IRRIGATION EFFECTS ON N AVAILABILITY

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ABSTRACT

Irrigation is necessary for crop production in the western US where the climate ranges from Mediterranean to desert conditions. Management of irrigation can potentially have large effects on crop available N because nitrate-N readily moves with water and because soil moisture affects root activity and the uptake of N. Additionally, fertigation is commonly used to supply N to crops though the irrigation system. More efficient use of N can be achieved by assuring that an irrigation system has a high application uniformity, and by scheduling irrigations to match crop water needs so that nitrate leaching losses are minimized. Irrigation systems with a high application uniformity will also assure that chemigated fertilizer is uniformly distributed to a crop. Using weather and soil-based approaches, adjustments in irrigation amount and timing can be made during the season to minimize deep percolation. In many cases the amount of water used for the establishing new plantings of vegetable and row crops can be reduced without adversely affecting crop yield. Leaching fractions, applied to mitigate the buildup of salts in the root zone, should be appropriate for the salinity of the irrigation water and the salt sensitivity of the crop.

INTRODUCTION

The production of most horticultural and agronomic crops in the western US requires supplemental irrigation to maximize production. Because the predominant form of plant available N in cultivated soils is nitrate (NO_3), which moves readily with water, irrigation management strongly influence crop N use efficiency. Over-applying water will cause NO_3 to leach beyond the root zone of a crop, and can potentially contaminate ground water and surface water where tile drainage or surface run-off is present. Inadequate soil moisture can reduce root activity and crop uptake of N. Additionally, growers often supply nutrients to their crops by injecting fertilizer through their irrigation systems. Irrigation systems with poor application uniformity not only can lead to an uneven distribution of soil moisture but also can result in uneven applications of N fertilizer.

Improving water management can increase crop N use efficiency, save on fertilizer costs, and lessen water quality impacts. Maximizing the performance of an irrigation system and scheduling irrigations to closely match crop water needs are the key strategies to improving irrigation efficiency.

Improving application uniformity of irrigation systems

One of the strategies to improving irrigation efficiency is to assure that the irrigation system evenly distributes water to all areas of a field. The less evenly an irrigation system applies water, the longer the irrigation system must be operated and more water must be applied to assure adequate soil moisture in all areas of a field. Nitrate-N may leach beyond crop roots in areas that become oversaturated and crop growth will suffer in areas that do not receive adequate amounts of water.

The application uniformity of an irrigation system, also referred to as the *distribution uniformity,* can be assessed by comparing the average depth of water applied in a field with average depth of water applied to the area representing the driest 25% of the field area. A distribution uniformity (DU) with a value of 100% represents an irrigation system that applies water with maximum uniformly. Irrigation applications that result in DU values below 60% are considered very uneven. Between 2009 and 2016 we evaluated the DU of 109 irrigation systems used to produce commercial strawberries, caneberries, vegetables, grapes, and tree crops on the Central Coast of California. Average DU of the drip irrigated fields was 79%, which ranged from a maximum uniformity of 96% and minimum of 23% (Table 1). Average DU of sprinkler-irrigated fields was 71% and ranged from a maximum uniformity of 86% and minimum of 52%.

Table 1. Distribution uniformity of 109 irrigation systems in commercial fields on the central coast of California.

		Distribution Uniformity			
Irrigation method	# of fields	Mean	Median	Maximum	Minimum
		------------------- % DU_{lq} ----------------			
Drip	91	79	82	96	23
Sprinkler	18	71	73	86	52

Numerous factors limited the uniformity of the drip systems evaluated, including maintenance issues such as plugging of drip emitters, inadequate filtration, and leaks. However, poor pressure control was a major cause of low uniformity in many drip systems evaluated in vegetable and row crops. Most types of drip tape used for vegetables and row crops are affected by pressure, discharging more water under higher pressure and less under lower pressure. Because drip systems are generally operated near 10 psi, small differences in pressure along drip lines can result in uneven applications of water. Pressure variation measured within an irrigation block can be caused by a variety of factors. In some of the fields evaluated the diameter of the submains was not large enough to accommodate the flow of water, and resulted in a reduction in pressure towards the end of the submains. In other fields, the rows were too long, which causes excessive pressure loss along the length of the drip lines. Blocks that used multiple valves to connect the submains to the main line were often set to different pressures. Also, pressure of irrigation blocks commonly varied during the irrigation set when valves were opened or closed in other irrigation blocks. In some fields application uniformity was poor because the irrigation blocks were operated at very low pressures (< 5 psi). Elevation differences also caused pressure variation in drip lines. Drip systems located on fields with slopes greater than 5% usually had reduced application uniformity.

Pressure variation can be minimized in drip systems through proper design and management. Professional designers should be consulted to assure that a drip system is designed to minimize pressure losses and maximize uniformity. Pressure regulating valves should be used to maintain a consistent pressure in irrigation blocks and to counteract fluctuations in mainline pressure.

Similar to drip, poor application uniformity in sprinklers was usually related to problems with design, pressure management, and maintenance. Spacing sprinkler heads too far apart did not provide adequate spray overlap and reduced application uniformity. Long lateral pipes resulted in excessive pressure loss and less water applied at the far end of fields. Operating too many sprinklers simultaneously resulted in insufficient pressure and poor uniformity. Different sized nozzles or a mixture of different sprinkler head models resulted uneven application rates. Leaks in aluminum pipes often contributed to run-off observed in furrows. Inadequate flushing of the sprinkler lateral lines also led to the clogging of sprinkler nozzles. Wind was another factor that limited the uniformity of overhead sprinklers. Uniformity of most sprinklers dramatically drops when wind speeds rise above 5 mph.

A key part of efficient irrigation is implementing an effective maintenance program. Irrigators should regularly check and clean filters, flush drip lines, fix broken sprinkler heads, and repair leaks. Irrigators should be trained on how to properly take pressure readings and adjust the submain pressure. Installing Schrader valves at different locations on an irrigation system can allow irrigators to quickly determine if the pressure needs to be adjusted. Finally, maintenance records need to be updated regularly to assure that an irrigation system is being properly maintained.

Scheduling irrigations

Applying the right amount of water to match the requirements of the crop can minimize run-off and leaching losses of NO_3. The amount of water needed by most crops is primary related to weather conditions and the development stage of the crop. Evapotranspiration (ET) data and crop coefficients can be used to estimate water needs of most crops. Daily reference ET (ET_0) data are available in most western states from online systems such as the California Irrigation Management and Information System (CIMIS) in California or AZMET in Arizona. A number of publications outline the steps in developing irrigation schedules from ET_0 data. Additionally, several free online tools are available to assist with estimating crop water needs using ET_0 data, including CropManage (UCANR), Wateright (Fresno State University), Irrigation Scheduler (Washington State University) and Irrigation Management Online (Oregon State University).

The appropriate irrigation interval will be influenced by the water holding capacity of the soil, rooting depth, and water demand of the crop. A crop grown on a sandy textured soil with a low water holding capacity will need more frequent irrigation than a crop grown on a clay loam textured soil with a high water holding capacity. Water needs are often low during the early stages of a crop, when canopy cover is still small, and therefore, less frequent irrigations may be needed compare to during mid and late season when the canopy cover reaches maximum size.

Monitoring soil moisture can help verify that irrigations are keeping up with the water demand of a crop, and identify areas of the field that may be exceptionally dry or wet. Both soil moisture sensors as well as probing the soil with a hand tool can be helpful. Tension-based soil moisture sensors such as tensiometers and resistance blocks are most often used for scheduling irrigations in vegetables and berries. Soil moisture tensions significantly greater than 30 centibars (30 kPa) are considered high for most leafy green vegetables and strawberries and may lead to reduced growth and yield. Other vegetables, such as processing tomatoes and deep rooted cole crops may tolerate tensions higher than 60 cbars midseason without yield loss.

Volumetric soil moisture sensors are frequently used in grape and tree crops, which tend to be deep rooted and can often tolerate significant deficits in soil moisture in the upper layer of the soil.

Watering for efficient crop N use during the season

Water and N status of a crop change throughout the season, and should be considered together at each stage of development to minimize nitrate leaching losses. Water and N requirements of most vegetables and row crops are low at the beginning of the season, so over applying water and/or N fertilizer can result in significant leaching losses of nitrate. As crop water and N requirements increase during the season, application rates need to be adjusted appropriately.

Preplant irrigation: Applying water before planting is often necessary to create optimal soil moisture conditions for tillage and bed shaping. Applying an appropriate amount of water can prevent leaching of residual soil nitrate. Often less water can be applied if rains have recently saturated the soil profile. Checking soil moisture can help determine if pre-plant water can be reduced.

Stand establishment: Though sufficient moisture is needed to establish a crop of uniform size and population, over irrigating will leach soil nitrate. After the first establishment irrigation, the amount of water applied for subsequent irrigations should be appropriate to maintain uniform moisture in the field. Because water losses are due to evaporation from the soil surface, the amount of water needed will be closely related to the reference ET. Irrigating more frequently, but for short periods, may better match applied water with ET demand than applying water less frequently but for long periods. Frequently checking soil moisture at the depth of transplant roots or seed can provide guidance on the amount of water and timing of irrigations.

Post establishment: Leaching losses of nitrate can be high just after the crop is established. This is because crop ET requirement is still low, and roots are still relatively shallow. In addition, soil nitrate levels are often quite high, especially if the crop was recently fertilized. Over irrigating at this stage can result in significant leaching of nitrate. Irrigations do not usually need to be very long to re-saturate the soil profile. Careful monitoring of soil moisture in the root zone of the crop can determine an appropriate interval to irrigate.

Mid to late season: Crop water requirements often quickly increase in the midseason as the canopy rapidly expands and reaches maximum coverage. At the same time, N uptake demand of a crop may quickly increase. This is a phase when irrigations can get behind the water demands of the crop. The soil on the shoulders and edges of beds may become dry and difficult to resaturate using drip if insufficient water is applied. Poor lateral movement of moisture on beds can reduce the ability of vegetable and row crops to fully utilize nutrients in the soil. Estimating crop ET requirements can determine how much water should be applied to prevent stressing the crop. Soil moisture monitoring as described earlier can be used to determine if a crop is becoming water stressed and needs to be irrigated.

Fertigation

The uniformity of fertigation applications is limited by the uniformity of the irrigation system and procedures used for injecting fertilizer. Drip and sprinkler systems that have low application uniformities will also unevenly distribute injected fertilizer. Fertilizer should be injected upstream of a filter to prevent clogging of emitters and nozzles. Many drip irrigation systems that we evaluated had high uniformities at the beginning of the season, but in the late season the uniformity of the same drip systems was much lower due to clogged emitters. Periodic flushing of the drip lines may also help prevent clogging of emitters.

Assuring that injected fertilizer thoroughly mixes with irrigation water is also critical to distributing fertilizer uniformly through an irrigation system. Because irrigation sets are often brief in small vegetable and strawberry fields, many irrigators prefer to inject fertilizer at the irrigation block rather than the well to minimize the time for the fertilizer to travel to the field. Fertilizer injected at the irrigation block needs to thoroughly mix with the water before reaching branches in the irrigation system or the fertilizer will not distribute evenly within a field.

Equally important to achieving a uniform distribution of fertilizer is allowing sufficient time for all injected fertilizer to flush from the drip tape before ending the irrigation set. Some irrigators believe that injecting fertilizer at the end of the irrigation set is best practice to reduce leaching of fertilizer; however, when irrigation sets are short (< 2 hours), waiting too close to the end of an irrigation set to inject fertilizer can lead to poor fertilizer distribution. By injecting food dye, one can accurately determine the amount of time required for injected fertilizer to travel to the furthest point of a drip system. Since the time to flush fertilizer can be longer than the initial travel time, allowing at least twice the travel time for injected fertilizer to clear the irrigation system is recommended. For long irrigation events (>2 hours), injecting fertilizer during the middle third to half of the irrigation set time will assure that the injected fertilizer is efficiently applied to the crop and is adequately flushed from the drip lines before the irrigation set ends.

Leaching requirements

Most crops are sensitive to salts that accumulate in soil, and yields will decline when soil salinity becomes too high. Although extra water, known as a leaching fraction, may be needed to prevent salts from accumulating in the root zone, a leaching fraction can also contribute to leaching losses of NO_3. Using an appropriate leaching fraction for the salinity of the water and for the salt sensitivity of the crop can minimize leaching losses of NO_3. For example, processing tomato irrigated with water with an EC of 1 dS/m) may require less than a 10% leaching fraction to prevent salt build up during the season. Because the accumulation of salt in the root zone occurs slowly over the season, leaching fractions do not need to be applied with every irrigation. Monitoring soil salinity during the season can identify when leaching is needed. Also avoiding leaching when soil NO_3 is high, such as after a fertilizer applications, can minimize NO_3 leaching losses.

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