Apple Growth and Crop-load Management

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"It's easier to make a big apple small than a small apple big"

Crop load, determined as the number of bushels produced per acre, or on a smaller scale the number of fruit per tree, is a major determinant of fruit size at harvest. Getting the crop load right not only means fruit size will be where you want it to be, but will also make harvesting and packing the crop a more efficient process. So putting effort into managing crop load can make a huge difference to your profitability in different ways. An understanding of some of the physiology behind the process of apple growth will help you to make sound crop load management decisions that will pay off where it counts.

Cells in the Apple Divide First then Expand

An apple fruit is made up of lots of cells. Exactly how many cells are in a mature apple at harvest depends on many factors, including which research report you read. The data vary from 'Gala' having around 26 million cells to 'Golden Delicious' having up to 120 million cells. Developing fruit undergo a period of rapid cell division that lasts somewhere between three and eight weeks after bloom, again depending on which research report you read. The cell division phase is probably shorter and more intense at warmer temperatures but less intense and more prolonged at when temperatures are lower. Cell numbers are higher and fruit size greater when temperatures during the cell division phase are higher. Cell division is certainly finished by the time of June drop. After June drop occurs the growth of fruit is due entirely to cell expansion.

There are a couple of important points to remember regarding cell number. The first is that differences in fruit size at harvest are primarily the result of differences in cell number and not differences in cell size. In a study published back in 1967 small 'Golden Delicious' fruit were found to have only two thirds as many cells as large fruit on the same tree whereas the average size of cells in small fruit were 90 percent the size of those

Figure 1. Stages of apple fruit development during the season. Left to right: king and lateral flowers of 'Royal Gala' within a dormant bud (slide courtesy of T. Foster); 'Gala' spur at full bloom with king flower open and five lateral flowers at the balloon stage; 'Rome' spur in June with two dominant fruit, two weaker fruit, and two fruit about to drop (partially obscured by lower fruit); 'Suncrisp' at harvest.

in large fruit. The second point relates to the fact that the cell division phase is completed relatively early in the season. This means that the number of cells in a fruit, and therefore its potential size, is established at the end of the cell division phase. The cell division phase probably occurs during the first five to six weeks after bloom in the Southeast. What this means is that a fruit that is small in June will still be small at harvest; you cannot make a little apple big. If you want big apples at harvest then you will need to make sure that any thinning you do, chemical or hand, removes only the smallest fruit. Fortunately, most chemical thinners do in fact result in drop of the smallest, weakest fruit within a spur.

What is a Sink?

Developing apple fruits produce practically no carbohydrates themselves so they demand a continuous supply of carbohydrates from elsewhere in the tree. Another way of saying this is that fruit are a sink for carbohydrates. The carbohydrates required for early season growth of spur leaves, shoots and fruit during the period from bud break until bloom come from the remobilization of reserves that were accumulated in the previous year. Most of the reserves are used to fuel growth of the rapidly expanding spur leaves since they also are a sink for carbohydrates during this time. However the reserves in the tree are usually depleted by about bloom, coinciding with when the spur leaves themselves stop being a carbohydrate sink and start to export carbohydrates to other nearby sinks such as flowers and growing shoots.

Apple fruit are carbohydrate sinks for the entire season. Furthermore, during much of the cell division phase fruit are weak sinks, meaning they are not able to compete for carbohydrates as well as other sinks on the tree, particularly growing shoots. Even individual fruit within a spur exhibit different sink strengths, some growing at much faster rates than others. Weaker fruit within a spur are more likely to drop, either in response to environmental conditions or to application of a chemical thinner.

Fruit are weaker sinks than shoots, so when the level of carbohydrates in the tree is low then fruit production can be limited due to a slowing down of the fruit growth rate. If there is a severe limitation in the supply of carbohydrates to growing fruit then they may even start dropping from the tree, beginning with the smallest fruit first. This is one reason why chemical thinners have greater activity when they are applied during periods of cloudy weather or warm nights. Cloudy days reduce the level of carbohydrates available to growing fruit due to reduced photosynthesis whereas warm nights have the same effect because more carbohydrates are used up in the process of respiration.

How Does Crop Load Management Fit Into All This?

If potential fruit size is determined by cell number, then anything you can do to enhance cell division will increase the fruit size potential of your crop. There isn't much you can do to increase air temperatures, at least in the immediate future. However, this may be one situation where global warming will work in your favor. Seriously though, the one area where you can (and do) influence fruit size is with crop load management (chemical and hand thinning). Thinning stimulates growth of the remaining fruit because it reduces the total number of fruit sinks on the tree, increasing the supply of carbohydrates to each remaining fruit and increasing the rate of cell division. As you well know, chemical thinning responses are notoriously

Figure 2. 'Rome' apple spur in June with two dominant fruit, two weaker fruit, and two fruit about to drop (partially obscured by the largest fruit).

unpredictable, because they reflect the combined effects of the chemical thinner and environmental effects on the level of carbohydrates available for fruit growth. If the carbohydrate supply to each fruit is low, perhaps due to a very high initial fruit set (many competing fruit sinks) or to a combination of cloudy days and warm nights, then the chemical thinner will have greater activity.

The Size Thinning Method

The goal of hand thinning is to reduce the number of fruit per tree to a more commercially acceptable level when there has been a poor chemical thinning response. There are some principles that are commonly followed when deciding which fruit to remove at the time of hand thinning. Damaged or misshapen fruit are normally the first to go. Then the number of fruit per spur might be reduced down to one or two; and finally fruit are removed so that the remaining fruit are spaced 6-8 inches along the branch. Do these hand thinning rules sound reasonable? Note however that the number of fruit per tree and fruit size was a primary consideration in any of these decisions. One problem with the traditional approach to hand thinning is that in the process of reducing the number of fruit per spur and spacing the remaining fruit at intervals along a branch many of the largest fruit may be removed and many of the smallest fruit may remain on the tree.

You can make a big apple small, by leaving too much crop on the tree, but you can also grow a crop of small apples by leaving the smallest apples on the tree and removing many of the largest apples when you hand thin. I visited several 'Gala' orchards in Henderson County the day after the trees were hand thinned in 2008 and measured the diameter of a random sample of 100 apples on a tree and the diameter of a further 100 apples lying on the ground beneath the same tree. When I compared the sizes in these two samples, I found that there was no difference between them. After hand thinning, many of the smallest fruit remained on the tree while many of the largest fruit on the tree had been removed.

'Size-thinning' is an alternative approach to hand thinning that uses fruit size (diameter) as the primary basis for deciding which fruit to remove. This method places a lower priority on the number of fruit remaining per spur and on the spacing between fruit compared to traditional hand thinning methods. Before adopting this method there are a couple of things you need to know. You must have an accurate count of the number of fruit on each tree after the completion of fruit drop (pre-thin number), and you must have determined a crop load target (target number) for your trees that is based on fruit number. The actual number of fruit per tree can be counted on five or six representative trees, taking two people three or four minutes per tree for typical trees on M.9 or M26 rootstock. From these two numbers (the actual fruit number and the target fruit number) the percent of the crop that must be removed in order to reach a crop load target can be calculated. For example, if an average of 400 fruit were counted on each tree and the target is only 300 fruit then 100 fruit, or 25 percent of the total number, will need to be removed from each tree.

Figure 3. The size thinning method only results in removal of the

The 'size thinning' method of hand thinning ensures that only the smallest fruit on the tree are removed. In order to do this you will need to determine the size limit that defines the upper limit of the smallest 25 percent of all the fruit on the tree in this example. This is achieved by first measuring the diameter of a random sample of 100 individual fruit; a procedure that will take approx. ten minutes with a digital caliper. Then you will need to arrange the diameters in order from the smallest to the largest which is easily done using the sort command in any spreadsheet. Finally, run down the column of sorted diameter measurements until you find the 25th data point from the smallest and you will have the upper size limit. Hand your thinning crew an apple the same diameter as the upper size limit and instruct them to remove all fruit that size or smaller and you should end up with the largest 300 apples remaining on each tree and the smallest 100 apples on the ground. The

size thinning method has two main advantages: first it ensures that only the largest fruit remain on the tree after hand thinning, and second it can be a reliable way to reduce the number of fruit per tree to a desired target crop load based on fruit number. The size thinning method may have some disadvantages that you will need to consider. Size thinning will probably result in more spurs in the tree carrying multiple fruit which will negatively impact red color development in some cultivars such as weak coloring strains of 'Gala'. Here in the southeast we have also found that hand thinning according to the size thinning method can result in an uneven distribution of fruit throughout the canopy with fewer fruit in the lower, shaded regions of the canopy and more fruit in the upper canopy. This phenomenon is probably a result of the uneven pattern of flowering that can occur across the tree here in the southeast, and may not occur in areas where flowering is more synchronous.

Summary

Apple fruits grow first by cell division and then by cell expansion. The cell division phase continues for the first 5 to 6 weeks after bloom. Large fruit have more cells than smaller fruit, indicating that the fruit size potential is determined within 5 to 6 weeks after bloom. Fruit growth can still be limited after the cell-division phase by factors which will slow cell expansion, such as excessive crop load or drought. Fruit are weaker sinks than shoots, and the weakest fruits are more likely to drop, either in response to adverse environmental conditions (cloudy days and/or warm nights) or to a chemical thinner. You can make a potentially big apple small but you cannot make a small apple big. The smallest fruit should be targeted for removal in the hand thinning process. Size thinning is a method for reaching a crop load target based on fruit number per tree that removes only the smallest fruit.