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Uses Of Water In Florida Crop Production Systems[1]

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Water has many important and beneficial uses in Florida agricultural crop production systems. The most obvious beneficial use of water is that applied for crop evapotranspiration requirements. However, water required for crop cooling, cold protection, irrigation system maintenance, crop fertigation and chemigation, salt leaching, water table management, crop establishment, field preparation, soil/dust erosion control, and other uses provide benefits that may be essential for crop production. When natural rainfall is insufficient, water is supplemented from either surface or groundwater sources to meet agricultural demands. While this list may not be complete, these uses should be considered when determining the water use requirements of agricultural production systems.

This publication introduces and describes each of the aforementioned water uses for Florida production systems. However, individual requirements will vary with crop type, cultural practices, and site conditions. Other publications are planned to provide greater detail on these topics for the major Florida crop/commodity groups. This information is required by irrigation and crop production system managers and designers, and by water management district personnel so that crop water needs can be confidently and sufficiently estimated.

IRRIGATION EFFICIENCIES

In water management, the term efficiency generally relates to the fraction of the resource that is diverted or used from a given source (surface or groundwater) that is beneficially used. Diverted water which is unused or recovered after irrigation and returns to the source can alter the efficiency of the system. Thus, when the term efficiency is used it is necessary to provide a clear understanding of the type of water use, the sources, and system characteristics.

Application Efficiencies (Ea)

Irrigation application efficiency is generally defined as the ratio of water stored within the root zone of the crop, and thus available for use by the crop, to the amount delivered by the irrigation system. Values of irrigation application efficiency are generally reported for properly designed and

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well-managed systems irrigating mature crops under average irrigation conditions.

Irrigation system application efficiencies must be known so that the systems can be properly designed and managed. The Ea must also be known by water managers to estimate the gross irrigation requirements necessary to meet the crop evapotranspiration (ET) requirements. This definition does not include other beneficial uses of water.

Water Use Efficiencies (Eu)

Water use efficiency may be defined as: (1) the water use per unit of crop yield produced, or (2) the ratio of the amount of water which was beneficially used for crop production to the amount diverted from the water source. These terms are described in greater detail in Florida Cooperative Extension Service Bulletin 247.

The first definition is typically used when making economic or yield comparisons as functions of water use or irrigation system type. For water management purposes, the second definition is often more meaningful. Minimizing the waste of water can be achieved by maintaining high values of Eu. This definition, however, requires that all beneficial uses of water be identified and defined for each crop production system.

Comparing Ea and Eu

Irrigation application efficiencies can only be high if the water applied can be stored in the soil and available for crop use. Thus, Ea is reduced when irrigation amounts which exceed the soil water-holding capacity are applied or when irrigations occur on a soil which is at or near field capacity. Sometimes irrigations must be performed with wet soil conditions for the benefit of the production system. Examples include irrigation applications for freeze protection, leaching or salinity control, and crop cooling. These applications normally occur when the soil is already wet.

Because irrigation for other beneficial purposes may be necessary when the soil is already wet, Ea may be low while Eu remains high. Examples include: 1) fertilizer applications that must be made through an irrigation system; 2) irrigation system maintenance applications (especially chlorination or other chemical applications) that are a periodic requirement; 3) and other similar irrigation applications which are made for purposes other than meeting the ET requirements of the crop.

In the following sections of this paper, various uses of water in Florida crop production systems are described. Because these uses are beneficial for crop production, the associated water use efficiency remains high when water is applied for these purposes. All of the uses described are not appropriate for all Florida crop production systems. Likewise, the amounts of water required for each purpose may vary widely, or some uses may not be appropriate for all production systems.

USES OF WATER

Evapotranspiration (ET)

Climatic factors including solar radiation, air temperature, relative humidity, and wind levels create conditions which result in water movement from crops, water surfaces, and soil surfaces. This movement or transfer of water from the liquid to vapor form is called evapotranspiration (ET) and is required for crop cooling, growth, and development. Crop ET is discussed in detail in Florida Cooperative Extension Service Bulletin 840 and Circular 822. Agricultural systems such as orchard and field crop operations, container and greenhouse grown plant operations, and ponds for crop, livestock, and aquacultural operations all require irrigation for water supplements when rainfall amounts are not sufficient to meet ET demands.

Crop water deficits created by the evapotranspiration demand can induce a stress on plants and reduce growth and development and may in turn affect the yield and quality of the crop. Supplemental irrigations are scheduled to eliminate or reduce the level of stress on the crop. Florida Cooperative Extension Service Circulars 431, 487 and 872, and Bulletins 208, 245, 249 and 254 discuss irrigation scheduling methods and practices for crop production in Florida. Many types of irrigation systems exist for use in crop production and are discussed in Florida Cooperative Extension Service Circulars 533, 808 and 821.

Ponds are used to provide a water source for crop irrigation, livestock drinking and washing needs, and are used in aquacultural production systems. Ponds are also used as settling basins to remove suspended materials from a water supply system (Florida Cooperative Extension Service Fact Sheet AE 65). They can act as a primary filter for certain water sources used with microirrigation systems. Because ponds are typically exposed areas of water, they are subjected to the same environmental conditions as a crop and consequently water evaporates in response to the environmental demand. These losses will vary with the size of the pond and may not be very large but must be accounted for in the water budgeting process.

Crop Cooling

Sometimes the plant cannot provide water at rates sufficient to meet the ET demand, even though soil or growth media water levels are satisfactory. When this occurs, plants are stressed and start to lose turgor, wilt, and growth is reduced.

This inability to meet the water demand may be due to an insufficient root system compared to the leaf area or due to internal plant or leaf water transport capacities. Small or insufficient root systems compared to leaf area are common on young plants or plant propagation cuttings. Different plant varieties have different water transport resistances. Under similar conditions some plants can transport water to the leaves at rates sufficient to meet the demands while other plants must overcome greater internal resistances resulting in less than sufficient rates. Overhead irrigation can cool the crop and reduce stress levels by providing water to the leaf surfaces which may evaporate and thus satisfy the evapotranspiration demand.

Another need for crop cooling exists when warmer than normal temperatures are experienced during winter and early spring months of the year. These conditions may initiate early flowering. Subsequent frost or freeze conditions could damage the flowers or young fruit. Therefore, cooling irrigations are used to maintain plant temperatures at lower levels, thus inhibiting early flower development.

Cold Protection

While the environment can become too hot for some plants, it can also become too cold for others. Irrigation for frost and freeze protection is common in Florida. Excessively low temperatures may damage the entire plant, leaves, flowers or fruit of certain plant varieties. Water can be applied to the crop in the form of overhead irrigation to provide heat to the crop and to maintain the crop at non-damaging temperature levels.

Because the irrigation water is warmer than the air, some heat is provided by the temperature of the water, on the order of 1 calorie per gram of water per degree C of temperature difference. However, the majority of the heat is provided when the water freezes, releasing 80 calories of energy per gram of water. If water is not provided at rates sufficient to balance the heat losses of the crop, excessive damage can occur from the evaporation of water from the plant surface. This process can consume 596 calories of energy per gram of water evaporated. Thus, under certain conditions, inadequate irrigation levels for frost/freeze protection can be more damaging than no irrigation at all.

More information on cold protection can be obtained from Florida Cooperative Extension Service Circular 348 and Fact Sheets FC 24, FC 69, FC 75 and FC 76.

Maintenance

All working systems require some type of periodic maintenance for proper and continued operation. Irrigation systems are no exception and must be properly maintained to ensure that they will operate as designed and when needed. Improper operation can result in non-uniform water and fertilizer distribution as well as insufficient or excessive application amounts of these inputs in attempts to meet the needs of the crop.

The level and type of maintenance will vary with the system. For example, the maintenance associated with the flood type of systems may be quite minimal, such as a pre-season system operational check and leak detection. However, the more efficient microirrigation systems generally require higher maintenance levels. Typical maintenance activities may include:

- Initial and periodic flushing of the irrigation system to remove settled and accumulated debris,
- Pre-season system operation checks,
- Regular chemical treatment and water amendment,
- Periodic leak detection, and
- Back-flushing of the filtration system.

Some of these activities can occur during normal irrigation cycles, but some may require a special irrigation activity to perform the intended maintenance task. For example, consider a microirrigation system that has been operated for a certain period of time and its next irrigation cycle is to be used for a chlorination treatment. Rainfall delays the need to irrigate. However, bacterial organisms within the irrigation system will continue to grow and clog the system unless treated. Thus, a maintenance irrigation cycle may become necessary.

Fertigation

Fertigation and other chemigation activities involve the application of chemicals (fertilizer or other) into the irrigation system and use the irrigation system to convey the chemical to the crop. Because microirrigation systems can place water with high levels of uniformity in the crop root zone, they are particularly adapted to chemigation.

Fertigation can be used to provide nutrients to the crop as needed. This can improve the overall fertilizer application efficiency and reduce the amount of nutrients leached out of the crops root zone. However, situations may arise which would reduce the apparent application efficiency of the irrigation system. For example, a fertigation cycle may be necessary during a period when rainfall provides sufficient water to meet the evapotranspiration requirements of the crop. Thus, the irrigation system is operated solely to transport nutrients to the crop.

The time required for the fertilizer (or chemical) to travel from the injection point to the most distant part of the hydraulic network (which includes, mains, submains, lateral and drip tubes) must be considered for any chemigation event. Flow velocities within the pipes directly affect the travel time. Properly designed irrigation systems use a maximum flow velocity of five feet per second to avoid surge pressures (water hammer - see Florida Cooperative Extension Service Circular 828) within the system. In actuality, flow velocities may vary from 6 feet per second to less than 2 feet per second, and maximum travel distances may exceed 2000 feet of pipe, even in well designed systems. The travel time along this length could range from 5 to 15 minutes or more. In addition, injection periods may last from 30 to an excess of 60 minutes. Therefore, the total irrigation time for a fertigation cycle would include initial system pressurization, plus chemical travel time to the most distant part of the field, plus chemical injection time, plus the travel time again to flush the chemical from the lines. This irrigation time may exceed the required operation time to meet only the evapotranspiration requirements of the crop.

Leaching Requirement

Some plants have greater salt tolerances than others and may not be affected by increased soil salinity levels. However, excessive soil salinity levels can reduce plant growth and development on plant varieties with lower tolerance levels. Soil salinity levels can increase from residual fertilizer salts or from irrigating with saline water. As the plants take water out of the soil for evapotranspiration, salts remain in the soil. Without rainfall or excessive irrigation, soil salinity levels will increase with time to toxic levels. Therefore, periodic leaching irrigations may require scheduling to over-irrigate and move the excess salts out of the root zone of the crop. These irrigations supply water in excess of the root zone water holding capacity, resulting in a downward flow of saline water. However, this is a beneficial use of water for the crop production system.

Water Table Management

Some agricultural fields, greenhouse operations, and aquacultural operations may require that high water tables be maintained for crop, cultural, or environmental conditions. These water uses may be necessary and very effective for these types of agricultural operations.

Agricultural fields with naturally high water tables may not require much additional water to increase and maintain the water table level for crop production. The water table may be managed at some distance below the soil surface or for a certain depth over the soil or production surface. Water table management may be used for field preparation, crop establishment, weed control, nematode control, crop water requirements, or subsidence or soil oxidation control in the case of muck soils.

Greenhouse and other intensely managed vegetable and ornamental operations may use water table management or even hydroponics for irrigation in highly controlled settings. Some containerized plant operations use growing or production bays with impermeable floors or benches. Water is ponded in the production bays, and after sufficient water rises into the containers for irrigation, the areas are drained. Additional areas are flooded using the recycled drainage water. After the last bay is flooded, the water is recirculated back to the source and treated for re-use.

Florida has several aquacultural operations ranging from production of fish (catfish, tilapia, etc.) or crustaceans (crayfish and prawns) for consumption, to tropical fish for aquariums. Many of these industries use outside ponds for their production areas. Sometimes the natural water supplies of rainfall, surface runoff, or naturally high groundwater levels are not sufficient to maintain the ponds at the proper management levels. Supplemental water is then required to augment the ponds for proper management and operation. Florida Cooperative Extension Service Bulletin 257 discusses the use of farm ponds in Florida agricultural production systems.

Crop Establishment

Water is applied for crop establishment to germinate seeds or to minimize stress levels on young plants. This application is basically used for crop cooling as discussed in a previous section. However, this use is only in the early stages of plant growth to allow the plants to develop a well established root system for future growth and development. For example, strawberries which are set as bare-rooted transplants, commonly use overhead irrigation to cool the transplants for the first 10 to 14 days in the field until a root system is established. This may require daily irrigation events of 8 to 10 hours each. Similarly, many ornamental plants are derived from cuttings from stock plants. The cuttings are placed in a growth media and are misted with water several times per day until a root system is established.

Other plant establishment requirements exist with young plants or transplants after initial placement in the fields. These young plants already have a root system, but one which is generally restricted in size from the container within which it was grown. Excess water is sometimes necessary to minimize the initial shock of transplanting until the root system expands sufficiently for normal crop support.

Field Preparation

Many of Florida's agricultural production systems require moist soil or growth media conditions for field preparation operations. These operations include soil bed formation, fumigation, and soil or growth media capillary establishment.

Field operations which use bedded cultures require that the soil moisture be sufficient to maintain the pressed or formed bed shape. If natural rainfall has not been sufficient, supplemental water is required. In addition, some soil fumigants require maintenance of certain soil moisture conditions, and systemic herbicides and pesticides may require supplemental irrigation for maximum effectiveness of the applied chemical.

Sandy soils and other growth media with relatively large particle interstices or capillaries, require initial uniform wetting and establishment prior to operation of the drip system. This initial wetting 'primes' the capillaries with water allowing improved operation of the drip systems and other capillary distribution irrigation systems. Without this initial 'priming', water distribution could be very poor, resulting in potentially low application efficiencies, low application uniformities, and potential reduction in plant growth and development.

Soil Erosion and Abrasion Control

Dry soil conditions can present problems with wind erosion. Under windy conditions, dry, loose soil particles can become dislodged and airborne. This had been a serious problem in other parts of the country prior to implementing erosion control conservation practices, such as wind breaks and cover crops. Many microirrigated fields result in dry row middles and other non-cropped areas of the field. Similarly, fields between crop cycles may have bare, non-cropped soil conditions which become susceptible to drying and potential erosion.

Airborne soil particles, particularly sands, can also become abrasive to plants and fruit. These abrasions may provide an entrance on the surface of the plant tissue for plant pathogens or they may simply scar the surface of the fruit. Either situation can result in lower quality plants and fruit.

Drought tolerant cover crops may assist in preventing erosive conditions by taking advantage of natural rainfall. However, sometimes these crops may need initial irrigation water for germination or a periodic irrigation during periods of very low or infrequent rainfall.

Other Beneficial Uses

Other beneficial uses of water include overhead irrigation for crop washing, water applications to unpaved road areas to improve field traction conditions, and water for crop chemical sprayers. The amounts of water usually associated with these applications are generally small, but are still necessary, reasonable, and beneficial. In addition, uses such as crop washing or chemical applications may reduce the amount of water consumed from the growth media for evapotranspiration.

SUMMARY

Uses of water in agricultural production systems were listed and discussed. A common misunderstanding is to consider crop evapotranspiration as the only required or beneficial use of water in agricultural production. Many other uses are necessary, reasonable, and beneficial for crop production, but are often neglected as part of the water budget for the cropping system. As allocations of water resources become more restrictive, the need to identify and quantify each of the appropriate uses increases in importance. An under estimation of the true water requirements of the production system, could result in reduced production, economic losses, or regulatory consequences associated with pumpage in excess of permitted quantities.

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