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A REVIEW OF ALTERNATE BEARING IN CITRUS

Muhammad Sohail Mazhar*, Raheel Anwar and Mehdi Maqbool
Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan
*Email: sohailuaf@gmail.com

Abstract

Citrus is the second largest fruit crop of the world after grapes, which is being grown in more than 100 countries. It is a very valued fruit crop and the citrus production and trade imparts major contribution in domestic industry and foreign exchange earning of major citrus producers. Many areas have some crop specific as well as some common diseases relevant to a crop in that particular area. One of the common problems of world citrus industry is the alternate bearing. Almost all the areas of world encounter the problem of alternate bearing with all the commercial varieties of citrus inclusive of mandarin, oranges, grapefruit etc. The production of citrus remains fluctuating over the years due to the problem of biennial bearing and thus the trade and consumption of the producer countries is affected. This review article will help understanding the problem, its basic reasons and the possible management practices of the problem.

INTRODUCTION

Citrus is a very important fruit crop and during the year 2004, its world production was 110,898,698 Mt (Anonymous, 2004). Alternate cropping (biennial bearing) is a common problem with many citrus varieties, such as Valencia orange (El-Zeftawi, 1973), grapefruit, Tangerines (Anonymous, 2006b) and mandarins (Forsyth, 2003; Hodgson, 1989; Maurer and Bradley, 1998; Morton, 1987; Anonymous, 2005a; Anonymous, 2005b; Anonymous, 2006c). After a heavy crop, the tree often responds by carrying a light (or nil) crop. Once this cropping pattern is established it is difficult to return to regular annual cropping (Anonymous, 2006a). Figure 1 represents the production pattern of citrus for some of the major citrus production countries of the world.

The severity of alternate bearing varies over time and also among citrus varieties (Sposito et al., 1998). At times, alternate bearing for a variety occurs synchronously over the state. Alternate bearing occurs more frequently on individual blocks, individual trees within a block, or even on individual branches on a single tree. Although there are many exceptions, as it is generally a minor problem on Valencia oranges, a moderate to severe problem on Pineapple orange and some grapefruit, and frequently a serious problem on mandarin varieties (Wheaton, 1997). The loss of leaves and fruit occurs quite suddenly during the fall or winter of an ON year crop, and is known as Murcott collapse (Stewart et al., 1968).

Alternate bearing, in oranges grown for processing, is common but usually is not a major problem. However, the impact of alternate bearing on fruit size and quality for fresh market fruit is a major factor in profitability. Heavy crops of grapefruit lead to small sizes and misshapen fruit of little commercial value. Heavy crops of mandarins cause delayed maturity, poorer external color,

and small sizes that are unmarketable or are sold only at a reduced price. Fruit size is a major factor in the returns of mandarin varieties (Wheaton, 1997).

The alternate bearing in citrus can be studied by the graphical user interface by the relationship between the hyper spectral image of the tree crops and their yields. Since the spectral images acquired have a large amount of data and are multi-dimensional, the interface provides aid in the processing and analysis (Garciano et al., 2005).

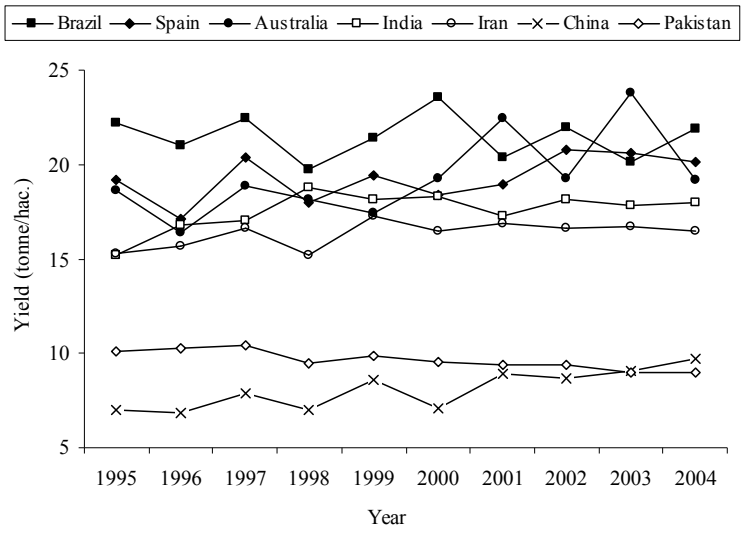

Figure 1: Fluctuations in the yield of citrus of world top citrus producers (Anonymous, 2004)

CAUSES OF ALTERNATE BEARING

The factors leading to alternate bearing tendency in citrus are not well understood; also the attempts to relate the factors of alternate bearing in other fruit crops are not completely successful. According to one study, the phenomenon seems to be related with the time of flower bud differentiation and crop load. Flower bud differentiation in citrus usually occurs at the time of initiation of new growth in spring. In sweet orange, the terminal primordia differentiates when the shoot is about to emerge, while the axillary flower buds differentiate when the shoot is about 5.5 mm long. The poor growth in spring in an 'on' year is possibly the main cause which results in poor flower bud differentiation and consequently a light crop in succeeding year. The production of few flowers subsequent to a heavy crop is depletion of carbohydrates in the tree fruits as the lower levels of carbohydrates are not conducive for flower development. When the balance between source and sink is disturbed alternate bearing rythum sets in (Anonymous, 2006a).

Carbohydrate depletion is a major problem under heavy crop load (Goldschmidt, 1997; Goldschmidt and Golomb, 1982; Smith, 1976); it may be argued that there should be no carbohydrate limitation under regular bearing conditions (Garcia-Luis et al., 1988). But, in fact, both vegetative (Ideo et al., 1991) and reproductive development (Downtown et al., 1987) are strongly promoted by CO_2 enrichment. Under lack of root restriction, there is a large and persistent increase in photosynthetic capacity, followed by remarkable growth increments (Ideo and Kimball, 1994; Li et al., 2003). Fruit set, which is believed to be limited by carbohydrate availability (Garcia-Luis et al., 1988; Schaffer et al., 1985), increased by 70% after CO_2 enrichment. All this strongly indicates that under most normal growth conditions citrus trees are "source-limited". The prevalence of high starch levels in citrus organs does not imply that there is a surplus of carbohydrates reserve accumulation takes place even while the needs of developing fruit are not fully satisfied (Fishier et al., 1983). The accumulation of reserve carbohydrate seems to have a high priority in citrus, as part of a general survival strategy (Goldschmidt and Koch,

1996). In another study, it was known that as there are many alternative carbohydrate sinks in large field-grown citrus trees, so the effect of fruit load on photosynthesis is not significant (Monselise et al., 1986). However, in phloem-girdled branches and defruited trees, carbohydrates and N accumulate (Monselise et al., 1983; Sanz et al., 1987), resulting in increased flowering and yield in citrus trees that are alternate bearing (Agusti et al., 1992). The increase in flowering was related to the higher carbohydrate reserves in the previously defruited trees than in full-crop trees, because such responses mimic the alternating annual carbohydrate concentrations and yields that occur in alternate-bearing citrus trees (Syvertsen et al., 2003).

In an investigation conducted on the relation of ABA (cis-transabscisic acid) in the dormant buds of alternate bearing 'Valencia' orange (*Citrus sinensis* Osbeck) trees, ABA did not appear to be related to alternate bearing but t-ABA (2-transabscisic acid) did. There was 5-10 folds more t-ABA than ABA in the buds. There was more t-ABA in the buds of the "on" trees than in the buds of the "off" trees, and a drastic drop in t-ABA in both types of buds as spring growth approached (Goldschmidt, 1984; Jones et al., 1976). In a study on 'Pixie' mandarin, the buds collected during the summer from on-crop were characterized by high indoleacetic acid and low isopentenyladenosine concentrations compared to buds from off-crop trees. It revealed that although alternate bearing is initiated by climatic undulations, the endogenous factors of tree are also important in alternate bearing of citrus (Verreynne and Lovatt, 2005).

Alternate bearing in sweet oranges is caused by fruits, inhibiting flower formation on the wood on which they are borne and this is brought about by a flower inhibiting substance diffusing from the fruit. From a comprehensive study on *Citrus reticulata* with seven different root stocks (Ram et al., 1999; Turner, 2004) and from the other studies (El-Zeftawi and Thornton, 1975; Hoblyn et al., 1936; Huff, 2001; Monselise and Goldschmidt, 1982), it is evident that the tendency of the tree towards alternate bearing increases with the increase in age of the tree and the root stock has no significant role in the alternate bearing of the citrus.

Environment is often a big factor in causing this disturbance. The drought from December to January increases the number of flowers but drought later in the winter reduces the number of flowers. Higher winter temperature resulted in increased flowering in spring. Increased number of fruits resulted in reduced vegetative development and proposed that the dominance of fruit over vegetative growth has obvious relevance to alternate bearing on field grown citrus trees (Anonymous, 2006a).

Trees irrigated with high salinity water had reduced flowering intensities and lower rates of fruit set, suggesting that reserve carbohydrate was utilized for growth during this period. Twigs on high salinity trees had much reduced starch content at the time of floral differentiation in winter. Twig starch content and extent of floral differentiation varied in a similar way when examined as a function of leaf abscission. This suggests that reduced flowering and fruit set in salinized citrus trees is due to low levels of reserve starch, most of which has been utilized to support fruit growth in the absence of carbohydrate production during summer and autumn (Howie and Lloyd, 1989).

MANAGEMENT OF ALTERNATE BEARING

Managing alternate bearing involves either increasing production during the OFF year, or decreasing crop load during the ON year. The ability to increase yield during the OFF year is limited, although some increase in yield in the OFF year by girdling branches during the previous summer has been reported (Wheaton, 1986). Several possibilities exist for decreasing yield during the ON year including hand thinning, chemical thinning (El Kassas et al., 1994; Hield and Hilgeman, 1968), mass removal by mechanical hedging or topping, and altering management practices. Hand thinning is expensive and is practiced only to a limited extent.

Early harvest of crop well before the onset of spring flush is reported to be advantageous in minimizing the malady. The idea is to activate the flower bud differentiation. Also leaving the crop on, after the next crop has set, may reduce the yield of the subsequent crop and thereby may

induce the rhythm of alternate bearing, but some studies did not indicate such advantage with early varieties of sweet orange viz., Pineapple and Hamlin, which have also shown alternate bearing tendency in addition to Valencia oranges in Punjab. Thinning of fruits in the 'on' year was also suggested to overcome alternate bearing in citrus; chemicals like NAA were also used. However, adoption of the practice of thinning to secure regular crops in citrus is not reliable. In Japan by thinning larger fruit was obtained in the same year and more number of flowers and yields in the subsequent year. Nevertheless, thinning of fruits in an 'on' year is definitely advantageous. One undesirable feature of the alternate bearing pattern is the inferior size of the fruits during the 'on' year. Thinning leads to an increase in average size of the fruit. During 'on' year the crop loads are so heavy that major tree branches are broken. Trees in a single orchard as well as in a single district tend to become synchronized in their alternate bearing, resulting in marketing troubles. While fruits of 'on' year are unduly small, the fruits of 'Off' year are large but generally are of poor quality (Anonymous, 2006a).

Chemical thinning is an option that has been available to growers for a number of years (Maurer, 1994), but has received little attention. Naphthalene acetic acid (NAA) is currently registered for use as a chemical thinning agent. As with all chemical thinning agents, the amount of thinning obtained by application of NAA varies with the condition of the tree, and with the environmental conditions. However, a number of experiments with this material demonstrated potential benefits of NAA in improving fruit size and quality (Wheaton and Stewart, 1973).

In an effort to equalize bearing, plant growth regulators (PGRs) such as napthaleneacetic acid (NAA) are used to promote fruit thinning (Jones et al., 1977; Lewis et al., 1964; Monselise et al., 1981; Plummer et al., 1989) in heavy years and gibberellic acid improves fruit set in light years. NAA can be used to control seedling suckers as well. The herbicide 2,4-D is also used as a PGR to reduce fruit drop in navel and pineapple oranges as well as grapefruit. Upon the first year of bearing, an orange tree produces about a box (90 pounds) of fruit. Each subsequent year, the tree bears an additional one-third box until the age of about 35 years, after which the yield decreases at about the same rate (El-Otmani et al., 2000; Knapp et al., 1992). It is concluded from the application of IAA and ABA to the mandarin varieties that the high degree of alternate bearing in 'Aoshima' is due to the low ratio of sprouting nodes, and high ratio of vegetative shoots. The above results suggest that the ABA contents in leaves may be related to sprouting and floral initiation, which determines the degree of alternate bearing (El Kassas et al., 1994; Moss and Bevington, 1973; Okuda, 2000).

Ethephon and 2,4,5-T treated trees exhibited less tendency towards alternate bearing (El-Zeftawi, 1976b; Galliani et al., 1975; Hutton, 1992; Morton, 1987). Antimetabolites, gibberellic acid, growth retardants, abscission chemicals and white oil, alone or in combination, when used in a series of trials to regulate the alternate bearing of 'Valencia' and 'Navel' orange trees, it was observed that these reduce the "On" year crop in "Navel" but has no effect on "Valencia", which indicates that the different times of harvest and different bearing habits have impact on the cropping pattern of the plant (El-Zeftawi, 1976a).

Improved cultural pactices can help managing the pattern of alternate bearing in citrus (Awtar et al., 1999; El Kassas et al., 1994; Lallan et al., 1999; Moss, 1971). Also the time and amount of harvest affect the tendency of alternate bearing (Hodgson et al., 1941).

Pruning or mechanical removal of fruit is the most common method of reducing crop load (Procopiou and El-Gazzar, 1972). Most mature citrus grooves are hedged either every year or every other year to maintain access for equipment and to provide light to the lower portions of the canopy. Trees are topped to maintain a height that can be harvested. Topping always causes a yield reduction which is undesirable when growing oranges for processing. However, it can be beneficial for fresh fruit grooves where fruit size and quality are critical. Many fresh fruit grapefruit and mandarin grooves are maintained at a low height by annual topping and produce small or moderate crops of high quality fruit. A substantial reduction in yield may occur if trees are kept too small. Scheduling topping and hedging operations to reduce crop load during heavy

crop years is beneficial. These operations can be done in the early spring before flowering occurs if there is certainty that the coming crop load will be excessive or a decision can be made after flowering and fruit set is largely completed. The final major drop period for citrus generally occurs in mid-may. The benefits of reducing crop load are greater, earlier in the season, if it is done. Thus it is important to complete the hedging and/or topping operations as soon as possible after crop load can be estimated. It is very difficult to estimate crop load of Murcotts and some mandarins in mid-May because of the small fruit size and distribution in the canopy. A history of alternate bearing may provide an adequate basis for scheduling hedging and topping even before the current season's crop load can be estimated.

Modification of irrigation (Golomb and Goldschmidt, 1987) and nutritional management may help reduce the magnitude of alternate bearing. Supplementing a fertilizer is recommended for Murcotts during a heavy crop year. Leaf potassium levels decline to very low levels as this nutrient is used by the developing crop. It is common to make one or more additional potassium and nitrogen applications during late summer to reduce the nutritional stress of an excessive crop of Murcotts. Supplement irrigation may reduce the incidence of Murcott collapse by maintaining more favorable water relations during periods of root loss from the stress of excessive crop load. The importance of alternate bearing depends on several factors including the severity, the importance of fruit size and maturity for the intended market, and the potential for tree damage from over production. Cropping of most citrus varieties is self regulating. For these varieties, alternate bearing following an unusually heavy crop does not last long. However, some other varieties experience severe alternate bearing over long periods of time. The methods described for controlling crop load will reduce the amount of alternate bearing for these varieties.

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