ALTERNATE BEARING

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Alternate or biennial bearing is a problem common to a number of fruit tree species including citrus. Alternate bearing is the tendency of a fruit tree to produce a heavy crop (on-years) one year followed by a very light crop (off-year) the following year. Both the terms alternate and biennial are commonly used. Alternate bearing is the preferred term, however, since the changes in crop load may not always occur biennially or every other year. Alternate bearing may occur over an entire region, for a block of trees, for an individual tree, or even for part of a tree or one branch.

Alternate bearing occurs in a range of deciduous and evergreen tree fruits and has been reported in 11 different plant families. It has been extensively studied in a number of important commercial crops including apples, olives, pecans and other nut crops, and citrus. In citrus, alternate bearing of mandarins is a recognized problem throughout the world and has been studied in Australia, Israel, Japan, as well as in Arizona, California, and Florida in the United States. Alternation is less severe on oranges and grapefruit although it is an important problem for Valencia oranges in certain climatic districts of California and Australia.

In Florida, alternate bearing is a major problem on some mandarin varieties and also occurs in the production of oranges and grapefruit. The oldest important mandarin variety in Florida is Dancy tangerine which is subject to severe crop alternation. Figure 1 shows the production of Dancy tangerines in Florida each year from 1964 to 1980. In 13 of these 16 years, alternate bearing is present.

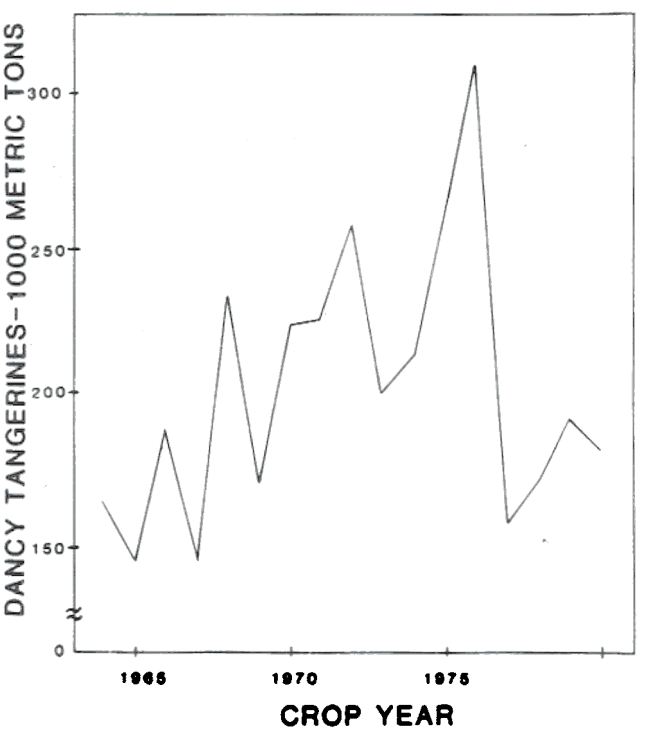

Fig. 1. Alternate bearing of Florida Dancy tangerines, 1964-1980.

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The Murcott or Honey tangerine is also subject to severe alternate bearing in Florida. An excessive crop load 1 year may be followed by 1 or more years of severely reduced crop or even death of the tree. Seedy midseason orange varieties such as Pineapple and Jaffa have a tendency for alternation as does the Duncan grapefruit. Alternate bearing has also been observed on Florida Valencia oranges and Marsh grapefruit.

In California, production records over many years have been used to document alternate bearing of various citrus varieties. Valencia showed moderate alternation in several studies. The magnitude of alternate bearing was less for navels, but was very high for Wilking and Kinnow mandarins. Alternate cropping is also a problem on Valencias in Australia.

A method of quantitative evaluation is necessary in studying or comparing alternate bearing. Two indices have been developed. One index is labeled "B" and is related to regularity or consistency of alternation. The "B" value is the percentage of years that yield alternates; i.e., an increase in yield one year is followed by a decrease the following year, or vice versa. In the example in Figure 1, yield alternated 13 out of 16 years giving a "B" value of 13/16 or 81%. The second index is the intensity or "I" value and measures the intensity or amplitude of crop fluctuation. It is calculated by dividing the difference in yield for 2 years by the sum of yield for those 2 years. An "I" value of 0 indicates equal yields whereas complete alternation would result in an "I" value of 1. Where observations are made over a number of years, the "I" value is an average for each pair of years with yield records. An "I" value of 0.2 to 0.3 is typical for a moderately alternating crop but values of 0.6 to 0.8 are common for mandarin varieties with severe alternate bearing.

Causes of Alternate Bearing

A number of exogenous and endogenous conditions may trigger or contribute to alternate bearing. Some of the environmental conditions inducing alternation are readily observable. However, the internal mechanisms of the plant that regulate cropping behaviour are incompletely understood. Differences in genetic composition clearly influence the tendency toward continued alternate bearing following a triggering event, but the physiological or biochemical basis of these differences is not known.

Environmental stress frequently triggers an unusually light crop which can be the beginning of a few to many years of alternation. Under Florida conditions, a winter with a damaging freeze that reduces the crop is probably one of the most common initiators of alternation. Other factors which may severely reduce a crop include severe water stress or pest and disease agents.

Endogenous factors which may perpetuate alternate bearing include excessive crop load and associated tree stress, competition between vegetative and reproductive growth, depletion of carbohydrate or mineral reserves, and changes in hormones. Late harvest dates and the presence of fruit on the tree during flowering may also contribute.

A large number of studies have failed to satisfactorily explain the physiological effects of excessive crop loads on citrus trees. A great deal of evidence points to severe depletion of carbohydrate reserves, particularly starch, during the on-year. Starch levels in the leaves, stems, trunk, and roots are all depressed. Depletion of mineral elements also occurs during the on-year. Lowered levels of carbohydrates and minerals may contribute to reduced root vigor during

the on-year. The large number of fruit sinks competes for carbohydrates and reduces the amount of vegetative growth which will be the primary source of flowering the subsequent year. However, not all carbohydrates and minerals stored in the tree are available for recycling, and manipulation of starch levels by fruit removal or other experimental techniques has failed to clearly demonstrate a central role of reserve levels in alternate bearing.

Plant hormone imbalance has also been suggested as a factor in alternate cropping. There are important exceptions, but many of the varieties with severe alternate bearing are quite seedy. Seeds may be an important source of hormones such as gibberellic acid which tend to promote vegetative and reduce reproductive growth. Again, a number of studies have been conducted which support the role of gibberellins, abscisic acid, or cytokinins in alternate bearing. However, the significance of endogenous plant hormones in alternate bearing is not clear at this time.

Control of Alternate Bearing

A number of management practices may be employed to control alternate bearing. These include reducing flowering during an on-year, fruit thinning or pruning to reduce crop load, adjusting harvest date, and cultural practices. Many of these have been tried experimentally and also used commercially. Fruit thinning on some deciduous fruits is a standard commercial practice and has been used successfully on citrus. Approaches to the control of alternate bearing include increasing flowering and fruiting during the off-year or reducing flowering and fruiting for the on-year.

Increasing the crop load during light crop years has had little success to date. Stimulating flowering during the off-year has not been successful. Gibberellic acid applied during flowering improves fruit set in some citrus varieties, but has not been helpful in controlling alternate bearing. Some benefit may be obtained from optimizing cultural practices for the light crop year, including supplemental nutrition during a preceding heavy crop year if the crop load is sufficient to induce tree stress. In addition, it may be possible in some situations to harvest at an earlier date to avoid the inhibitory effect of an existing crop on a subsequent crop. These methods, however, are not always successful.

Reducing the crop load during the on-year has been used extensively. Reducing flowering during an on-year is one method of reducing crop load and alleviating alternate bearing of citrus. For blocks of citrus that are in a regular alternate bearing cycle, it is possible to predict which year will be the on-year. Gibberellic acid sprays applied 1 to 2 months prior to flowering may reduce the intensity of flowering, perhaps by inducing a more vegetative state in the shoots emerging in the spring. This method has been studied and used most extensively in Australia for controlling moderate alternate bearing of Valencias. It may be more successful with Valencias than with mandarin varieties with a much stronger tendency toward alternation. In Australia, 1 or 2 applications of gibberellic acid at 25 to 50 ppm are applied during winter when an on-year is expected.

Fruit thinning during the natural "June drop" period or early summer is a more common method of reducing crop load. For deciduous fruits and for citrus in some areas, hand thinning is used to reduce crop load to a desirable level. Hand thinning is commonly used in Japan where extensive studies have determined the optimum fruit to leaf ratio to maximize production of commercially desirable

Satsuma mandarins. This results in fruit of excellent size, quality, and appearance.

Fruit thinning using chemical thinning agents has developed rapidly in both deciduous fruits and citrus due to the high labor costs of hand thinning. A number of materials have been evaluated, and some are quite useful. Most chemical thinning agents either induce ethylene formation by direct tissue damage, promote ethylene formation without tissue damage, or chemically release ethylene. In addition, some photosynthesis inhibitors have been considered, as have other materials with an unknown mode of action. The role of ethylene in thinning is to induce abscission of the flower or young fruit, thereby reducing the crop load.

Compounds which induce or release ethlene may be applied either during flowering, or more commonly, during the "June drop" period which in Florida is a period of natural drop generally occurring in May. Several compounds which induce ethylene by direct tissue damage have been applied during flowering to reduce the flower number. However, due to the large number of flowers and the uncertainty about the degree of initial set, fruit thinning during the "June drop" period is usually preferred. By that time, it is possible to determine if an excessive crop load is developing and to plan crop reduction measures accordingly.

Compounds that induce ethylene formation by tissue damage include strong acids, 2,4-dinitroanisole, sodium azide, and related materials. Materials that promote ethylene formation without tissue damage have been most extensively used and include napthaleneacetic acid (NAA) and some phenoxyacetic acids at non-phytotoxic concentrations. The ethylene releasing compound ethephon is also effective as a fruit thinning agent.

NAA has been used in Japan and the United States for fruit thinning of several citrus varieties. It is currently registered and labeled for fruit thinning in this country for apples, pears, olives, oranges, mandarins, tangelos, and tangors. For citrus, application is made during the period of "June drop" (during May in Florida) at concentrations of 100 to 500 ppm. The degree of thinning is variable and dependent on tree condition and the environment. Severe overthinning may result from application to trees under stress. Underthinning may occur for vigorous trees under cool weather conditions. Thus, the application rate depends on the amount of thinning desired as well as tree and weather conditions.

In Florida, NAA has been evaluated most completely on Dancy tangerines and Murcotts. It has been very effective on both of these crops. For Dancy tangerines, alternate bearing has been reduced and the problems with small fruit and late maturity during heavy crop years is avoided. On Murcotts, NAA effectively reduced crop loads and the associated tree stress of heavy crop years. Return crop load was improved, and freeze damage and tree breakage from stressed trees was reduced.

Ethephon is also effective as a fruit thinning agent applied to citrus during the "June drop" period. It has been used in Australia for Valencia thinning. In Florida, it is effective for thinning mandarins but appears to underthin or overthin more frequently than NAA. It is also applied during the "June drop" period at approximately 200 to 300 ppm.

Pruning by hedging or topping is also an effective method of fruit thinning or reducing crop load and is the most frequently used practice in Florida. For non-alternating citrus varieties, hedging and topping are generally performed on some regular basis as a means of confining tree size to its allocated space. For

mandarin varieties in severe alternate bearing, however, hedging and topping is frequently scheduled for spring of the on-year to reduce the crop load that year and induce more vegetative growth for flowering and fruiting the following year.

Importance of Alternate Bearing

The importance of alternate bearing depends on a number of factors including the severity, long-term effects on yield and tree condition, and effects of fruit size and maturity dates in relation to market requirements. For example, slight to moderate alternate bearing of Florida oranges for processing is not critical since average yield over a number of years is probably not significantly affected and market requirements for size or maturity date are generally not critical. In California or Australia, however, alternate cropping is greater than in Florida and a fresh fruit market orientation makes alternation a greater problem.

Severe alternate cropping of mandarin varieties, however, creates many problems. Heavy crop years result in small fruit size, poor fruit quality, and late maturity. For Dancy tangerines in Florida, heavy crop loads frequently result in less than 50% of the fruit reaching minimum commercial standards. For Murcotts, excessive crop loads cause tree stress, reduced crop for 1 or more years, tree dieback, reduced freeze tolerance, and in severe cases, death of the tree. Severe alternate cropping of a mandarin variety over an entire production area such as Florida makes orderly marketing impossible since the available crop one year may be only half what it was the previous year. In addition, severe alternate cropping reduces not only marketable fruit production, but total fruit production averaged over a period of years.

The economic benefits of regular cropping are significant. Cropping of many citrus varieties is self regulating. For these varieties, an unusual environmental event that triggers an unusually light or heavy crop will not result in prolonged alternate bearing. However, for some other varieties, induction of alternation may result in continued or increased alternating behaviour over a number of years. For these varieties, a number of management practices are available which should be employed to regulate cropping. Once regular cropping is resumed, special management considerations may not be required again until some unusual event triggers another light or heavy crop.

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