Fertigation - Injecting soluble fertilizers into the irrigation system: Part 2

by Thomas D. Landis, Jeremy R. Pinto, and Anthony S. Davis

The first part of this article in the Summer 2009 issue covered basic mineral nutrition, the 3 components of a fertigation system, and the chemical calculations for formulating your own custom fertigation solutions. In this second and final part, we'll discuss types of fertilizer injectors, fertigation scheduling, and how to check injector function and determine exactly how much liquid fertilizer is going on your crop.

The simplest way to fertigate is to mix a large batch of applied strength solution and just spray it directly on your crops. Some bareroot nurseries fertigate their beds by spraying an applied strength fertilizer solution through a tractor-drawn sprayer (Triebwasser and Altsuler 1995).

Because of the sheer volume of fertigation solution and higher labor costs for mixing and application, this method is only practical in smaller container facilities. One obvious benefit of applying a diluted fertilizer solution is that there is no risk of fertilizer burn.

Types of Injectors

Most fertigation systems use some type of mechanical injector to mix small volumes of concentrated fertilizer solutions into the irrigation water; a wide variety of injectors are available (Table 1). The best and most current information on fertilizer injectors can be found on-line (Kessler and Pennisi 2004; Pennisi and Kessler 2003), and be sure to check the manufacturers websites for the latest information. For example, recent publications mention one injector, the Gewa, but that company has recently gone out of business and only replacement parts are now available.

The simplest and least expensive fertilizer injectors are the venturi types, such as the Hozon (Figure 1A),

Table 1 – Technical specifications for common fertilizer injectors

Brand name	Multiple heads	Injection ratios	Water Flow rate (gpm)	Water supply pipe diameter (in.)	Approx. cost (2010)	Acid injection possible	Remarks
Venturi							
Hozon	No	1:12 to 1:16	Any	0.75	$30	No	Requires 35 psi water pressure
E-Z Flo	No	Varies with model: 1:400 to 1:1,000	Any	Varies with model: 0.75 to 3.00	$50 to $750	No	www.ezfloinjection.com/
Positive displacement hydraulic pump							
Smith MeasureMix	Yes	Varies with model: 1:100 or 1:200	Varies with model: 3 to 200	Varies with model: 0.75 to 6.00	$1,600 to $4,600	Yes	www.smithpumps.com
DosMatic	No	1:50 to 1:200	Varies with Model: 5 to 20	0.75	$500 to $700	Yes	www.DosMatic.com
Dosatron	No	1:50 to 1:500	Varies with model: 0.5 to 100	Varies with model: 0.75 to 2.00	$500 to $2,000	Yes	www.dosatronusa.com
Flow-metered hydraulic or electric pump							
Anderson	Yes	Adjustable: 1: 100 to 1:20,000	Varies with model: 0.75 to 300	Varies with model: 0.75 to 10.00	$800 to $5,000	Yes	www.heanderson.com

which continuously injects stock solution at an approximate 1:16 ratio. As water passes through the Hozon, it creates a negative pressure that sucks the fertilizer solution from the stock tank (Figure I B). One limitation is that a water pressure of at least 35 psi (pounds per square inch) is needed to create sufficient suction. Siphon injectors can be used to apply other water-soluble chemicals, such as insecticides and fungicides, but cannot be used to inject acids (Pennisi and Kessler 2003). More sophisticated injectors, such as the Smith Measuremix* (Figure 1C), feature a water motor that injects stock solution at a specified ratio. For example, an injector with a 1:100 ratio injects one part fertilizer stock solution for every 100 parts of irrigation water (Figure 1D). Many of these injectors have separate heads to inject two or more solutions and some models have plastic parts that that are compatible with acid injection. Again, check the web publications and manufacturer website for specifications (Table 1).

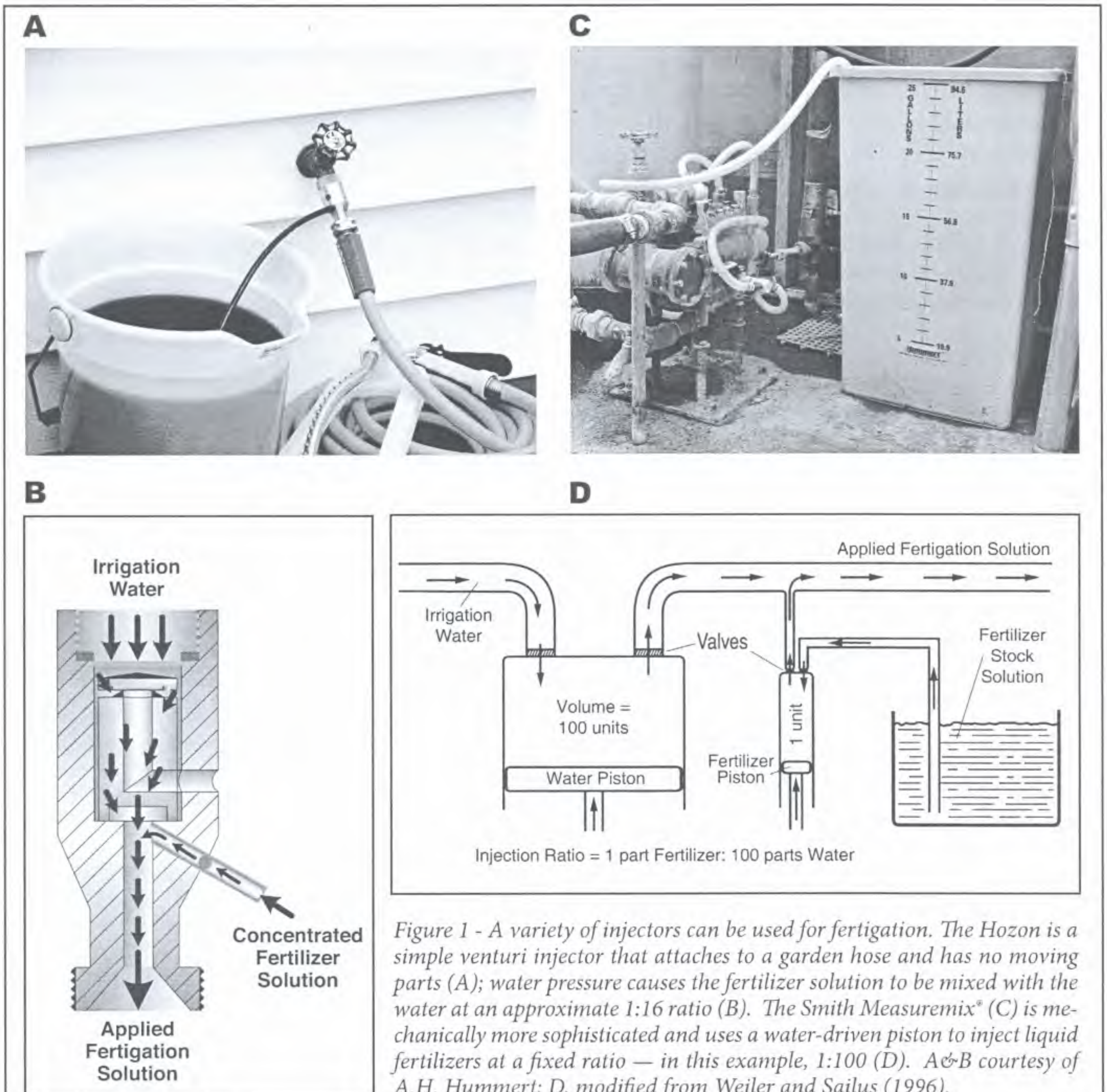

Figure 1 - A variety of injectors can be used for fertigation. The Hozon is a simple venturi injector that attaches to a garden hose and has no moving parts (A); water pressure causes the fertilizer solution to be mixed with the water at an approximate 1:16 ratio (B). The Smith Measuremix® (C) is mechanically more sophisticated and uses a water-driven piston to inject liquid fertilizers at a fixed ratio — in this example, 1:100 (D). A&B courtesy of A.H. Hummert; D, modified from Weiler and Sailus (1996).

Several things should be considered before purchasing an injector (Kessler and Pennisi 2004; Pennisi and Kessler 2003; Weiler and Sailus 1996):

Size and complexity of your nursery - Small nurseries growing a few species with hand watering or with an irrigation system with only a couple of zones can get by with a simple and inexpensive injector such as the Hozon or E-Z Flo. However, as the number of crops and the area to be fertigated increases, more sophisticated injectors are required. If you haven't done so already, it's a good idea to separate your different crops into nutrient requirement zones such as low, medium, and high. Native plant crops vary considerably in their response to fertilization, especially nitrogen, so grouping species by fertility zones makes fertigation much easier and more efficient.

Water flow rate - Because injectors supply a proportionate amount of liquid fertilizer to a given amount of water, you must know how much water your irrigation system can supply per unit of time. Flow rates can be divided into three categories based on gallons per minute (gpm): low (0.05 to 12 gpm), medium (12 to 40 gpm) or high (> 40 gpm). If you don't know your water flow rate, there are a couple of ways to find out. The simplest is to turn your irrigation on full, and measure how long it takes to fill a container or tank of known volume. Dividing the volume in gallons by the time in minutes gives you gpm.

If your nursery has a permanent irrigation system, then you hopefully have an in-line water meter that measures total volume usage; if not, we'd recommend getting one installed. Knowing your irrigation flow rates is essential to effective fertigation; writing down the starting and ending water usage along with the amount of stock solution consumed in a daily log book is an easy and effective way to confirm the actual injection ratio and check if the injector is working properly.

Injection ratio - This is simply the ratio of the amount of fertilizer injected per volume of irrigation water and most fertilizer injectors can be ordered with a wide variety of injection ratios (Table 1). Most injectors have a fixed injection ratio and the most common are 1:100 or 1:200, but some brands feature adjustable injection ratios. In-line venturi injectors used in hand watering have relatively low injector ratios. For automated irrigation systems, injectors with ratios less than 1:100 aren't practical because a very large fertigation tank would be required. On the other hand, using injectors with ratios >1:200 means that the fertilizer solution must be very concentrated, which leads to insolubility problems.

Multiple injector heads - Simpler injectors such as the Hozon can handle only one fertilizer stock solution at a time, but many fertilizer injectors can be ordered with two or more injection ports, or heads (Table 1). Commercial brands of soluble fertilizer can be mixed in a single stock solution tank so an injector with one head is adequate. However, when injecting acids to correct high water pH or when formulating custom fertigation solutions from stock chemicals, separate injector heads are necessary (Figure 2A). For example, calcium and sulfate cannot be mixed in the same stock solution tank because they form an insoluble precipitate (gypsum) that can plug up the injector or irrigation nozzles (Figure 2B). A list of incompatible fertilizer chemicals can be found in Landis and others (1989).

Water quality - The amount of dissolved chemicals or particulate matter suspended in your water supply must also be considered before purchasing an injector. With

A

Figure 2 - Fertilizer injectors with multiple heads, such as the Anderson Ratio:Feeders® (A), are necessary when using more than one fertilizer stock solution. In stock solutions, high fertilizer concentrations cause chemical reactions that form insoluble precipitates (B) that can plug up the injector or irrigation nozzles.

B

the simpler venturi-type injectors water quality isn't as much of an issue but, with more sophisticated injectors, high amounts of sediment or very hard water can cause excessive wear of the pump mechanism.

Mobility - Fertilizer injectors are typically installed in a permanent protected location, such as a headhouse, where the fertilizer solutions can be mixed and the stock solutions stored. These injectors are plumbed directly into the main irrigation line with valves and a bypass to allow normal irrigation. Some injector models can be mounted on a dolly or cart with quick-connections so that they can be used at several different locations.

Installation of Fertilizer Injectors

When permanently installing a fertilizer injector, we recommend the following. First, install injectors in the headhouse or other insulated building to prevent freezing damage and wear from exposure to the elements. Second, install a filter in the water supply line before the injector to filter debris and reduce wear. Third, install water pressure gauges before and after the filter — a large difference in the pressure readings means the filter is plugging up (Pennisi and Kessler 2003). Plumbing codes require that all potable water systems be protected with a backflow prevention device to insure that contaminated water is not accidentally mixed with water that is used for human consumption. Injecting any chemical without backflow prevention is against the law. Backsiphoning occurs when negative water pressure causes contaminated water to be sucked back into the water supply line. The most commonly used backflow preventer is the vacuum breaker (Figure 3). Under normal water pressure, the valve remains closed (Figure 3A); however, if the pressure in the supply line drops below a predetermined level, the check valve will close and shut off the water supply (Figure 3B). Backflow devices should be installed between the last control valve of the supply system and the fertilizer injector (Koths and others 1976).

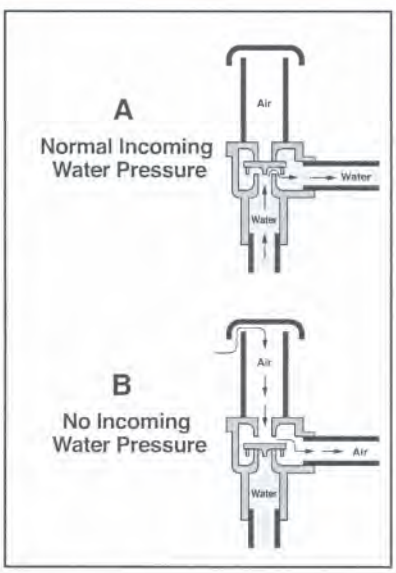

Figure 3 - Vacuum breakers are one type of backflow device that prevents water that has been mixed with fertilizer from being sucked back into the water supply line (modified from Koths and others 1976).

Scheduling Fertigation

Two basic schedules for applying liquid fertilizers are constant and periodic. The application of a dilute fertilizer solution each time the crop is irrigated is known as constant fertilization (Landis and others 1989), and the concentration of this applied fertilizer solution is exactly the nutrient concentration desired in the growing medium solution. Periodic fertilization consists of applying a more concentrated fertilizer solution according to some fixed schedule, such as once a week or every other irrigation. The applied fertilizer solution during periodic fertilization may therefore be several times more concentrated to allow for the dilution that occurs during subsequent irrigations. Because periodic application applies a more concentrated solution, growers should rinse crop foliage with irrigation water following each fertigation, as well as carefully monitor to avoid fertilizer salt build-up in the growing medium. An example of a periodic fertilization schedule is given in Table 2. One option is to use continuous fertigation early in the growing season to force growth and build-up plant nutrient reserves, and then change to periodic fertilizer applications to finish the crop. In one study, early season continuous fertigation followed by late season weekly fertigation reduced fertilizer costs by approximately 50% without any growth loss (Struve and Rose 1998). An alternative method is to fertigate using the exponential fertilization method whereby plants receive proportional amounts of fertilizer relative to their growth rate and size (Dumroese and others 2005).

Table 2 - Periodic fertigation schedule for the USDA Forest Service Nursery at Coeur d'Alene, ID

Plant Growth Phase	Timing (weeks)	Type of Fertilizer	Frequency
Germination	0 to 4	H_3PO_4	As needed
Establishment	4 to 8	7-40-17	Every irrigation
Rapid Growth	8 to 12	20-7-19	Every other irrigation
Hardening	12 to 14	4-25-35	Every third irrigation
Pre-Shipping	Prior to harvest	20-7-19	Once

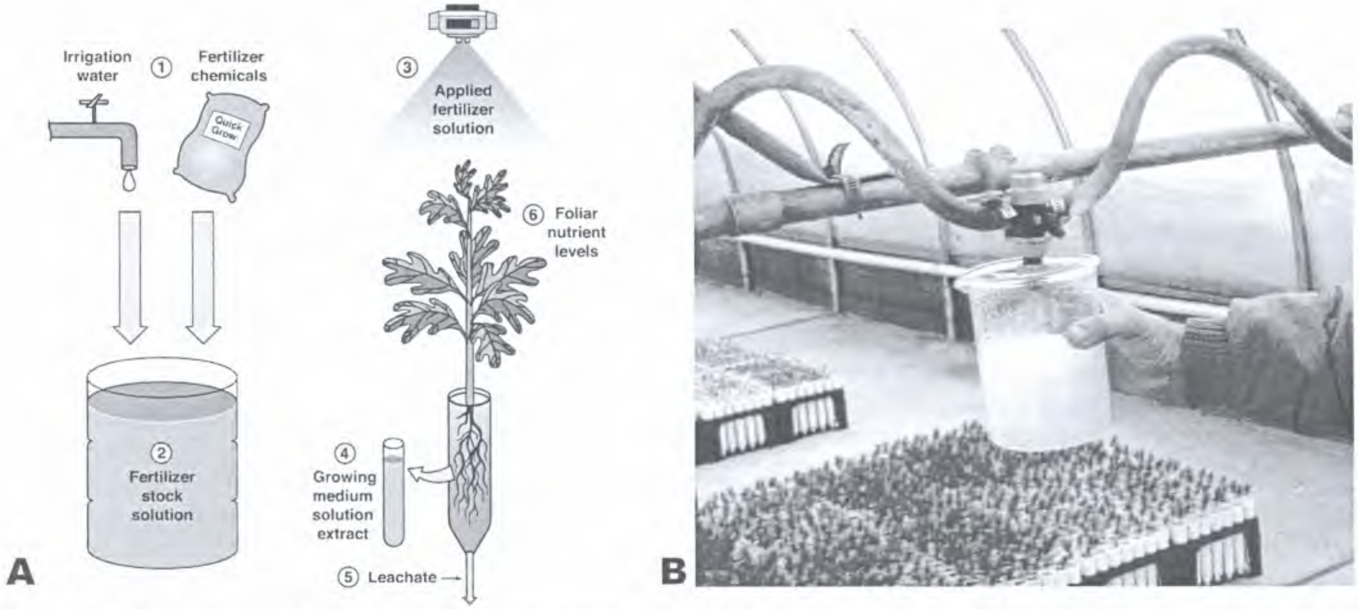

Figure 4 - Checking the electrical conductivity at each stage of the fertigation process (1-5) ensures that the injector if working properly and regular foliar analysis (6) proves that your crop is receiving the proper levels of all mineral nutrients (A). The most critical check is the applied fertilizer solution that goes on your crop (B).

The best way to determine when to fertigate is to carefully monitor plant growth and foliar nutrient levels. Accumulating test results in a spreadsheet program along with seedling growth data allows easy analysis and creates a permanent database that only improves as you gain experience with each crop. As growth versus nutrient curves are developed, it is easy to identify the critical point in the curve when growth begins to flatten out. When this happens, applying more fertilizer will only lead to luxury consumption and, in the case of nitrogen and phosphorus, may cause environmental pollution. Inexperienced growers have the tendency to overfertilize "just to make sure:' and because fertilizer is relatively inexpensive (Landis and others 2005).

How to Monitor Fertigation

Fertigation is a powerful cultural tool but must be carefully monitored. There are two way to check your fertigation program: electrical conductivity (EC) and foliar nutrient levels. The best way to determine if your fertilizer injector is working properly is to monitor the EC of the various fertilizer solutions. EC is a measure of the salinity (total salt level) of a solution and therefore gives an indication of the dissolved fertilizer salts. An EC meter measures the electrical charge carried by the ions that are dissolved in a solution — the more concentrated the ions, the higher the reading. By checking the EC at each step in the process (Figure 4A), you can be sure that your injector is functioning properly.

1. Irrigation water - The base EC of the irrigation water should be monitored monthly, or until you are certain that it does not vary significantly during the season.

2. Fertilizer stock solutions - The efficiency of the fertilizer injector can be checked by making an "applied strength" dilution of the fertilizer stock solution and measuring the EC level. For a 1:100 injector, add one part of stock solution to 100 parts of irrigation water. The EC reading of the diluted fertilizer solution should be approximately the same (within 10%) as the EC of the fertigation solution that is applied to your crop.

3. Applied fertilizer solution - The applied fertilizer solution is by far the most important of the fertilization checks because this solution actually contacts the seedling foliage and enters the root zone. Even if you don't check anything else, be sure to do this test regularly. The applied solution is-collected directly from the irrigation nozzle (Figure 4B) and the EC reading should be approximately the sum of the base salinity of the irrigation water plus the salts added by the fertilizer stock solution. Send a sample of this solution to a testing laboratory and check the levels of the mineral nutrients against your calculated values.

4. Growing medium extract - Samples of the irrigation water and the applied fertilizer solution can be collected directly, but liquid samples must be extracted from the growing medium. The amount of growing medium solution is relatively small and is strongly absorbed, and so special sampling techniques must be used to collect enough solution to measure. The amount of growing medium solution is relatively small and is strongly

absorbed, and so special sampling techniques must be used to collect enough solution to measure. See Landis and Dumroese (2006) for details on the various options.

5. Leachate - The final check involves taking EC readings on the "leachate" solution that drains from the bottom of the containers. Leachate can be obtained by taping a test tube or other container to the drain hole of the container or by placing a tray under a block of containers during fertigation. If the EC of the leachate significantly exceeds the EC of the applied fertilizer solution, then excess salinity is building up in the growing medium and proper leaching is not occurring.

6. Foliar nutrient levels - While EC readings can reveal when overall problems with your fertigation system, the only comprehensive test is to chemically analyze the foliage of your crop and determine its nutrient status. The mineral nutrient concentration of the seedling foliage reflects the actual uptake of all the mineral nutrients. Several commercial suppliers of horticultural products are offering chemical testing of irrigation water, fertilizer solutions, growing media, and seedling tissue at very attractive prices. These labs are equipped with the latest analytical equipment such as the ICAP (Inductively Coupled Argon Plasma) spectrometer and so the tests are done quickly and accurately. They will even telephone, FAX, or email the results back to the nursery so that cultural corrections can be made within a matter of days. Interpretation of foliar tests can be intimidating, but general standards and helpful hints can be found in Landis and others (2005).

Summary

Fertigation is one of the most efficient ways for growers to fertilize their crops because all the essential mineral nutrients are applied at their ideal concentration and in the proper balance. In addition, fertigation does not suffer from the delayed response of solid fertilizers because the nutrients are already dissolved in water and can be quickly absorbed by the roots. Most growers use some type of injector to mix concentrated fertilizer solution into the irrigation system and a wide variety of injectors are available to meet the needs of any size of nursery. Injectors must be properly installed with a backflow device to prevent siphoning of liquid fertilizer back into the water source. Fertigation can be applied with each irrigation or at scheduled intervals; the choice will depend on crop response and the risk of excessive nutrient runoff. A well-designed fertigation system can be monitored at several stages in the process to ensure that the injector is working properly and that the plants are receiving the proper amount of fertilizer.

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