Drip Irrigation for Tree Fruit Orchards in Pennsylvania

Irrigation is the application of controlled amounts of water to plants at needed intervals.

Drip irrigation in orchard. Photo: Long He, Penn State

Irrigation helps grow agricultural crops, maintain landscapes, and revegetate disturbed soils in dry areas and during periods of inadequate rainfall. Precipitation in Pennsylvania averages about 37 inches each year. About 13 inches of this precipitation runs off the land into streams, while 24 inches infiltrates into the soil, where it can be used by crops. While uneven precipitation can cause plant stress during critical growth periods, which will affect both crop productivity and produce quality, most horticultural crops require supplemental irrigation to minimize plant stress. Proper timing of water applications during appropriate periods can increase the yield and quality of most horticultural crops in Pennsylvania in most years. Critical periods for the irrigation of apples are during flower formation, early fruit set, and during final fruit swell (Penn State Extension, 2017: Irrigation for fruit and vegetable production).

Figure 1. Tall spindle apple orchard in PA with drip irrigation. Photo: Long He, Penn State

For high-density apple orchards, water relations are even more important. Irrigation is essential for ensuring optimum growth of newly planted and young apple orchards and also to obtain the desired fruit size. For high-density orchards, the economic success really depends 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 three years after planting. However, one of the biggest problems we see with new high-density orchards is inadequate tree growth during the first three years. It is estimated that when poor tree growth in the early years delays cropping of a new orchard, peak investment is delayed by 20% and the total profits are reduced by 66% over the 20-year life of the orchard (Robinson et al., 2013: Precision irrigation management in apples). Much of the problem of poor tree growth can be traced to inadequate water supply during the first three years. Therefore, it is very important to have a precision irrigation system for high-density apple orchards.

Irrigation Systems for Tree Fruit Orchards

Typically, there are three major irrigation systems in tree fruit orchards, namely, drip irrigation, under tree sprinkler, and overhead sprinkler. In humid climate regions, drip irrigation is primarily used. Therefore, in our project, we used a drip irrigation system for the test apple orchard.

Figure 2. Methods of irrigating tree fruit orchards. (Left) Drip irrigation; (Middle) Under tree sprinkler; and (Right) Overhead sprinkler. Photo: Long He, Penn State

Drip irrigation system

Drip irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of the plants, either above the soil surface or buried below the surface. Drip is the most efficient way to irrigate. It is usually about 90% efficient compared to about 70% for sprinkler and often 50% for surface irrigation. Besides the high water use efficiency (90%-95%), drip irrigation also reduces the risk of plant diseases that thrive in wet conditions. A typical drip irrigation system includes a water source (e.g., well water, river water), pump, a pressure regulating system, valves, pipeline, emitters, and other accessories. Figure 3 illustrates a simplified drip irrigation schematic diagram. Drip irrigation is suitable to all soil types because of its extremely slow application rate and the high degree of control over timing and amounts (Peters, 2015: Drip irrigation for agricultural producers).

For the details of drip system components, installation and operation, growers can refer to the Drip Irrigation Handbook.

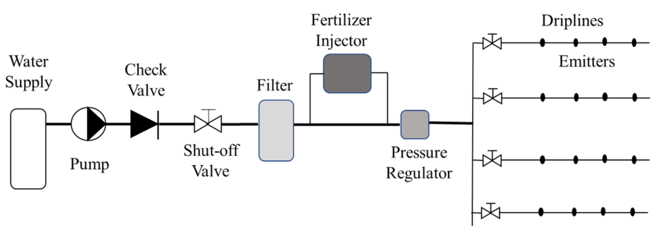

Figure 3. A simplified drip irrigation system schematic diagram

Irrigation application rate calculation

As described in Peters, 2015 (Drip irrigation for agricultural producers), water movement capability varies in different soil types, e.g., sandy soil (1-1.5 ft radius); loam soil (1.5-2.5 ft radius); and clay soil (2.5-3.5 ft radius). These are important for setting the lateral distance between the emitters. Meanwhile, a smaller root zone is more sensitive to water and nutrient stress because crop roots have no motivation to and will not grow into dry soil. Therefore, a larger root zone can be encouraged by running the drip system for longer amounts of time. In order to calculate the application rate of the drip irrigation system, the emitter flow rate, the emitter spacing among the tubing, and the distance between drip lines must be known. The calculation equation is as follows:

$$ApRt = 231.1\frac{EmitterFlow}{RowSpc \times EmitterSpc}$$

Where: ApRt is the application rate in inches per hour, EmitterFlow is the emitter flow rate in gallons per hour, RowSpc is the spacing between rows in inches, and EmitterSpc is the spacing between emitters in inches.

Irrigation Scheduling Strategies

Conventional irrigation

Conventionally, irrigation is applied based on grower experience/ simple observations, or by scheduling a regular time for irrigation, for example, irrigation every day or certain days of the week for certain durations at each time. This may lead to the waste of over-irrigation or the ineffectiveness of under-irrigation. The improper water supply for the crops also may cause nutrient leaking or insufficient nutrient uptake. When correctly employed, appropriate irrigation scheduling methods may reduce water usage and increase profitability and sustainability. Therefore, sensor-based irrigation is essential for precise irrigation in terms of saving water and obtaining maximum production.

ET-based irrigation

Weather-based irrigation is also called evapotranspiration (ET)-based irrigation. The ET rate equals the total loss of water by evaporation from the soil surface, plus the transpiration from plants, over a given area in 24 hours, in inches per day. With ET-based irrigation, the application rate of an irrigation system would be the total ET rate subtracted from the precipitation rate. ET-based irrigation requires a complete set of weather parameters from a nearby weather station to calculate the ET rate. The ET rate can be calculated using the Penman-Monteith equation. Of course, crop itself and planting situation are also effects for calculating ET. The ET is an estimated value which may not be very accurate, and also modeling irrigation needs from ET data can be a challenge for an inexperienced grower.

Plant-based irrigation

Canopy temperature has been shown to be an indicator of plant water stress. Plant-based thermal optimum approaches scheduling irrigation based on plant infrared thermal response to water status. Crop water stress index (CWSI) can be used to indicate the status of the crop. The index is based on the difference between canopy temperature and air temperature normalized for the vapor pressure deficit of the air. The index can be used to determine when to irrigate based on the stress level of the plant. Meanwhile, the climate data will also be taken into consideration.

Soil moisture-based irrigation

Soil moisture measurements acquired in the field adjacent to the crops being irrigated are one of the best and simplest ways to support water management decisions. Soil water content and soil water potential are two indicators of plant-available water used by soil-based irrigation systems. There is a wide range of measuring instruments for measuring soil moisture, including neutron probes, time-domain reflectometry/transmissivity (TDR) sensors, capacitance sensors, tensiometers, and granular matrix sensors. These devices range from inexpensive gypsum blocks to costly TDR sensors. Variable soil texture and structure, as well as the difficulty of accurately locating the root zone, are two challenges for soil moisture-based irrigation technology. Despite these difficulties, soil sensors report conditions directly from the field and can be polled locally or remotely to control irrigation.

In the 2018 growing season, we conducted irrigation research in a Fuji apple research block at the Fruit Research and Extension Center with using different sensors. The detailed results will be presented in the March 2019 issue of the Fruit Times newsletter.

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Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Code: ART-5703