and packing costs without a proportionate increase in fresh fruit prices. One study found that, averaged over a season of operation, the packinghouse's profit per packed carton could be increased up to $0.06 for every 10% increase in pack-out.

There are several steps that can be taken to avoid losses from peel blemishes in fresh fruit blocks. The first major consideration is that less than 1/10 of the orange crop and 1/2 of the total grapefruit crop are used annually in fresh fruit channels. Considering this and based on good past histories of high pack-out, each grower should select an appropriate number of grove blocks 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 travel. Hedged rows oriented 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. The current trend toward higher density plantings of smaller trees in hedgerows can be advantageous toward reducing fruit blemishes. Good hedgerows can reduce wind scar and, with wide middles, no mechanical injury should occur. Smaller trees will allow better spray coverage for pest control. 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. An example of pest upsets is the increased incidence of armored scale blemishes in groves where growers rely heavily on sulfur. This is especially likely if two or more sulfur dusts or sprays are used in sequence.

Because of potential phytotoxicity, the choice of spray materials is of importance in minimizing blemish incidence. 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.

The grower and shipper should be aware that climatic conditions prior to harvest and grove practices 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. Maintenance of good fertility is important since low N and K fertility can lead to increased fruit plugging at harvest. Handling losses, particularly on mandarins, can also be reduced by applying ethrel preharvest to reduce plugging and improve color of early harvested fruit. The ethrel may also reduce decay because less degreening time is required.

The need for improved blemish prevention in Florida citrus groves is obvious. Many blemishes can be prevented by using sound practices. The grower should consult the current Florida Citrus Spray Guide for the latest control recommendations for insect and disease problems. Better practices on fewer acres will save Florida money and increase profits. Spraying fewer acres for fresh market also would reduce the use of cosmetic sprays intended primarily to control fruit surface blemishes thereby reducing the pesticide impact on Florida's environment.

References

1. Abbitt, B., J.O. Whiteside, and L.G. Albrigo. 1978. A comparison of spray costs and fruit pack-out. Citrus Veg. Mag. 41(7):10, 14, 36, 38.

2. Albrigo, L.G. 1975. Water relations and citrus fruit quality. Proc. 2nd. Int. Citrus Short Course--Water Relations, Oct. 17-18, 1975, pp. 41-48, Univ. Fla.

3. Albrigo, L.G. 1978. Occurrence and identification of preharvest fruit blemishes in Florida citrus groves. Proc. Fla. State Hort. Soc. 91:78-81.

4. Albrigo, L.G. 1986. Peel morphology and fruit blemishes. Proc. Citrus Short Course--Citrus Flowering, Fruit Set and Development, March 26-27, 1986, pp. 73-80, Univ. Fla.

5. Albrigo, L.G., M.A. Ismail, P.W. Hale, and T.T. Hatton, Jr. 1981. Shipment and storage of Florida grapefruit using unipack film barriers. Proc. Int. Soc. Citriculture 2:714-717.

6. Bar-Akiva, A. 1975. Effect of potassium nutrition on fruit splitting in 'Valencia' orange. J. Hort. Sci. 50:85-89.

7 Caprio, J.M. 1956. An analysis of the relation between regreening of 'Valencia' oranges and mean monthly temperatures in Southern California. Proc. Amer. Soc. Hort. Sci. 67:222-235.

8. Florida Citrus Integrated Pest and Crop Management Handbook. 1983. Fla. Coop. Ext. Service, IFAS, Univ. Fla., Gainesville, SP-14.

9. Florida Citrus Spray Guide. 1988. Coop. Ext. Service, IFAS, Univ. Fla., Gainesville, Cir. 393-E.

10. Grierson, W. 1957. The effect of pack-out on grower profits. Proc. Fla State Hort. Soc. 70:21-28.

11. Grierson, W. 1958. Causes of low pack-outs in Florida packinghouses Proc. Fla. State Hort. Soc. 71:166-170.

12. Grierson, W., M.F. Oberbacher, and W.L. Thompson. 1960. Fruit color, grove practices, and fresh fruit pack-out with particular reference to tangerines. Proc. Fla. State Hort. Soc. 73:96-100.

13. Jones, W.W. and T.W. Embleton. 1959. The visual effect of nitrogen nutrition on fruit quality of 'Valencia' oranges. Proc. Amerc. Soc. Hort. Sci. 73:234-236.

14. Jones, W.W., T.W. Embleton, M.J. Garber, and C.B. Cree. 1967. Creasing of orange fruit. Hilgardia 38:231-244.

15. Klotz, L.J. 1961. Color handbook of citrus diseases. Univ. Calif. Press Berkley and Los Angeles, CA, USA, 75 pp.

16. McCornack, A.A. 1966. Blossom-end clearing of grapefruit. Proc. Fla. State Hort. Soc. 79:258-264

17. McCornack, A.A. and W. Grierson. 1965. Practical measures for control of rind breakdown of oranges. Univ. Fla. Agr. Ext. Service Cir. 286, 3 pp.

18. Monselise, S.P., M. Weiser, N. Shafir, R. Goren, and E. E. Goldschmidt. 1976. Creasing of orange peel--physiology and control. J. Hort. Sci. 51:341-351.

19. Oberbacher, M.F. 1965. A method to predict the post-harvest incidence of oleocellosis on lemons. Proc. Fla. State Hort. Soc. 78:237-240.

20. Pratt, R.M. 1958. Florida guide to citrus insects, diseases, and nutritional disorders in color. Univ. Fla. Agr. Expt. Sta., Gainesville, FL, USA, 191 pp.

21. Tilley, D.S. 1976. Florida citrus packinghouse cost-volume relationships Proc. Fla. State Hort. Soc. 89:183-185.

22. Turrell, F.M. 1950. A study of the physiological effects of elemental sulphur dust on citrus peel. Plant Physiol. 25:13-62.

23. Turrell, F.M., S.P. Monselise, and S.W. Austin. 1964. Effect of climatic district and of location in tree on tenderness and other physical characteristics of citrus fruit. Bot. Gaz. 125:158-170.

24. Wardowski, W.F., A.A. McCornack, and W. Grierson. 1976. Oil spotting (oleocellosis) of Citrus fruit. Univ. Fla. Coop. Ext. Service Cir. 410, 4 pp.

Whiteside, J.O. 1986. Diseases of fruit. Proc. Citrus Short Course--Citrus Flowering, Fruit Set and Development, March 26-27, 1986, pp. 81-89, Univ. Fla.

Woodruff, R.E. 1972. The coffee bean weevil, Araecerus fasciculatus (DeGeer), a potential new pest of citrus in Florida (Coleoptera:Anthribidae). Fla. Dept. Agr. and Consumer Service, Div. Plant Ind., Entomol. Cir. 117, 2 pp.