# Improving Nutrient Application Uniformity of Water-Run Fertilizers

Larry Schwankl, UCCE Irrigation Specialist, UC Kearney Ag Center
9240 Riverbend Ave., Parlier, CA 93648
Ph. (559) 646-6500, ljschwankl@uckac.edu

Carol Frate, UCCE Farm Advisor, Tulare County, 4437 S. Laspina St.
Suite B, Tulare, CA 93274
Ph. (559) 685-3309 ext. 214, cafrate@ucdavis.edu

**Introduction**

Injection of fertilizers, particularly nitrogen, in flood irrigation (furrow and border check) systems is common in California, and it is often the only practical method of fertilizer application during the mid- to late-season. Both commercial fertilizers and dairy manure water are used as water-run fertilizers in the California Central Valley. Applying a pre-determined amount of fertilizer is more easily done with commercial fertilizer since its formulation is known. The nutrient content of dairy manure water is often unknown unless sampling has been on going or a “quick test” analysis is done at the time of irrigation.

The non-uniformity of the irrigation applications is an added complication for using water-run fertilizers in flood irrigation systems. The water intake opportunity times, and therefore the infiltrated water, vary along the field due to the time it takes water to advance down the field. Frequently, and especially in furrow systems, the infiltrated water is greatest at the head of the field and decreases down the field length. Conversely, if a large amount of water is allowed to stand at the end of the field following irrigation, usually the result of allowing the irrigation water to run too long, the tail of the field may receive the greatest infiltrated water. The infiltrated water non-uniformity may lead to nutrient application non-uniformity if the nutrient, e.g. nitrates and ammonium, infiltrates with the irrigation water.

Adjusting the injection rate commonly controls the water-run fertilizer applied during irrigation. This is more easily done using commercial fertilizers as compared to dairy manure water. The method of manure water injection is often a floating pump or a pump on the edge of the dairy lagoon that adds manure water to the low-head flood irrigation system. These pumps are often sized fairly large to provide adequate capacity to lower the lagoon. The injection rate of manure water can be controlled with a valve downstream of the pump. This is often incompatible with the large manure pumps and large pipelines, designed for high flow rates that dairies currently have. Running small flow rates of manure water through large pipelines can result in settling and clogging of the pipeline. In addition, the pumping efficiency of a large pump is decreased when it is forced to operate at a small flow rate. Growers often choose to operate the manure water pump at full capacity during the entire irrigation event, resulting in an over-application of nutrients along with nutrient application non-uniformity. Unfortunately, diary manure water is still often considered a waste to dispose of rather than a useful fertilizer resource.

**Improving Nutrient Application Uniformity**

Improvement of flood irrigation application uniformity is one approach to improving the uniformity of nutrient applications. Various management techniques, such as furrow torpedoes (Schwankl et al., 1992), surge irrigation (Hanson et al., 1998), and flow rate modification, may result in some improvement in application uniformity. Shortening field lengths, which reduces the difference in intake opportunity times between the top and bottom of the field, is the most effective way of improving irrigation uniformity (Schwankl and Frate, 2004). Shortening field lengths is expensive and inconvenient for growers and is seldom adopted.

Another potential management method of improving nutrient application uniformity is to adjust the timing of nutrient injection during an irrigation event. This strategy of changing the timing of manure water additions hinges on infiltration characteristics varying during irrigation. The infiltration rate is high when water first contacts a dry soil location and then decreases until a final, relatively constant, intake rate is reached. Delaying fertilizer injection until the upper portions of the field have reached the lower, final infiltration rate offsets the effects of the longer water intake opportunity times at the head of the field.

**Field Project**

Due to the importance of dairy nutrient management, manure water additions to irrigation events were selected as the water-run fertilizer scenario for evaluation. A field project on a Tulare County dairy was conducted during the summers of 2001 and 2002 to evaluate techniques for improving the irrigation and nutrient management of flood irrigation systems applying manure water. Improved irrigation systems should apply water (and water-run nutrients) more evenly on the field and allow the application of the correct amount of water to match crop water demands. Manipulating the timing of manure water additions to the fresh irrigation water was evaluated, along with a number of irrigation water management strategies, to determine if they could improve the nutrient application using a furrow irrigation system.

Multiple irrigation events at the Tulare County commercial dairy were evaluated. For an initial visual evaluation, a tracer (sulfur fertilizer) was added to the irrigation water at various delayed times during the irrigation event. The sulfur fertilizer tracer turned the irrigation water milky in appearance and could be visually tracked as it moved down the furrow. The sulfur fertilizer was not used as a tracer of infiltrated nutrients into the soil profile. From monitoring the tracer, it became evident that nutrient additions to the irrigation water could begin quite late in the irrigation set and still have time to advance to the end of the field before the end of the irrigation set.

From the sulfur fertilizer tracer tests, it was determined that addition of manure would start when clean irrigation water had advanced approximately 900 feet along the 1200-foot long field. This resulted in the advancing front of the manure water / freshwater mix catching the advancing front of the freshwater at the 1050 foot furrow distance. It took the clean irrigation water 4 to 5 hours to advance to 1050', but it took the delayed manure water-advancing front less than an hour to reach the 1050' mark.

Water samples were collected at frequent time intervals (e.g. 15 minutes but sometimes modified to more accurately measure any water quality changes) and at multiple locations along the furrow. These water samples traced the movement of the manure water along the furrow and provided the spatial and temporal distribution of water quality during the irrigation event.

RBC flumes were placed in furrows to monitor furrow flow rate. The field was surveyed and its slope was determined. Advance / recession measurements were also gathered. The results from the irrigation evaluation were used to provide inputs to a two-point Volume Balance furrow irrigation model (Walker and Skogerboe, 1987) used to determine infiltrated water amounts along the furrow and to determine the irrigation uniformity.

As described below, the results of delaying additions of manure water to the irrigation water during an irrigation event were very promising. By delaying addition of manure water to irrigation water, not only could a lesser amount of nutrient be applied using the existing manure water application equipment, but also the nutrients could be applied more uniformly.

**Water quality**

The fresh irrigation water / manure water mix used for irrigation had approximately 100 mg/l ammonium and 150 mg/l total nitrogen. For example, nitrogen samples taken 30 minutes after manure water traveled 900 ft. along the field recorded the following $NH_4$-N (mg/l) / Total Nitrogen (mg/l) levels: Head of field – 101/ 155, 300' along field – 106 / 155, 600' along field – 107 / 131, and at 900' along field – 101 / 139. There was little change in ammonium content and a slight change in total nitrogen of the water along the furrow. As is common with dairy manure waters, there was no nitrate in the manure water because dairy manure ponds are most often anaerobic. The manure water used for irrigation was relatively low in solids since the dairy had a solids separator and a multi-pond manure handling system.

For this manure water, the majority of the nitrogen nutrients were tied up in the ammonium form and in the organic form as small particles in suspension. The constant nitrogen content of the irrigation water along the furrow may not hold for manure water high in large particles that settle out at the head of the field. In such a case, it is possible that the organic nitrogen content of the water would decrease more significantly as it moves down the furrow.

**Infiltration and Irrigation Uniformity**

An early-season irrigation event following cultivation was monitored. Water advanced across the field in approximately 5.5 hours. The average irrigation depth applied was 7.1 inches with irrigation distribution uniformity of 64% (Table 1). As with many dairies in Tulare County, the irrigation system was operated to minimize tailwater runoff. Therefore, once water advanced to the end of the field, it was allowed to run only a short period of time before the irrigation set was switched. This resulted in the top end of the field receiving substantially more infiltrated water than the tail end of the field. For the monitored irrigation event, the head of the field received approximately 9.4 inches of infiltrated water while the tail of the field received approximately 3.1 inches.

If manure water had been added to the irrigation flows during the entire irrigation event, the uniformity of nitrogen application would have been the same as the water application uniformity – 64%. The top end of the field would have received significantly more nitrogen than the tail of the field. Adding manure water during the entire irrigation event would have resulted in the field receiving an average of 242 lbs. of nitrogen per acre (Table 1).

When manure water was added to the irrigation water after freshwater had advanced 900' along the furrow, the manure water application uniformity was increased from 64% to 69%. At least as importantly though, the average nitrogen application to the field was reduced from 242 lbs/acre to 86 lbs/acre (Table 1). A major challenge for dairies injecting manure water is applying too many nutrients during an irrigation event. When injecting during the entire irrigation event, the manure water injections could be "valved back" to reduce the injection rate. Injecting during only the latter stages of the irrigation event would achieve the same lowered nutrient application while improving the nutrient application uniformity.

Table 1. Irrigation evaluation results of various manure water irrigation strategies. Field is furrow irrigated and 1200 ft. long.

| Nutrient Application Strategy | Avg. Irrigation Amount (in.) | Irrigation Uniformity (DU - %) | Avg. Manure Water Infiltrated (in) | Manure Water Uniformity (DU - %) | Nitrogen Applied (lbs/ac) |
|---|---|---|---|---|---|
| Manure water added during entire irrigation | 7.1 | 64 | 7.1 | 64 | 242 |
| Manure water started when freshwater advance = 900'. Shut-off when advanced to end of field. | 7.1 | 64 | 2.5 | 69 | 86 |
| Simulation 1: Manure water started when freshwater advance = 900'. Shut-off = end of field advance + 1 hr. | 7.6 | 70 | 3.0 | 69 | 102 |
| Simulation 2: Manure water started when freshwater advance = 1000'. Shut-off when advanced to end of field. | 7.1 | 64 | 0.9 | 91 | 31 |
| Simulation 3: Manure water started when freshwater advance = 1000'. Shut-off = end of field advance + 1 hr. | 7.6 | 70 | 1.4 | 88 | 49 |

With the field data available for model verification, simulations of other irrigation and manure timing strategies were investigated using a two-point Volume Balance Model. They included:

**Simulation 1:**
Manure water additions began when freshwater reached 900 ft. along the furrow. Irrigation water was shut off one hour after it reached the end of the field. This strategy would result in nutrient application uniformity nearly the same as the irrigation uniformity (69% vs. 70% - Table 1), but the average nitrogen application amount is reduced from 242 lbs/acre for the continuous manure water addition strategy to 102 lbs/acre for this delayed manure water addition practice.

**Simulation 2:**
Freshwater was allowed to advance 1000 ft. along the furrow before manure water was added to the irrigation water. The irrigation supply was shut off shortly after water reaches the end of the field. The result of this practice would be a small amount of nitrogen (31 lbs/acre) applied to the field and it is applied very uniformly (DU = 91%). This would be a good strategy if frequent, small applications of nitrogen were desired.

**Simulation 3:**
In this delayed manure water addition strategy, manure water was added to the irrigation water after freshwater has advanced to 1000 ft. Irrigation is allowed to continue for 1 hour after water advances to

the end of the field. This strategy would allow the application of a limited amount of nitrogen to the field (49 lbs/acre) while applying it with a high uniformity (88%). Of all the strategies evaluated, this would be preferable since it increases both the irrigation and nutrient application uniformities (see Table 1) compared to adding manure water during the entire irrigation event stopped when water reaches the end of the field.

**Summary**

Delayed addition of manure water holds promise as a means of improving nutrient application uniformity and of applying less nitrogen during an irrigation while still using existing high flow rate manure water pumps and pipelines. Two disadvantages of delaying manure water applications are that there is a delay once manure water pumps are turned on until manure water reaches the irrigated field. For the field evaluated in this study, that delay was approximately 20 minutes. Secondly, it is quite common for dairies to be irrigating multiple fields at the same time, often at different locations on the dairy and utilizing complex piping systems, to deliver the water. This makes delayed manure water additions, as well as any form of manure water nutrient management, a complex and sophisticated task.

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