Fertigation: The Basics of Injecting Fertilizer for Field-Grown Tomatoes

MISSISSIPPI STATE UNIVERSITY EXTENSION

Fertigation refers to injecting fertilizer into an irrigation system. This is accomplished in drip (trickle) by using some type of injector to meter the concentrated fertilizer solution into the irrigation water. The basics of the system design are outlined in this publication.

A theory behind why fertigation has become the standard in vegetable nutrition is that nutrients can be applied to plants in the correct dosage and at the right time for each specific stage of plant growth. When plants receive conventional preplant fertilizer and then two (or more) sidedressings, they get more fertilizer than they need at the time it is applied. Between applications, there may be a deficiency of fertilizer.

With fertigation, plants can receive small amounts of fertilizer early in the crop's season when plants are vegetative. The dosage is increased as fruit load and nutrient demands grow and then decreased as plants approach the end of the crop's cycle. This gives plants the needed amounts of fertilizer throughout the growth cycle, rather than just a few large doses.

Timing

Fertilizer can be provided in different frequencies—daily, every other day, several times each week, or weekly—depending on irrigation needs, soil type, and other factors. For Mississippi conditions, once per week is typically adequate. On very sandy soils, more frequent fertigation might be necessary. Don't hesitate to irrigate if moisture is needed at times other than during the fertigation.

Rates

The amount of fertilizer to apply is recommended in terms of pounds per acre per day, week, or whatever application increment you select. The amount can vary during the growing season, starting off low, increasing as plants set fruit, and then declining toward maturity. With tomatoes, for example, nitrogen use might be in the neighborhood of 7 pounds per acre per week early in the crop, 10 pounds per acre per week as plants approach fruit set, and 14 pounds per acre per week when plants have the heaviest load of fruit. In the last 2 weeks, the rate can be reduced to a lower level. This could be applied once per week or more frequently (7 lb/acre/week = 1 lb/acre/day) to best fit cultural practices and Mississippi conditions.

Fertilizer Choices

Typically, nitrogen (N) and/or potassium (K) are injected. Phosphorus (P) should not be injected, since it does not move much in the soil. It is best to incorporate all required P before planting.

All fertilizer sources must be highly soluble. It is difficult or impossible to unclog drip irrigation tubing once you have clogged it with insoluble fertilizers, algae, or sand.

Solid nitrogen sources include calcium nitrate, ammonium nitrate, potassium nitrate, and others. Potassium sources are usually potassium nitrate or potassium chloride. **Table 1** has the elemental breakdown of these fertilizers.

Commercially prepared liquid fertilizers for injection are also acceptable. These are usually combinations of N and K and include 4-0-8, 6-0-6, 7-0-7, 10-0-10, and others. Higher grade liquid fertilizers are preferred to lower grade liquid fertilizers, since you get more actual fertilizer and less water.

If soil test results indicate low K, liquid fertilizers such as 7-0-7, 8-0-8, or 10-0-10 are acceptable. In those situations where soil K is already high, you can inject straight N in commercially prepared solutions made from ammonium nitrate and urea. These include 19-0-0, 28-0-0, and others. Base fertilization amounts on soil tests and crop requirements.

Table 1. Nutrient composition of individual fertilizers commonly used in fertigation (elemental forms of P and K shown in parenthesis).		
Fertilizer	**% Nutrient Composition**	**pH***
Ammonium nitrate	34% N	A
Calcium nitrate	15.5% N, 19% Ca	B
Diammonium phosphate	16% N, 46% P_2O_5 (20.1% P)	A
Monopotassium phosphate (MKP)	52% P_2O_5 (22.7% P), 34% K_2O (28.2% K)	B
Nitrate of soda potash	15% N, 14% K_2O (11.6% K)	B
Potassium chloride (muriate of potash)	60% K_2O (49.8% K)	N
Potassium nitrate	13.75% N, 44.5% K_2O (36.9% K)	B
Sodium nitrate	16% N	B
Urea	46% N	B
*A = acidic (will lower soil pH); B = basic (will raise soil pH); N = neutral (no effect on soil pH)		

Solubility Limits

"Solubility limit" refers to how much of a fertilizer can be dissolved in a certain amount of water. If this amount is exceeded, the fertilizer will precipitate, which is commonly called "salting out." It is important that fertilizers completely dissolve; otherwise, they settle out in the tank, and plants do not receive the full dose. Also, undissolved fertilizer can clog irrigation tubing and emitters. **Table 2** shows the solubility limit of some fertilizers in 100 gallons of cold water. Putting more than these amounts of fertilizer in this volume of cold water results in some fertilizers' not being completely dissolved.

The temperature of the water influences how much a fertilizer will dissolve. So the time of year can help determine how much fertilizer will dissolve, as well. In cooler weather, such as very early spring or late fall, less fertilizer stays in solution in the cooler water.

The most limiting solubility in the listed fertilizers is potassium nitrate. You can avoid problems by remembering that not more than about 1 pound per gallon of potassium nitrate should be dissolved. You can get solubility beyond the limits listed in Table 2 by continuous agitation (mechanical paddle or recirculating pump) or by maintaining a warm water temperature.

Table 2. Solubility limits of fertilizers.	
Fertilizer	**Pounds per 100 gallons**
Ammonium nitrate	984
Calcium nitrate	851
Diammonium phosphate (DAP)	358
Potassium chloride	290
Potassium nitrate	108
Sodium nitrate	608
Urea	651

Calculating Amount of Fertilizer

To determine how many pounds of a fertilizer to use for a certain application rate, use this formula:

Pounds of fertilizer = [(pounds per acre desired) / (percent of element in fertilizer)] × 100

Example: If you want 7 pounds per acre of nitrogen each week and are using potassium nitrate (13.75% N):

Pounds of fertilizer = [(7 lb/a) / (13.75)] × 100 = 51 lb/a

Equipment

The irrigation system consists of a main line, sub-main lines (or headers), feeder tubes, and drip tubes. Drip tubes, or drip tape, are generally 8 to 10 mil thick for single-year use on vegetables. Headers often consist of vinyl lay-flat tubing (blue or black) or PVC pipe. You can drive a tractor over the "lay-flat," so it does not need to be buried. The drip tubing is rated in gallons per hour per foot, or per 100 feet, at a specific design pressure. For example: 24 gallons per hour per 100 feet when operated at 8 psi pressure.

For any fertigation system, the basic components, in addition to the irrigation tubing, include a fertilizer tank, an injector, a filter, a pressure gauge, check valves, and a pressure regulator. A good filter is essential for limiting clogging and extending the life of any drip irrigation system. Inject the fertilizer solution into the line in front of the filter to be certain any undissolved solids are removed before they enter the rest of the irrigation system.

Application Technique

When injecting fertilizer into a drip irrigation system, be careful to take these precautions:

- Be sure the placement of the drip tubing does not interfere with the production system. For example: If you are planting tomatoes down the center of a raised bed, place the drip tubing about 6 inches off-center. This prevents damaging the tubing when cutting holes in plastic mulch for the transplants and when inserting tomato stakes.
- Make sure the fertilizer is compatible with the water into which it is being injected. Some fertilizers can cause a precipitant that will clog the drip system or filter system. For example: Calcium and phosphorus fertilizers should not be mixed with sulfates in a concentrated solution.
- The suction line in the fertilizer tank should not rest on the tank bottom. Keeping the intake end of the tube about a foot above the bottom of the container will prevent any undissolved solids from entering the system.
- Calcium nitrate and potassium nitrate sometimes leave a scum of impurities on the surface of the fertilizer tank; skim off the scum to prevent it from entering the irrigation system.
- Put a small screen on the intake end of the suction line to help eliminate solid particles or undissolved fertilizer from entering the system and causing clogging.
- Do not inject fertilizers in combination with pesticides or chlorine.
- The injection point must be upstream of the filter system so the filter will remove any undissolved fertilizer or precipitants that occur.
- Before beginning injection of a fertilizer, bring the drip irrigation system up to operating pressure. At this point, even the part of the irrigation system farthest from the source should be pressurized.
- After injecting all of the fertilizer, irrigate with plain water so the lines are flushed out and fertilizer is washed into the plant beds. Select fertilizer solutions to help adjust water pH if necessary.
- The time needed to distribute the fertilizer needs to be less than the time needed to supply enough water to the field; otherwise, too much water will be applied. Do not overwater, because this leaches some of the fertilizer out of the root zone. If the amount of fertilizer that must be applied is too much for the irrigation interval, split the application over time (such as twice per week or some other arrangement).

Fertilizer Metering Devices (Injectors)

Many types of injector pumps are available. You do not have to use a complicated or expensive injector to get good results. Positive displacement pumps are precise and operate on an external power source such as electricity (120 volt AC or 12 volt DC battery), an internal combustion engine, or water power. Other types of pumps work on differential pressure rather than positive displacement.

Positive displacement pumps are piston pumps or diaphragm pumps. Once a piston pump is calibrated to a given rate, it is accurate. But it has surfaces that might be exposed to corrosion, and it must be stopped to change calibration. Diaphragm pumps, on the other hand, usually are made of a chemically resistant material. They are accurate and can be adjusted as they run. These pumps inject at a constant rate regardless of flow or pressure changes in the system.

Proportioner injectors sense the rate of flow and adjust the injection rate as the flow rate changes. These pumps do not require an outside power source, and they work well in nurseries or greenhouses. One possible disadvantage is that these injectors require some pressure to operate, and pressure changes in the system might alter the rate of injection, which might or might not be proportional to the desired rate.

The **venturi bypass** is simple and relatively low-cost. It works from differential pressure in the system (usually 20 percent) from one side of the device to the other. Since the injection rate depends on the pressure differential, any pressure fluctuations in the system change the injection rate.

Positive displacement injection pumps give better control of injection rates and are preferable to venturi or pressure differential devices. The injection pump should be sized for maximum amount of fertilizer to be injected at any time during the season so the fertigation process can be completed in less time than required to meet the irrigation needs of the crop.

Backflow Prevention

Depending on the water source, different backflow devices might be required. Also, if you're not going to use the system to inject pesticides, you have to meet certain EPA backflow requirements. Basic protection for fertigation systems should be a check valve between the water source and the injection point. If you are using a positive displacement pump, install a check valve on the injection line between the pump and the injection point. The system should be interlocked so if the pump water supply goes off, the injector goes off as well. If you are using a hydraulic-driven injector, the only protection you can use is the check valve in the main line between the water source and the injector.

There should be a low pressure drain and vacuum breaker between the injection line and the water source to prevent seepage back into the water system when nothing is running. The low pressure drain should be discharged at least 20 feet from any water supply source and protected from draining toward it.

Injection Point Location

The injection point must be between the check valve and the filter. To allow enough time for the fertilizer soution to mix uniformly, use at least 25 feet of line between the injection point and the filter system. It should also pass through at least two 90-degree turns to ensure enough time for thorough mixing and for any precipitant to come out in front of the filter. This gives more uniformity to the fertilizer each plant receives and decreases the danger of a precipitant's plugging the system.

Calibration

You must know three factors in order to calibrate a system: the system flow rate, the injection pump flow rate, and system pass-through time.

The **system flow rate** is the flow rate of the system per unit time, usually expressed in gallons per minute or gallons per hour. Injection rate is the volume of material to be injected per unit time. The **system pass-through time** is the time it takes for all of the water in the system to be totally replaced with new water at operating pressure. Pass-through time could also be expressed as the amount of time it takes for fertilizer injected at the pump to reach the farthest point in the system from the pump. Knowing the system pass-through time is important to ensure the system runs long enough to inject the desired amount of material and to ensure that the injection rate is long enough to fill the system completely and be flushed out before the system shuts off.

The easiest way to calibrate an injector is to use a graduated cylinder that measures volume in ounces or milliliters. Fill the cylinder to a known volume with the material that is to be injected and place the injector suction in the cylinder. Time the injection cycle for one minute or any known time. Then convert what has been used in the cylinder in one minute to the desired rate per unit time.

The following example might help you with some of these calculations. The time for the irrigation cycle is based on the assumption that tomatoes need 1.5 inches of water per week. If they are already getting enough water from natural rainfall, then the length of time can be based on how long it takes to move the fertilizer from the concentrate tank to the field.

Example:

You have 5 acres of tomatoes, with 3,000 plants per acre. You want to irrigate 1 acre at a time, putting out 1.5 inches per acre and 7 pounds of actual N with the irrigation. The drip tape is rated at 24 gallons per hour per 100 feet of tubing at 8 psi.

The fertilizer you will use is potassium nitrate (13.75% N). Note that potassium nitrate has a solubility limit of 108 pounds per 100 gallons of water, or about 1 pound per gallon. In other words, if you are using cold water, not more than about 1 pound will dissolve in each gallon of water.

Calculate how much potassium nitrate is needed to get 7 pounds of actual N. To do this, divide the pounds of N needed by the percent N in the fertilizer and multiply by 100:

(lb N needed) / (percent of N in fertilizer) × 100 =
pounds of fertilizer required

(7 / 13.75 × 100 = 51)

You need 51 pounds of potassium nitrate to get 7 pounds of actual N. Keeping the solubility limit in mind, these 51 pounds will dissolve in 50 gallons of water.

Determine how many row feet will be fertigated. This will be the same as the number of feet of drip tubing. To do this, divide the number of square feet in 1 acre (43,560) by the spacing between rows. If the tomatoes have 6 feet between rows, this is calculated as:

(Square feet in 1 acre) / (spacing between rows) =
linear feet of drip tubing

(43,560 / 6 = 7,260)

Therefore, there are 7,260 feet of drip tubing in 1 acre. This can also be represented as 72.6 100-foot sections (7,260 / 100 = 72.6) per acre.

Calculate how many gallons per hour you needed to irrigate the field. Drip tubing is capable of delivering 24 gallons per 100 feet of tubing per hour. Therefore, to determine how much water can be delivered to an acre of tomatoes, multiply the 72.6 (100-foot sections) times 24 gallons of water per 100-foot section per hour:

(Number of 100-foot sections) × (24 gallons per 100-foot section per hour) = total flow per hour

(72.6 × 24 = 1,742 gal/hr)

The tubing in 1 acre can deliver 1,742 gallons in 1 hour. This equals 29 gallons per minute [(1,742 gallons per hour) / (60 minutes per hour) = 29 gallons per minute].

How long do you need to run the system to deliver the amount of water required? An acre-inch equals 27,000 gallons of water. One acre-inch per hour equals 450 gallons per minute (27,000 / 60). So, the flow rate in gallons per minute (gpm) divided by 450 gpm give you the number of acre-inches being pumped or applied.

The applied tubing requires 29 gpm, or 0.0644 acre-inch per hour (29 / 450). For tomatoes, apply 1.5 inches of water per week. Therefore, divide the flow rate in acre-inches per hour into the desired application to determine the total pumping time:

(1.5 inches) / (0.0644 acre inches per hour) =
23.3 hours of operation

This is how many hours per week it takes to apply 1.5 inches of water.

The injection time is determined by catching and measuring a volume of material from the injector pump over a known period of time. Assume 26.7 ounces of material are pumped by the injector in one minute. The fertilizer is mixed in 75 gallons of water. So, the injector can put out 1,602 ounces per hour (26.7 ounces per minute × 60 minutes per hour), which is equal to an injection rate of 12.5 gallons per hour (1,602 ounces per hour / 128 ounces per gallon). The 75 gallons of fertilizer solution, then, will take 6 hours of injection time (75 gallons / 12.5 gallons per hour = 6).

To inject for a 6-hour period, you should probably run the system about 8 hours minimum. If an irrigation time of 24 hours is too long, then the irrigation sets could be 8-hour-long runs three times per week (23.4 hours to apply 1.5 inches / 8 hours per set = 3 sets per week of 0.5 inch each).

Note: Check the injection pressure to make sure it is greater than system running pressure. The injector may need to be between the pressure regulators and the filter if injection pressure is less than water source pressure.

The examples are based on 1.5 inches of water per acre for tomatoes. But tomatoes do not form a complete crop canopy at maturity. The row spacing is too wide for a 100 percent crop canopy to develop. If 1.5 inches per acre are required to meet demand for a full-canopied crop of tomatoes, then the full 1.5 inches may not be needed, given the space between rows, since the canopy does not cover the full acre.

Assuming an 18-inch walkway between 6-foot rows, the actual plant canopy coverage would only be 4.5 feet of the 6 feet, or 75 percent. Thus, to apply an equivalent rate of 1.5 inches per acre would take only 75 percent of this, or 1.125 inches of water. You can do this, since the irrigation system covers only the shaded areas under the plants and the entire acre is not irrigated. Time of year may also affect water use.

Preplant Fertilizer Considerations

You can apply some of the required fertilizer (according to soil test recommendation) preplant incorporated into the bed or banded along the side of the row. This is usually 20 to 33 percent of the total N and K and all of the P. Alternatively, you can apply all of the N and K fertilizer via fertigation. Either method is acceptable. If phosphorus is recommended by the soil test, apply it preplant. If you are using a preplant fertilizer application of N and K, delay fertigation until about 2 weeks after plants are transplanted, since they will have enough fertilizer to start vegetative growth. But if you don't use fertilizer, begin fertigation right after planting.

Recommended Tomato Fertigation Schedule

To determine how much fertilizer to feed into the irrigation system, first decide how much N and K the crop needs for the entire season. For tomatoes, the usual recommendation in Mississippi is 120 pounds of N, P_2O_5, and K_2O. Adjust this according to the soil test results.

The second step is to decide how many weeks you are likely to grow the crop. A Mississippi spring determinate tomato crop is probably in the ground about 14 weeks. The weekly feeding, then, is 120/14 or about 8.5 pounds per week. This amount is adjusted by two other factors. First, if you use a preplant fertilizer, the amount applied via fertigation needs to be reduced accordingly. For example, if 20 percent of the N and K is applied preplant (24 pounds each), then only 96 pounds will be applied by way of fertigation (80 percent × 120 = 96).

This time, since the preplant fertilizer supplies needs for the first 2 weeks of the 14-week cycle, the fertigation is delayed for 2 weeks. With 12 weeks remaining for fertigation, the weekly application is 8 pounds (96 / 12 = 8).

The second factor that influences the weekly application is the stage of growth of the crop. As mentioned, less is needed earlier, while more is needed as the fruit load increases. Using the example, for the first couple of weeks, 6 or 7 pounds per acre (per week) should be enough. As the load increases, apply 8 to 10 pounds per acre (per week).

Suggested schedules for fertigating an acre of transplanted tomatoes in Mississippi are shown in **Table 3**. This table assumes that all of the N and K are supplied through the fertigation system. If the soil test shows that less of either is needed, adjust the numbers in the table accordingly.

Table 4 shows numbers for a field of tomatoes in which 20 percent of the recommended fertilizer has been applied preplant in the bed. If the actual cropping season is longer or shorter than that shown in the tables, the numbers need to be adjusted.

Table 3. Suggested fertigation schedule for transplanted tomatoes in Mississippi, using all fertilizers via fertigation (14-week schedule).

Total lb/a		Growth stage	No. of weeks fertigated	Injection rate (lb/a/week)	Total injected at stage (lb)
N 120	K_2O 120	vegetative	2	6	12
		bloom	3	8	24
		fruit set	7	10	70
		fruit set ended	1	8	8
		maturation	1	6	6
Totals			**14**		**120**

Table 4. Suggested fertigation schedule for transplanted tomatoes in Mississippi, using 20% of N and K_2O preplant (12-week schedule).

Total lb/a		Growth stage	No. of weeks fertigated	Injection rate (lb/a/week)	Total injected at stage (lb)
N 96	K_2O 96	vegetative	2	0	0
		bloom	3	7	21
		fruit set	7	9	63
		fruit set ended	1	7	7
		maturation	1	5	5
Totals			**12**		**96**

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