

Automation aids efficient irrigation

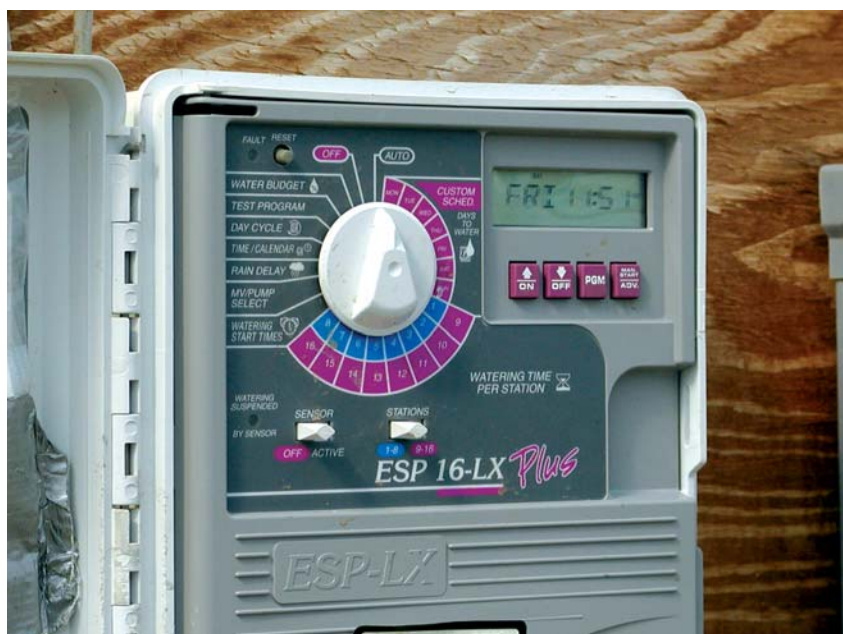
The purpose of automating the irrigation system is to water more efficiently so that the plant receives just what it requires at a particular growing stage. But what should you measure to assess the plant's needs? Most methods have advantages and disadvantages.

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How do you decide when to water and how much water do you need to apply? There really is no good quantitative information on how much water plants need. One reason for this is that water has long been a relatively cheap and plentiful resource. However, that is rapidly changing. Population growth and increased urbanisation has increased the demand for limited water supplies. Environmental regulations are becoming stricter thus, the pressure on greenhouse growers to use water more efficiently will increase, for both economical and environmental reasons. Based on research we have done in the last year, plants need less water than you would expect. However, plant water needs are not constant and as you may expect, increase as the plant grows. That raises the question of how automated irrigation systems can adjust the irrigation amounts based on actual plant water needs.



Temperature and humidity sensors should be in an enclosure to keep them in the shade. This container has a fan and filter, both of which should be checked regularly, to provide adequate air flow past the sensors.



Irrigation timers are the simplest way to automatically turn irrigation on and off. Unfortunately they cannot automatically adjust the watering schedule to meet the changing needs of the plant.

How to automate

The most common way to automatically turn irrigation on and off is through the use of a timer. However, timers are unable to adjust watering based on changing water needs of the plants or as weather conditions change. An experienced grower can look at the plants to determine if they need water, but this approach is not practical for automation. There are different ways to automate irrigation based on crop water needs, and each method has benefits and drawbacks.

Measuring environmental conditions

The amount of water used by plants depends on a variety of environmental conditions, such as light, temperature, air movement, and relative humidity (which is closely related to the vapor pressure deficit or VPD). By measuring one or more of these parameters, you may be able to estimate the amount of water used by plants and irrigate accordingly. Computer models that estimate water use can be incorporated into the software for your greenhouse environmental control, and the greenhouse computer can control your irrigation.

Irrigation

One approach is to control irrigation based on VPD. The simplest way to do this is to measure the relative humidity and air temperature in the greenhouse. From these two measurements, the computer can calculate how much water vapour is actually present in the air as well as how much water would be present at 100% humidity. The amount of water vapor in the air at 100% humidity minus the actual amount of water vapour is the VPD. The larger the VPD, the more water plants will transpire, and VPD can thus be used to predict water needs.

To make these predictions more accurate, you can measure the temperature of the leaves. That would allow the computer to calculate the amount of water vapour inside the leaf. Transpiration depends on the difference between the amount of water vapour in the leaf and the amount of water vapor in the air. In many cases it is not practical to measure real leaves, and the temperature of an 'artificial leaf' is measured instead.

Directly measuring water needs

It is also possible to measure water needs directly. This can be done in different ways. The first decision to make is what to measure: the water status of the plant or the substrate? Measuring the water status of the plant has the advantage that you may be able to directly determine if your plants are suffering from drought stress. The drawback, though, is that plant water status changes gradually throughout the day, even if the plants are not too dry. This can make it difficult to distinguish between regular, diurnal changes and changes induced by drought. The other option is to measure the substrate water status. Instead of trying to determine whether plants are suffering from drought, this determines if there is enough water in the substrate for the plants. If there is too little water in the substrate, the irrigation is turned on.

Measuring the plants

As plants transpire, leaves are cooled. Because of this, the leaf temperature of well-watered plants is normally slightly below the temperature of the air, while the leaf temperature of drought-stressed plants is above that of the air. Thus, the difference between leaf and air temperature may indicate plant water status.

Leaf temperature can be measured in different ways using leaf temperature sensors or with infra-red thermometers. Because infra-red sensors are not attached to the plants, measurements are made via 'remote sensing'. Infra-red sensors are readily available and can easily be connected to many greenhouse control systems.



A tensiometer can measure the water tension in the substrate. If this drops below a certain point the watering system can be turned on automatically.

Other remote sensing options under development are determining movement of the leaves and measuring specific wavelengths of light reflected by leaves. When plants dry out, leaves eventually wilt. By using remote sensing, it is possible to measure slight changes in leaf angles, and wilting can be determined well before the human eye can see it. Measuring the light reflected by leaves also can be used to determine drought at early stages. By measuring small changes in different wavelengths of infra-red radiation reflected by leaves, it is possible to determine impending drought stress. This approach works in laboratory applications, and may be ready for 'real-world' applications in the near future. Remote sensing techniques have the advantage that it is possible to measure many plants at once, and the readings can be averaged. That way, irrigation decisions are not based on measurements of one or a few plants, which may or may not be representative of the whole crop. A difficulty that many remote sensing techniques still struggle with is to distinguish between the plants and everything else in the picture. Because of this, remote sensing techniques are easier for crops with large canopies, such as greenhouse vegetables.

Measuring the substrate

Since irrigation and plant water use both directly affect the amount of water in the substrate, substrate water level is a logical measurement for use in irrigation control. There are two substrate parameters that can be measured, the water tension and the water content. Substrate tension, or water potential, determines how tightly water is held by the substrate. As a substrate dries out, the remaining water is held more and more tightly, until plants can no longer take it up. So as the water tension in the substrate approaches the minimum tension for plant use, irrigation is necessary. Water ten-



In future it may be possible to have chips embedded in a container to measure water content, EC and pH. The chips could alert a computer when action is required.

sion can be measured with tensiometers, which have been around for a long time. However, tensiometers have been difficult to use in soilless substrates, because of the required maintenance and the need for very close contact of the sensor with the substrate. With traditional tensiometers, any disturbance could break the contact between the sensor and the substrate, resulting in bad readings. Recent improvements in tensiometers have made them easier to use and their use in irrigation control is likely to increase.

Water content measurements

The other option for substrate water measurements is to measure the amount of water in the substrate (water content). Water content measurements traditionally have been either expensive or inaccurate. However, in recent years cheaper and more accurate soil moisture sensors have become available, and these have great potential for irrigation control. The idea is similar to that behind the use of tensiometers: as plants use water, the amount of water in the substrate drops and when it drops below a certain level it needs to be replenished by irrigation. By using this approach, plants get watered when needed, excess irrigation can be prevented. We have worked with Brower Electronics Labs (Pittsboro, NC) on a controller that uses soil moisture probes (ECH₂O-5 probes) made by Decagon Devices (Pullman, WA). This controller allows growers to set a minimum substrate moisture level at which the plants will be irrigated, the irrigation duration, and a minimum interval between subsequent irrigations. This single station controller can be interfaced with existing systems or used as a stand-alone controller. One to four moisture probes can be connected to the controller, and the controller will use the average reading from the probes for irrigation control. Dynamax (Houston, TX) has developed a similar con-

troller, the Moisture Klik™. A soil moisture sensor can be buried in the substrate, and a 24 VAC relay is activated when the substrate water content drops below a grower-determined level. Although this controller was developed for regular soils, it works in soilless substrates as well. We have used this controller successfully in our greenhouse, but so far our experience is limited. It is likely that it will soon be possible to connect these soil moisture probes to a greenhouse environmental control system as well, so that they can control irrigation based on real-time measurements.

Using a somewhat different approach, Rain Bird has developed an irrigation controller for outdoor use (model MS-100) with a soil moisture probe that is buried. As long as this probe measures a sufficient amount of water in the soil, it overrides the irrigation timer and prevents irrigation. Thus, a timer can be programmed for frequent irrigations, but as long as there is ample water in the soil, the irrigation system will not come on. Unfortunately, the soil moisture probe used by Rain Bird is highly sensitive to EC and thus not suitable for greenhouse use. However, a similar approach could easily be adapted for greenhouse applications. Another exciting new product, developed by Decagon Devices is a probe that can measure both the water content and EC of the substrate (ECH₂O-TE). This may make it possible to automatically irrigate with plain water or fertiliser solution, based on the requirements of the plants. Fertiliser could be injected into the irrigation water when the substrate EC drops too low, while automatic leaching could occur when the substrate EC is too high.

Some final thoughts

So, what is the best method to determine how often and how much to irrigate? We don't think that there is one approach that fits all situations. If you decide that automation is the right thing for you, consider the different options. In many cases, you may end up with a combination of different approaches. For example, a system that irrigates when the substrate becomes too dry and one that irrigates when the leaves are getting too warm (or it at least sets off an alarm). A combination of different, independent approaches has the advantage that if your main system fails, another system may notice this, reducing the chances of serious problems. But, no matter how many sensors or computer models you may use do not expect that you will ever be able to turn over irrigation to a computer and walk away from it. Although automation may be able to reduce the amount of labour needed to grow a crop, it cannot and should not replace the grower. Think of automated systems as a tool to aid you, not to replace you. ■

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