Precision Irrigation Management

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The ability to repeatedly produce high quality apples of the optimum economic size is critical to grower’s economic success. The two most important biological and management factors affecting fruit size are crop load and water stress. To repeatedly produce consistent crops of large fruit size requires precise control over crop load and tree water status. Irrigation is essential to preventing water stress in dry summers and small fruit size. The apple market expects growers to deliver large size apples (160-200 gram fruits). Growers attempt to achieve this fruit size by properly reducing crop load with chemical thinners in the spring but if the summer turns out to be dry they will still not achieve the desired fruit size and crop value will be severely compromised. To precisely manage fruit size requires precision in chemical thinning and precision in irrigation.

A second critical value of irrigation is to improve and maximize tree growth of newly planted or young apple trees. The economic success of high-density orchards depend on obtaining significant yields in the third, fourth and fifth years to repay the establishment costs. To obtain the expected high yields requires excellent tree growth during the first 3 years after planting. However, one of the biggest problems we see with new high-density orchards is inadequate tree growth during the first 3 years. Gerling (1981) has estimated that when poor tree growth in the early years delays the ability to repeatedly produce high quality apples of the optimum economic size is critical to grower’s economic success.

Irrigation is essential to producing large fruit size in dry summers. We have developed a new web-based irrigation model (Cornell Apple Irrigation Model) that uses weather data from the network of weather stations in NY, MA, VT, NY and Pa which allows growers to determine the quantity of irrigation water to apply to both young and mature apple orchards of various densities. This allows growers to more precisely manage soil moisture in the humid and often rainy climate of the eastern US for consistently achieving the optimum fruit size.

A third benefit of irrigation in the eastern US is to improve uptake of calcium and other nutrients from the soil. When the soil dries and the trees undergo water stress, uptake of many nutrients is limited since they must be in solution in the soil to be taken up by the plant. Work done at Geneva by Sergio Lopez and Terence Robinson showed that 2-week periods of poor water balance during different periods of the season resulted in more bitter pit with Honeycrisp. The most critical periods were in May during and after bloom and July. Precise management of irrigation could reduce bitter pit by ensuring a steady uptake of soil calcium.

As a result of these 3 significant benefits of trickle irrigation (improved fruit size, better tree growth and yield of young trees and improved bitter pit control) many apple growers in the humid eastern growing areas who plant high-density orchards are increasingly adding trickle irrigation as an important ingredient to ensure the success of the new planting. However with both mature trees and young non-bearing trees the amount of irrigation needed by apple orchards is difficult to estimate and often is estimated imprecisely by experience or “feel” or by using imprecise “rules of thumb” or models using crop coefficients.

Cornell Apple Irrigation Model

In 2006, Alan Lakso and his graduate student Danilo Dragoni (Dragoni and Lakso, 2010) developed an improved mathematical model to calculate water use by apples trees. The model is based on the famous Pennman-Monteith model, which calculates water use by a field of grass using weather variables. The new Cornell apple evapotranspiration model more accurately estimates apple orchard water use from a discontinuous orchard canopy than using the Pennman-Monteith model with corrections for orchards (crop coefficients Kc).

In 2011 and 2012 we developed a web-based tool to use the output of the ET model to estimate for both young, medium aged and old apple orchards the amount of water needed each day or week. This web-based tool has been placed on the NEWA website and allows growers and consultants to daily or weekly access the model to estimate orchard irrigation requirements using local (on-farm NEWA) weather stations or regional weather stations (airports) to determine water needs.

The website allows users to select a weather station close to their farm and then enter information on the spacing and age of the orchard (Figure 1). The model will then calculate and display the amount of water needed for that orchard for each of the last 7 days and for the upcoming 6 days based on the weather over the last 7 days (from the weather station data) and from forecasted weather data expected over the upcoming 7 days (Figure 1). The
calculated water volume needed by the orchard is displayed in gallons/acre. If the number is negative the grower should add that amount of water to his orchard. If the number is positive it means that rainfall exceeded transpiration and more water is available than needed and no more water should be added. The website also allows a user to enter his own recorded rainfall since rainfall varies considerably within short distances and the weather station data may not represent the actual rainfall at the farm.

The Cornell ET model has the feature that rainfall is considered and subtracted from the water requirement of the trees. It also considers the effective rooting area of different age orchards to include only the portion of the rainfall that is available to the trees in the calculations of tree water requirement.

**Precision Irrigation Management**

This new model and website will allow more precise management of tree water status in both wet and dry year than previously possible. Precisely managing soil water supply will require:

1. The grower or his consultant to weekly log onto the NEWA website (http://www.newa.cornell.edu) and determine the daily water requirement for his specific orchard (spacing and age) for the previous week and the upcoming week.
2. Irrigate the orchard to fully replace the estimated water requirement of the particular orchard via trickle irrigation.
3. To avoid oversaturating the soil when irrigation water is applied just before a large rainfall event or just after a large rainfall event we suggest not applying the suggested irrigation amount for 1 day before a predicted large rainfall event (0.5 inches or more) or for 3 days after a large rainfall event (Figure 2).
4. The frequency of adding the required water depends on soil type. With sandy soils water should be added either daily or every 2 days. With silt or clay soils the daily amount of water needed can be summed up for several days and then added in one irrigation cycle.
5. In the early part of the season (early May to mid-June), we suggest that water be supplied once per week for both sandy and clay soils.
6. From mid-June until the end of August we suggest that water be supplied twice per week in clay soils and every other day with sandy soils.

**Results from 2012**

In 2012 we used the model to calculate transpiration and water balance for a mature and a newly planted tall spindle orchard in Western NY. The daily water requirement showed that in the early season transpiration was about 1,000 gallons per acre and progressed to about 4,000-5,000 gallons/acre in mid-summer (Figure 3). A newly planted tall spindle orchard required much less water (never exceeding 500 gallons/day) due to smaller trees with a fraction of the leaf area of mature trees. Daily effective rainfall was quite variable but in general 2012 was a dry year with infrequent rains that exceeded ¼ inch (7,000 gallons/day) (Figure 4). The effective rainfall for a newly planted trees was usually less than 1,000 gallons/day.

The difference between tree water requirement and rainfall is the water balance with a negative number indicating the need for irrigation and a positive number indicating too much water. In 2012 there were only about 20 days when water supply exceeded water requirement and more than 100 days where water supply was less than the need (Figure 5).

Accumulating the water balance values from bud break gives cumulative water supply and water demand. In 2012 the cumulative graph showed that water supply from rainfall was sufficient to meet water requirement by the tree until June 10 after which
water needs of the tree far exceeded rainfall (Figure 6). With newly planted trees the cumulative water requirement exceeded supply from rain earlier (27 May) indicating the need to irrigate young trees earlier. From these data we see the significant need for irrigation in 2012. It also illustrates the need to regularly add water and precisely manage soil moisture. If growers delay adding trickle irrigation it becomes very difficult to “catch up” when the cumulative water deficit become large.

Summary

Irrigation is essential to maximize fruit size at any given crop load. Water stress at any time of the season reduces fruit growth rate with a permanent loss in fruit size, which is difficult to recover later. Water stress also limits uptake of calcium into the fruit and can result in more bitter pit. With more precise water management growers will be able to limit plant water stress and more consistently achieve the optimum economic fruit size and calcium content for each variety. The new Cornell Apple Irrigation Model will allow growers to more precisely manage soil moisture in the humid and often rainy climate of the eastern US. In the future with automated electronic irrigation controls growers could precisely add the needed water each day based on the forecast for that day.

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