

Fertigation of Row-crops Using Overhead Irrigation

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Producers are making an increasing number of requests for information on fertigation materials, timing, and rates, especially for center-pivots. This publication will address some of these basic questions and provide a starting point for those who are new to fertigation.

Fertigation vs. foliar-feeding

Fertigation is the application of fertilizer to a crop through an irrigation system. More specifically, it is the application of fertilizer to the soil, through which the crop acquires its nutrients. The soil buffers and stores nutrients, making them available to the crop as needed. Incidentally, some nutrients fall on the crop canopy and a small portion may enter the leaves directly. Foliar-feeding, on the other hand, is the frequent application of small amounts of nutrients directly to the leaves and canopy as the crop needs them using a ground rig or a low-flow irrigation system. Only specific nutrients are suitable for foliar-feeding. Smaller molecules are better able to permeate the leaf's waxy cuticle and can diffuse more rapidly through the leaf. There are also small (less than 1 nm) negatively charged pores in the cuticle. Therefore, positively charged ions (cations) and uncharged molecules diffuse much faster through these pores than negatively charged ions. For row crops, foliar-feeding

can only supply a small portion of the macronutrients (nitrogen, phosphorous and potassium) required by the crop and, therefore, is best used to alleviate micronutrient deficiencies that may develop during the season.

Advantages and limitations

There are several advantages to fertigating row crops as compared to conventional side-dressing of fertilizers using ground equipment. Most importantly, it gives us the ability to apply nutrients at critical periods of crop demand without having to traverse the field thereby reducing compaction and crop damage, saving time and labor, and reducing fuel and equipment costs. However, there are also some disadvantages with fertigation. It may shorten the lifespan of irrigation equipment due to corrosion unless proper cleanout is performed. It may also increase the expense of additional equipment (fertilizer pump, mixing tank, etc.). Producers are more limited on choice of fertilizer materials, and the uniformity of nutrient application is only as good as the uniformity of the irrigation system.

Federal and state laws require fertigators to protect their water source from contamination by using approved safety

devices or approved alternatives. These safety devices include the following:

- Irrigation check valve between well and injection point.
- Injection line check valve at injection point.
- Vacuum relief valve between check valve and well.
- Low pressure cutoff on irrigation line.
- Low pressure drain between well and irrigation check valve.
- Normally closed solenoid valve between injection pump and chemical tank.
- Interlock between injector and irrigation pump panels.

Fertigation materials

Nitrogen

Nitrogen fertilizers add ammonium (NH_4^+), nitrate (NO_3^-), and/or urea ($\text{CO}(\text{NH}_2)_2$) to the soil solution. Soil bacteria contain the urease enzyme that quickly converts urea to ammonium. In addition, soil contains bacteria (*Nitrosomonas* and *Nitrobacter*) that convert ammonium to nitrate within five days of application in soils with pH greater than 6. Young plants require ammonium and produce enzymes to convert nitrate to ammonium in order to make use of it. Seedlings less than 3 weeks old have insufficient quantities of one of these key enzymes (nitrate reductase) and cannot make use of nitrate directly. Nitrate (negatively charged) is easily leached from the soil whereas ammonium (positively charged) can be held by the soil until it is converted to nitrate by microorganisms. Therefore, fertilizers that produce ammonium are more efficient for a young

crop. Later in the season, nitrate-based fertilizers are just as effective but are more prone to leaching.

The three most common nitrogen (N) sources used for fertigation are urea solution, urea ammonium nitrate (UAN) and calcium ammonium nitrate (CAN). Urea (46-0-0) can be purchased as a solution (23-0-0) or you can mix it yourself. Dissolved urea is not as corrosive to irrigation equipment because it has a low salt index. However, urea may burn certain crops if the biuret concentration is greater than 0.3 percent when foliar-applied or greater than 2 percent when soil applied. Biuret is a compound formed during the production of urea. In the past, urea contained about 5 percent biuret. However, now most urea produced in North America contains 1 percent biuret. The biuret concentration is a much greater concern for foliar-feeding of concentrated solutions than for fertigation of much more dilute products. Feed-grade or micro-prill urea, where available, is more easily dissolved and contains less biuret that might burn tissue than does regular urea. Urea ammonium nitrate (32-0-0) is a solution of 45 percent ammonium-nitrate (NH_4NO_3), 35 percent urea, and 25 percent water. UAN is corrosive (high salt index) to irrigation equipment. Calcium ammonium nitrate (17-0-0-8.8 Ca) is more commonly used on horticultural crops with a high calcium requirement. Most of the nitrogen in CAN-17 is readily available to the plant. **Never mix UAN and CAN** — it will produce a white milky precipitate that will plug up nozzles. Also, do not mix concentrated fertilizer solutions with other concentrated fertilizer solutions.

Table 1. Common fertilizer solutions used for fertigation.

Name	Analysis (N-P ₂ O ₅ - K ₂ O)	Density (lb/gal)	Nitrogen conc. (lb N/gal)	Produces	Notes
Urea solution	23-0-0	9.5	2.2	23% ammonium	Non-corrosive, lowers temperature when mixing
Urea-ammonium nitrate solution (UAN-28)	28-0-0	10.7	3.0	21% ammonium 7% nitrate	Corrosive
Urea-ammonium nitrate solution (UAN-32)	32-0-0	11.1	3.5	24.25% ammonium 7.75% nitrate	Corrosive, prone to salting out in cold temperatures
Calcium ammonium nitrate (CAN-17)	17-0-0- 8.8 Ca	12.6	2.1	5.9% ammonium 11.1% nitrate	Corrosive, used for crops with high calcium requirement
Ammonium nitrate solution (AN-20)	20-0-0	10.5	2.1	10% ammonium 10% nitrate	Corrosive, never mix with concentrated sulfuric acid, phosphoric acid or hydrochloric acid.

Purchase "Solution Grade" granular fertilizers whenever possible when mixing it yourself. Many granular fertilizers have coatings either to keep the fertilizer dry during storage or to delay the release of nutrients to the crop. Do not use these fertilizers because the coatings can plug up nozzles.

Phosphorus

Phosphorus (P) fertilizers add orthophosphate ions (H₂PO₄⁻, HPO₄²⁻) to the soil solution. While these forms of P are readily available to plants, they are also easily fixed into forms not available to plants. Orthophosphate can bind with lime (CaCO₃) under high pH conditions (greater than 7) or iron and aluminum under low pH conditions (less than 7), making it insoluble. P is also adsorbed onto soil particles and is relatively immobile in soils. Therefore, only a small portion of fertigated P is likely to penetrate the soil to a depth available to most plant roots. In addition, plants require a majority of P early in the season for root growth and late-applications of P by fertigation are unlikely to have any advantage over preplant applications.

Potassium

Potassium (K) is another nutrient that is often not economical to apply by fertigation.

Potassium ions (K⁺) are resistant to leaching as they cling to soil particles in a form readily available to plants in most soils. If the soil K levels are adequate at planting, there is usually little benefit to fertigating K on most soils, especially for corn or soybean. Although there are reports of increased lint yield and improved fiber quality of cotton under certain conditions from foliar-feeding K with a ground rig, there is little research on fertigating K through an overhead irrigation system. The water application rates of an irrigation system are much higher than a spray rig causing a majority of K to be applied to the soil rather than the canopy. Until additional research is available, we cannot provide recommendations for fertigating K on cotton.

When and How Much to Fertigate

Fertigation gives producers more flexibility in how and when nitrogen is applied to their crop. It is not meant to be a replacement for all broadcast or variable rate soil-applied nitrogen. Producers who are new to fertigation may want to apply a larger percentage of nitrogen at planting or as a side-dress with ground equipment followed with fewer fertigation applications until they determine a balance that works for them. Producers should take into account the characteristics of their soils and the capacity of their equipment.

Amount of Water to Apply

The amount of water to apply at each fertigation event is very important. Insufficient irrigation will leave the fertilizer on or near the surface and prone to runoff or gaseous losses (e.g., ammonia volatilization). Applying too much irrigation at once may cause fertilizer to runoff or move past the rooting zone, making it unavailable to the crop and prone to leaching. Be especially careful to avoid fertigating near or on open waterways, drainage ditches or other bodies of water.

Most center-pivot irrigation systems are designed to apply about 2 inches of water per week (or 3/10 of an inch per 24 hours). At this rate, the risk of driving nutrients down below the root zone is low except on sandy soils. However, ensuring adequate incorporation of nutrients may be a challenge. Therefore, we suggest fertigating with as much water as possible while avoiding runoff on most soil types. Rinsing the irrigation system out after each fertigation event will prevent corrosion and prolong the lifetime of the system.

Corn

For corn, apply up to one half of the total recommended N at planting, accounting for any residual N from previous manure applications or legume. This amount should be applied by ground rig as an ammonium-based fertilizer (urea, ammonium nitrate, anhydrous ammonia, ammonium sulfate) to provide a readily-available source of nitrogen. Fertigate about 60 percent of the remaining recommended N around V6 and the remaining prior to tasseling at 20-30 pounds N per acre per irrigation event. This amount will reduce corrosion of irrigation equipment and risk of clogging.

Cotton

For cotton, we recommend applying 20 percent of total recommended N at pre-plant using a ground rig. Fertigate 50 percent of total recommended N through squaring and the remaining 30 percent no later than early bloom (Lemon, et al. 2009) at a rate of 20-30 pounds N per acre per irrigation event. This rate will reduce corrosion of irrigation equipment and risk of clogging. Applying fertilizer after early bloom may result in excess N at cut-out, which in turn may cause excessive growth, impede defoliation and delay maturation. Cotton is susceptible to burning using certain nitrogen sources. Dissolved urea is the safest because it has low potential for burning.

Soybeans

We do not currently recommend fertigating soybeans. Only a limited amount of nitrogen is required at planting. Once soybeans are nodulated with nitrogen-fixing rhizobium, they begin fixing sufficient amounts of nitrogen. Applying too much N to soybeans early will inhibit nodule formation.

Calculating N Content in Liquid Fertilizer

Suppose you want to apply a less common N formulation (not listed in Table 1) that has an analysis of 30-0-0 (N-P₂O₅-K₂O) and a density of 10.3 pounds per gallon of product.

To determine the amount of N per gallon:
30 percent N (0.30) x 10.3 lb/gal = 3.1 lb N/gal

Calculating Fertilizer Injection Rates

Suppose you want to apply 20 pounds N per acre as UAN-32 through a center pivot. Your center pivot is 1,400 feet from pivot-point to the end of the water throw. You can apply 3/10 inches of water to your field before generating runoff. To do so, your pivot requires 24 hours to make a complete rotation. Here are the basic steps to calculate the injection rate:

1. Determine irrigated area:
 $3.14159 \times (1,400 \text{ ft})^2 = 6,157,520 \text{ ft}^2 \div 43,560 \text{ ft}^2/\text{ac} = 141.36 \text{ ac}$
2. Determine application rate of liquid fertilizer (product):
 $20 \text{ lb N/acre} \div 3.5 \text{ lb N/gal (Table 1 or calculate)} = 5.7 \text{ gal/ac}$
3. Determine minimum tank size:
 $5.7 \text{ gal/ac} \times 141.36 \text{ ac} = 805.8 \text{ gal}$
4. Determine injection rate:
 $805.8 \text{ gal} \div 24 \text{ hr/rotation} = 33.6 \text{ gal/h}$

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