AN OVERVIEW OF CLIMATIC EFFECTS ON CITRUS FLOWERING AND FRUIT QUALITY IN VARIOUS PARTS OF THE WORLD

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Citrus is produced commercially in over 30 countries worldwide. The major growing regions are located primarily between 40° north-south latitude where minimum temperature is generally greater than 20°F. Within these latitudes there are several important climatic areas that affect the growth and development, yields, and fruit quality of citrus. These include the low, middle, and high tropical regions and the arid, semi-arid and humid subtropical areas. The objective of this review is to discuss the effects of climate on flowering and fruit quality of citrus trees. The climatic characteristics of each region will be discussed followed by a general review of the specific effects of climate on flowering and fruiting. More detailed examples of climatic effects on the physiology of flowering and fruiting will be given in subsequent papers.

Tropical Growing Regions

The tropics consists of a region between the equator and 23.5° north and south latitude. It is bounded by the Tropic of Cancer in the northern hemisphere and the Tropic of Capricorn in the southern hemisphere. The average temperature within this area is greater than 65°F and there is little diurnal or seasonal fluctuation in temperature or day length. In addition, freezes rarely occur except at the highest altitudes. However, altitude has a pronounced effect on tree growth and development. Therefore, the tropics can be further subdivided into the low (sea level to 3000 feet), middle (3000 to 6000 feet), and the high (above 6000 feet) regions. The transitions between regions are not absolute but are part of a continuum. Moreover, there are distinct microclimates within each region that have unique rainfall, wind or sunlight patterns that also impact on flowering and fruiting.

Low Tropics. The low tropics are typified by a hot humid climate during most of the year (wet tropics), or by distinct wet-dry seasons in some areas (wet-dry tropics). There is little diurnal or seasonal variation in temperature or day length. Rainfall and relative humidity are high either throughout the year (wet tropics) or seasonally (wet-dry tropics). Generally, citrus production in this area is low and fruit are used primarily for local consumption resulting from the adverse effects of hot, humid climates on fruit quality of most important citrus cultivars. Disease, pest and weed pressures are especially severe throughout most of these regions.

Flowering usually occurs rather continuously throughout the year with peak levels occurring when rainfall occurs following periods of dry weather. Flowering intensity is controlled primarily by availability of water (wet-dry tropics). As a result, there may be several different stages of fruit and flower development on the same tree, which may cause difficulty in determining fruit maturity and harvest time.

Fruit growth rate is rapid, but fruit quality for oranges and mandarins is poor. Peel color is typically green and juice color pale, light yellow. Moreover, total soluble solids (sugars) and acids tend to be low due to high average temperatures throughout the year which cause respiratory metabolism of sugar and acids. On the other hand, grapefruit and limes develop characteristic peel and juice color and low acid which produce fruit with high internal quality. For example, even 'Star Ruby' grapefruit develops a deep red color at sea level in this region. External fruit quality (peel blemishes) is a problem for fruit from the low tropics. The high average temperatures and relative humidity are very conducive to disease and pest development.

Middle Tropics. Middle elevation tropical regions have lower average temperatures than the low regions and also may contain high rainfall and humidity (wet) regions or regions with distinct wet-dry seasons. Again, there is little fluctuation in seasonal or diurnal temperatures or day length. Generally the middle tropics have very pleasant climates throughout most of the year. Many of the larger cities in this region are located in the middle tropics, e.g., San Jose, Costa Rica.

Flowering occurs in more discrete time periods than in the low tropics, usually one or two distinct times per year, again related to wet-dry seasons. Fruit growth rate is slower, and quality better than in the low tropics for oranges and mandarins. Peel and juice color are orange to red, and total soluble solids are higher than in the low tropics because of lower average temperatures. However, pest, disease and weed pressures are also a problem and may cause damage to fruit or reduce tree vigor or production. Thus, few mid-tropical regions are major sources of citrus production.

High Tropics. The high tropical areas are not well-suited for commercial citrus production due to climatic constraints, but many of these areas have developed local selections of citrus that are specifically adapted to these regions. Generally citrus does not grow and produce well at altitudes greater than 7500 feet. Average and diurnal and seasonal temperatures are lower in the high tropics than in the other tropical regions and often there is cloud cover or fog that interrupts sunlight, thus reducing total soluble solid levels in the fruit. Day length is also more variable in the high tropics. In addition, ultraviolet radiation tends to be high in these regions, a factor that may adversely affect tree growth.

Flowering occurs in one or possibly two distinct flushes in this instance regulated by low temperatures or wet-dry cycles. Fruit growth rate is slow and internal fruit quality is poor for grapefruit due to low juice total soluble solids and high acids. Peel and juice color, in contrast, are quite good for oranges and grapefruit because of the low temperatures that are necessary for color development.

Subtropical Growing Regions

Subtropical regions that produce citrus encompass the area from 23.5 north-south latitude to about 40° north-south latitude depending on local climatic conditions, in particular minimum temperature, of the region. For example, 40° north latitude is near Philadelphia on the east coast of the United States which is of course too cold to grow citrus, while citrus can be grown commercially at the same latitude in Europe. Subtropical climates have at least one month with average temperature

less than 65°F, with 8 or more months averaging more than 50°F. These regions are also subject to frosts or in some cases severe freezes. The subtropical regions account for a large part of the world's citrus production. They can be further subdivided in arid or semi-arid and humid growing regions. Climatic differences among these regions have significant effects, particularly on fruit quality and ultimately on whether the fruit is marketed as fresh or processed.

Dry Subtropical Regions. These regions, which also include Mediterranean-type climates, are characterized by hot, dry days and cool nights. In addition, the low relative humidity (RH) contributes to large diurnal fluctuations in temperature. Average rainfall is low in these areas (generally, 15 to 30 inches/yr) and generally falls in the winter. Relative humidity is also very low, often being less than 20%. Some of the major producers in the region include the Mediterranean area (Spain, Italy, Morocco, Greece, Turkey, Israel, Egypt), California, northwest Mexico, Australia, and northern South Africa among others. Within this regions, there are also arid regions such as those of the southern California or Arizona deserts which often average less than 10 inches of rain/yr.

Flower induction and flowering are regulated by temperature in subtropical regions. Flower induction occurs as temperature decreases in the fall and winter and growth rate decreases substantially or growth ceases. This "non-apparent" growth period is important for flower induction and the transition from vegetative to flowering shoots. Flowering occurs the following spring as temperatures again increase. There is generally one major flowering period, although a second much less intense bloom may also occur a few months later (termed the "June" or off-bloom). The duration, intensity and type of flowering is also regulated by temperature prior to or during bloom and will be discussed in subsequent papers.

Fruit quality is excellent for the fresh fruit market due to the excellent peel and juice color that develops as temperatures fall below 55-60°F. Moreover, peel blemishes are less intense than in tropical regions due to the lower relative humidity and rainfall. The low relative humidity and average temperatures also reduce pest and especially blemishes caused by fungi. Consequently, the major fresh fruit producing countries in the world are located within the Mediterranean-type (semi-arid) climates.

Humid Subtropical Regions. Humid subtropical regions are characterized by high average temperatures and high relative humidity and rainfall (generally 48 to 60 inches/yr). For example, the average relative humidity in Florida is 72% vs. 20% or less in the semi-arid regions. Major citrus producing countries in this region include Florida, Brazil, central China, Japan and coastal areas of Mexico. Florida and Brazil are the major producers of processing fruit in the world largely because of the climatic conditions found in the humid subtropics.

Flower induction occurs in the fall and winter again coinciding with a cessation of growth. Flowering then occurs when favorable temperatures occur in the spring. However, in some years high temperatures may also occur in December, January or February causing earlier than normal flowering. Moreover, a second flowering period may occur in April or June when this happens. The second bloom is called an off-bloom or "June" bloom, and in some years is large enough to warrant harvesting. Therefore, temperature has a pronounced effect on regulating flowering in this region.

Fruit growth is rapid and total soluble solids and juice content are high, producing fruit with high pounds-solids per box. Thus, fruit from this region is well-suited for the processing market.

Coastal areas with high humidity also produce excellent quality fresh grapefruit. Peel and juice color are generally not as vivid as in arid or semi-arid climates, but are still acceptable for the fresh market, especially in the case of grapefruit. Pest, disease and weed pressures are more severe than in semi-arid or arid regions, but less intense than in most tropical areas.

Summary

Climate has a dramatic effect on flowering and fruit quality of citrus. Climates such as those in the Mediterranean region produce primarily fresh fruit because the low nighttime temperatures and relative humidity of the region yield a relatively blemish free, brightly-colored fruit. In more humid subtropical regions fruit are less cosmetically perfect but have higher total soluble solids and juice and are thus more suitable for the processing market. Flowering generally occurs once a year and its intensity and duration are regulated by temperature.

The situation in the tropical regions is different. Flowering occurs throughout the year in the low tropics and is more seasonal in the middle and high tropics. Fruit quality is generally poor in the low tropics for oranges and mandarins, but improves at higher altitudes of the mid-tropics. Therefore, much of the citrus production in the tropics is for local consumption, rather than for export to international markets.

Selected References

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