Drip Fertigation: Achieving Uniform Applications

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With the increase use of drip irrigation on the Central Coast, fertigation, the practice of injecting fertilizer through the irrigation system, has become more common. When fertigation is used with drip irrigation, nutrients can be directly supplied to the roots of the plant, and can be spoon-fed at a rate that follows the pattern of uptake of the crop. Because of the ability to deliver nutrients efficiently, fertigation can potentially save fertilizer, improve crop yields, and minimize leaching of nitrate below the root-zone.

To achieve these potential benefits, fertigation applications need to result in an even distribution of fertilizer in the field and in the soil. However, obtaining an even application using fertigation can be challenging under conditions common to Central Coast agriculture. Growers are often managing many small fields with different shapes and sizes, located at varying distances from where fertilizer is injected into the irrigation system, and therefore may not know how much time is needed for the injected fertilizer to travel through the irrigation system of each field. Many growers prefer to irrigate for short intervals which can limit the amount of time available for fertigating. Finally, because the drip systems of some fields do not distribute water uniformly, fertigation applications can also be uneven. The purpose of this article is to discuss some of the key points for attaining uniform applications of nutrients across the field and in the soil using drip fertigation.

Irrigation uniformity and fertigation

Because fertigation relies on water to distribute nutrients to the crop, rather than a tractor rig, the uniformity of the fertilizer application will depend on the uniformity of the drip system. Figure 1 shows that the amount of nitrogen applied along the length of a drip hose is closely related to the amount of water discharged from the emitters. Essentially, where water goes, the fertilizer goes. Drip systems that are not designed or operated to irrigate uniformly will not deliver nutrients evenly to a field. Plugging of the emitters and lateral lines will reduce uniformity and excessive pressure loss or gain along the drip line will also lower the distribution uniformity. Large changes in elevation between the head and tail of the field, using drip tape that is too narrow for the length of the beds, or using submains that are too narrow for the flow rate into the irrigation block can be a cause of uneven pressure in the drip system.

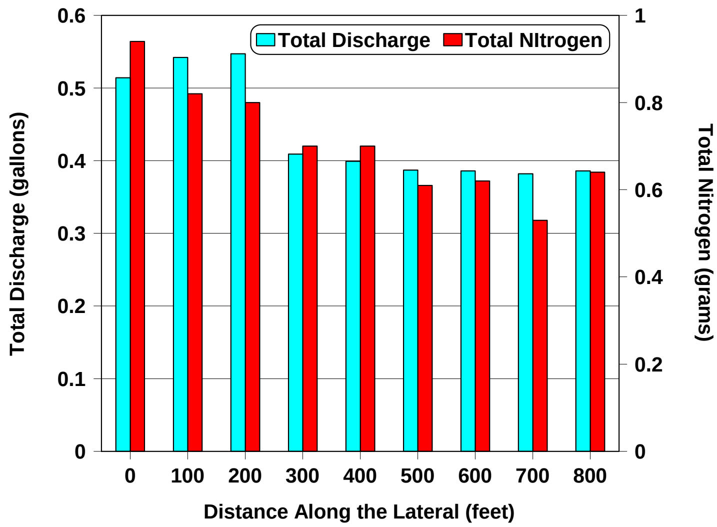

Figure 1. Discharged water and nitrogen fertilizer collected along a drip lateral line (Hanson et al. 1996)

The distribution uniformity (DU) of the drip system should be periodically evaluated to assure that fertigation applications can result in an even distribution of nutrients. Mobile irrigation laboratories and irrigation consultants can perform these evaluations, or they can be conducted on-farm by measuring the discharge rate of the tape at 20 or more locations in the field after the system has pressurized.

The discharge rate of the tape is measured by collecting water during a 10 minute period from individual emitters at locations that represent the head, middle, tail, and sides of the field or irrigation block. The distribution uniformity of the lowest quarter can be calculated from these data by computing the ratio between the average of 25% of the measurements that represent the smallest volumes collected and the average of all the volumes measured. For example, if 20 locations were sampled, the 5 locations with the smallest volume of water would represent the lowest quarter of the field (See Equation below):

$$\textit{Distribution Uniformity of lowest quarter} = \frac{\textit{average of lowest } 25\% \textit{ of volumes measured}}{\textit{average of all volumes measured}}$$

A well designed and maintained drip system can have a DU greater than 0.85 (or 85%). A DU of 0.5 means that 25% of the area of the field received half of the amount of water applied to the whole field, and would also indicate that 25% of the area of the field will receive half of the amount of fertilizer applied to the whole field. This large variation in fertilizer rates within the field could lead to variable growth in the crop and increase nitrate leaching.

Observations on injecting fertilizer

Frequently irrigators who need to fertigate many small fields or blocks will prefer to inject fertilizer quickly so that they can move their injection equipment to the next field. During our workshops on fertigation, participants compare fast and slow injections of equal amounts of fertilizer. They often observe that:

1. Injecting quickly does not move the fertilizer to the tail end of the field any faster than injecting slowly.
2. The injected fertilizer travels rapidly at the head of the field but then moves progressively slower towards the tail end of the field.
3. For both rates of injection, the fertilizer is poorly distributed in the field if not enough time is allowed for the fertilizer to completely flush out of the system.
4. A fast injection can distribute fertilizer as uniformly within a field as a slow injection if sufficient time is allowed to completely flush the tape of fertilizer; however, a slow injection will often distribute fertilizer more uniformly in the soil profile than a fast injection.

The first two observations can be explained by the fact that injected fertilizer moves in the drip lines at a rate dependent on the flow of water, which is determined by the tape discharge rate and the length of the drip lines. Fertilizer will travel fastest in high flow tape and in drip lines that are long (Figure 2). Near the head of the field, the flow rate is highest because there are many emitters discharging water downstream, but the flow rate at the tail of the field is lowest because few emitters are discharging water downstream. Hence, injected fertilizer quickly reaches the middle of the field but progressively slows as it moves towards the tail-end. Figure 2 shows that a majority of the travel time is needed for the injected fertilizer to move through last quarter of the drip line. Ending the irrigation before the fertilizer has reached the end of the line or completely flushed from the drip line will cause the application to be uneven.

Also, because the flow rate of the water stream determines the travel time of an injected chemical, the rate of injection will not affect the uniformity of a fertigation application as long as the irrigation continues for a time sufficient for all the chemicals to be flushed from the drip tape. However, when injecting over a short interval, most of the fertilizer is at the head of the field before it has reached the tail-end. A quick injection, risks leaching a mobile nutrient, such as nitrate, deeper at the head of the field than at the tail end. Injecting slowly would distribute the fertilizer in the soil at the head and tail of the field more similarly than injecting quickly. In addition, injecting during the middle of the irrigation cycle can minimize leaching of nitrate, but enough time must be allowed after the injection for completely flushing the tape.

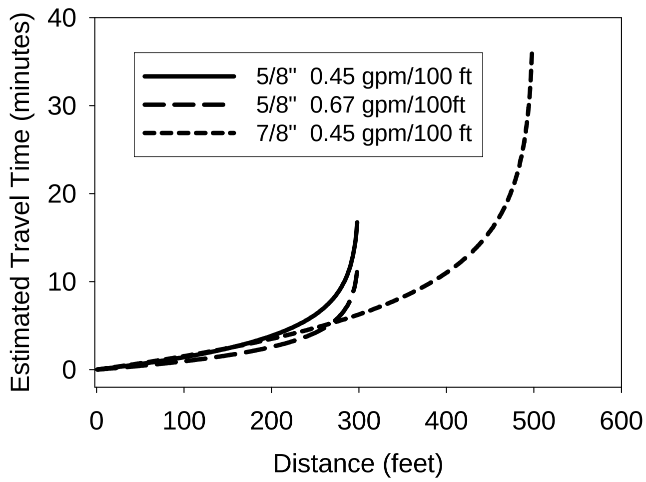

Figure 2. Estimated travel times for the fertilizer injected into drip tape of 5/8 and 7/8 inch diameters.

Rules of thumb for injecting fertilizer

Based on the above observations and discussion, two rules should be followed when fertigating to achieve even applications of fertilizer:

1. After injecting, allow enough time to flush the system completely of fertilizer.
2. For mobile nutrients, such as nitrate, inject as slowly as possible to achieve similar distributions in the soil at the head and at the tail of the field.

Determining travel and flush times

As discussed above, not allowing sufficient time to flush the irrigation system after injecting fertilizer is a common reason for fertigation applications to be uneven. The flush time needs to be at least as long as time for a chemical to travel to the point furthest from the injection site. The travel time can be determined by injecting food dye or bleach for a short period (5 minutes) and then recording the time after starting the injection for the dye or bleach to reach the furthest point in the irrigation system. For example in Figure 3, 50 minutes were required for the dye to travel from the injection point to the tail of the field. If bleach is used in place of dye, chlorine chemical test paper can be used to measure when the level of bleach has increased in the irrigation water. A handheld, electrical conductivity meter can also be used to detect the travel time of many fertilizers because most fertilizers increase the salinity of the water.

The travel time is usually a good estimate of the minimum time needed for flushing the system; however, the actual flush time may be greater than the travel time if there are branches in the main lines or other connections in the irrigation system that could potentially trap some of the injected fertilizer. The flush time can be determined directly by measuring the time for the water to turn clear after the injection of dye ends. Figure 3 illustrates that the flush time is 5 minutes longer (55 minutes) than the travel time.

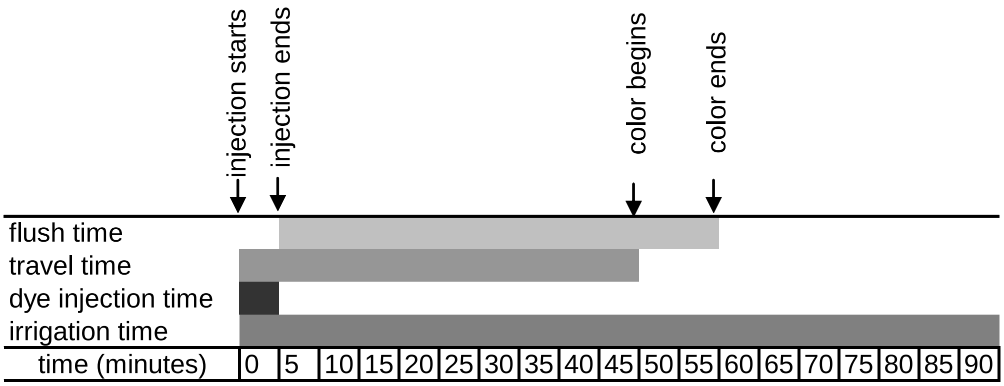

Figure 3. Estimating travel and flush times by injecting colored food dye.

Timing injections

One needs to decide when and how long to inject during an irrigation cycle to optimize the distribution of the fertilizer in the root zone. Figure 4 illustrates how nitrate may distribute in a loam soil when injected at different times in the irrigation cycle. Injecting all the fertilizer early in the irrigation cycle leached nitrate below the roots and injecting at the end of the irrigation cycle did not sufficiently move nitrate into the root zone. Injecting during the middle of the irrigation cycle resulted in the most uniform distribution of nitrate in the root zone. For a well-drained, sand textured soil, fertigating at the end of the irrigation cycle may be the best strategy for minimizing leaching of nitrate. For an immobile nutrient, such as ammonium, injecting earlier in the cycle may produce the best distribution in the soil profile.

For many coastal crops, the injection strategy may depend on the length of the irrigation cycle. Strawberries and lettuce are commonly irrigated for short but frequent intervals. For irrigations of less than 3 hours, injection may need to start soon after the system has pressurized and may need to end after a short period to allow sufficient time for flushing. If the injection time is too short, then it may be necessary to increase the irrigation period on days when fertilizer will be applied.

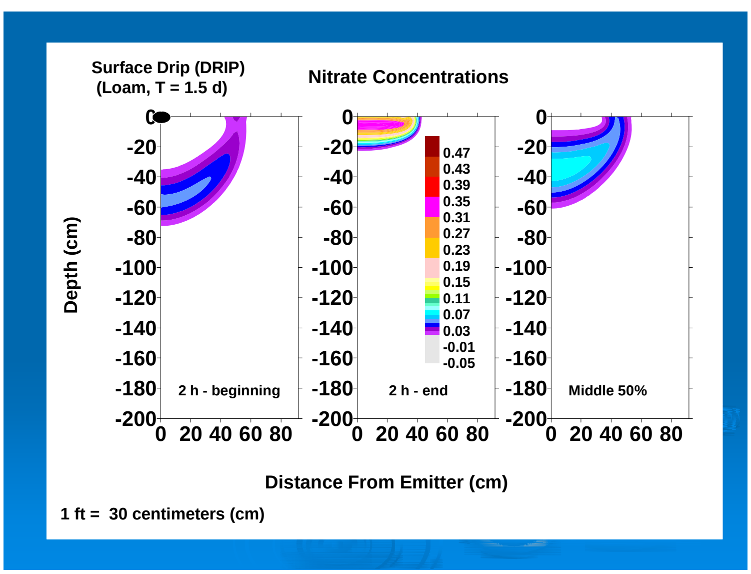

Figure 4. Effect of fertigation timing in the irrigation cycle on nitrate distribution in the soil (Hanson 2004).

Summary

Fertigation can be a useful tool for applying nutrients to drip irrigated crops if steps are taken to assure that applications are uniform. The key points to fertigating uniformily are to 1. check that the drip system has a high distribution uniformity, 2. inject fertilizer slowly during the irrigation cycle, and 3. allow time for the fertilizer to travel to the tail-end of the field and for complete flushing of the system after injecting.