

Converting From Gallons — To Inches — To Runtime Hours For Row Crop Drip Irrigation Systems

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Conversion from surface irrigation to drip requires more than just capital. Growers and irrigators must adjust their management strategies to accommodate the new irrigation system. In particular, drip systems are not designed to apply the large amounts of irrigation water that most surface systems are capable of applying. Depending on the design and layout of the drip system, it can take several hours to apply an inch of water while most surface systems can apply 4-8 inches within 12 hours. Because of this difference, growers using drip systems need to closely monitor the soil water status of their drip fields and irrigate appropriately. There are several publications on crop water use, irrigation scheduling, soil water monitoring, measuring water flow, etc.; all found on The University of Arizona's Arizona Crop Information System (ACIS) Irrigation Web Site at (<http://cals.arizona.edu/crops/irrigation/irrigation.html>)

In addition to the obvious challenges of converting from surface to drip irrigation, there are two factors often overlooked by growers: how to determine both flow rates and application amounts. In traditional surface systems, growers worked with flow rates in units of gallons per minute (gpm) or cubic feet per second (cfs), and application amounts were measured in acre-inches of water applied or simply inches of water applied. However, in drip systems, flow is given in gallons per hour (gph) or gpm and application amounts are usually in gallons, not inches.

This publication discusses the relationship between gallons and inches, and the hours of operation for drip irrigation systems used with rows crop production. Examples are given on how to determine application amounts and hours of operation needed to apply a targeted amount of water. Simple formulas that can be used on a hand-held calculator are given, as well as the option to download a Microsoft Excel program from the Internet.

Gallons to Inches

Growers who convert from surface to drip irrigation often have difficulty with the concept of applying gallons of water instead of inches of water. This is especially true for row crops. Although many of the available irrigation scheduling programs provide information on crop water use and irrigation water requirements, these programs

typically use inches of water, not gallons. Furthermore, traditional crop water use (evapotranspiration - ET) data are normally given in inches per day, inches per week or inches since the last irrigation.

The challenge of converting from inches to gallons and back again is that a gallon is a volumetric unit and an inch is a depth or unit of length. In order to better understand the relationship, we need to convert these two parameters into similar units. One inch equals 0.0833 feet; a gallon can be represented in cubic feet (ft³); the conversion is 7.48 gallons per cubic foot. This means that a plastic container one foot wide, one foot long and one foot deep can hold 7.48 gallons. Therefore, one gallon is equal to 0.134 ft³.

To relate inches to gallons, one needs to know the area of coverage. An inch of water that covers an acre is a much larger volume than an inch of water in a sink, although they are both one-inch deep. Thus, depending on the area of coverage, a depth of water (in inches) can be converted to a volume of water (in gallons). For drip systems, it is the area covered by an emitter that is of concern. The area of coverage by an emitter operating at a given pressure is dependent on the emitter spacing and the tape or bed spacing.

Flow data for drip tape is given in many different units. These units include gallons per minute per emitter (GPMe); gallons per hour per emitter (GPHe); gallons per minute per 100 feet of tape (GPM100); or gallons per hour per 100 feet of tape (GPH100). The industry is slowly moving toward a standard of GPM100, although all of these flow rates are currently used.

Let's take a typical drip system that has emitters every 12 inches, a bed spacing of 40 inches and one drip line per bed. The emitter flow rate is 0.34 GPM100. First, calculate the surface area covered by one emitter, namely the distance between emitters multiplied by the distance between drip lines. In this case, it would be 12" x 40". Convert these measurements to feet, then multiply them together:

$$12 \text{ inches} * \frac{1 \text{ ft}}{12 \text{ inches}} * 40 \text{ inches} * \frac{1 \text{ ft}}{12 \text{ inches}} = 1 \text{ ft} * 3.33 \text{ ft} = 3.33 \text{ ft}^2 \quad (1)$$

Thus, one emitter covers an area of 3.33 ft².

Now, determine how much water (in inches) is applied in an hour by an individual emitter. Since our flow rate is in GPM_{100} , we need to convert this to GPM_e . To do this, take the emitter spacing (in feet) and divide it by 100. In the example, the equation would be:

$$0.34 GPM_{100} * \frac{1 ft}{100 ft} = 0.0034 GPM_e \quad (2)$$

Then, take the flow rate, now in GPM_e and convert it to ft^3 per hour.

$$0.0034 GPM_e \frac{60 min}{1 hr} * \frac{1 ft^3}{7.48 gal} = 0.027 \frac{ft^3}{hr} \quad (3)$$

Take the ft^3 per hour and divide by the area (ft^2) to get ft per hour applied:

$$\frac{0.027 \frac{ft^3}{hr}}{3.33 ft^2} = 0.008 \frac{ft}{hr} \quad (4)$$

Finally, convert the feet to inches:

$$0.008 \frac{ft}{hr} * \frac{12 inches}{ft} = 0.096 \frac{inches}{hr} \quad (5)$$

Thus, the system delivers 0.096 inches of water per hour.

Once the inch per hour rate is known, the system's runtime can be adjusted to apply the required amount of water. For this system to apply 1-inch of water, take the application rate and divide it into the target application amount to determine the runtime:

$$\frac{1 inch}{0.096 \frac{inches}{hr}} = 10.4 hr \quad (6)$$

REMEMBER: Although drip systems are highly efficient they are not 100% efficient. Therefore, an efficiency factor should be used. Most drip system run well above 90% efficiency. If the system is new and running properly, use 95%. If it is a few years old, reduce the efficiency to 92%. Using an efficiency of 95% for this example, the actual runtime would be:

$$\frac{10.4 hours}{0.95} = 11 hours \quad (7)$$

With these numbers, the runtime can be adjusted to apply any amount. Using a calculator, the following equation will determine inches applied per hour:

Given:

Spacing between tape: S_t (inches)

Emitter flow rate: q_{GPH100} (gal/hr/100 ft)

Find: Depth applied per hour: da (inches/hr):

$$da = \frac{0.193 * q_{GPH100}}{S_t} \quad (8)$$

If the flow rate (q) is in gal/min/100 ft (q_{GPM100}), use:

$$da = \frac{11.58 * q_{GPM100}}{S_t} \quad (9)$$

If the flow data is per emitter, not 100 ft of tape, then the emitter spacing S_e (inches) is needed and the formulas read:

If the flow rate (q) is in gal/min/emitter q_{GPME} , use:

$$da = \frac{13,860 * q_{GPME}}{S_e * S_t} \quad (10)$$

If the flow rate (q) is in gal/hr/emitter q_{GPHE} , use:

$$da = \frac{231 * q_{GPHE}}{S_e * S_t} \quad (11)$$

Hours to Inches

There may be some cases where the hours of operation are known but the amount of water applied is needed. To determine this, take the answer from one of the previous "depth applied" equations and multiply it by the hours of operation. Using the same system with a runtime of 8 hours, calculate the amount of water applied. From Eq. 5, we know that the system applies 0.096 inches per hour, multiply that by 8 hours:

$$0.096 \frac{inches}{hr} * 8 hr = 0.77 inches \quad (12)$$

REMEMBER the efficiency: the 0.77 inches is the **gross** amount of water applied. To calculate the **net** water applied, multiply the gross water applied by the efficiency (0.95):

$$0.77 inches * 0.95 = 0.73 inches \quad (13)$$

To use a calculator to convert from hours to inches, use Eq. 8 – 1, multiplying the answer by the hours of operation. For example:

Given:

Spacing between tape: S_t (inches)

Emitter flow rate: q (gal/hr/100 ft)

Time: t (hours)

Find: Depth: d (inches):

$$d = \frac{0.193 * q_{GPH_{100}} * t}{S_t} \quad (14)$$

To account for the efficiency, simply multiply the depth by the efficiency to get the effective depth applied.

$$d(\text{effective}) = \frac{0.193 * q * t}{S_t} * \text{efficiency} \quad (15)$$

Alternative Tape Configurations

For many crops and bed configurations, having just a single line per bed is not very efficient. This is especially true for vegetable crops grown on 80-inch beds with several rows per bed (Fig. 1). For example, a recent demonstration project at the University of Arizona's Maricopa Agricultural Center grew broccoli on 80-inch beds. The beds were wider than the normal 40-inch bed, with 6 rows of broccoli per bed. In order to assure that the entire bed was adequately irrigated, the researchers used three tape lines buried 19 inches apart. For these types of situations, use bed spacing instead of tape spacing and simply divide the required time by 3 to get the run time or multiply the gallons applied by 3 to calculate the inches applied.

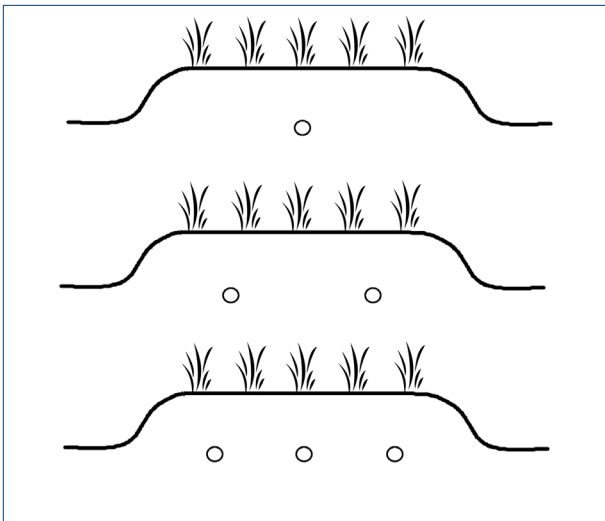


Figure 1. Schematic of various subsurface drip irrigation tape configurations used for crop production.

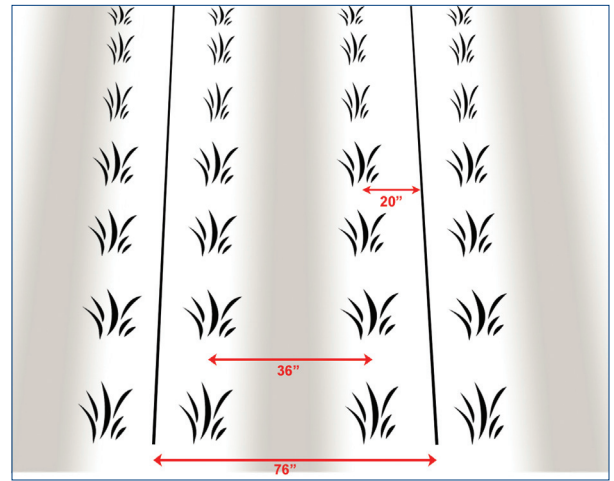


Figure 2. Example of a field where the drip tape is evenly spaced (76 inches apart) but the rows are not.

Also, some designs are set up so the tape is evenly spaced in the field but the beds or rows are not. For example, some growers have fields with tape spaced every 76 inches and rows of cotton planted at a spacing of 20 inches on each side of the tape. This makes the bed configuration 40" – 36" – 40" – 36" (See Fig. 2). In such cases, use the tape spacing.

Using a Computer

There is an easier way to determine your runtimes and/or amount of irrigation water applied. A Microsoft EXCEL program called Drip System Flow Conversion (DripCon) was developed by researchers at the University of Arizona and requires the user to enter basic irrigation system data to obtain either runtime or inches applied. The software requires the following information:

- Emitter spacing (inches)
- Row / Bed / Tape spacing (inches)
- Number lines per bed
- Emitter flow (GPH_E , GPH_{100} , GPM_E , GPM_{100})
- System efficiency (percent)
- Target application amount (inches) OR Runtime (hours)

The emitter spacing and flow rate can be provided by the tape manufacturer. Make sure to double check the units and choose the correct unit of flow for the tape being used.

The bed spacing depends on the field layout. Remember to use tape spacing if the tape is evenly spaced but the beds are not. If tape spacing is used, the lines per bed should be set to one. Finally, enter the system's efficiency.

The next input is either runtime or target application. The runtime is simply the number of hours the system ran. The target application is the amount of water to be applied. Several sources of crop water use information are available. In Arizona, crop advisories, available on the web at (<http://cals.arizona.edu/crops>) contain information on weekly crop water use. For the more adventurous, there is a computer program called AZSCHED (AriZona SCHEDuling system) which can be downloaded with the User Guide at:

<http://cals.arizona.edu/crops/irrigation/irrigation.html>

Where Do I Sign Up?

The same web site (<http://cals.arizona.edu/crops/irrigation/irrigation.html>) that contains the AZSCHED program also has the DripCon program available for download. Simply follow the download instructions and enter the data required.

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