miss the temperature at the time of application a having any significant effect on subsequent thinning. The day after application, the temperature was quite cool, but the next day the maximum temperature exceeded 80°F. Three and four days after application the temperature was acceptable for thinning but on the lower range of what we hope for. Our interpretation of the temperature profile is that the weather was acceptable to somewhat favorable for a good thinning response. Temperature may be important since previous experience with BA indicates that good thinning is dependent upon above-average temperatures following application. We interpret this, base not upon this year's data but previous years experience, that the current formulation of BA, MaxCel, is less influenced by unfavorable temperatures following application than experienced with Accel and other earlier BA formulations. Thus, we feel that MaxCel may thin well over a wider temperature range.

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A Method to Predict Chemical Thinner Response on Apples

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Chemical thinning is one of the most important management activities an orchardist is required to do because of the importance of the decisions involved and the uncertainties associated with the outcome. Poor thinning will have significant repercussions for two years. In the year of application, inadequate thinning will result in small fruit that will bring a very low price. The year following poor thinning, return bloom is likely to be inadequate or nonexistent.

Traditionally, the majority of thinning was done at the time fruit are most vulnerable to chemical thinners, at the 7 to 10 mm stage of fruit development (Williams and Edgerton, 1981; Forshey, 1986). In many years thinner activity is variable, due in large part, to variable weather following thinner application, (Byers et al., 1990; Williams and Fallahi, 1999) and varying sensitivity. The loss of crop due to over-thinning is obvious, but occurs less often than under-thinning. The negative economic consequence of insufficient thinning have forced most orchardists to reappraise the thinning strategy used in the past which was based upon a single thinner application. Increasingly, local thinning recommendations suggest using multiple thinner applications, starting as early as bloom (Greene, 2002; Schwallier, 1996). Increased thinner activity is often achieved, because thinner applications have greater probability to coincide with weather that is favorable for thinning. Using this thinning strategy, growers are urged to observe responses to earlier thinner application and make a decision about the need for additional sprays. A problem with this approach is that no guidelines have been provided to help growers estimate the effects of the first thinning treatment in a timely manner. An easy-to-use system is needed to help growers decide if a supplemental thinner application is necessary to achieve adequate thinning.

A number of researchers have noted that fruit destined to drop during the June drop period, stop growth well in advance of the time that they actually abscise (Byers et al., 1991; Greene and Krupa, Lakso et al., 2001; 1999; Marini, 1998; Ward and Marini, 1999). Ward and Marini (1999) evaluated a number of ways to assess thinner response and concluded that fruit growth measurements were the only accurate and practical way to assess thinner response. Greene and Krupa (1999) suggested that measurements of fruit growth

rate has the potential as a predictor of chemical thinner response. In a series of thinning trials the usefulness and accuracy of this method were confirmed (Greene et al., 2004).

Over a several-year period we have developed, and continue to refine, a grower-friendly system to predict thinner response and final fruit set based upon following the growth rate of individual fruit in a spur. The purpose of this article is to provide a general description of this procedure and to provide evidence that this is an accurate way to predict final fruit within 7 days of thinner application in good thinning weather, and within 9 days when unfavorable weather follows application.

Generalized Procedure

When fruit size reaches the 7- to 8-mm stage, 70 to 100 spurs are selected randomly on 4 to 8 trees. These spurs are tagged and identified with numbered, iridescent-orange tags so that they can be located easily on the trees. Fruit are individually identified in the spur by either writing a number of individual dots on each with a permanent marker or by some other method. Just prior to spraying, all fruit in the cluster on all spurs are measured with a digital or recording caliper at the location on the fruit where it was identified with a permanent marker. Thinners are applied, and at 2- to 3-day intervals, all fruit in cluster are measured at the point where fruit were numbered and then recorded. This measuring process is continued for 12 to 14 days. There are two key things that must not be deviated from during the measuring and data collection process. First, fruit must be measured at the same location on the fruit each time, since fruit are frequently asymmetrical and measuring the fruit at a different location can cause variability that is greater than the fruit growth over an individual measurement period. Secondly, the growth of individual fruit must be identified so that their growth rate can be calculated individually.

Identifying fruit that will persist to harvest

Initially it may appear that identification of fruit that will persist to harvest may be an impossible task. In actuality, identification of these has proven to be relatively easy and very reliable. It is generally accepted, and confirmed in the literature, that the largest and fastest growing fruit are most able to compete with smaller and slower growing fruit and persist to harvest. We like to have the average of about 20 fruit in the fastest growing group. For example, we have selected the three fastest growing fruit from the 7 trees from which data are taken for a total of 21 fruit in these experiments. Their growth rate is calculated over the most recent measurement period and then an average growth rate of the fruit is calculated. Experience has shown that usually 99% of the fastest growing fruit persist.

Predicting which fruit will persist or drop

Although the relationship between fruit drop and fruit growth rate is a curve, based upon previous experience, we have selected 50% as our simplified cut-off level (Figure 1). We predict that a fruit will persist if the growth rate of that fruit is 50% or greater of the growth rate of the 20 fastest growing fruit. Conversely, we predict that a fruit will drop if the growth rate of that fruit slows to less than 50% of the growth rate of the fastest growing fruit during a measurement period of 3 or more days.

When can you make a reliable and accurate prediction?

Once applied, a thinner must be absorbed by the plant and must be translocated to the site of action to elicit a response. The first measurable response that signals that a fruit will abscise is a reduction in growth rate. This reduction in growth rate may occur over a several-day period, but eventually it will stop growing and ultimately abscise. The growth rate of a fruit that will persist to harvest and one that will abscise as the result of thinner application are illustrated in Figure 2. In a normal thinning year when temperatures are favorable, it is possible to measure a reduction in fruit growth within about 4 days of thinner application. This reduction is measurable even if it is less than 1 mm. As growth slows further, the reduction can be used to predict if the fruit will persist or abscise. In a normal thinning year, usually by 7 days after application, the growth rate reduction is sufficiently large so that an accurate prediction of whether it will persist or abscise can be made. There are years when cold and unfavorable weather follows thinner application. Under these conditions it takes longer for the thinner to act, thus the rate of fruit growth does not slow sufficiently such that an accurate prediction of abscission can not be made until 8 or 9 days after application (Figure 3.). We feel that the length of time required before an accurate prediction can be made is primarily tempera-

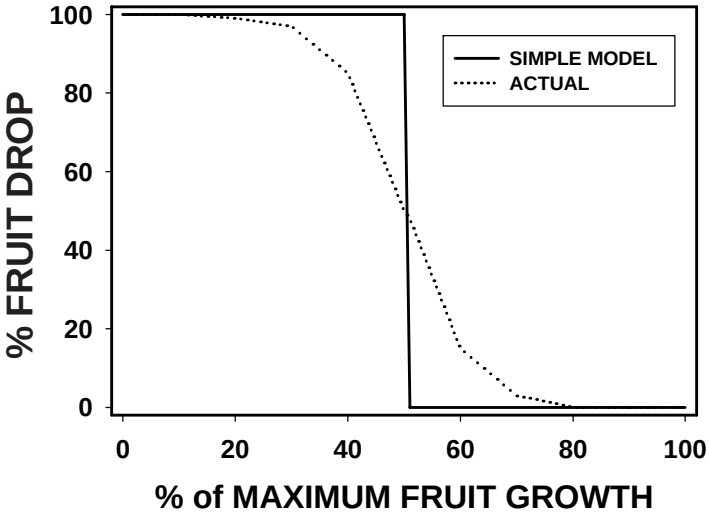

Figure 1. The general relationship between apple fruit drop often found in experiments (Actual) and the simplified 50% cutoff method used in estimation of fruit drop or retention.

ture related. If it is cold, the prediction will be delayed but the window of opportunity for follow-up thinning will also be longer. In subsequent work we hope to be able to provide growing-degree-day guidelines that will aid in determining when the prediction can safely be made.

Testing the Prediction Model

During the 2004 thinning season the prediction model was tested in three different experiments in Massachusetts and New York.

Golden Delicious - Massachusetts. Three limbs 15 to 20 cm in diameter on 7 mature Golden Delicious apple trees were selected. Fifteen spurs on each limb were selected and tagged. The fruit on these spurs were individually identified and then when fruit size reached 8 to 10 mm all fruit in the cluster were measured. NAA at 10 ppm + 0.5 lb/100 gal carbaryl (80 WP) was applied to one limb as a dilute spray and 125 ppm Maxcel + 0.5 lb/100 gal carbaryl to a second limb as dilute sprays on 25 May. A third limb served as an untreated control. Fruit were subsequently measured at 2- to 3-day intervals. Three and 5 days after application, a large number of the fruit had slowed growth to less than 50% of the growth rate of the fastest growing fruit (Figure 4). Since temperature was favorable for thinning, we feel that an accurate prediction of final set could have been made by 7 days after application. The prediction made at this time was 18% set while actual set measured in July after June drop was 15%, a prediction that was within 3% of the actual final set. Spurs on the limb treated with MaxCel and carbaryl showed similar accuracy in prediction of final set (Figure 5). At 7 days after application, we predicted a final set of 18% when final set was actually 16%.

Delicious - Massachusetts. Twenty one trees were selected and divided into 7 groups of 3 trees each in a block of mature Ace Delicious/M26. Fifteen spurs per tree were selected and tagged and fruit numbered and measured similar to that described for the Golden Delicious. One

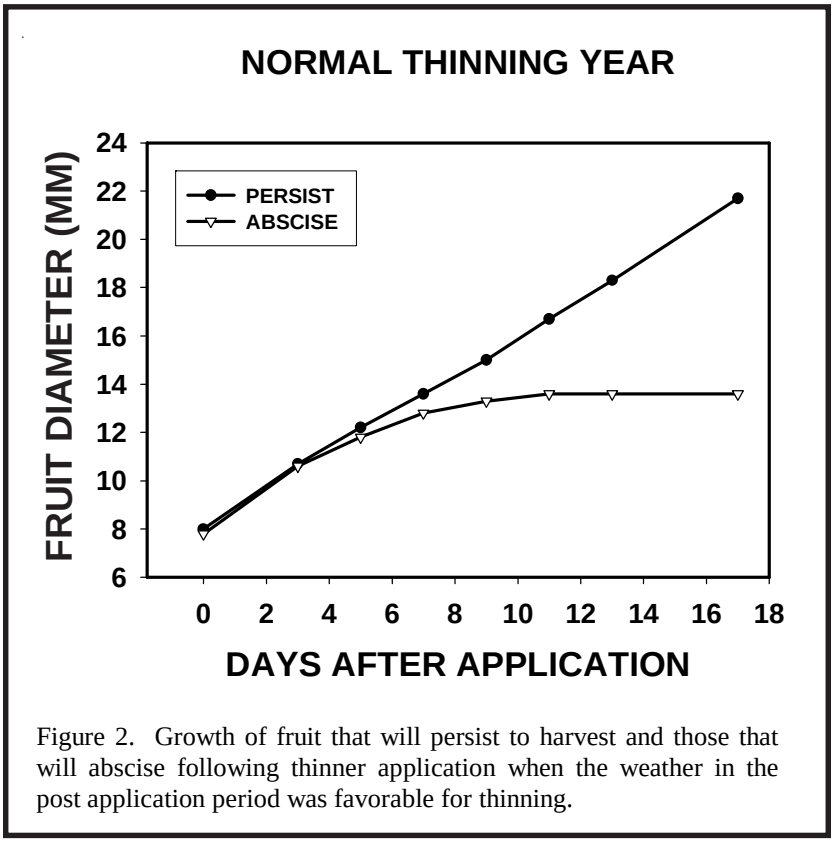

Figure 2. Growth of fruit that will persist to harvest and those that will abscise following thinner application when the weather in the post application period was favorable for thinning.

tree in each block was sprayed with 7 ppm NAA + 0.5 lb/100 gal carbaryl and another with 125 ppm MaxCel + 0.5 lb/100 gal using a commercial airblast sprayer and applied at tree row volume dilute. A third tree in each block served as an untreated control. All fruit were measured just prior to application and again at 2 to 3 day intervals.

Prediction of final set on trees treated with NAA + carbaryl and MaxCel + carbaryl are illustrated in Figure 6 and Figure 7, respectively. Final set was determined in July at the end of June drop. In general, the greater the time period after application the more accurate was the prediction of final set. The goal with this system is to make a prediction within 7 days of application so that it will be possible to apply a supplemental thinner while fruit are still susceptible to chemical thinners. At 7 days after application, the model predicted 26% set on trees treated with NAA + carbaryl and the actual set was 18%. Similarly, on trees treated with MaxCel + carbaryl set was predicted to be 13% and actual set was 10%.

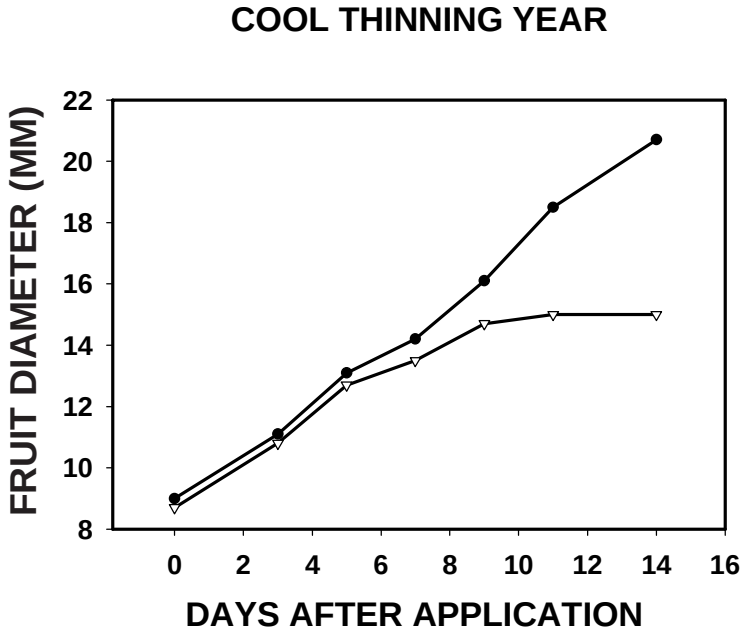

Figure 3. Growth of fruit that will persist to harvest and those that will abscise following thinner application when weather in the post application period was unfavorable for thinning.

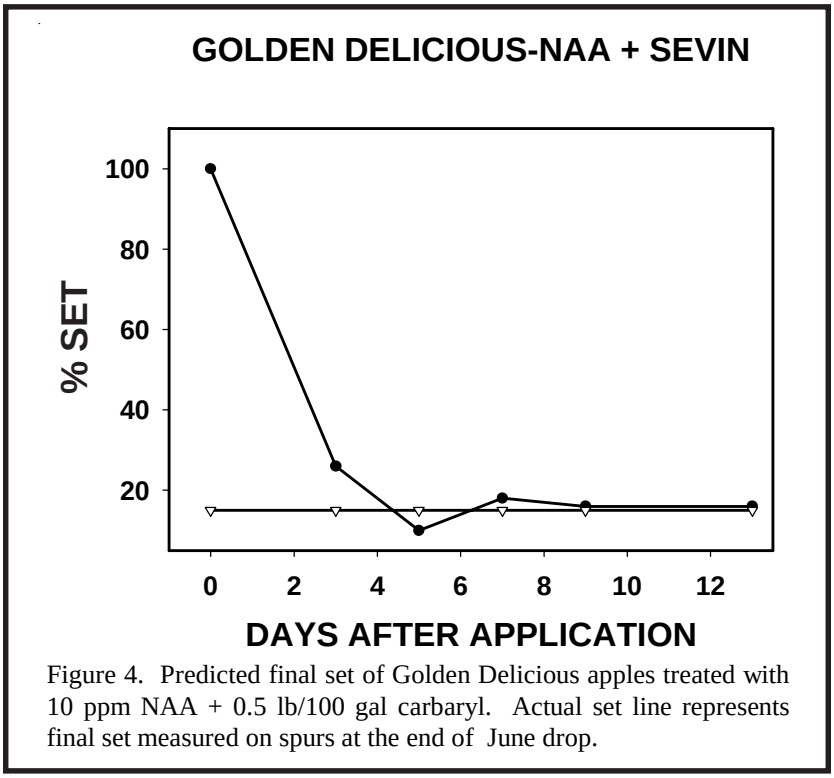

Figure 4. Predicted final set of Golden Delicious apples treated with 10 ppm NAA + 0.5 lb/100 gal carbaryl. Actual set line represents final set measured on spurs at the end of June drop.

Gala - New York. In a block of mature Gala/M.9, 4 blocks of 2 trees each were selected. Twenty spurs were selected and tagged and individual fruit marked and measured when fruit were about 11 mm in diameter. NAA at 7 ppm + carbaryl at 0.5 lb/100 gal was applied with an airblast sprayer at tree row volume dilute. Because of poor weather at bloom, initial set prior to thinner application was low (Figure 8). Weather conditions following application were conducive to good thinning so prediction of final set at 8 days after application is appropriate. Prediction made at his time was quite precise. This also showed that the poor weather before thinning had already caused many fruit to stop growing even before treatment. So in this case much of the final apparent "thinning" was actually induced by poor weather with only a relatively small additional thinning by the chemical thinner. Showing these effects is an-

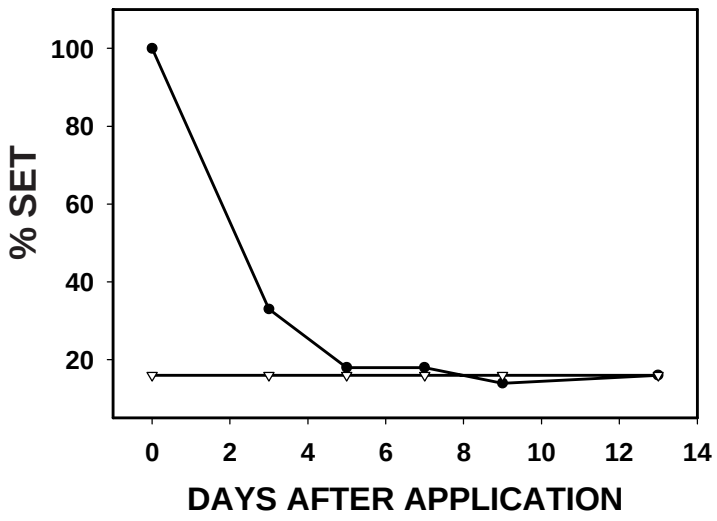

Figure 5. Predicted final set of Golden Delicious apples treated with 125 ppm MaxCel + 0.5lb/100 gal carbaryl. Actual set represents final set measured at the end of June drop.

other strength of this method.

What additional things need to be done to make this an effective, accurate, and grower-friendly system to predict thinner response?

1. Refine the selection of spurs to give an accurate representation of those on the tree. We are very close on spurs we monitor, but improved precision for the whole tree is needed.

2. Make the predictive system a user-friendly process. Currently, measurements are done at 2- to 3-day intervals starting at the time of application. A focus this coming year will be to make just two measurements: one about 4 days after application and a second at 7 to 9 days after application, depending on the temperature.

3. Develop a spreadsheet template into which to enter all information. We hope to build in as many automatic calculations as possible. Currently, calculations can be time consuming at a busy time.

4. Change the way we approach chemical thinning. This approach involves making an estimation of the number of fruit that you would like to have on a tree at harvest. Count bloom on a tree or tree unit. Calculate the number of fruit per spur that you need to get the ideal number of fruit that you would like to set. That calculated number is the one you will try to achieve in your percent set estimation.

5. Revive studies to improve thinning at the 12 mm to 15 mm stage. Supplemental thinning, if deemed necessary, will be done on fruit in this size range.

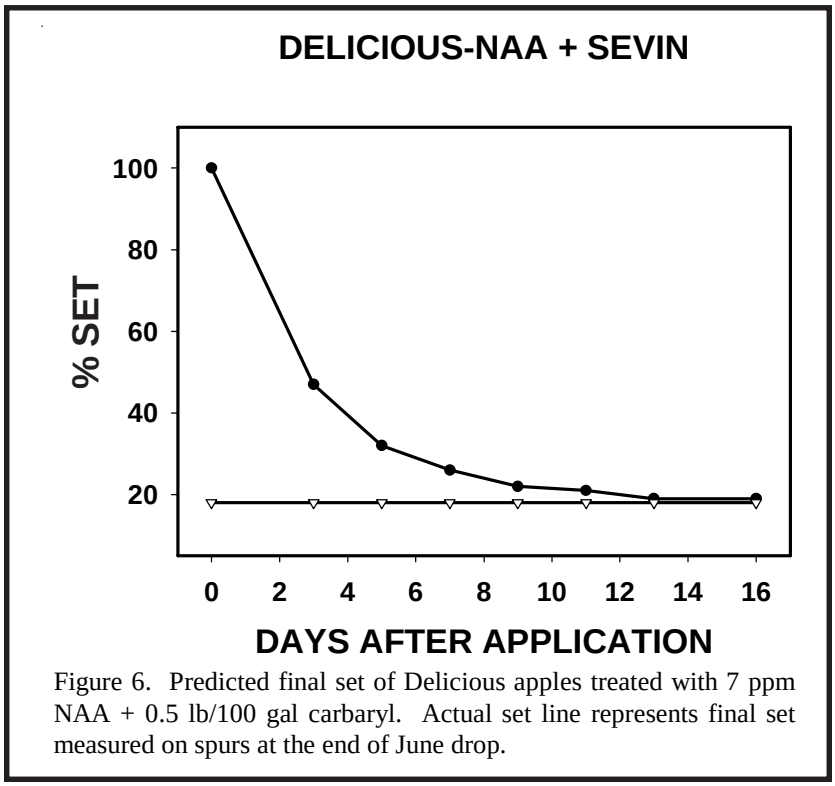

Figure 6. Predicted final set of Delicious apples treated with 7 ppm NAA + 0.5 lb/100 gal carbaryl. Actual set line represents final set measured on spurs at the end of June drop.

Acknowledgement

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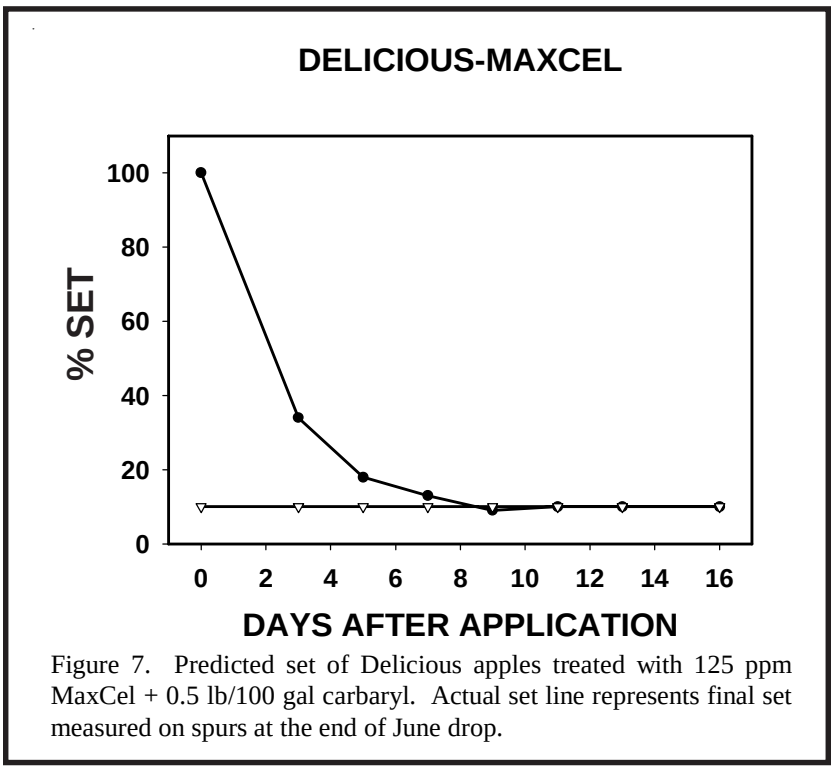

Figure 7. Predicted set of Delicious apples treated with 125 ppm MaxCel + 0.5 lb/100 gal carbaryl. Actual set line represents final set measured on spurs at the end of June drop.

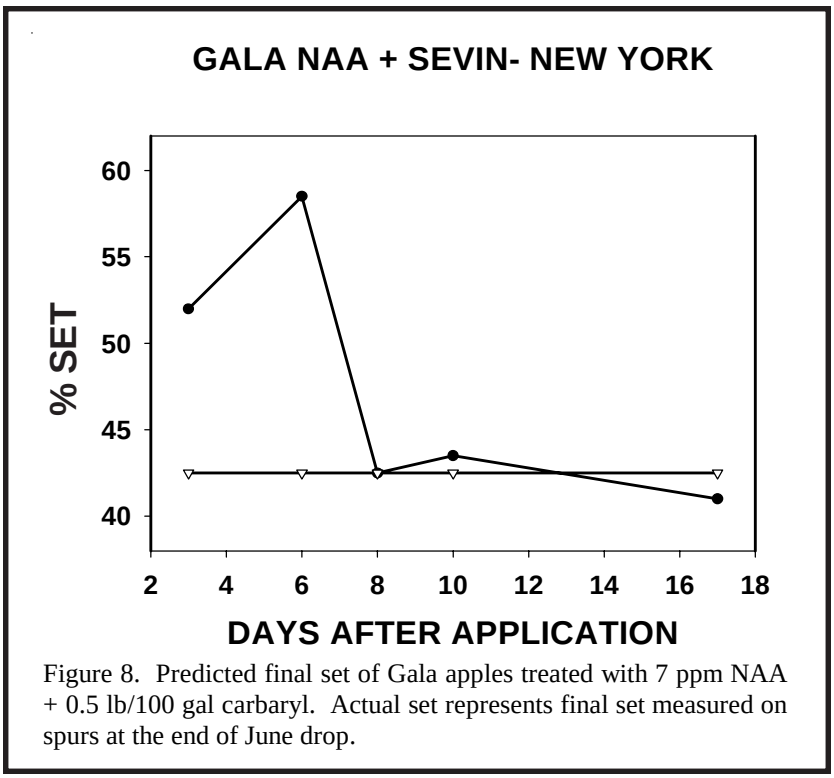

Figure 8. Predicted final set of Gala apples treated with 7 ppm NAA + 0.5 lb/100 gal carbaryl. Actual set represents final set measured on spurs at the end of June drop.

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