HOW TO GROW BIG PEACHES[1]

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Produce buyers have been demanding larger and redder peaches. Fifteen years ago it was possible to sell peaches that were 2 1/8" in diameter, now the minimum diameter is 2 ½". There is a negative relationship between yield and fruit size, so the challenge now is to produce fruit of marketable size while obtaining yields that are high enough to make a profit. There are a number of factors that influence fruit size and this paper will provide a discussion of those factors.

Peach fruit growth.

Peach fruits have three fairly discrete stages of growth (Figure 1). The first stage (Stage I) lasts from full bloom until about 50 days after bloom. During this time the fruits grow fairly rapidly and growth is primarily due to cell division. Most of the cell division probably occurs during the first 30 days after bloom, but the length of stage I may be influenced by temperature. There is an increase in both fruit size
and fruit dry weight. During stage I, shoot growth begins but there is too little foliage on the tree to support the growth of the fruit and shoots. Therefore much of the carbohydrates for early fruit and shoot growth come from reserves stored in the tree during the previous season. The period of cell division may be prolonged during cool weather. Stage two begins with pit hardening, which is the lignification of the endocarp. During this stage the fruit increases little in size, but there is an increase in fruit dry weight. Rapid shoot extension occurs and adequate leaf surface develops to support fruit growth. During this stage carbohydrate is preferentially partitioned into vegetative parts of the tree rather than into the fruit. The duration of stage II depends on the variety, and it may last only a few days for early-season varieties or it may last 6 to 8 weeks in late-season varieties. The final phase of fruit growth, Stage III, is often called the "final sweet" because the fruits growth very rapidly during the final 6 weeks before harvest. Fruit growth during this stage is due primarily to cell expansion as the fruit flesh accumulates water and the nearly fully developed canopy supplies fruits with sugars.

Because the number of cells in a fruit and the size of those cells influence fruit size, there are really two ways we can influence fruit size. During stage I we can try to provide conditions for maximum cell division and during Stage III we can try to provide conditions for maximum cell size.

Genetics

All commercial peach producers know that some varieties are bigger than others. Johnson and Handley (1989) thinned several varieties to different number so fruit per tree and then estimated average fruit weight at harvest. To simplify variety comparisons, I have taken just part of their data set to compare average fruit weight at one crop load. When there were 800 fruit per tree, average fruit weight was 90 (about 2.2"), 140 (about 2.6"), and 210 (about 2.8"), respectively for 'May Crest, 'June Lady', and 'Elegant Lady'. The other aspect of this is that we can use these data to estimate the yield for each variety when the average fruit diameter is about 2 ½" (130 g). 'May Crest' can support 190 fruit per tree, which gives a yield of 88 lbs/tree, whereas 'June Lady can support 1000 fruit per tree, which is 130 lbs/tree. From this study we can see that 'May Crest' produces smaller fruit at all crop loads than 'June Lady', and to obtain a high percentage of saleable fruit, we will only get about 30% of the yield with 'May Crest' that we can obtain with 'June Lady'.

About 15 years ago Dr. Ralph Scorza, a peach breeder with the USDA, asked me why some varieties were small: was it due to low cell numbers or to small cell size? I didn't know the answer and he could find anyone who did, so he and his team (Scorza et al., 1991) sampled fruit from two large varieties and two small varieties throughout the season to measure fruit numbers and cell size. They found that the large varieties ('Loring' and 'Suncrest') had more cells than the small varieties ('Boone' and 'Bailey') (Table 1), but cell size was not consistently large for large varieties. In addition, the differences in cell size were apparent during the fall before bloom.

There are several take-home lessons from these studies.

1.Some varieties have greater potential to produce large fruit because they have more cells.

2.We can maximize fruit size by maximizing cell division during Stage I of fruit growth.

3. Although most early-season varieties produce small fruit, growers should plant the varieties within a season that produce the largest fruit.

Water Relations.

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During the summer, water is taken up by the roots and moves to the leaves. Holes in the undersides of leaves, called stomates, allow water vapor to exit the leaf and carbon dioxide to enter the leaf. With energy from the sun, chlorophyll molecules within the leaf use water and carbon dioxide to produce carbohydrates in the process of photosynthesis. When water is limiting, the leaves conserve water by closing the stomates. Not only does this stop transpiration, but it also stops photosynthesis. During periods of drought stress water is not available for cell expansion or the production of carbohydrates that are used for plant growth. The amount of water an orchard uses depends on the availability of water, the environmental conditions, and the amount of foliage per acre. Small trees or trees with few leaves use less water than trees that have filled their space and have a full compliment of leaves. Using a lysimeters (a very large pot on a scale) Worthington et al. (1989) determined that mature 'Redglobe' trees used about 37 gallons of water per day.

In the east there have been few good experiments to evaluate the benefits of irrigation because trees response most only during drought years. Worthington and Llasswell (1994) performed a 3-year study with 'Redskin' in Texas. The trees were 12 years old and planted 30' by 30' (48 trees/A). The trees were trickle irrigated with 0, 20, 40, or 60 gallons/tree/day. After three years, cumulative yield was not significantly effected by treatment, but marketable yield was increased from 117 to about 230 lbs per tree. They concluded that mature low density planting may not respond very well to trickle irrigation.

Morris et al. (1962) performed a three year study with mature 'Elberta' trees where the trees were irrigated during the final swell with no water, 2" every 2 weeks or 1" every 2 weeks. In two of the 3 years there was adequate rain and fruit size was not improved by irrigation. However, in the third year the percentage of fruit that was marketable was 5%, 11%, and 20% for 1", 0.5", and 0" of irrigation.

Chalmers et al. (1981) experimented with regulated irrigation in Australia. They applied trickle irrigation during only Stage I and III, only during Stage III, or all season long. They found that all three treatments produced similar yields and similar fruit size.

From these studies and others, we can conclude that during dry conditions it is important to irrigate peaches during the final swell, but trees can be drought stressed during Stage II without adversely affecting fruit size. Irrigation will not be beneficial every year in the humid east.

Canopy Position & Light

Experienced peach producers know that the largest, reddest, and earliest fruit is located on the outside of the tree, especially in the tree tops. Research from France indicates that the largest fruit with the reddest color and the highest sugar levels are produced in the tree tops, where light levels are high and on large fruiting shoots. It is difficult to determine if canopy position or light is the important factor because the outside of the tree receives the most light. Work from Australia indicates that fruit on the outside ripen early because they are located furthest from the roots and not because they develop in high light. In the mid 1980s we found that the open center form is very good for light penetration throughout the canopy. We have also found that summer pruning in June is important to allow enough light into the tree to maintain live fruiting wood throughout the tree.

In the late 1980s we performed an experiment to determine how much light is needed for various aspects of fruit quality and when the light was needed. Scaffold branches of 'Biscoe' trees were shaded during the first half of the final swell, during the second half of the final swell, or during all six weeks of the final swell, with varying levels of shade cloth. The results are presented in Table 2. Only one branch was shaded to simulate shading at the tree interior, where the majority of the tree receives adequate light. Shade during **for** the first half of the final swell did not influence fruit size at harvest. Shading during the second half of the final swell reduced fruit size, but excessive pre-harvest fruit drop for 9% full sun caused greater than expected fruit size. When trees were shaded for the entire final swell, more than 45% full sun was required for maximum fruit size.

We have also been trying to quantify the effects of canopy position, light, and date of fruit maturity on fruit size. We have been using ground color as an indication of maturity, and we quantify color with a colorimeter. The values obtained from the colorimeter are used to calculate hue angle values that correspond to color. A value of 90 is yellow. As the value decreases there is redder, so a value of about 80 is orange-yellow, 70 is orange, and 40 is red. As values increase above 90 the color becomes greener. A value of 95 is green-yellow and 100 is yellow-green.

To illustrate the daily changes in fruit size and ground color, fruit were randomly selected each day to provide a sample of the population of fruit on the tree on each harvest date. Figure 2 shows that fruit grow about 4 g (about 3%) per day during the final swell and the ground color changes from yellow (hue angle=90) to orange-yellow (hue angle = 68). Simply delaying harvest as long as possible for a particular market will improve packout.

In an attempt to sample fruit with similar maturity from different parts of the canopy, fruits with similar ground color were harvested on two dates. Average hue angle for outside fruit was 91.2 and for inside fruit it was 92.3, indicating that the fruit had similar ground color, however, average fruit weight was 132g and 104g for the outside and inside fruit, respectively. This experiment suggests that the difference in fruit size is not caused by differences in maturity.

In another experiment designed to separate the effects of canopy position and light, a graduate student of mine (Kara Lewallen) tagged 'Norman' fruit on the outside, middle, and inside of the canopy. Three treatments were applied to one side of a tree: control, reflective mulch placed under the tree, and 45% shade cloth were applied 2 weeks before harvest. We hoped to increase the amount of light in the tree interior with reflective mulch and to reduce the amount of light at the outside of the tree with shade cloth. Fruit were then harvested randomly from each treatment every two days until fruit fell off the tree. Fruit represented the population of maturities on the tree because ground color was not considered while sampling the fruit. Table 3 shows data from this experiment. Light was measured on 6 sides of each fruit (top, bottom, north, south, east, and west) to determine how much light individual fruits intercepted. Compared to the control, the reflective mulch increased light by about 15% and shade reduced light by about 30%. Fruit weight and hue angle were positively related to the amount of light intercepted by the fruit. Therefore, light may have indirectly increased fruit size by advancing maturity. As we expected, light interception increased, as the fruit were located closer to the outside of the canopy. Fruit size was largest and ground color most yellow for fruit located at the outside of the canopy. Therefore, the effect of canopy position on fruit size may have been related to fruit maturity.

We still have not totally been able to evaluate the direct effect of canopy position on fruit size, but we can make a few conclusions from this series of experiments. *Continued on page 8*

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1.) To obtain the maximum potential size, peaches need to develop in a region of the canopy receiving about 20% full sun during the final three weeks before harvest.

2.) Peaches developing on the outside of the tree receive high light and mature several days earlier than fruit developing at the tree interior.

3.) Peach diameter increases 2 to 4% each day the fruit is on the tree. Therefore, delaying harvest as long as possible will improve fruit size and packout.

4.) Even when harvested with the same ground color, fruit from the tree interior tends to be smaller than fruit from the outside of the tree. The amount of shade at the tree interior is usually not great enough to limit fruit size, so the small fruit size at the tree interior may be due to a lack of leaves in the immediate vicinity of the fruit. To obtain larger fruit from the tree interior, I suggest that growers thin the interior portions of the tree more severely than the exterior portions of the tree.

Mineral Nutrition.

Like any green plant peach trees require certain mineral nutrients to grow. Fruit size may be negatively effected when nutrients are present are deficient or toxic levels. The nutrients most likely to be deficient in the mid-Atlantic region are nitrogen and potassium. Maximum fruit size is generally associated with leaf nitrogen levels from 2.8% to 3.4%, and higher nitrogen levels do not result in larger fruit. Work in California (Lilleland et al., 1963), where an orchard site had been leveled for irrigation, showed that maximum fruit size was associated with leaf potassium levels of about 1.0%, above which there was no increase in fruit size.

Crop Load Adjustment

All commercial peach produces know that tree usually set more fruit than the tree can properly size, and some of the fruit must be removed early in the season. The older literature indicates that there should be 30 to 45 leaves per fruit for maximum fruit size. Fruit thinning is the most expensive cultural practice in peach production, but the results are so dramatic that it is cost effective. Fruit size at harvest is influenced both by the number of fruit left on the tree and the date of thinning. Havis (1962) showed that maximum fruit size was obtained by thinning at bloom and that early thinning hastened maturity (Figure 3).

Researchers have been looking less expensive methods for thinning peaches. Thus far, no post-bloom chemical agents are available. Chemicals that kill flower parts and prevent fertilization are registered for peach, but results have been erratic and are probably influenced by timing of application, weather conditions, and sprayer calibration. Because timing is so critical, it is unlikely that this approach will ever consistently provide satisfactory results. Physically removing a portion of the flowers with rope drags has been cost effective in West Virginia (Bauger et al., 1991), but for consistently acceptable results the tree must be pruned to a very open form so the ropes can fall through the tree. Physically removing some of the blossoms with fingers or commode brushes seems to be cost effective and is used by many Virginia growers.

There are many fruiting shoots (1-yr-old shoots) within a tree and these shoots posses both flower buds and vegetative buds that may develop into leafy shoots that may supply fruits with carbohydrates. I have been interested in using pruning to reduce the number of flowers per tree and thus reduce the cost of hand thinning. In 1925, professor Blake observed that peaches developing near the terminals of fruiting shoots were larger than fruit at the shoot base. Spenser and Couvillon (1975) confirmed these observations and also reported that flower buds at the terminal nodes bloomed earlier than buds at the basal positions. Corelli-grappadelli and Coston (1991) reported a similar pattern of bloom development and noted that fruit were smallest at the distal end terminal end of fruiting shoots. These conflicting results may be partly related to the physiological age of fruit at harvest, because Spencer and Couvillon (1975) harvested all fruit on the same calendar date, whereas, Corelli-Grappadelli and Coston (1991) used multiple harvests so that all fruit were harvested at the same stage of maturity. In an attempt to further understand the importance of fruit position on a shoot we performed several experiments with ‘Redhaven’ trees (Marini and Sowers (1994). First we evaluated the effect of fruit position and auxillary shoots (shoots developing from nodes of fruiting shoots). Shoots, 18” in length, with and without auxillary shoots were thinned to retain 3 fruit. The fruit were either evenly spaced along the length of the shoot, or limited to the terminal, middle, or basal portions of the shoot. We found that fruit size was similar regardless of the shoot position, but shoots with auxillary shoots produced fruit that were 26% larger than fruit on shoots without auxillary shoots.

We then studied the effect of number of fruit per shoot and shoot length by varying the number of fruit per shoot on shoots of different length and fruit were harvested on the basis of ground color. Fruit weight increased nonlinearly with increasing shoot length. Fruit weight was 110g, 111g, 115g, and 122g, respectively for shoots that were 3”, 6”, 12”, and 18” long. The reason long shoots produced large fruit is probably because total axillary shoot length increases with increasing shoot length. Corelli-Grappadelli et al (1996) reported that fruit growth during the first 4 weeks after full bloom depended on carbohydrates from axillary shoots developing at the same node as the fruit. At about 4 weeks after full bloom the shoot developing from the terminal bud started contributing to fruit growth. Later in the season fruit growth mostly depended on carbohydrates from the terminal shoot and axillary shoots not associated with fruit. Fruit growers can use this information to determine which fruit to retain during thinning. Fruit that will be largest at harvest are those that are large at thinning time, are borne on shoots longer than 12”, and are at nodes with an axillary shoot.

Morris et al. (1962) pruned peach trees normally or pruned to remove 1/3 more wood than normal. They found that severe pruning reduced total yield from 359 to 316 pounds/tree, but the percentage of fruit greater than 2” in diameter increased from 58 to 85% and the percentage of fruit greater than 2 1/4” in diameter increase from 3 to 20%. Based on this work it seemed that pruning could be used to reduce the number of flowers per tree and improve fruit size while reducing thinning costs. We first tried reducing the number of flowers per tree by heading shoots. In an experiment with ‘Redhaven’ we found that heading all shoots by half resulted in a slight improvement in fruit size, from 134 to 138 g per fruit. We confirmed these results with another experiment with ‘Cresthaven’ (Marini, 2002). First the trees were pruned normally, then all shoots shorter than 12” were removed, then shoots were headed by varying amounts. Fruit set was negatively related to the proportion of the shoot remaining after heading. Although trees were hand thinned at 40 days after bloom to a certain number of fruit per tree, the number of fruit harvested per tree was greater for the less severe pruning treatments. Average fruit weight at harvest was similar for all treatments, but given that severely pruned trees had the fewest fruit, severe heading probably negatively affected fruit size. From these a two other experiments, we concluded that heading shoots by half can reduce fruit set and lower thinning costs, but fruit size was not consistently improved.

Rather than heading the shoots, another set of experiments involved removing entire shoots Marini, unpublished). For three years we pruned the trees normally, and then removed all shoots less than 12” long. Then the shoots were removed to obtain a range of shoots from 71 to 250 shoots per tree. At thinning time, the trees were thinned to retain 500 fruit per tree. So all trees had the same number of fruit, but on varying numbers of shoots. Therefore the number of fruit per shoot varied from 7 (71 shoots/tree) to 2 (250 shoots/tree). Results presented in Table 4 show that fruit set was positively related to the number of shoots per tree, and average fruit weight, percentage of marketable fruit, and crop value were not influenced by treatments. However, the most severely pruned trees tended to have slightly larger fruit than the least severely pruned trees. Therefore, it is possible to drastically reduce thinning costs, while slightly improving fruit size by limiting the number of shoots per tree.

Tree Density.

There is an international trend toward orchard intensification. The primary motivation for increasing the number of trees per acre is to obtain higher yields early in the life of the orchard. Giulivo et al. (1984), working with 'Suncrest" peach and 'Redgold' nectarine in Italy, increased the number of trees per acre from 506 to 810. With both peach and nectarine yield efficiency (kg of fruit/unit trunk cross-sectional area) declined about 14% and average fruit weight declined 5% as tree density increased. In a tree spacing experiment with 'Norman' peach in Virginia, we planted 250 or 500 trees per acre (Marini and Sowers, 2000). Cumulative yield was 28% greater for the high-density plots, but cumulative marketable yield (2 ½" diam.) was only 16% higher because fruit size was lower for high-density plots. Even when analysis of covariance was used to adjust fruit size for number of fruit per acre, fruit weight was lower for high-density trees. These reports were confirmed by Dr. Jim Flore, in Michigan, (nonpublished data), where fruit size was also reduced by increasing the tree density. We don't know why high-density plantings produce smaller fruit, but it may be related to water stress or shading. Until more is learned about this phenomenon, growers may want to thin their high-density plantings a little more severely than their low-density plantings.

Summary

I have tried to review all the factors known to influence peach fruit size. Fruit size can be maximized by increasing the number of cells per fruit early in the season and by increasing the size of those cells later in the season. Below is a list of orchard practices growers should consider for maximizing fruit size.

While planning the orchard

- Select varieties that are large for their season
- Test the soil and adjust soil pH and fertility levels accordingly
- Make plans for irrigating the orchard
- Be aware that high-density orchards may produce smaller fruit and be prepared to adjust crop load accordingly

Pre-bloom

- Prune trees to remove all shoots shorter than 12" long and retain only enough shoots so that workers will retain about 4 fruits per shoot while thinning.
- Use leaf analysis every 3 or 4 years to aid in developing an orchard fertility program
- Apply half the fertilizer about one month before bloom, and if there is a crop apply the second half at about shuck split

Bloom

- Partially thin the trees by spraying fertilization-inhibiting chemicals, or by physically removing about 50% of the blossoms.

Early-Season (stage I of fruit growth)

- Complete the thinning job before pit-hardening
- While thinning retain the largest fruit and the fruit on shoots with axillary shoots. Where possible retain fruit at nodes with axillary shoots.
- Summer prune trees at about 40 days after bloom to remove the vigorous upright shoots arising at the tree interior to improve light penetration into the tree

Mid-season (stage II of fruit growth)

- Do not irrigate
- Use a good pest control program to maintain functional foliage

Late-season (stage III of fruit growth)

- Depending on the market the fruit is intended for, delay harvest as long as possible, based on ground color or flesh firmness
- Irrigate to prevent water stress

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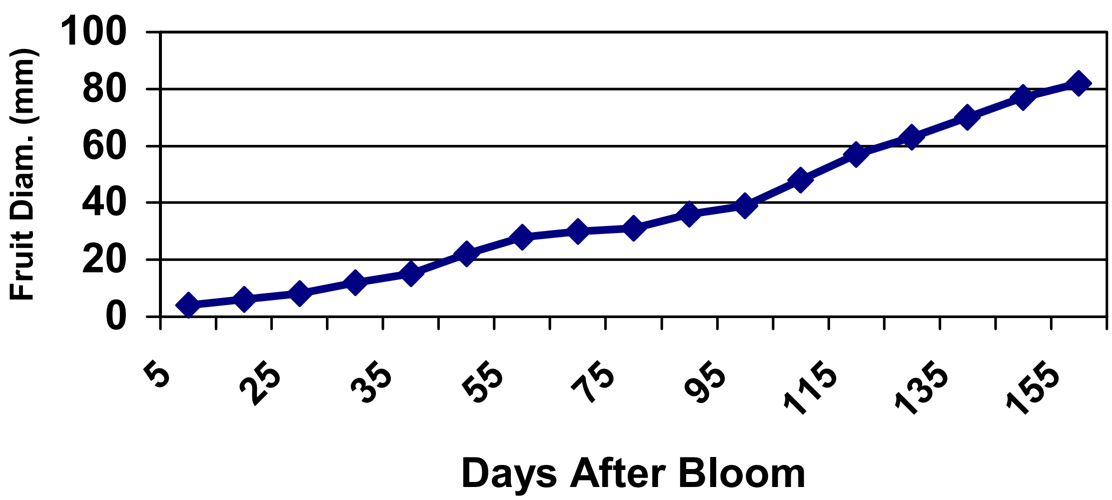

Figure 1. The pattern of peach fruit growth. Stage I is a period of rapid growth for about the first 50 days after bloom. Stage II is a period of relatively little fruit expansion from 65 to 85 days after bloom. Stage III is a period of rapid fruit growth during the final six weeks before harvest.

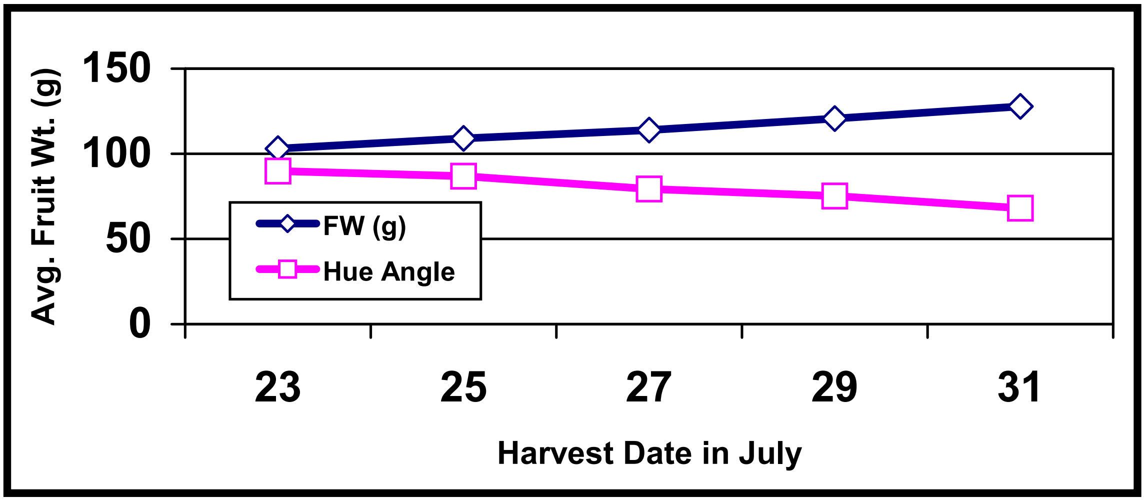

Figure 2. Changes in average fruit weight (g) and ground color (hue angle) as harvest of 'Norman' peaches is delayed from July 23 to July 31. A fruit weighing 130 g is about 2 ½" in diameter.

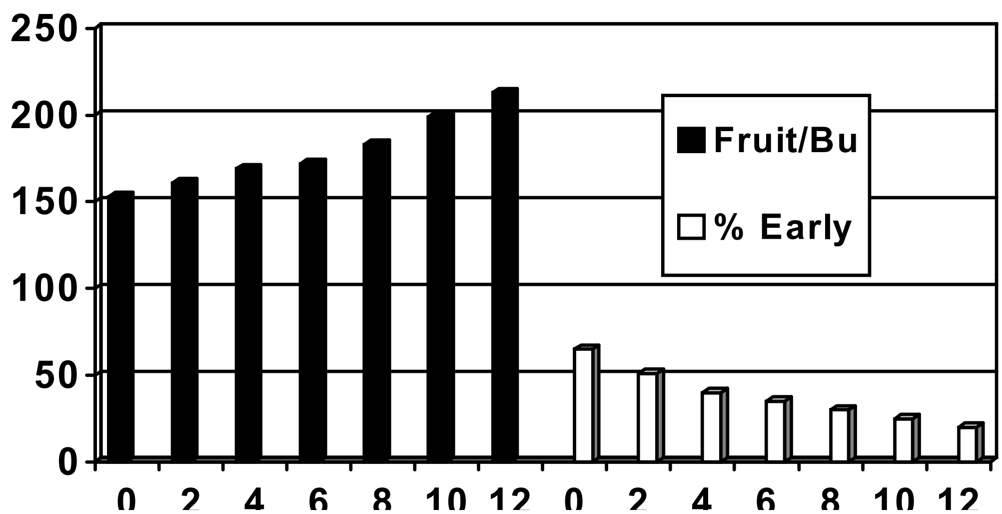

Figure 3. The effect of time of thinning on fruit size (number of fruit per bushel) and the percentage of fruit harvested early (Havis, 1962).

Table 1. Cell numbers and cell size of four peach varieties at different times of the.

Variety	Cells per fruit cross section				Fruit diam. at harvest (mm)	Cell size (sq. micrometers)
	14 Oct.	13 Apr	23 July	Harvest		
Sun Crest	0.8	20	371	581	80	10,500
Loring	0.7	19	427	564	72	8,720
Boone	0.3	11	117	236	44	9,330
Bailey	0.3	15	153	257	60	7,840

Table 2. The effect of shade during the final swell on average peach fruit weight (g/fruit). A fruit weighing 130 g is about 2 ½” in diameter.

	Time of shade (days before harvest)		
% Full Sun	**44 - 20**	**20 - 0**	**44 - 0**
100	**148**	**153**	**160**
45	**150**	**140**	**130**
23	**142**	**138**	**135**
9	**145**	**159**	**143**

Table 3. The effect of shade treatments and canopy position on Average fruit weight and hue angle of ‘Norman’ peaches.

Treatment	% Full Sun	Avg. FW (g)	Hue Angle
CK	12.1	114	78.9
Ref. Mulch	14.2	121	73.3
Shade	8.2	110	87.6
Position			
Inside	6.5	104	86.9
Middle	7.9	112	82.4
Outside	20.1	128	70.6

Table 4. the effect of number of shoots per tree on fruit set, thinning, average fruit weight, and crop value of ‘Norman’ peach trees.

Shoots/tree	Fruit set/tree	Fruit thinned/tree	Avg. FW (g)	Crop Value ($/tree)
71	829	240	136	72.29
83	987	390	142	77.63
100	1,034	505	136	62.03
125	1,321	761	140	73.29
167	1,510	936	125	54.98
250	1,929	1,408	132	60.71