FERTIGATION TECHNIQUES FOR DIFFERENT IRRIGATION METHODS

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Note: The contents of this paper are taken from a new book published in 1995 by the ITRC on behalf of the California Energy Commission. Reference: *Burt, C.M., T. Ruehr, and K. O'Connor. 1995. Fertigation. Irrig. Training and Research Center, Cal Poly, San Luis Obispo, CA 93407. 295 p. ISBN 0-9643634-1-0*

HIGHLIGHTS

- The irrigation method influences whether or not chemicals must be injected at a constant rate.
- The irrigation method influences the optimum duration of chemical injection.
- Chemical injection rates may inadvertently vary during an irrigation set for many reasons: improper mixing, system flow rate fluctuations, and system pressure fluctuations.
- Drip systems must account for the disposal of filter flush water.

CALIFORNIA CONSIDERATIONS

Most of the literature on chemigation originates east of the Rocky Mountains, and because some California irrigation systems are often distinct from Midwestern U.S. irrigation systems, differences in recommendations should be noted. First, many of the eastern studies are done on center pivot irrigation systems. Literature on “sprinkler” chemigation usually means “center pivot sprinkler.” Second, herbicide and pesticide injection are more common through the center pivot systems than through most other types of irrigation systems.

In California, there are relatively few center pivots and therefore herbicide and pesticide injection, which requires foliar applications, is not as common as it is in some other regions. California irrigation systems may require people to be in the fields to move the sprinkler irrigation equipment, thereby creating a health hazard if non-fertilizer chemicals are injected. Second, the majority of California irrigation systems (drip, microspray, furrow, and border strip) are incapable of wetting the leaves, where many pesticides must be applied.

California does have some widespread chemigation situations which are more rare than in other areas. These are:

- Low infiltration, caused by water chemistry (either very pure water or with an imbalance of certain ions in soil or water). (*Chapter 13 of the Fertigation book has details on this problem*)
- Plugging in drip systems, either externally from root intrusion or internally from mineral accumulation or biological growth. (*Chapter 12 of the Fertigation book has details on this problem and solutions*)

MOVING VS. STATIONARY IRRIGATION SYSTEMS

CONTINUOUS MOVE IRRIGATION SYSTEMS – GENERAL

Examples of continuous move irrigation systems are:

- Center pivot sprinklers
- Linear move sprinklers
- Travelers (big sprinklers)
- Furrow
- Border strip

Moving irrigation methods have two special chemigation requirements:

1. Fertilizer injection *must* be done at a *constant rate* to ensure uniform chemical distribution.
2. The rate *must* be calibrated so that the injection continues for exactly *the duration of the irrigation event*.

The "constant rate" requirement for continuously moving sprinkler systems is fairly easy to understand. If the chemical injection rate changes while a linear move travels across a field, chemical application will vary across the field. Additionally, if the injection does not occur throughout the entire irrigation duration, a section of the field will not receive chemicals.

MOVING SYSTEMS – SURFACE IRRIGATION

There are several key rules for effective fertigation with surface irrigation (e.g., furrow and border strip) systems:

1. Irrigate for a high irrigation distribution uniformity. This means the following will occur:
   a. Tailwater will run off, to be collected and reused.
   b. Water will advance to the end of furrows in about half (or less) of the total irrigation time on non-cracking soils.
   c. Different irrigation sets on the same field will be irrigated for the same duration, using the same flow rates.
2. Inject fertilizer into the incoming irrigation water at a constant rate.
3. Inject fertilizer continuously.

The tailwater will have the same fertilizer concentration (ppm) as the irrigation water at the head of the field. Therefore, blending source water with tailwater will not cause problems. This assumes that the flow rate coming onto the field remains constant, and it is not reduced when the tailwater system recycles water.

Some people recommend beginning the fertigation after water advances half way down a furrow. However, this is a very cumbersome procedure once the first set has been completed, because it generally does not account for how the tailwater is handled. Furthermore, if a good irrigation distribution uniformity is achieved, such complex actions are not warranted.

The following points may shed some light on the dynamics of surface irrigation, and how those dynamics influence the rules above, especially the recommendation of injecting chemicals at a constant rate throughout the irrigation set.

1. Time is necessary for water to advance down a border strip or furrow (Figure 1). This is somewhat analogous to a moving center pivot.

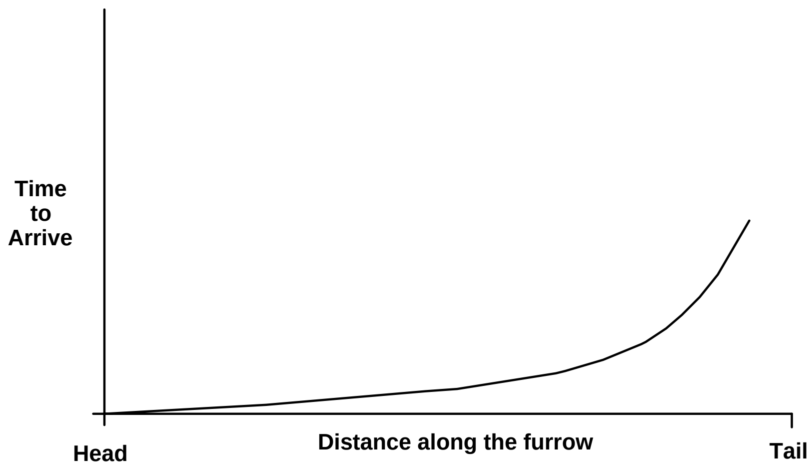

Figure 1. Distance vs. advance time along a hypothetical furrow.

2. The rate of water infiltration into the soil at a point varies with time. This is shown in Figure 2.

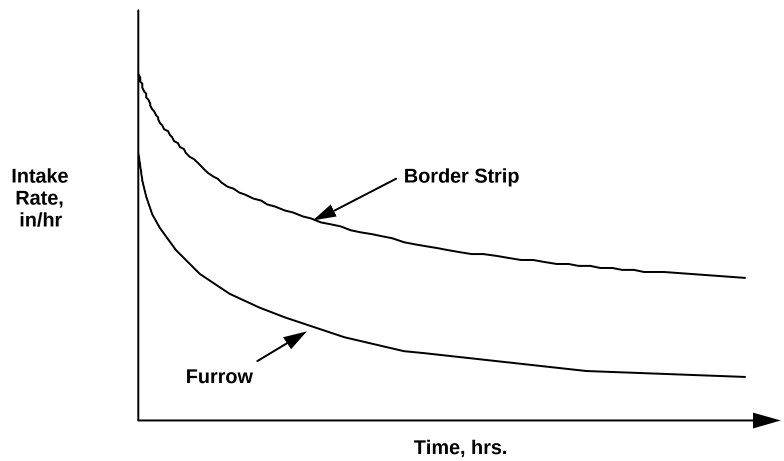

Figure 2. Infiltration rates decrease over time at a point along a furrow or border strip.

3. The concepts of unsteady (i.e., something which changes with time) advance and unsteady infiltration for furrows are combined in Figure 3.

4.

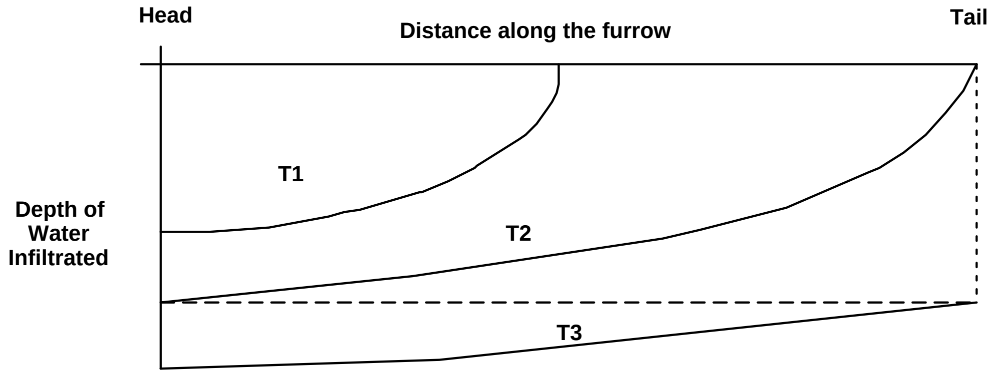

Figure 3. Depths of water infiltrated at various distances along a furrow at three times (T1, T2, and T3). T3 = 2 ¥ T2. The dashed horizontal line indicates the depth of water needed if perfect irrigation scheduling occurred. Assumes a uniform soil.

Figure 3 shows that in a furrow with runoff (tailwater), more water always infiltrates at the head end than at the tail end. It is theoretically possible to reduce deep percolation of chemicals at the head end of furrows if one waits until the water has advanced about one-third of the distance down the furrow before beginning chemical injection. However, furrow and border strip management for a high Distribution Uniformity (DU) generally requires the existence of tailwater runoff, and the subsequent recycling of that tailwater. The tailwater will have the same concentration of chemical as the irrigation water itself. When one considers tailwater management schemes which are simple, one generally finds that it is impractical to withhold chemical injection during the first third of the advance phase of furrows, because tailwater is often used as part of the water source at that time. Instead, the key is to minimize the deep percolation of both water and fertilizer by having a good DU and the proper irrigation set duration.

STATIONARY IRRIGATION SYSTEMS

Stationary irrigation methods include:

- Hand move sprinklers (during a single set)
- Permanent undertree sprinklers (during a single set)
- Microirrigation (during a single set)

Fertigation with stationary irrigation methods is quite simple if the fertigation begins and ends within a single set. A *quantity* of fertilizer is applied to a set (i.e., an area). With stationary irrigation methods, one must consider two injection characteristics pertaining to uniformity:

1. Spatial uniformity (i.e., point-to-point) of fertilizer application within a set. If fertilizers are well mixed with the irrigation water, the fertilizer will be applied with the same uniformity as is the irrigation water.
2. Time uniformity of fertilizer application rate within a set. As long as all of the fertilizer is applied during that set, the fertilizer spatial variation does not depend on fertilizer injection *rate* variation.

The injection process is repeated for every set, until the whole field has been fertigated.

Fertigation can be accomplished continuously (as opposed to beginning and completing discrete fertigations for each irrigation set) on stationary irrigation systems having multiple sets, if *all* of the following conditions are met:

1. Fertilizer injection rate is constant.
2. Irrigation durations are the same for each set.
3. Each set has the same acreage.
4. Each set has the same total flow rate.

If these conditions are not met, and continuous fertigation occurs from set to set, different sets will receive different amounts of fertilizer, when measured as pounds per acre.

VARIATIONS IN CHEMICAL INJECTION CONCENTRATIONS WITH TIME

There are three general reasons why chemical concentrations in the irrigation water will vary with time:

1. Improper mixing/agitation of the chemical in the holding tank. This is especially important with solid fertilizers.
2. The injection hardware changes the injection rate with time.
   a. Differential pressure tanks start injection at a high rate, and end with a low rate of chemical injection (although the rate of fluid flow through the tanks remains constant).
   b. Diaphragm pumps may vary their discharge if the irrigation line pressure changes. The irrigation pump discharge pressure will change as center pivots move up- or downhill, or as new irrigation blocks are started with different distances or elevations from the irrigation pump.
   c. Venturi devices will have a change in suction pressure if the flow rate through them changes with time.
   d. Some gravity feed injection systems may vary their rate as the fertilizer tank empties.
   e. Suction screens on the injection devices may become dirty with time, and the chemical flow rate will be reduced.
3. The irrigation flow rate changes with time.
   a. Different irrigation sets may irrigate different acreage, with a different number of sprinklers or emitters per set.
   b. Elevation changes of a moving sprinkler irrigation system may result in different flow rates with time.
   c. Center pivot irrigation systems have different flow rates as end guns and corner units are activated and deactivated.
   d. Pipeline systems which are interconnected on a farm, and receive water from several sources and/or supply water to different fields, are notorious for wide pressure (and flow rate) fluctuations at outlets. This problem is especially severe for low pressure systems such as furrows and border strips which are supplied by such pipelines.

Acids and chlorine are typically injected into drip irrigation systems to prevent or clean out plugged lines. Chlorine is injected at a constant ppm rate, and acid is injected to maintain a constant pH. In both cases, the chemical must be injected at a constant proportional rate to achieve the desired result. Chlorine is generally injected through a gas chlorine injection system capable of constant rates.

Pesticides must be injected according to label requirements and generally require a specific concentration (i.e., constant chemical injection rate).

Consequences of not injecting these compounds at a constant rate include plant damage due to pH fluctuations or to toxic levels of chemical applications.

CENTRALIZED VS. MOBILE INJECTION UNITS

Traditional fertigation discussions assume a stationary, centralized injection system. However, some growers use a mobile unit to fertigate fields which have many small blocks. This is particularly popular for vegetable fields in which blocks may be planted in intervals of several days or weeks, and for orchards with many different blocks of tree varieties.

If a drip system supplies a number of fields, it is often best to use a mobile unit, sometimes in conjunction with a central injection system. There are two types of "mobile" units:

1. An injector pump and chemical tank mounted on a trailer.
2. An injector pump and portable tank/stand.

A central injection system can be used for water pH control and chlorine injection. Gas chlorinators, for instance, should be located behind a locked, chain link fence. The mobile unit would be used for fertigation. Mobile fertigation units allow one to customize fertigation according to the soil, planting date, and crop type within each block.

Another factor in selecting mobile units is the possibility of some fertilizers gravitating to the bottom of long irrigation pipelines, thus not distributing evenly at the various irrigation outlets. This does not appear to be a problem with smaller irrigation systems, but long mainlines may create such a problem. It is probable that poor mixing at the injector, plus high fertilizer dosages, accentuate the problem. Limited work at the Cal Poly ITRC has not been able to duplicate this problem, although it has been reported by a few growers. More research needs to be done to verify whether or not this is a significant problem.

If mobile units are used with drip systems, the injection points must be designed so that dirt does not enter into the drip system when the hose is connected. It may be necessary to have a second tank of rinse water on the trailer to be able to spray off fittings, thereby preventing this problem. Also, because the injection occurs downstream of the drip system filters, it is important to have a 120 mesh filter on the injection hose so that the drip system is not contaminated by dirt from the fertilizer tank.

CONTINUOUS VS. NON-CONTINUOUS INJECTION

There are two different practices used by growers regarding when to start and stop injecting fertilizers during an irrigation set in a stationary system. These are:

1. Only fertigate during the middle half of the irrigation set (quarter-half-quarter rule).
2. Fertigate continuously at a constant rate.

The quarter-half-quarter rule is justified as follows:

1. By waiting until the irrigation is one quarter completed, it is assured that the system is up to normal operation pressure and the water is being applied uniformly.
2. By not injecting fertilizers during the last quarter of an irrigation set, any remaining chemicals are flushed from the system.

The quarter-half-quarter rule is necessary if occasional, large dosages of chemicals or especially corrosive materials are applied. Obviously, such conditions could cause damage to fittings and emitters if there was prolonged contact with the chemical. In such a case, it is important to go one step further than the simple rule of "shutting off with one quarter time left". One must verify that the quarter time is sufficient to cleanse the system. The next section, dealing with chemical travel time computations, is helpful in this regard. For mobile injection units, this is particularly important because the dosages tend to be relatively high.

Growers who "spoon-feed" their crops by continuously injecting small dosages of fertilizers (a highly recommended practice) generally do not have to worry about flushing the lines because the chemical concentrations are so low they do not damage fittings and emitters.

For the non-continuous injection practices, it is important that the chemical be injected long enough to reach the last emission point (on sprinkler and drip systems). The irrigation duration must then be long enough to flush completely that last emission point. Knowledge of the chemical travel time in pipelines is important.