CLIMATE AND FRUIT QUALITY

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INTRODUCTION

Specialists have long recognized that there are large differences among citrus growing regions, not only in growth and yield of trees, but also in physical and chemical characteristics of the fruits. Also, there are marked differences in the time lapse between anthesis (bloom) and market maturity and in the period that marketable fruit may be stored on the tree. Indeed, these factors, among others, determine the adaptability of a specific variety for commercial exploitation in a particular citrus growing region.

Only in recent years have there been studies with citrus aimed at disentangling climatic influences from cultural and soil factors. The data so far obtained indicate that within fairly broad parameters of adaptable soil and reasonably good cultural and crop protection practices, climate is the most important component of the climate-soil-culture complex causing differences in growth, yield, and fruit qualities among commercial citrus producing areas.

Much of what we know concerning the influence of climate on quality of citrus fruits has been acquired in subtropical climates in the major commercial citrus producing regions. Moreover, most of such knowledge is inferred from comparative orchard studies in which climatic factors were, of necessity, uncontrolled variables. Relatively few studies of fruit quality have been made in climate-controlled facilities or in the tropics. In spite of our inability to do much about isolating climatic effects in orchard studies, quality studies comparing fruit grown in sharply differing climatic regions, together with the few controlled environment experiments make certain broad relations clear. Among all the elements of climate obtaining in the commercial orchard, the temperature or energy regime during fruit development is probably the dominant one influencing fruit quality.

GROUND LEVEL CLIMATIC FACTORS

General Considerations

Studies with citrus and other fruit all indicate that the various physical, chemical, and other elements which make up market quality cannot be directly or precisely correlated with the commonly available meteorological data such as air temperature, humidity, wind movement, hours of sunshine, rainfall, etc. This is so because the biological processes controlling growth and development of tissues and organs such as fruit are strongly influenced by such factors as tissue temperature, cell turgor, and meristematic activity (cell division), among others. All of these are in turn influenced in complex ways by air temperature, wind velocity, relative humidity, sunshine, soil moisture, and other factors which together influence the exchange of energy between the plant's tissues and its environment. Thus on a given tree, shaded fruit inside the leaf canopy will be cooler during sunny days and warmer during the night than exposed or partly shaded fruit. However, during windy and/or rainy

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overcast periods, such differences may be largely obliterated. Variations in seasonal and regional energy flux conditions in relation to stage or fruit development play an important role in determining ultimate market quality.

To further complicate matters, the several tissues making up citrus fruit tend to respond independently to climatic diversity during the course of development and maturation. Thus under certain climatic conditions, some varieties have internal juice characteristics still of good market quality after the peel has entered the senescent stage. This is why the growth regulator, gibberellic acid, is used nowadays to delay the onset of peel senescence. This enhances shipping, handling, and shelf life qualities and extends the marketing season. Conversely, under certain other climatic conditions, some varieties obtain optimum peel color and other characteristics suitable for marketing before juice characteristics reach market quality.

The discussions which follow will emphasize energy-related aspects of climate in relation to fruit quality. Throughout, a closer relation of "air temperature" to fruit temperature is implied than is justified, since energy flow to and from the fruit and other plant tissue is influenced by numerous other environmental factors. Nevertheless, in terms of the great diversity of climates among regions growing citrus, seasonal air temperature regimes, as indicated by monthly mean maxima and minima, provide a readily available rough index of energy levels prevailing during the course of fruit development. A better index would reflect actual tissue temperature, but such data are not widely available.

Cyclic Factors: Dormancy, Growth and Bloom

During the winter months in subtropical citrus regions, mean air and soil temperatures normally fall below about 15°C (59°F) for several months. This causes growth to cease and the tree to become dormant for 3 to 5 months. This dormancy, among other things, causes changes within tissues which induce flowering when warmer temperatures in the early spring cause resumption of vegetative growth. Thus, in a typical subtropical climate with cool winters, citrus tends to bloom profusely in the spring and typically produce only one major crop which matures in fall, winter, or spring, depending on the variety. In a tropical climate, in contrast, there is no period of cold temperature to induce dormancy, and given ample year around soil moisture, most citrus species produce some bloom in every month of the year (Figure 1). However, with periods of less than ample soil moisture, flushes of bloom and vegetative growth normally follow periods of drought in the tropics. Thus, flower induction and blooming is not fundamentally dependent on low temperature, short days, or dormancy *per se*. Evidently there are cyclic internal factors involved with past physiological and fruiting history which will ultimately cause flowering of a particular branch in the absence of external conditions favoring dormancy.

From the above considerations, it is clear that climatic conditions, even season to season variations, can influence time and amount of bloom and the subsequent temperature regime experienced by the fruit during the course of its growth and maturation. Such differences in the thermal highway travelled by the fruit (and the tree that bears it) on its road to maturity cause differences in both external and internal aspects of fruit quality. For example, in Florida, February bloom fruit is generally of better quality than June bloom fruit. The latter is likely to be of coarser texture and thicker rind and develop faster from bloom to market maturity than the former. The June bloom fruitlet goes through its first stage of development rapidly in response to warm growing conditions, while the February bloom fruit go through this first stage of development (from petal fall to fruitlets about 2 cm diameter) which more slowly

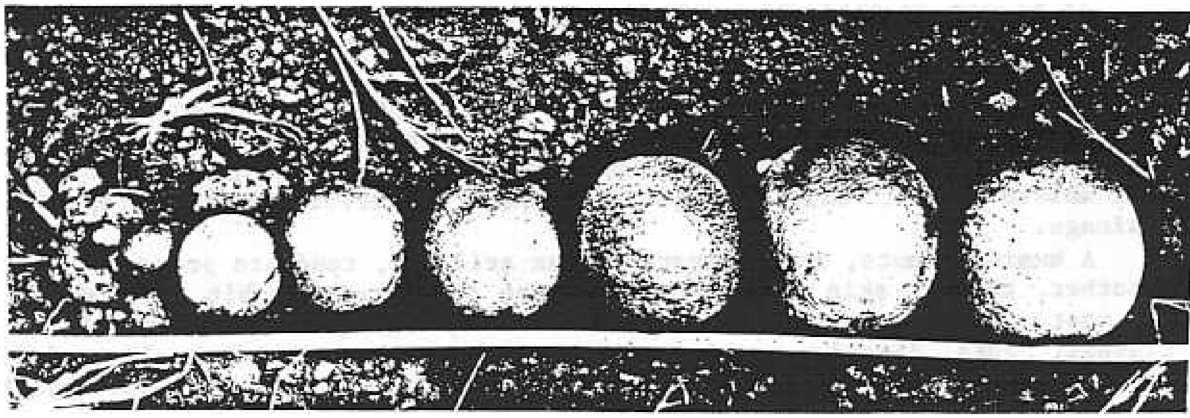

Figure 1. Fruits harvested the same day from an orange tree growing at Palmira, Colombia, near the equator. They range from 1 cm to 7 cm in diameter, and represent 8 different blooms on a single tree.

in cooler weather. During this first stage of fruit development most of the cell division takes place which lays down the basic morphology of the fruit. Subsequent growth is very largely by cell enlargement. Except in the peel, no further cell division takes place after this first stage. On the other hand, most of the solids which accumulate in the fruit do so during the period after the fruit has attained 2/3 to 3/4 of its ultimate size. This occurs later in June bloom than February bloom fruit in Florida, and hence during cooler weather. These and other factors account for much of the differences in quality of fruit originating from different blooms.

Concurrently with the influence of temperature factors on fruit quality there is a strong influence of the vigor of vegetative growth on fruit development and quality. In a sense, vegetative growth is competitive with fruit growth for available nutrients such as sugar and minerals. Flushes of heavy vegetative growth will reduce the solids available to developing fruits, while a period of dormancy will increase the solids available. Dormancy due either to low temperature or moisture stress, in initial stages at least, reduces photosynthetic efficiency or net carbon assimilation less than it reduces growth. This competition between vegetative growth and fruit development for nutrients is one reason for the somewhat reduced solids concentrations often found in tropical oranges as compared to subtropical oranges. Also tending to reduce solids is the relatively high rates of respiratory loss of carbon during the warm nights typical of the tropics. In the subtropics, the cooler fall months check growth somewhat but favor high rates of photosynthesis, while in much of the tropics, the climate resembles midsummer subtropical growing conditions throughout the course of fruit development. Similarly, irrigation in the drier fall and winter in Florida may reduce total soluble solids in fruit in some seasons through its tendency to stimulate vegetative growth, among other factors.

The above discussions point out that climatic factors tend to interact in complex ways with growth, flowering, and metabolic factors to influence fruit growth and maturity, and ultimately, market quality of the fruit.

Rainfall, Humidity and Wind

It is not feasible here to discuss the influence of rainfall or humidity on citrus responses *per se* because it is difficult to isolate them as discrete aspects of the environmental complex. Rainfall and relative humidity are interrelated, and both moderate energy flux, which in turn influences tissue temperature, cell turgor, and the metabolic processes within tissues. The amount and distribution of annual precipitation have a major direct effect on soil moisture, but this can be manipulated artificially by irrigation and drainage.

A humid climate, when compared to an arid one, tends to produce fruit with smoother, thinner skin and trees with more open growth habit (Figure 2). But its most significant effect is on the ability of diseases to parasitize tree tissues. Thus, diseases causing rind blemishes affect market quality of fruit. Diseases of the leaves and other tissues of the tree may reduce photosynthesis and yield and adversely affect juice quality.

The amount, velocity, and seasonal distribution of winds are of some importance in determining the adaptability of a region to citrus culture. Excessive wind, especially when the fruits are young, causes scarring and consequent loss of market value of fruits and stimulates abscission of leaves and fruit. Gentle air movement or breezes with velocities up to 15 or 20 km per hour are often beneficial and promote drying of tissues, thus reducing fungus or bacterial disease damage noted above.

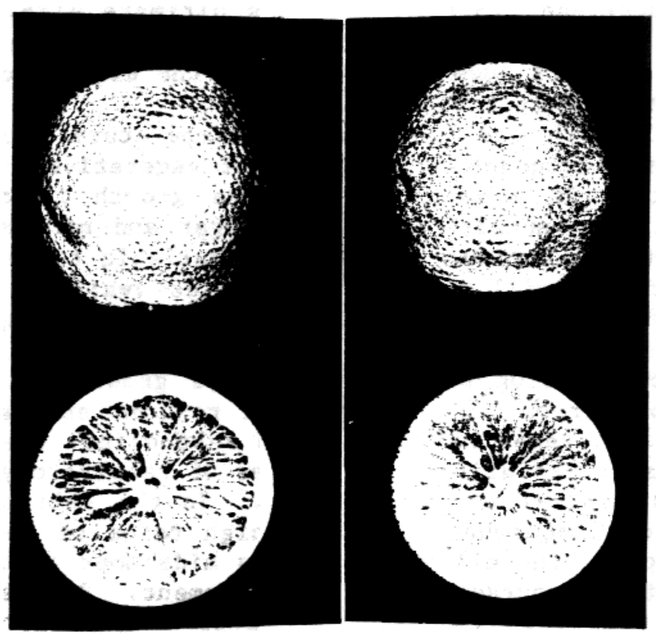

Figure 2. Typical effects of climate on peel texture and thickness of 'Valencia' oranges. Left: grown in the hot, arid Salt River Valley of Arizona. Right: grown in the hot, humid central "Ridge" section of Florida.

Day Length and Light

Within the parameters of the climates supporting commercial citriculture it is unlikely that length of day has much direct effect on fruit quality. Under controlled climatic conditions in artificial growth chambers, it has been shown that long days stimulate shoot growth when temperature conditions are favorable for rapid growth.

There is little direct evidence available on the effect of light intensity or light quality on fruit quality. Fruit of excellent internal and external quality can be produced on trees in the shade of other trees such as sabal palms in Florida and date palms in California and elsewhere. However, yield is usually about 1/2 or less of comparable unshaded trees.

Studies of the juice composition comparing fruit borne in various positions on the tree canopy show clearly that inside, heavily shaded fruit may have 10 to 15% (1 to 1.5 percentage points) less total soluble solid than outside, exposed fruit (Figure 3). Light levels inside the tree canopy of a healthy citrus tree are 10% or less of those impinging on the unshaded, outside portion. At 1.2 meters (about 4 feet) within the canopy, light levels may be 1% or less of full sunlight. Other studies suggest that a light level of about 25% of full sunlight is needed to sustain maximum net photosynthesis of leaves under ordinary orchard conditions. Hence it is clear that insufficient light contributes to reduced total soluble solid concentration of inside fruit nourished by heavily shaded leaves.

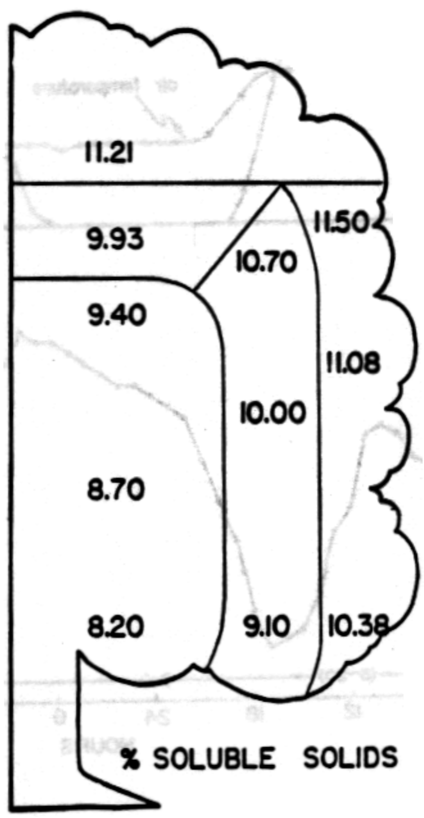

Figure 3. The TSS (% in juice) of 'Valencia' oranges in relation to the position on the tree (After Reitz and Sites. FSHS 61:80-90, 1948).

There is little evidence to indicate that citrus fruit quality is greatly affected by season to season variations in solar radiation (hours of sunshine) *per se*. However, there may be some differences in quality among regions due to solar radiation, but not directly because of limiting light for photosynthesis. The data summarized in Figure 4 indicate that fruits do not grow (increase in volume) during bright sunshine; in fact, they shrink in volume. Most growth takes place during the night. However, during cloudy days, growth may occur during overcast periods in the daytime. Hence in a wet, humid climate like Florida, fruit (especially during its early active cell division stage) is not subject to as great an amplitude of diurnal shrinking and swelling as in the drier climates of California or Arizona, with fewer hours of cloudiness. This probably is partially responsible for the thicker, coarser texture of the rind (and lower juice content) commonly observed associated with dry climate as compared to humid climate citrus fruit (Figure 2).

TEMPERATURE EFFECTS

Fruit Growth and Maturation

Typical Valencia fruit growth curves in four very diverse climates are shown in Figure 5. The corresponding sensible air temperatures are shown in Table 1 (Orlando, Florida, not shown, is very similar to Lake Alfred, Florida).

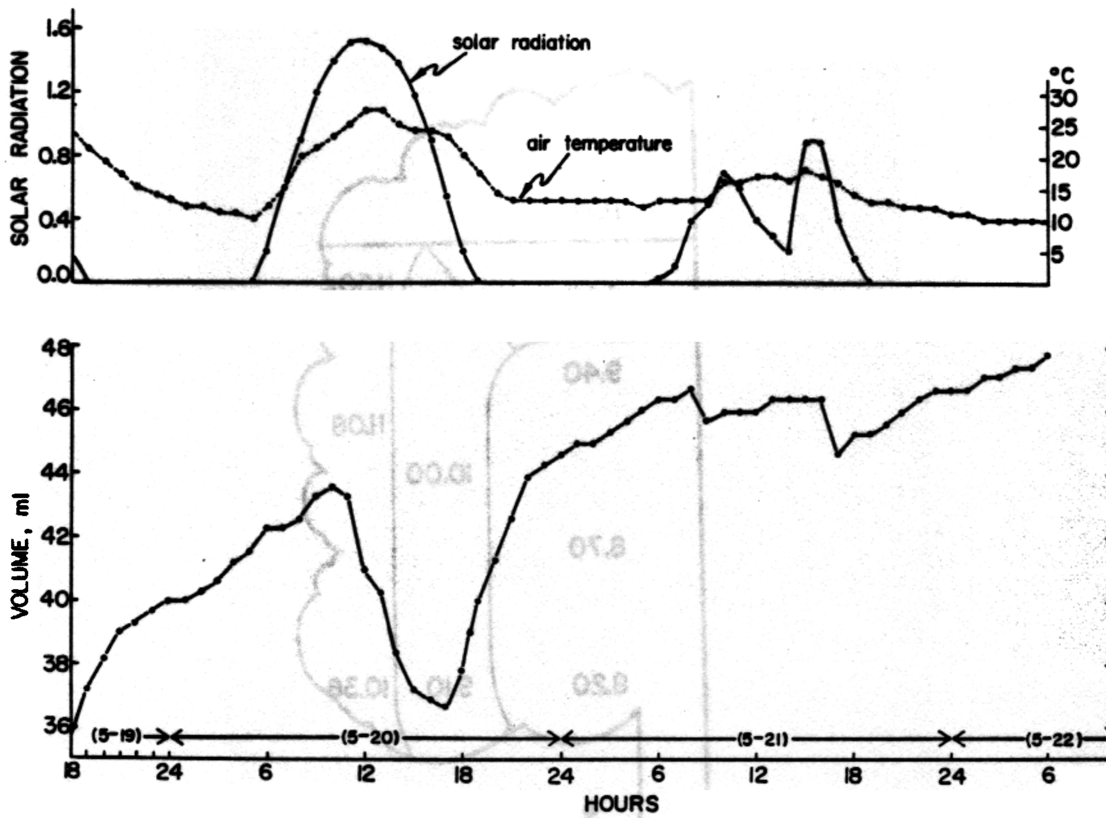

Figure 4. Typical diurnal cycles of changes in volume of a young 'Valencia' orange fruit in relation to solar radiation (sunshine) and air temperature in Riverside, California.

Table 1. MONTHLY MEAN MAXIMUM AND MINIMUM TEMPERATURES IN SELECTED CITRUS-GROWING AREAS
Temperatures (°C)

Day/Night	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
Homestead, Florida. Latitude, 25°30'N; Elevation 3 m; 1931-60.												
Max	25.4	26.2	27.5	29.1	30.7	31.8	32.3	32.7	31.7	29.8	27.4	25.9
Min	12.0	12.2	13.7	16.2	18.1	20.5	21.2	21.4	21.5	19.3	15.5	12.9
Lake Alfred, Florida. Latitude, 28°06'N; Elevation, 55 m; 1938-60.												
Max	22.9	24.0	26.0	28.5	31.2	32.8	33.1	33.3	31.9	29.3	25.4	23.1
Min	9.6	10.3	12.5	15.2	18.1	21.2	22.2	22.2	21.5	17.8	13.0	10.1
Weslaco, Texas. Latitude, 26°09'N; Elevation, 34 m; 1923-60.												
Max	22.2	24.6	26.9	30.1	32.2	34.0	34.8	35.7	33.4	30.6	25.8	22.5
Min	10.2	11.9	14.6	18.1	20.8	22.7	23.2	23.2	21.8	18.1	13.4	10.8
Indio, California. Latitude, 33°44'N; Elevation, 3 m; 1897-1960.												
Max	21.1	23.5	26.7	30.5	34.1	38.8	41.6	40.8	38.6	33.1	27.0	22.1
Min	3.4	6.3	9.6	13.8	17.6	21.8	25.2	24.4	20.8	14.5	7.5	5.8
Lindsay, California. Latitude, 36°11'N; Elevation, 120 m; 1915-60.												
Max	13.7	17.4	20.8	25.2	29.5	34.2	38.1	36.8	33.2	27.1	20.2	14.3
Min	1.5	3.1	4.5	7.2	9.7	12.8	15.9	14.7	12.3	8.1	3.2	1.9
Riverside, California. Latitude, 33°57'N; Elevation, 250 m; 1897-1960.												
Max	18.8	19.7	21.5	24.0	26.3	30.3	34.5	34.3	32.9	28.1	24.0	19.8
Min	3.2	4.4	5.1	7.5	9.7	11.6	14.0	13.8	12.1	8.7	5.3	3.5
Santa Paula, California. Latitude, 34°21'N; Elevation, 86 m; 1947-1960.												
Max	19.0	20.7	21.9	22.8	23.5	25.2	28.1	27.2	29.0	26.7	24.3	21.5
Min	4.8	5.0	5.4	7.8	9.1	10.7	12.4	12.2	11.7	9.6	7.3	5.9
San Pedro Sula, Honduras. Latitude, 15 1/2°50'N; Elevation, <100 m.												
Max	28.5	30.4	32.4	33.8	34.0	33.7	32.4	33.2	33.0	30.7	29.4	27.9
Min	17.9	17.8	19.5	20.0	21.7	22.1	21.8	21.7	22.0	20.9	19.9	18.9
Palmira, Colombia. Latitude 3 1/2°N; Elevation, 1006 m.												
Max	30.3	30.7	30.5	29.7	29.1	29.4	30.5	30.7	30.5	29.4	29.1	28.6
Min	17.9	18.2	18.4	18.4	18.3	18.0	17.5	17.7	17.7	17.9	18.1	18.1

These data illustrate that monthly mean maximum and minimum air temperatures and rates of fruit growth are related only in a broad general way. The rates of fruit growth and maturation are much more rapid in the tropical climate of Palmira, Colombia, with year around warm temperatures, than in Santa Paula, California, with a year around cool temperature. In between are the more typical subtropical climates like Orlando, Florida, and Indio, California. The desert climate of Indio, California, is, however, very much hotter in summer and very much cooler in winter than Orlando, Florida (Table 1) yet their growth and maturation rates are similar.

In the Santa Paula region, 'Valencia' fruit typically require about 13 to 14 months from bloom to market maturity, while in the Indio, California, and Orlando, Florida, areas, only about 11 months are required. In tropical Palmira, Colombia, only 6 1/2 to 7 months are required. There is a similar relation between seasonal temperature regime and the length of time Valencia fruit may be stored on the tree after reaching market maturity. Thus, the Santa Paula region mostly harvests Valencia oranges during the summer months, 2 to 5 months after market maturity is first reached. Harvest of Valencia oranges in Indio, California, and Orlando, Florida, is largely during the spring and early summer, 0 to 4 months after reaching market maturity. In the Central Valley of California (growth curve not shown) the harvest of 'Valencia' orange is confined largely to about 4 months (April-June), also 0 to 4 months after market maturity is reached.

The data summarized in Figure 5 emphasize that the influence of climate on growth and maturation rate is only very broadly influenced by air temperature

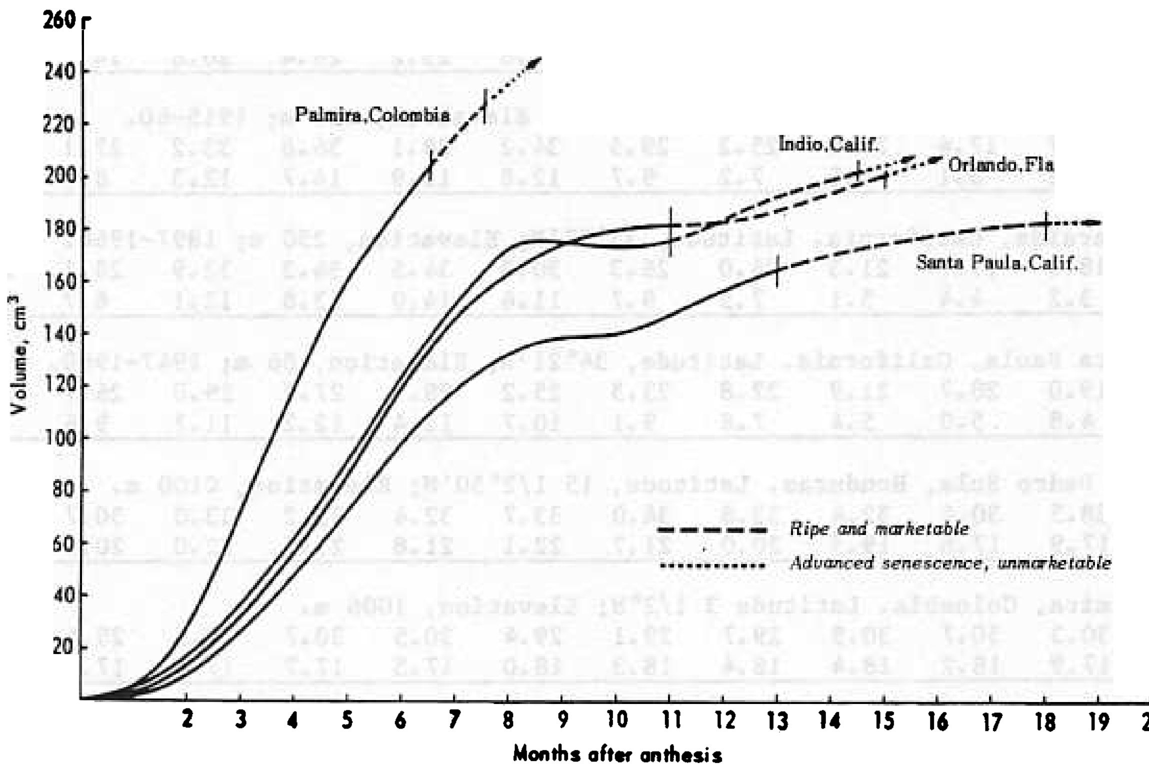

Figure 5. Typical 'Valencia' orange growth curves in four widely different climatic regions. All represent conditions of adequate soil moisture throughout the growth periods indicated. Comparative periods of immaturity, market maturity, and advanced senescence are approximated.

regimes and may sometime be similar in sharply differing air temperature regimes such as Indio and Orlando, for example. There is evidence that a better measure of heat flux, such as heat accumulation, would closely approximate tissue temperature regimes and thus rèlate better to rate of fruit growth and maturation than conventional sensible air temperatures.

The data shown in Figure 6 compare the trends in the concentration of total soluble solids to the concentration of acid in juice of 'Valencia' orange in three of the locations shown in Figure 5. A ratio of 9 to 1 was arbitrarily selected to be the threshold of market maturity and represents the thresholds indicated in Figure 5. These data further emphasize the strong influence of climate, especially temperature, on the rate of maturation.

Physical Characteristics: The fruit shown in Figure 7 illustrate typical differences in size and shape of fruits of the 'Dancy' variety (loose-skinned mandarin group) in response to differences among four major climatic zones in southern California. All were harvested during the last week in January and grafted on Troyer rootstock. The two on the left (L = Santa Paula and SC = Tustin) are cool, coastal climates not suited to this variety. The two on the right (LC = Lindcove near Visalia and T = Thermal near Indio) are hot inland valley and desert climates better suited to this variety.

Variations of such effects of climate on fruit morphology, including rind texture, color, thickness, and shape may be noted with most other varieties of citrus. The illustrations shown in Figure 7 emphasizes the effect on size and shape, including the tendency to produce a neck. Such effects may be moderated by non-climatic factors, such as crop load, rootstock, and certain cultural practices. Nevertheless, the temperature regime during fruit growth and development plays a dominant role influencing fruit morphology.

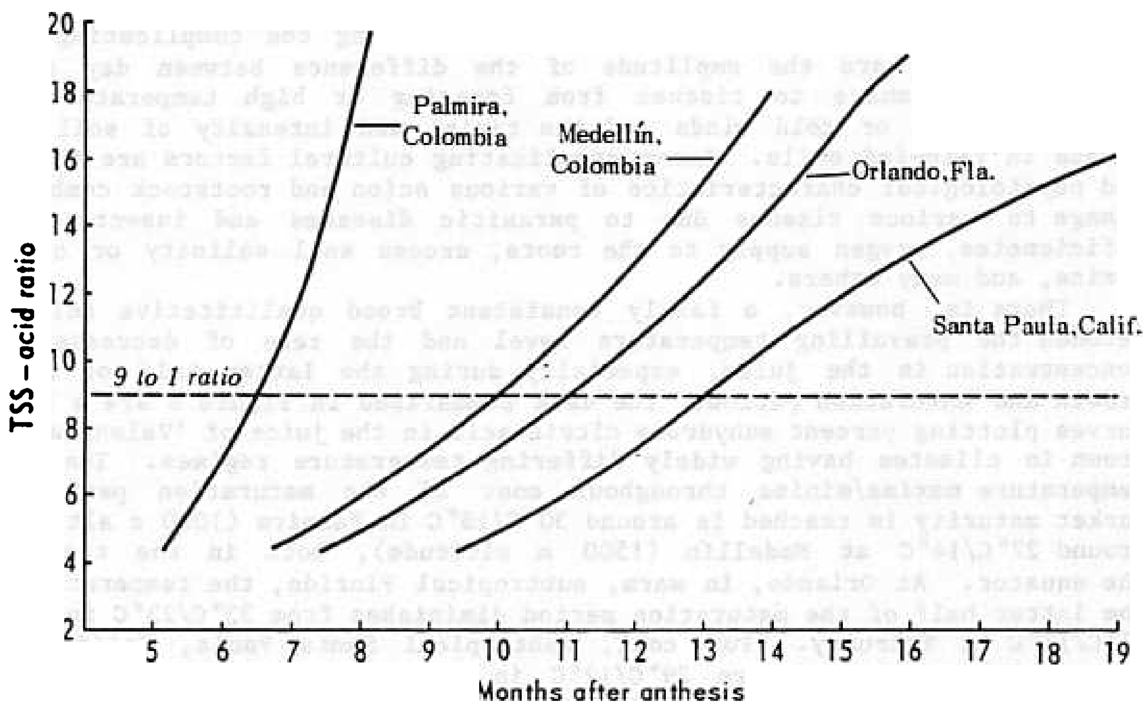

Figure 6. Trends in the rate of maturation of 'Valencia' oranges in four widely differing climates.

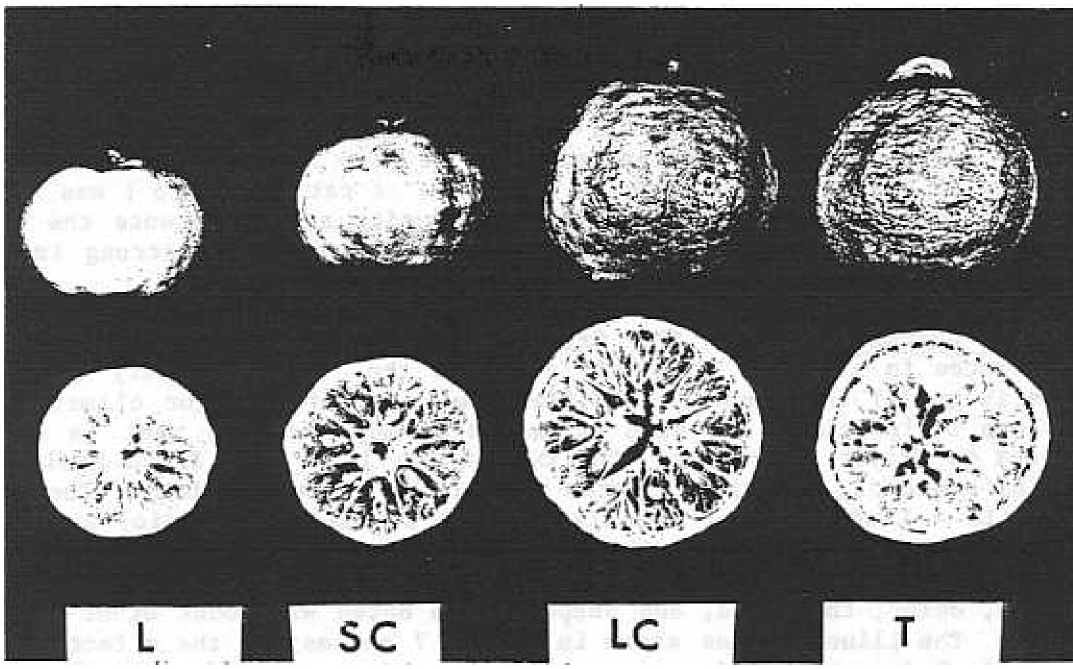

Figure 7. Typical variation in the size and shape of the 'Dancy' variety grown in four major citrus growing regions of southern California.

Juice Composition: It is not possible to formulate any very meaningful generalizations on the effect of diverse temperature regimes during maturation on the total soluble solids content of the juice. Among the complicating climate-related factors are the amplitude of the difference between day and night temperatures, damage to tissues from freezing or high temperature stress, dessicating hot or cold winds and the timing and intensity of soil moisture stress in rain-fed soils. Among complicating cultural factors are the genetic and physiological characteristics of various scion and rootstock combinations, damage to various tissues due to parasitic diseases and insects, nutrient deficiencies, oxygen supply to the roots, excess soil salinity or other soil toxins, and many others.

There is, however, a fairly consistent broad qualititative relationship between the prevailing temperature level and the rate of decrease of acid concentration in the juice, especially during the latter half of the fruit growth and maturation period. The data summarized in Figure 8 are a family of curves plotting percent anhydrous citric acid in the juice of 'Valencia' oranges grown in climates having widely differing temperature regimes. The mean air temperature maxima/minima throughout most of the maturation period before market maturity is reached is around 30°C/18°C in Palmira (1000 m altitude) and around 27°C/14°C at Medellín (1500 m altitude), both in the tropics near the equator. At Orlando, in warm, subtropical Florida, the temperature during the latter half of the maturation period diminishes from 33°C/23°C in August to 23°C/11°C in February. For cool, subtropical Santa Paula, California, the comparable temperatures are 29°C/12°C in August diminishing to 22°C/10°C in May. This inverse relation of temperature and acid is generally true, under orchard conditions, for oranges, grapefruit, mandarins, pummelos and their hybrids. Lemons and limes, however, mostly appear to have as high acid content in juice in a hot as in a cool climate, but there are exceptions.

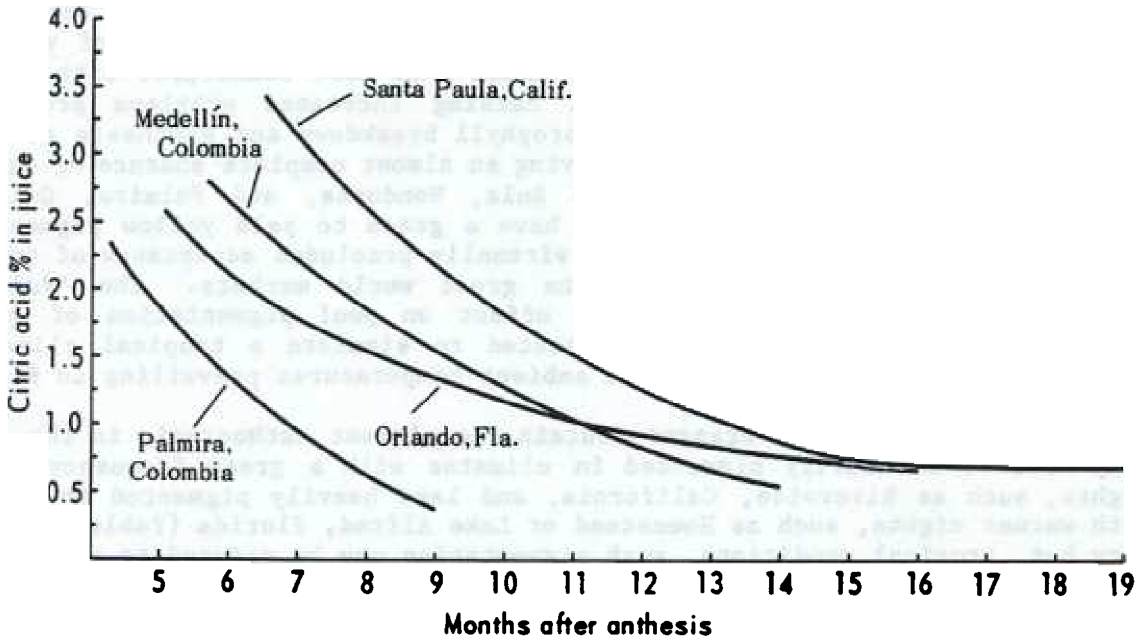

Figure 8. Seasonal trends in percent acid in the juice of 'Valencia' oranges in four widely different climatic situations.

The genetic level of acidity in the juice of a cultivar, together with its rate of decline as maturation progresses in relation to the seasonal temperature regime, are important factors determining the ultimate quality of fruit, as well as earliness or lateness of maturity. Thus the rapid decrease in acidity of Navel cultivars and its slower decrease in Valencia types are important factors, among others, determining their ranges of climatic adaptations, as well as their seasons of maturity and ultimate market quality.

Seediness: Several studies have shown that the average number of seed per fruit from specific, mature trees surrounded by established orchard may vary from season to season. For example, a study of the seediness of 'Valencia' oranges in 9 locations in Florida, Texas, Arizona, and California during 2 seasons indicated that the seasonal effect was significant, but smaller than the effect due to location. The strong variation in seed number among locations was probably due in large part to variations in the proximity of the experimental trees to other varieties effective in cross pollination and to a lesser extent to climate, disease, activity of bees, or other influences on seed formation. Other studies have shown that, on a given tree, there is a direct effect of seediness on fruit size.

Pigments: There are some striking effects of the seasonal temperature regimes on rind color, especially with oranges and mandarins. For example, the deeper orange color of the peel (greater carotinoid content) of mature oranges such as the Navel and Valencia varieties in California and Arizona is due mostly to the greater incidence of chilling temperatures (below 59°F or 15°C) in the West than in Florida (Table 1). Especially significant in this regard are the much cooler night temperatures during the fall months in the drier climates prevailing in the California and Arizona citrus regions.

The effect of chilling temperatures on the flesh or juice color is less striking than the effect on the peel.

It has been suggested that the commonly observed relation between the onset of chilly nights in subtropical climates and the beginning of yellow or orange coloration of the peel ("color break") of most commercial citrus varieties is a chilling injury reaction causing increased ethylene production, associated with a stimulation of chlorophyll breakdown and synthesis of carotenoids. In hot, tropical climates having an almost complete absence of chilling (<15°C) temperatures (see San Pedro Sula, Honduras, and Palmira, Colombia, Table 1), oranges characteristically have a green to pale yellow pigmentation of the peel when market mature. This virtually precludes acceptance of tropical oranges and mandarins in most of the great world markets. The 'Valencia' oranges shown in Figure 9 show the effect on peel pigmentation of growing 'Valencia' oranges in a greenhouse heated to simulate a tropical climate in contrast to oranges grown under the ambient temperatures prevailing in Riverside, California.

The so-called blood oranges contain the pigment anthocyanin in the flesh. They tend to be heavily pigmented in climates with a great frequency of cool nights, such as Riverside, California, and less heavily pigmented in climates with warmer nights, such as Homestead or Lake Alfred, Florida (Table 1). Under very hot, tropical conditions, such pigmentation may be reduced to a few flecks or even be completely absent. In grapefruit and pummelos in particular, certain varieties have a pink or red flesh color due to another pigment, lycopene. In contrast to the pigment of blood orange, hot climates tend to increase lycopene concentration in the flesh, and cool climates to reduce it. In fact, in the cool, coastal climates of California, the 'Redblush' variety of grapefruit, for example, may develop only a very pale pink flesh color.

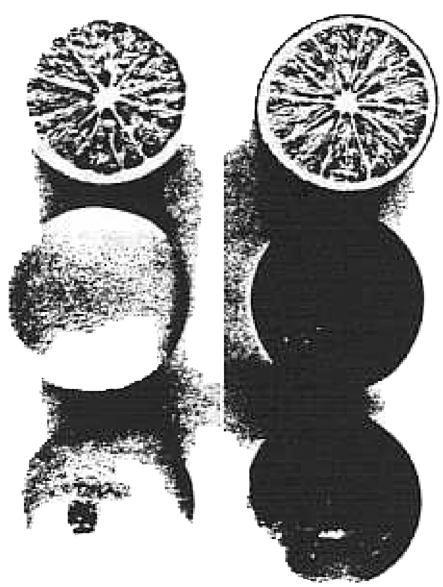

Figure 9. Right: Dark green peel color of 'Valencia' oranges grown in a greenhouse heated to maintain temperatures between 34° C and 20° C throughout the period October through March. Left: Orange peel color of comparable fruit grown under ambient temperatures at Riverside, California, during the same period.

Varietal Interactions: There is considerable diversity among cultivars and species of citrus in their response to climate, especially as regards to market quality of the fruit. For example, the navel group of cultivars develops its best eating and eye-appeal qualities in a Mediterranean type climate with cool, wet winters and hot, dry summers such as is found in the inland valleys of California. In wet, tropical regions, it tends to be large, coarse textured, with poorly colored rinds, and low total soluble solids in juice. The wet, humid climate of Florida does not have enough chilling in winter to produce navels of prime quality. On the other hand, cultivars of the 'Valencia' type are adapted to a broad range of climates, producing excellent to acceptable fruit quality in most of the important citrus regions of the world. Most cultivars of the satsuma group produce high market quality fruit in semi-arid to humid climates having abundant chilling temperatures in winter. The wet maritime climate of Japan tends to produce high quality satsumas, while the very hot, very arid climate of the low deserts of southern California and Arizona produce very poor quality satsumas.

Unlike the navel cultivars, most grapefruit cultivars develop optimum internal quality in warm climates with little winter chilling such as is found in much of the Caribbean basin, where the parent clone originated as a chance hybrid. However, in this region rind blemishes due to pests and diseases typically reduce eye appeal.

In the hot, low desert areas of southern California and Arizona, good market quality of most grapefruit cultivars is ultimately attained, but much later than in Florida or Texas, with warmer winters.

The cultivar 'Temple,' a tangor, does not attain high internal juice quality comparable to Florida grown fruit anywhere in California, but produces a much deeper orange peel color in the warmest California citrus regions than anywhere in Florida.

The cultivar 'Kinnow,' a 'King' orange 'Willowleaf' mandarin hybrid, is grown commercially to a limited extent in California and Arizona (<300 ha) where it produces good eating quality, but experiences various production, handling, and marketing difficulties. In Pakistan, however, it is the principal citrus variety, some reports suggesting that more than 50,000 ha are grown.

Currently, our knowledge is not adequate to predict the market quality characteristics of a new cultivar in a previously untried climatic region — for this, there is no substitute for field testing. We do know, however, that the warmer climates of tropical and semi-tropical regions will produce orange, mandarin, and grapefruit culitvars of earlier maturity and lower acid content than in cooler, cold winter subtropical climates. Also, peel color of oranges and mandarins will be more intense and of greater eye-appeal at maturity in the cold-winter subtropical climates. Most citrus cultivars may tend to have somewhat lower soluble solids in juice in tropical climates having no cool temperature of drought-induced dormant periods, as compared to subtropical climates with distinct cool temperature-induced dormant periods.

SOIL CLIMATIC FACTORS

The physical environment of the root system of a citrus tree is, with the exception of soil atmosphere composition, much more stable than the above ground environment of the trunk, branches, leaves, and fruit of the citrus tree. Temperature conditions in particular do not change as rapidly in root as in above ground tissues. The thermal energy level of the root environment is a much dampened reflection of the above ground environment.

The available evidence suggests that the root system of a citrus tree responds to temperature in much the same way as the above ground tissues. If root temperatures are low, dormancy is induced or maintained even if the top temperatures are favorable for growth. Thus root temperatures indirectly influence fruit quality through effects on the timing of bloom and hence the temperature regime during maturation.

Another possible indirect effect of soil climate on fruit quality may be the effect of chilling temperatures on water uptake by roots. There is evidence that soil temperatures of 15°C (59°F) or less may cause wilting of leaves even when the soil is amply supplied with moisture. Such low temperatures induced moisture stress will be reflected in the fruit, reducing growth. There is little evidence that this type of low temperature moisture stress occurs often enough in a climate like Florida to be of much importance, but it may be a factor reducing fruit size in some of the cooler California citrus regions, and elsewhere.

In contrast to the relatively constant composition of the above ground atmosphere surrounding the top, the gaseous content of the soil atmosphere surrounding the roots may vary in relation to soil moisture content, soil temperature, physical characteristics of the soil, and drainage conditions. Poor soil drainage, high soil temperature, and high clay content of soil tend to cause a reduction in oxygen and accumulation of carbon dioxide in the soil atmosphere. This in turn tends to kill roots and reduce their abiity to resist fungus and other infections. This in turn reduces the ability of the roots to supply the leaves and fruit with moisture and nutrients necessary for the production of large sized fruit of good juice quality.

From the above, it is clear that below ground climate related factors may interact with soil factors to exert important influences on fruit production and market quality.

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