GROWERTALKS

Features

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Defining Your Drip Game

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Drip irrigation is one of the most efficient and easy ways to irrigate plants; however, there are many decisions you need to make to ensure that your systems are operating at peak performance. Specifically, how to select the best emitter and how to use the flow rate to calculate run time.

Measure flow rate in pressure-compensated drip emitters is easy. Just put a drip emitter in a bucket and see how much water comes out.

Emitter flow rate

The flow rate (or discharge rate) is a volume of water produced in time and it's one of the main specifications of irrigation devices. A drip emitter's flow rate is generally expressed in gallons per hour (GPH) or liters per hour (LPH). In sprinklers, we express the flow rate in gallons per minute (GPM) since they produce a larger volume in time. Spray-stakes fall somewhere in between and their flow rate can be expressed in GPM or GPH.

Generally, drip emitters have a flow rate in the range of 0.1 to 2 GPH. It's critical that you know the flow rate of the emitters used in your irrigation system. Irrigation manufacturers make specifications available for each kind of drip emitter; often drip emitters are color-coded depending on their flow rate.

Knowledge of drip emitters' flow rate is very useful because it allows us to calculate the irrigation run time. For example, imagine we need to apply 10 fl. oz. (295 mL) of water to a 6-in. container using a 0.5 GPH emitter. A half gallon equals 64 oz., so the emitter produces 64/60 = 1.07 oz. per minute. To apply 10 oz. we need to run the system for 10/1.07 = 9.38 minutes. (In the following paragraphs, we'll walk you through the calculation of the volume we need to apply to a container.)

Finally, knowledge of the emitters' nominal flow rate is useful when auditing the performance of the irrigation system. An observed flow rate lower than the nominal indicates plugging.

Readily available water

The substrate acts like a sponge, holding water in its pores. Large pores have low tension and drain first, while small pores have higher tensions and it takes more force per unit area to drain. As a result, as the substrate dries, the water is held in smaller and smaller pores and develops larger and larger tensions. Plant growth and performance is strongly related to leaf water potential that's determined by osmotic potential (salinity in the soil solution), gravimetric potential (the plant's height) and matric potential that's the same as the tension described above. In other words, since plants are hydraulically connected to the water in the substrate, they “feel” the tension that develops in the substrate; as this dries, plants experience water stress, stop elongation growth, shut down stomata and wilt.

On the high end of water content (i.e. near saturation) the substrate develops tensions so low that it can’t hold water—not even against gravity. The water held in these large pores is called “gravitational water” and it drains from the bottom of the container. When this drainage ends, we say that the container is at a condition called “container capacity.”

The lower threshold of water availability is more difficult to define. It depends on many plant factors and also on the transpiration rate that’s determined by the evaporative demand of the atmosphere. In general, a threshold between 5 and 10 kilopascal (kPa) of tension is recommended for floriculture. This is very wet; we target 30 kPa for soil-grown vegetables and 100 kPa for grapevines or trees. However, this is one of the primary differences between soilless and soil-grown plants.

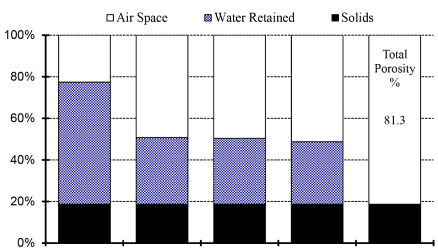


Figure 2 shows a laboratory analysis of the physical properties of a typical peat-perlite substrate used in floriculture. Starting from the column on the left, the substrate at container capacity has 58.7% of its volume occupied by water, while 22.6% of its volume is empty space (air-filled porosity). The rest of the volume (18.7%) is the solid particles (i.e. the substrate itself).

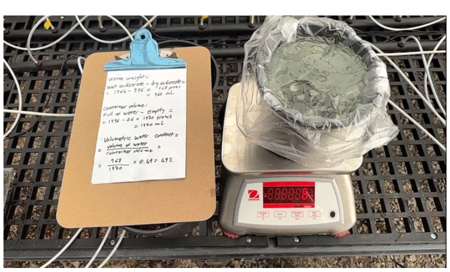
Substrate physical properties analysis.

In container-grown crops, readily available water is generally defined as the percentage of water volume held between container capacity and 10 kPa of tension. As you can see from the bars in Figure 2, it doesn’t really matter if we define the upper threshold as 5, 10 or 50 kPa since the substrate gave up very little water between 5 and 50 kPa. In other words, most water available to plants was held in larger pores (at tensions between 0 and 10 kPa) and there’s some water (about 30% in volume) held in smaller pores that a plant couldn’t access.

Using the figure below, if we define readily available water between container capacity and 10 cbar of tension, it’ll be 58.7-31.7= 27% of its volume.

How to measure container volume

So far, we’ve talked about percentages of substrate volume. To use these percentages, we need to measure the volume of the containers where our plants will grow. This can be done by lining a container with a plastic bag and filling it with water to the substrate fill line. Then the volume of water can be measured with a graduated cylinder. Alternatively, one can weigh the container filled with water, subtract the weight of the empty container and plastic bag, and use the trick that water density is one gram per mL (water’s weight and volume are the same) to obtain the container volume. In the example in Figure 3, the water weighed 1,970 grams and thus the container volume was 1,970 mL. Using ounces, water density is 1.043 oz. per fluid ounce. For example, if the water weighed 69.5 oz., its volume would have been 69.5 ÷ 1.043 = 66.6 fl. oz.



How long should I irrigate?

Let’s bring it all together. Just for the purposes of our discussion, let’s assume that in the 66.6 fl. oz. container above, all the substrate gets equally wet. Since only 27% of this volume is occupied water available to plants, then the irrigation volume should be 0.27 * 66.6 = 18 fl. oz. of water. Let’s say that we use a 1 GPH emitter to irrigate this container. One gallon per hour equals 128 fl. oz. per hour or 2.13 fl. oz. per minute. Thus, to re-wet the container from 10 kPa of tension to container capacity, we need to run the irrigation system for 18 ÷ 2.13 = 8.43 minutes.

Measuring container volume by weighing water in the container.

Good horticultural practice requires applying a leaching fraction to drain excess salts. A good rule of thumb is 15%. To increase by 15%, we need to divide by 0.85. This increases our run time to 8.43 ÷ 0.85 = 10 minutes.

Partial wetting of substrate

It's difficult to wet the entire volume of substrate in the container using drip irrigation. In reality, not all the volume of substrate will be uniformly wet by the irrigation water. Additionally, as plant roots grow, the percentage of empty space in the substrate decreases because pores become occupied by roots. Let's say you observed that only three quarters of the containers' substrate is getting wet by the drip irrigation emitter. The container volume over which calculating the water balance would reduce from 66.6 fl. oz. to 0.75 * 66.6 = 50 fl. oz. and the irrigation run time would reduce from 10 minutes to 7.5 minutes.

Reality check

While the numbers discussed above are theoretically sound, growers rarely dry the substrate to 27% of the containers' volume. The highest depletion we've ever measured between irrigation cycles was 13%. This may be because growers observe that irrigating with a shorter cycle and applying smaller volumes of water keeps the substrate wetter and often produces faster growth. The partial container volume wetting and the root biomass discussed above may also play a role in the grower's practice of applying smaller volume more often. The downsides of this practice are larger labor costs to operate the irrigation system and wetter conditions in the substrate that may facilitate the development of fungal diseases.

Additionally, in practice, the irrigation run time must be increased by another quantity to account for imperfect distribution uniformity of the irrigation system. This is called distribution uniformity or DU and ranges between 0 and 1 with higher values representing more uniform distribution. If the distribution uniformity is 0.85, then the irrigation run time increases from 7.5 minutes to 7.5 ÷ 0.85 = 8.8 minutes.

Conclusion

In conclusion, a good grower that uses drip irrigation needs to be aware of the flow rate of their drip emitters that generally ranges between 0.1 and 1 GPH. It's useful to send a substrate sample to the lab to measure physical properties; however, a rule of thumb of 10% to 20% of the container volume can be used as an estimate of Readily Available Water. This will be the volume of water applied to the container at each irrigation application, increased by 10% to 20% to account for a leaching fraction. Container volumes can be easily measured, volumetrically or gravimetrically, by filling a container with water. Partial substrate wetting can be estimated visually or minimized by installing multiple emitters. **GT**

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