Fertigation

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Fertigation is defined as the application of nutrients using an irrigation system by introducing the nutrients into the water flowing through the system. The first reported application of commercial fertilizer through a sprinkler irrigation system was in 1958. Today, we routinely inject fertilizer solutions and suspensions into irrigation systems via calibrated injection pumps that insure precision over both space and time.

Figure 10.1 Overhead sprinkler irrigation system.

Fertigation has increased dramatically in the past 15 years, particularly for sprinkler and drip systems. For drip systems, the expansion is mostly in horticultural and high value crops. In agricultural areas with declining water supplies, drip systems have also increased. With increased irrigation, a corresponding increase in fertigation has taken place. It will continue to grow since such systems result in less water usage and better uniformity and lend themselves to the technique much more readily than the less water-efficient and non-uniform furrow and flood systems being replaced.

Effective fertigation requires knowledge of certain plant characteristics such as optimum daily nutrient consumption rate and root distribution in the soil. Nutrient characteristics such as solubility and mobility are important and irrigation water quality factors such as pH, mineral content, salinity and nutrient solubility must be considered. The need for irrigation is the main factor in fertigation because the irrigation system is primarily installed to provide water. The opportunity to fertigate is an added benefit. This chapter will address issues that must be considered to achieve maximum benefits when fertigating.

Figure 10.2 Growers often plant vegetables under plastic mulch and fertigate using drip/trickle irrigation.

Soil Chemistry

Cropping and fertilization history as well as basic soil chemical properties also need to be considered prior to fertigation. Soil testing by the method recommended in a specific area is the best way to assess current fertility needs. Particular attention should be given to soil pH and its adjustment to an appropriate range for the crop to be grown. Proper pH can have a great effect on the availability of residual nutrients in soil as well as those added via fertigation. Any required soil pH adjustments should be made using conventional incorporation techniques. Fertigation is not utilized to alter soil pH’s.

Cation exchange capacity (discussed in The Soil Defined) is an important consideration in determining the quantity of cations that will be retained during fertigation. In order to maintain an acceptable concentration of cations in solution, a soil with a low CEC must have its cations replaced via fertigation more often than one with a relatively high CEC, which can hold a greater quantity of ions. Since nutrients are easily added with fertigation, it is most practical on sandy, droughty soils with low CEC. These soils need frequent irrigation and nutrient replenishment.

Previous chapters in this book have explained soil movement of nutrient elements when applied by conventional fertilization methods. Since fertigation does not negate classical soil chemistry, fertigated nutrients behave similarly to conventionally applied soluble nutrients followed by rainfall or irrigation. A reminder - only small quantities of nutrients applied by an overhead sprinkler system are absorbed by the foliage.

There is some concern that since nitrate nitrogen (NO_3-N) is highly mobile, it may leach past the root system and reach groundwater. However, leaching of NO_3-N in the sands of the Southern Coastal Plain has been evaluated. Georgia researchers compared conventional sidedress for corn with fertigation split 6 to 9 times during the growing season. Soil NO_3-N with depth was evaluated in late July (near maturity). Soil NO_3-N for the fertigated treatments was greater in the surface and to depths of 2 inches than for the conventional treatment. At a depth of 2 feet, greater concentrations of NO_3-N were found for the conventional application. Data such as these support the application of smaller amounts of N more frequently in order to expose lesser quantities to the possibility of leaching.

In contrast to nitrate N, phosphorus (P) fertilizer moves very little in the soil. When broadcast on the soil surface, it will not normally move more than l to 2 inches below the soil surface. Therefore, fertigation of P is highly inefficient when using sprinkler or flood irrigation techniques. However, P fertilizer applied in drip systems may be rather efficient. An advantage of drip irrigation is that plant nutrients can be applied directly in the root zone. Since the majority of roots in drip-irrigated crops are located within the wetting zone, drip applied P will be placed in the soil region containing the highest root density. Therefore, the P applied in this manner is generally used more efficiently by plants than if the same amount of P were surface applied.

Water Quality Considerations

For successful fertigation, careful attention must be given to water quality. The quality of water required depends on several factors, but foremost is the type of fertigation. Drip fertigation requires the highest quality water, i.e., free of suspended solids and microorganisms that plug small orifices in emitters. Only solutions should be used for drip/trickle fertigation. As the orifice size increases, e.g. on sprinkler systems, suspensions can be tolerated.

Precipitation of fertilizers within the irrigation systems can be a very serious problem if solubilities are exceeded. One such problem commonly encountered is with calcium concentrations exceeding about 100 ppm. As calcium concentration increases and phosphates are injected, the probability of precipitation increases. When the water contains very high levels of calcium and magnesium, an injection of ammonium phosphates will result in precipitates deposited on pipe walls as well as in orifices and sprinklers. Often this will completely plug the irrigation system.

If appreciable salts are in the water used for fertigation, one needs to consider the total amount of salts applied to the crop between leaching rains rather than only the amount applied in a single fertigation. Crops vary widely in their tolerance to salts; therefore, the number of irrigations as well as the salt concentration must be considered.

In some areas, high levels of boron (B) in irrigation water is a problem. Some sensitive crops can tolerate only about 1 ppm B. Total irrigation with water containing l ppm B applied to sensitive crops on light textured soils should not exceed 3 acre-inches between leaching rains.

Fertilizers for Injection into Irrigation

Three qualities are necessary for a good source of fertilizer for fertigation: (1) it must contain the needed nutrient elements in a form available to plants or in a form that is readily converted (i.e., urea is readily converted to available NH_4- and NO_3-N forms in good soil conditions); (2) it must be uniformly distributed--either uniformly broadcast for sprinkler, furrow, or flood or uniformly distributed among emitters for drip/trickle; and (3) the chemistry of the application must be such that plants are not burned or stunted and irrigation lines, emitters, or orifices are not restricted or plugged. Considering these limitations, a rather long list of nutrient sources can still be used. In order to provide for the latter two limitations listed, the materials must either be in solution or be in suspension. For drip systems, solution is always needed and only clear liquid should be used.

Nitrogen is the most fertigated element due to high plant nutritional needs, to its great mobility in soil following chemical and biological transformation to NO_3-N, and because of the many soluble sources of N fertilizers available for fertigation. Many forms of N have been used in fertigation. Urea and UAN solutions are probably most commonly used, but most any soluble form of dry fertilizer can be used. Anhydrous ammonia or any other N fertilizer that has free ammonia should not be applied through sprinkler systems.

Phosphoric acid, and ammonium phosphate solutions can be used as sources of phosphorus in drip systems. Ammonium phosphate solutions are subject to precipitation if injected into water with high calcium and/or magnesium concentrations.

Potassium fertigation is usually accomplished with potassium chloride (muriate of potash) due to its solubility and relative low cost per pound of K. For most crops, foliage burns are not a problem due to the great dilutions in irrigation systems. Relatively pure grades of potassium chloride (white, 62% K_2O equivalent) are normally used in fertigation. Potassium nitrate has been used as a source of K and N, and potassium sulfate as a source of K and S. These K sources are less soluble and cost more per pound of K than potassium chloride.

Sulfur, when needed, can also be provided as ammonium thiosulfate, ammonium sulfate or flowable S. It can be readily mixed with UAN and several other soluble fertilizer grades and injected. Magnesium sulfate (Epson salts) is often used to supply Mg and S.

Micronutrients such as iron, zinc, copper, and manganese may (if applied in forms such as sulfates or chlorides) react with salts in the irrigation water and cause precipitation and clogging. However, many of the micronutrients can be applied as chelates - such as iron or zinc EDTA. Chelates are generally highly water soluble and consequently, will cause little clogging or precipitation.

Use Fertigation Properly and According to Regulations

Fertilizer nutrients have the potential of getting into the irrigation water source if proper operating procedures and safety devices are not installed or maintained by the operator. Some states require a permit for fertigation. Be sure you are in compliance with your local regulations.

Reputable fertilizer and chemical dealers should be able to provide the type of equipment shown in Figure 10.3.

Figure 10.3 Safety devices and arrangements for fertigation through an engine powered irrigation system.

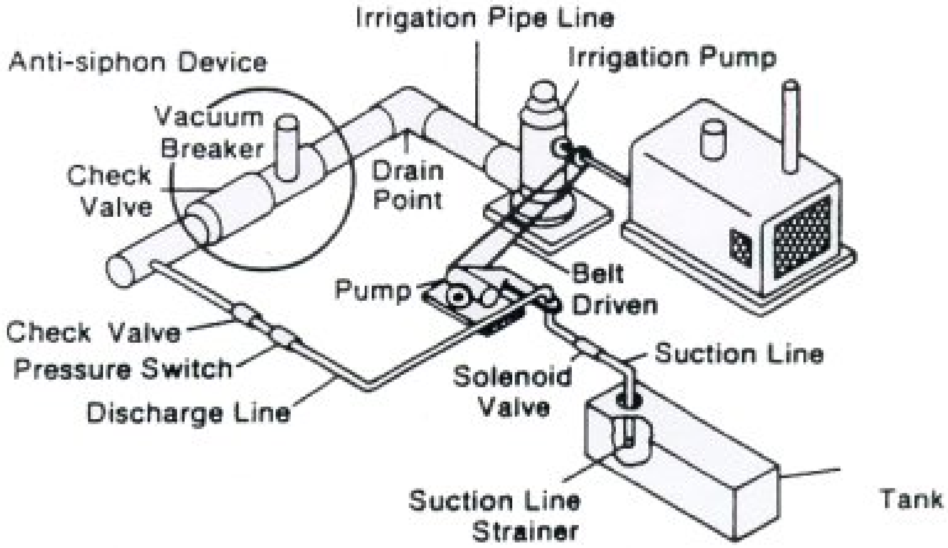


Figure 10.3 shows a recommended layout for direct injection of nutrients into irrigation pipelines. The following components are part of the system:

1. Backflow prevention device (check valve) in water line upstream of fertilizer injection - this prevents reverse flows from the irrigation system down a well or other water source.
2. Vacuum relief valve - prevents a vacuum from forming upstream of the check valve.
3. Backflow prevention device (automatic, quick-closing check valve) in fertilizer feed line - prevents reverse flows of water or fertilizer into the fertilizer storage tank.
4. Normally closed, solenoid-operated valve - located on the intake side of the injection pump to prevent fertilizer flow during irrigation system shutdown.
5. Electrical interlock for injection systems using electric-driven fertilizer pumps - this ensures that the injection pump will shut down if the irrigation pump does.
6. Low pressure drain valve - to drain water from the pipe between the check valve and the water source, including any leakage past the check valve.

Irrigation Scheduling and Fertigation

Successful moisture management calls for applying the right amount of water at the proper time. The amount of water needed will depend principally on the water-holding capacity of the soil, the soil profile depth, and the crop to be grown.

Research has shown that applying N solutions through sprinkler systems on sandy soils gives greater efficiency than from preplant broadcast and sidedress applications (Table 10.1). This also allows the N to be applied at the time the crop needs it. The data in Tables 10.2 and 10.3 illustrate the nutrient uptake of N and K for corn and cotton. Fertilizer applications can be timed with the irrigation to supply nutrients at the most optimum growth stage.

Table 10.1: Effect of Multiple Fertilizer Applications on Irrigated Corn

Fertilizer Schedule	Time of Last Application*	No. of Applications	Relative Yield %
Preplant and two sidedress	8	3	72
Bi-weekly starting at emergence	12	7	100

* Weeks after emergence (Source: F. M. Rhoads, University of Florida, Quincy)

Table 10.2: Percent of Nutrients Taken Up by 180-bu. Corn

Days After Emergence	%Uptake	
	N	K_2O
0-25	8	9
26-50 (silk)	35	44
51-75	31	31
76-100 (grain fill)	2	14
101-125	6	2

Table 10.3: Percent of Nutrients Taken Up by 1 1/2 Bales Cotton at Various Growth Stages

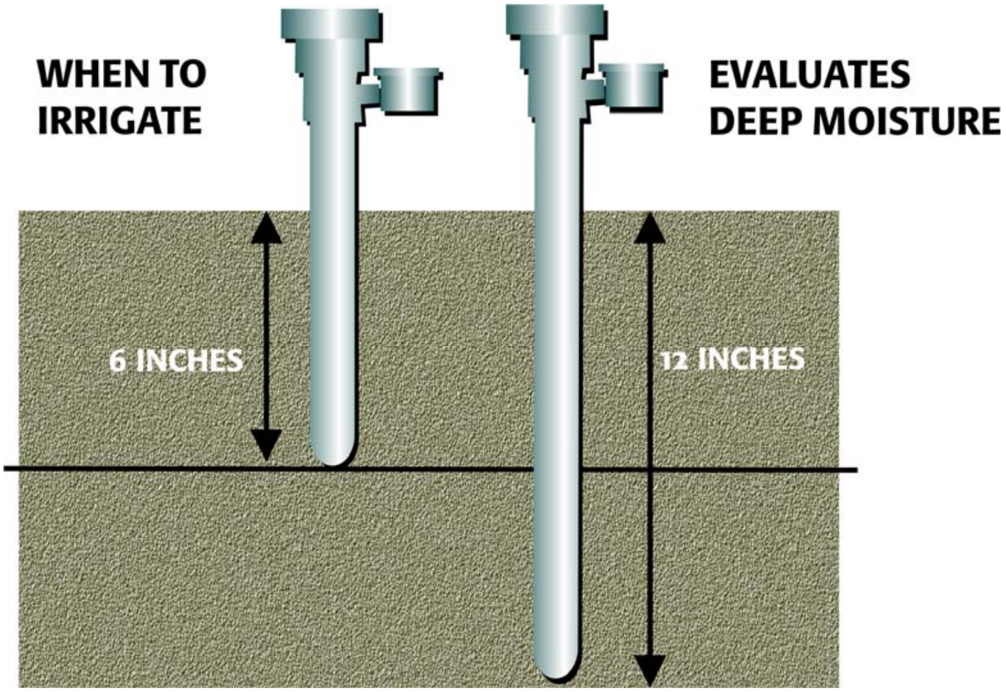
GROWTH STAGE	NITROGEN	POTASH
Seedling	6	5
Early Square	14	19
Early Boll	42	36
To Maturity	38	40

Researchers, using sprinkler irrigation, at the Coastal Plain Experiment Station in Georgia achieved increased N efficiency and highest yields when they applied 25% of the N at planting, 22.5% at the six, 12 and 18 leaf stages and 7.5% at tasseling. This technique generally utilizes conventional application of N at planting and the remainder via fertigation. This method improves N uptake early in the season when root systems are small and require high N. Later in the season, this sequence of applications anticipates N requirements while minimizing the risks of nitrate leaching. Fertigation is also sometimes used to apply supplemental applications of potash, sulfur and certain micronutrients. The need to apply such nutrients should be determined by plant analysis.

Frequency and timing of water application have a major impact on yields and operating costs. For the most efficient use of water it is desirable to frequently determine the soil moisture conditions throughout the root zone of the crop being grown. Two proven practical field methods for measuring soil moisture are tensiometers and electrical resistance meters.

Moisture measuring instruments should be installed at three to five locations in the field. The installation site should be representative of the soil types in the field and should be located so that it is convenient to read them on a daily basis. Figure 10.3 illustrates the installation of tensiometers. Since the tensiometers measure the soil water levels, they must be placed in a manner that accurately reflects what conditions the root system is encountering. One should be placed six inches deep and the other 12 inches deep. The six inch depth tensiometer is used to evaluate when to start irrigating while the twelve inch depth tensiometer is used to evaluate water penetration into the soil profile plus over-or-under watering.

Figure 10.5 Installation of tensiometers in a corn field.



A tensiometer (Figure 10.5) reading of less than 20 centibars indicates that the amount of available moisture in the plow layer is favorable. As the readings become higher, the amount of available water decreases, indicating drier conditions and a need to start irrigating. The response of corn to three selected refill points (readings on the tensiometer) on a loamy fine sand is shown in Table 10.4. The highest yields occurred by irrigating corn when the tensiometer reached 20 centibars.

Figure 10.5 Illustration of a tensiometer.

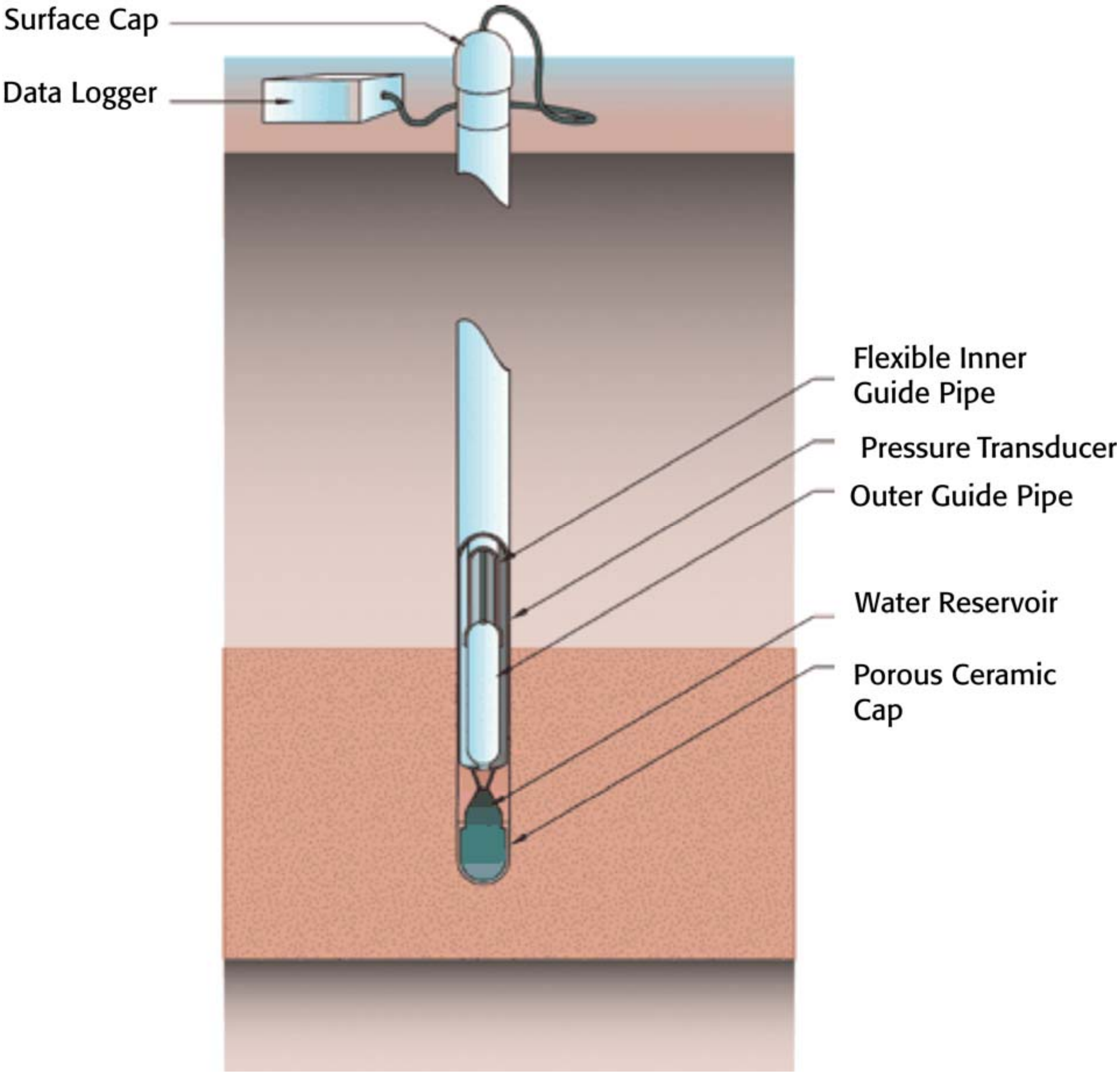


Table 10.4: Grain Yields of Irrigated Corn at Three Selected Soil/Water Refill Levels

Tensiometer Reading When Irrigated	Number of Irrigations	Total Irrigation Water Applied (IN)	YieldBu/A
20	11	8.7	190
40	6	7.1	175
60	4	4.7	160
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Source: The University of Georgia Coastal Plain Experiment Station

The type and size of the irrigation system will also influence scheduling. Center pivot systems that make complete 3600 circles require different schedules than center pivot systems that do not make complete circles. Cable tow systems require altogether different scheduling. Consult with your irrigation equipment supplier to determine the most efficient schedule for a particular system and field situation.

Other Important Factors to Consider when Fertigating

1. Distribution uniformity of the irrigation water is critical for uniform application of the fertilizer.
2. Surface irrigation systems generally produce surface runoff. Make sure that any surface runoff during fertigation is picked up and reused on the field being treated or a similar field that is also being treated. Fertigation may not be suitable on fields that are very susceptible to runoff (i.e. steep slopes and low infiltration rates).
3. Make sure the combination of fertilizers and water will not produce clogging if using a micro-irrigation system.
4. Know how much water is needed to refill the root zone during the irrigation and plan the fertilizer application accordingly. Over-irrigation during fertigation not only wastes water but could result in leaching of the fertilizer below the root zone.
5. The type of injection device is critical depending on the type of irrigation system being used. Some devices will inject at a relatively uniform rate throughout the irrigation, some will not. Be aware of which type is being used and which type is required by the situation.
6. Be aware of the requirements for flushing the irrigation system after fertigation. This may take 10 to 15 minutes. Also run clean water through the injection meter, discharge hose and check valve.
7. Irrigation systems should be monitored much more closely during fertigation, continuously if possible.

8. Under saline conditions, salinity problems can be intensified by fertigation and improper irrigation management. The level of salinity in soil may itself be increased, even temporarily, by fertilizer application as mineral fertilizers are for the most part soluble salts.

Summary

When the advantages of fertigation are exploited and the disadvantages are minimized, fertigation can be a very efficient method of fertilization. Although not an end in itself, fertigation can compliment a good base soil fertility program. An understanding of the types of soil, water quality, appropriate nutrient materials, safety precautions, and cropping systems are all important factors in making fertigation useful and economical.

Links to other sections of the EFFICIENT FERTILIZER USE MANUAL
History • MEY • Soil • pH • Nitrogen • Phosphorus • Potassium • Secondary • Micronutrients • Fluid-Dry • Sampling • Testing • Site-Specific • Tillage • Environment • Appendices • Authors