The Early Bearing and High Yield of Sweet Orange (*Citrus Sinensis* Osbeck) on Red Loam in Guangdong, China

NAN-SUN ZHOU[1]

Abstract: Citrus culture in Guangdong Province is renowned for its traditional method of close planting of 1,200-1,500 trees per hectare, its early fruiting in the third year following planting and its high yield. After about 15 years when the trees decline, they are cut down and the land is planted with other crops. In order to harvest the highest possible yield within this period, the growers have developed a series of unique cultural methods. The present paper aims at introducing the early bearing and high yield of sweet oranges in the hilly red loam regions of Guangdong.

For the purpose of early bearing, the taproot must be trained not to penetrate too deep and feeder root development must be encouraged. Adopting the method of temporary planting nursery trees, cutting back the overgrowth of lateral roots outside the tree canopy and applying manure inside will render the feeder roots to spread wide and deep. And resorting to repeated nipping off of the new shoots to promote a spontaneous and simultaneous outburst of fall flushes from the compound buds will help to form numerous parent fruiting shoots and a well-balanced solid framework. This is a prolific and productive tree management system worked out in Guangdong which results in dwarf scaffold with many branches and a thick green canopy. Subsequently, girdling is used to promote flowering and to prevent fruit drop. Fruit bearing is encouraged in order to surpress vegetative growth and heading back pruning is adopted to prevent premature filling up between the rows of oranges. Although these measures entail much labor, they may pay back with higher economic benefit.

Introduction

Guangdong Province is one of the major citrus-producing centers in China and has a long history in citriculture. In the past, the trees planted in the paddy fields began flowering and fruiting generally 3 years after planting. A portion of them fruited 2 years after planting and were renowned for their early bearing and high productivity. Since the 1950's the government has encouraged planting of citrus in the hilly regions. Most of the hilly soils are red loam. Heavy rainfall averaging 1,500 mm per annum and warm temperature approximating 21.8°C prevail in the region, causing rapid decomposition of the soil organic matter. Consequently, fertility is low and soil erosion is serious resulting in less than 1% of humus in this soil. The soil is acidic with pH 3-5. Such soil has poor granular structure and hardens quickly, and supports little vegetation.

The question was whether it was possible to achieve early bearing and high yield from citrus planted on such red loam hills. Over the years, research workers and growers in the citrus districts accumulated much experience. For instance, the Fruit Research Institute of Guangdong Agricultural Academy produced 39,000-48,000 kg/ha yield in a 3-year-old grove in 1982 in their red loam hill orchards. The largest citrus plantation in the country, Yang Cun Citrus Farm, successfully established extensive citrus orchards on hilly red loam soils. Dong Guan County is a new citrus region with large-scale plantings established during the last decade. Most of the orchards, mainly sweet orange, in that county fruited in the third year and the initial yield approximated 10,000-15,000 kg per hectare. The chief production center in Dong Guan, the Hueng Jiang Commune, with 52 ha of citrus plantation harvested 29,429 kg of fruit per hectare in 1982 (2).

The experience of early bearing and high yields of Guangdong's hilly citrus orchards can be summarized as follows:

[1]The Fruit Research Institute of Guangdong, Guangchou, The People's Republic of China.

I. Control the taproot growth, train the laterals to develop in the soil strata and encourage the production of feeder roots.

Most of the slope land of Guangdong is red loam with shallow top soil, high acidity, poor aeration, and low organic matter content. Citrus grown under such adverse soil conditions has roots clustered in the upper 15 cm of soil with sparse length laterals and few feeders. Thus, the trees easily succumb to adverse environmental changes, especially during the dry season. Defoliation is especially prevalent in winter or the leaves turn yellow and the tree appears sickly. To improve these conditions, large quantities of green manure and fertilizer were placed in the planting hole 1 m wide and 1 m deep in the 1960's. As a result, the taproot overdeveloped and penetrated very deep and the laterals overgrew, suppressing the feeder roots. Ou Yuan Que (9) observed orange trees on sunki rootstock planted in a 1 m^3 planting hole filled with green manure and noted more than 5 taproots formed toward the bottom of the hole in 1 to 2 years. He also found that horizontal lateral roots extended 1 to 2½ times the diameter of the dripline with little branching and the feeder roots appeared like a broom and were clustered at the end of the lateral roots (9).

The luxuriant growth of the taproots and horizontal lateral roots in young trees resulted in excessive shoot growth and delayed the initiation of flower buds. This was especially true with certain rootstocks which have a deep rooting habit, as *C. sunki* which causes vigorous top growth in the early years, and delays fruiting (3). Therefore, to obtain early bearing and high yield of citrus on red loam soil, taproot growth must be controlled to encourage lateral root development in the soil strata and maximize development of feeder roots.

1) Prevention of deep taproots:

The following methods of taproot growth control have been found effective in Guangdong:

a. Cut off the taproot and transplant temporarily. After the young trees are taken from the nursery, they should be temporarily transplanted after the taproots are cut back. This results in an ample lateral and feeder root system. This method is widely adopted in Sin Huei County, an important citrus region where most of the trees flower and fruit in 1 to 2 years after planting.

b. Place a depth blockage under the taproot. A clever measure for controlling the taproot growth was adopted by the first brigade of the Gu Xiang commune of Chao An County. Broken tile or stone was placed under them at planting. As a result, the taproots were only 20 cm deep, although the hole was 1 m deep and the laterals reached a depth of 50 to 60 cm with an abundance of feeders at 20 to 40 cm. The trees fruited in the third year after planting and produced 22,500 kg:ha.

c. Limit the depth of the planting hole to 50 to 60 cm instead of 100 cm as in the past. Taproot growth is restricted when they reach the hardpan-like bottom, thus inducing the development of a dense network of laterals and feeder roots. This has been an effective measure leading to early bearing and high yield.

d. Train the lateral roots to develop in the soil strata. The soil of the planting hole must be enriched initially. This can be done by putting 60 to 100 kg of green manure, grass or farmyard manure into the 50 to 60 × 100 cm planting hole in three layers to improve the soil condition. Neglected orchards which have not been refurbished should be deeply ploughed and turned over within 3 to 5 years after planting. Tests in our institute showed that the organic content and total

nitrogen in the soil increased conspicuously. The soil became loose and fertile, the volume weight decreased, and the water-holding capacity increased. Feeder roots formed in the 15 to 40 cm portion of the top soil instead of at 3 to 13 cm. The total amount of roots increased 2 to 5 times (Table 1) (2).

Deep plowing annually encouraged the continued renewal of lateral roots and they grew in layers. Meanwhile, the treatment stimulated growth of the feeder roots.

e. Increasing the quantity of feeder roots. It has been observed that feeder roots, especially their new growth, are the most active and have the greatest ability to absorb nutrients. The Horticulture Department of South China Agricultural College found 60% more feeder roots in a high-yielding orchard (7,500 kg/ha) than in a medium-yielding one (3,000 kg/ha). This observation was in the soil 2 to 12 cm deep at a point 60 cm away from the trunk (10). Cahoon et al. (1) studied the number of feeder roots at 0 to 3 feet in relation to fruit production. A curvilinear relationship between fruit yield and root quantity was found when roots were taken from sample holes (0 to 3 feet deep) between trees in 22 southern California orchards. The regression coefficient ($R = 0.9353$) was significant at the 0.01 level of probability (1). This suggests that encouraging a large quantity of feeder roots, especially the horizontal ones, is the most important measure in obtaining early bearing and high yield.

As stated above, following soil plowing and manuring in layers, the lateral roots extend in layers beyond the dripline. The feeder roots arising from them show annual renewal and quickly intensify in layers. To continuously increase the supply of nutrients to the ever-extending feeder roots, compost or manure is spread annually on the exposed soil under the canopy before the spring and autumn flush. Surface soil is removed until roots are visible. After fruiting, outside soil should be used to thicken the top soil layer under the tree to induce the development of more feeding roots in winter. Thereby, a deep, extensive and thick root system is formed which is deemed of crucial importance to the early bearing and high yield of citrus.

II. Training of the top structure for early bearing, high yield and stable production. The structure of the tree top is basic to early fruiting and high yield for citrus. The primary training is to encourage the development of different types of shoots. Within 2 years after planting, rapid development should be promoted of a planned framework which possesses ample bearing shoots and a dense leafy canopy. Subsequent to fruiting, emphasis should be on restriction of new shoot elongation, delaying crowding between rows and encouraging continuous high yields.

We refer to this type of tree canopy as being "dwarf trunk, thick branches, dense top and spherical in form with wide crotches and wavy contour" (5).

To accomplish this, we mainly adopt the technique termed "clip the bud,

Table 1. Differences in soil properties and root distribution in the 0-50 cm of top soil before and after plowing under of green manure.

	Active organic matter (%)	Total nitrogen (%)	Volume weight (g/cm^3)	Weight of fresh roots (g)	Feeder root depth (cm)
17 months after plowing under	1.79	0.10	1.03	1885.7	15-40
Before plowing under	0.82	0.07	1.30	373.6	3-13

control the shoot." This makes use of the compound buds of citrus and regulates the quantity of shoots to form an artificial, early-bearing productive top.

1) The training of young immature trees.

a. Training of the budlings. Short trunks can shorten the route of translocation which is beneficial for the formation of early-bearing, productive trees. Hence, the stem of a grafted plant in the nursery should be cut back to 25 cm above the ground, and 3 to 4 well-spaced new shoots kept to serve as primary scaffolds. The crotch should have an angle of 45°. All other adventitious buds should be removed.

b. Training after planting. High yield is related to not only the size of the top, but also to the amount of bearing shoots. Autumn flushes are the main bearing shoots in the young tree. Studies of 30 young trees showed that the amount of autumn shoots and yield are related (R = 0.708). The ratio between fruits and autumn flushes usually is 0.6 to 1. Hence, more than 100 shoots from the autumn growth cycle should be maintained during the second year to obtain yields of 12,000 kg/ha in the third year.

a) "Clip the early shoots to get uniform growth flushes." Orange trees tend to have apical dominance. Usually, shoots on the upper part of the top and the terminal buds sprout earliest during a flush cycle. These sprouts should be removed while they are 2 to 3 cm long in order to stimulate growth of the lower ones. This should be done several times until most of the shoots on the tree carry 2 to 3 new sprouts at the same time. Then, let all these sprouts grow. Fertilization and irrigation must be carried out during the period of clipping.

b) Adjusting the number of shoots. Thinning is done when the summer and autumn cycle shoots grow to 5 to 6 cm. Weak and excessive shoots are removed, and 2 to 3 summer cycle shoots and 3 to 5 autumn cycle shoots are kept. That is, keep the strong and remove the weak and give advantage to the autumn shoots. Autumn shoots are the bearing shoots for the next year. If more summer cycle shoots are retained, the development of autumn shoots will be affected.

c) Heading back to encourage new growth. Heading back of spring and summer cycle shoots is very effective in causing the subsequent new shoots to grow and make the top more dense. The best time for heading back is when the new shoots are turning dark green.

d) The best time for the emergence of new shoots. For 1- to 2-year-old orange trees, there should be 2 to 3 "outbursts": for spring flush — early spring, for summer flush — late May to early June, and for autumn flush — late August to early September. On trees which begin to bear quite well, all the summer sprouts should be removed unless the fruits are sparse. In such cases, the growth of one crop of summer flush should be allowed. In order to avoid competition for nutrients by summer shoots that would cause fruit drop on bearing trees, the "outburst" of summer sprouts should be trimmed until late June. However, they should be headed back and the buds thinned because an abundance will reduce autumn shoots. The "outburst" of autumn shoots should be allowed until early September. Generally, no summer shoots would be allowed to grow on trees more than 4 years old. Shoots of the autumn cycle would be allowed to sprout earlier and generally time for the middle of August.

2) Top management of bearing trees. Seven to eight years following planting, the tops of the trees in the closely planted orchard will begin to

overlap and fill up the rows. Then, fruits will be borne only on the upper portion of the tree, bringing about a sharp reduction in yield. Our observation in the Xia Jiao citrus orchard of Cheng Hai County, showed that the thickness of the trunk and branch layer of a 1-year-old tree is 3.6 m and the foliage layer is only 0.5 m. To prolong the years of high yields in the closely planted orange orchard, we have carried out a trial of pruning for 5 years and finally proposed a dual-pruning (summer and winter) program. This is in accordance with the climate of Guangdong and is quite effective in promoting the development of strong fruit-bearing and spring vegetative shoots, improving sunlight penetration, renewing of vigorous shoots, rejuvenation of tree health and increasing production of fruits (6). (Table 2)

3) Method of proposed pruning.

a. Summer pruning. Head back all peripheral shoots having a diameter of 0.5 to 0.8 cm which have flowered but borne no fruit or whose fruit has dropped, and those which have degenerated, leaving a stub of 6 to 10 cm in length, in order that the fall flush can grow from them. Thin out all barren overlapping branches between rows. Remove from the base, all protruding, vigorous, upright barren shoots. The time for summer pruning is 10 to 15 days before the sprouting of autumn cycle shoots.

b. Winter pruning. Subsequent to harvest but before mid-January, thin out all overlapping branches between trees. Head back all peripheral branches which bore clustered fruit and those showing signs of degeneration, but leave a stub 0.8 to 1 cm diameter and 6 to 10 cm long to allow the sprouting of new shoots. Further, a technique termed "Suppress the apex, eradicate the overly vigorous shoots, provide sky window" should be adopted to deal with old trees and those trees which after a heavy crop have topmost branches beginning to show signs of decline, including water sprouts from all trees. Remove shoots from the base to allow sunlight into the interior of the tree to encourage the sprouting of new interior shoots. At the same time suppress the height of the tree, thus shortening the route of translocation to concentrate the nutrients for use in encouraging strong spring flushes.

III. Coordination of vegetative growth and reproductive development to favor early bearing and to prevent fruit dropping. An early-fruiting and high-yielding top is apt to be formed on young orange trees following more than a year of vigorous growth of different types of flushes. At this stage, vegetative growth tends to be overly vigorous. If no action is taken to induce the tree to shift to reproductive activity, flower bud formation will be retarded at an early stage, particularly under close planting circumstances. Shy bearing would lead to vigorous top growth, premature crowding between trees, shortened duration of copious production and reduction in total yield. Therefore, it is necessary

Table 2. Response to pruning.[z]

Treatment	Light intensity 1.5 m above the ground (lux)	Leaf area of spring cycle shoots (cm^2)	Fresh weight per leaf (g)	Photosynthetic efficiency under 30,000 lux (mg CO_2/dm^2/hour)
Pruned	7030	32.01	0.71	5.3
Control	1360	11.8	0.33	3.3

[z]Light intensity under full sunlight was 84,000 lux, leaf area was the average of 100 fresh leaves.

to stimulate flowering and prevent fruit dropping, in order to suppress the expansion of the top growth and lengthen the period of high yields. This is another effective measure for the promotion of early bearing and high yielding in orange trees.

1) Measures for stimulating flowering in young trees. In addition to earlier-mentioned measures to build a well-regulated root system, to establish a healthy and strong top, to stimulate flowering by manuring at the physiological floral differentiation period in September to October and withholding water in winter, such measures as root pruning, ringing, and deep digging of the soil under the tree, the following measures should be taken according to the needs of the tree:

a. If the taproot of a 2- to 3-year old orange tree does not grow deeply and the main feeder roots are repressed in the 20- to 30-cm region below the soil surface, cut the roots by deep digging to a depth of 20 to 30 cm under the dripline in October, after the fall flush matures.

2) For a flourishing tree which also has a deep taproot, a better method to induce flowering would be girdling on the trunk or on the primary scaffold branches. Our experience indicates that girdling should be done in mid-September or early- to mid-December. This is very effective and will not cause defoliation. For those trees which show luxurious growth, the first step would be to ring the central strong leader in September, and ring the trunk or main scaffolds in December.

3) For bearing trees, deeply dig the soil in the whole orchard to a depth of 15 to 20 cm in order to excise the upper feeder roots to reduce the absorption of water and increase the concentration of the tree sap.

The three measures mentioned above have, to a varying degree, the following effects: depression of root growth, reduction of nitrogen and water absorption, increase in the accumulation of carbohydrates in the tree top, and increase in tree sap concentration. (Tables 3 & 4)

The above-mentioned measures have been taken in recent years and unfruitfulness of young trees has practically been eliminated. In our institute, we began to girdle 2-year-old trees and have ringed them for 5 consecutive years. The average yield for the treated trees has been about 37,000 kg per hectare each year. The trees are still vigorous, and the so-called premature decline from ringing has not been observed. (Figure 1)

4) Measures to reduce fruit droppage from the tree. Emphasis was on preventing the second and third physiological droppage of fruit.

a. Apply readily available nitrogenous fertilizers subsequent to shedding of flowers to replenish nutrient loss during flowering.

b. Foliage spray of fertilizers and plant regulators. It has been demonstrated that after the first physiological dropping of fruit, a foliage spray of 1% complete fertilizer or 0.5% urea + 0.3 to 0.5% KH_2PO_4 or 0.5% of urea

Table 3. The effects of girdling on the chemical constituents of leaves from 2-year-old orange trees in 1978.[z]

Dry matter content in the leaves (%)						
		Sample date				
		10/23	11/6	11/27	12/16	1/15
Total N	Girdled	3.5	2.9	2.8	2.5	3.0
	Control	3.6	3.8	3.9	3.5	3.8
Starch	Girdled	2.4	2.5	2.5	2.7	2.8
	Control	2.7	2.1	2.2	2.4	2.6
Soluble sugar	Girdled	1.1	1.9	1.4	1.1	1.3
	Control	1.4	1.6	1.0	1.6	1.4

[z]Replication, 4 times; date of girdling, October 23; 677 flowers per tree when girdled, and 103 flowers without girdling.

Table 4. Effects of root pruning on the soluble solids content of trees.[z]

Treatment	No. of trees treated	Soluble solids content in shoots (%)	Soluble solids content in leaves (%)
Root cutting	5	5	7.75
Control	5	4	6.5

[z]Date of root pruning, 9/27/78; date of analysis, 8/12/78; 2 g of shoots or leaves were macerated and boiled with 3 cc of distilled water for 20 minutes, and a refractometer was used for analysis after cooling.

+ 5 to 10 ppm of 2,4-D applied one to three times in April to May is effective in reducing the droppage of young fruit.

c. Girdling. Young orange trees are inclined to be strongly vegetative. Therefore, when the fruit are still small, the competition for nutrients between leaves and fruit can lead to serious fruit droppage. Excessive cloudy and rainy spring days reduce the absorption capability of the roots and the photosynthetic activity of leaves further aggravates the competition between fruit and leaves. Then, it is necessary to girdle the main branches and thin out a portion of the spring cycle shoots before they turn green. Our ringing trial in 1978 showed that fruit set on the treated trees was 63% higher than that of the control.

d. Removal of summer cycle shoots. Shoots of the early summer cycle must be removed to prevent serious fruit drop. Fruit drop becomes significantly less when the fruit reach 2.6 cm in diameter. The late June summer flush does not cause fruit drop. In recent years, trials to replace the manual have been conducted. Spraying with 2,000 ppm of MH when most of the shoots reach 3 cm causes them to drop 3 to 4 days after application.

IV. Discussion.

1) Close planting is a traditional method of citrus culture in Guangdong. Tree density ranges up to 1,200

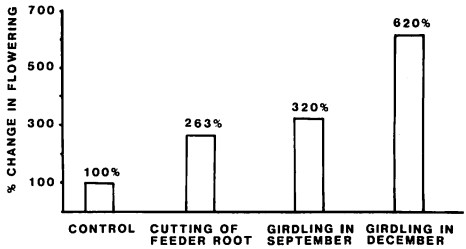

Fig. 1. Effects of different measures for stimulating flowering.

to 1,500 per hectare. Fruiting begins in the third year after planting. Branches of neighboring trees will overlap in 10 to 15 years and the yield begins to decrease due to crowding. The trees usually are cut down in 15 years and land planted to other crops. Total fruit production in these years is 453,000 kg per hectare. Economic benefit from this cultural system is higher than that from the more widely spaced and longer-lived trees. Other advantages are renewal of the variety and renovation of cultural techniques. At the same time, there is an attempt to double the density of trees in an orchard by planting 3,000 trees per hectare at the outset. Afterwards, they are thinned out in two operations. After 10 years, only 750 to 900 trees per hectare are retained. Further investigation is needed to determine which system best suits the circumstances.

2) The present cultural system of Guangdong is laborious and its per-laborer production is low. However, in this populous country, the present emphasis in technical change is to increase the soil productivity and we can gradually raise labor productivity by mechanization and chemical treatments.

3) Girdling has been practiced in portions of our orchards up to three times per year and for 8 years. We have not yet observed any reduction in yield or decline in tree vigor as reported in the past. If early bearing, high production and a 15-year rotation

are desired, then the spread of girdling will still be necessary.

4) The effect of rootstock on early bearing and high yield of sweet orange is great. According to our experiment and investigation in an extensive area, some mandarins (cvs. Huang Pi Ju and Jian Xi Hong Ju), *Citrus limonia, Poncirus trifoliata* (small leaf, large flower type) and *C. madurensis* are all good stocks for attaining the desired qualities. Other mandarins (cvs. Tai Shan Suan Ju and Hong Pi Shan Ju) tend to cause sweet oranges to delay fruiting.

5) Temporary planting for 1 year before permanent planting encourages young trees to flower early and facilitates intensive management of the trees. This causes trees to fruit 1 year after planting. This method reduces production costs and intensifies land utilization.

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Evaluation of Dessert Apple Varieties

"Schweizerische Fachkommission für Obstsortenprüfung," (1984, 20 pages) is an evaluation of dessert apple varieties produced by the Swiss Federal Research Station for Fruit-Growing Viticulture and Horticulture, CH-8820 Wadenswil, Switzerland. This book, published in the Swiss language, reviews 10 early, 12 mid season and 12 later season varieties. The harvest season and many other factors are compared with detailed descriptions of many cultivars including: Discovery, Jersey Mac, Klarapfel, Goro, Karmijn, Gala, Jonagold, Marigold, Gloster and many others.