ACID, CHLORINE, NITROGEN, AND PHOSPHORUS MANAGEMENT FOR SUBSURFACE DRIP IRRIGATION SYSTEMS

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ABSTRACT

Subsurface drip irrigation (SDI) is expanding at a rapid rate in the western U.S. The efficiency of this irrigation system is higher than with center-pivots. Chemical maintenance, i.e. continuous acidification and periodic chlorination is required to prevent clogging of emitters by precipitates of calcium carbonate, iron or manganese salts, and from bacterial wastes. Fertigation with nitrogen (N) and phosphorus (P) fertilizers is discussed, and current fertigation research in SDI in Texas is presented.

INTRODUCTION

Subsurface drip irrigation (SDI) acreage has been growing at a rapid rate in the western U.S.A. In West Texas, small, irregular-shaped fields, and fields that are currently in furrow irrigation are being converted to SDI. Efficiency of water application to cotton in SDI systems approaches 100 %, as evaporation and deep leaching losses are negligible. (Bordovsky and Lyle, 1998). However, N and P fertilizer research for cotton in SDI has not kept up with the water management research.

Timing of N fertigations in SDI is an important management decision that can result in improved N use efficiency in crops like cotton. Chua et al. (2003) observed that modifying the timing of in-season N applications by applying N when chlorophyll meter readings were low, resulted in reduced N fertilizer applications and reduced residual soil NO_3^--N. However, more research is needed on improving the timing of N fertilizer injections to SDI cotton. The main researchable issue on timing is not when to commence N injections (this should be at the same time irrigation starts, at first square in mid-late June), but when to terminate the injections for the season. The window for this is probably somewhere between first bloom and peak bloom. At this point, the plant has taken up all the N it requires and it will remobilize N into the developing cotton seed.

Before planning a fertigation strategy in a SDI system, a chemical management program must be implemented that will prevent chemical and or biologically-induced clogging of SDI emitters, which are only 0.5 to 1 mm in size.

ACID

The pH level and high salt content in irrigation waters such as the Ogallala aquifer are the main management concerns in SDI systems. Bicarbonate, typically 230 to 350 mg/L in the Ogallala is the main source of alkalinity in hard irrigation water, and this results in pHs of 7.6 to 7.7 (Hopkins, 1993). Pumping high pH water into SDI systems without acidifying it can result in serious consequences. Problems could include scale formation and related blockage of emitters from calcium carbonate, iron oxides or manganese oxides. Un-plugging cogged emitters is difficult, and in some cases is not even possible, therefore preventive maintenance is the best.

Acidifying alkaline irrigation water in SDI is the most importance maintenance program a producer can undertake. The minerals Ca^{+2}, Fe^{+2}, and Mn^{+2} are more soluble and less prone to precipitate out as pH decreases. Target pH is 6.5 to 6.8. Sulfuric acid is the acid source of choice. Phosphoric acid (H_3PO_4) is also commonly used, since producers like the approach of acidifying as well as fertilizing. However, H_3PO_4 has the tendency to produce insoluble calcium phosphates, while the salt formed by neutralizing $CaHCO_3$ with sulfuric acid (H_2SO_4) would be the more soluble $CaSO_4$. A commercial product, N-pHURIC is a mixture of urea and H_2SO_4, making it safer to handle. It comes in the grades 15-49-0 and 10-55-0 (N - H_2SO_4). We recommend continuous acidification to pH 6.5 to 6.8 with the use of a pH meter cum programmable pump (~ $ 500).

CHLORINE

Addition of chlorine (Cl) into SDI systems with sodium hypochlorite (NaOCl) (bleach) disinfects the water and prevents bacterial growth and related slime formation that clog emitters. We recommend chlorinating SDI systems to about 10 –15 ppm residual Cl twice a month during the irrigation/growing season. If effluent or wastewater with a high biological load is the irrigation source, than continuous chlorination at about 2 ppm free Cl is required. Residual Cl test kits are available at SDI dealers. Simple household bleach (5.25 % hypochlorite) is a good Cl source. The main precaution is to allow at least 6 feet in between the chlorine port and the acid port to prevent toxic Cl_2 gas from forming (Alam et al, 2002). If Fe^{+2} or Mn^{+2} are > 0.2 ppm in the irrigation water, then chlorination will result in oxidation reaction to form the insoluble Fe^{+3} (ferric) oxide and Mn oxides. In this case, the Cl injection needs to be before disk filters (Alam et al., 2002).

NITROGEN

Fluid nitrogen (N) fertilizers based on urea-ammonium nitrate (32-0-0 or 28-0-0) can be injected on a daily basis into SDI systems, in a similar manner as they are used in center pivot systems. In center pivots, however, 25 to 30 lb N/ac is the usual rate that is possible, which means that N fertigation is performed only a few times during the season. For SDI, daily injections of small amounts of N fertilizer are possible with the daily irrigation, which can result in > 60 % recovery of added N in cotton plants (Table 1, Yabaji et al., 2006).

Annual soil testing is recommended for determination of N fertilizer requirements of cotton. We recommend soil sampling to 24 inch depth for nitrate-N analysis in the western US.

Multiplying the nitrate-N content of your 24-inch soil sample by 8 gives lb nitrate-N/ac. For a typical 2.5 bale yield goal with SDI, we recommend subtracting the soil test result of lb nitrate-N/ac from the total N requirement of 150 lb N/ac to arrive at a seasonal N requirement (Zhang et al., 1998). We have developed a N fertilizer requirements calculator that is available at: http://lubbock.tamu.edu/cotton/calcinstructions.html

This calculator can be used for any yield goal, soil test data, etc. for SDI (and center pivot and dryland) cotton. Testing irrigation water for nitrate-N content is highly recommended as well, and the N calculator will adjust recommendations based on this input.

We recommend pre-plant N applications of 30 lb N/ac be applied with a ground rig in sandy soils, or loamy, clayey soils with high amounts of residue, or if soil test nitrate-N is less than 4 ppm in a 0- 6 inch soil sample. The pre-plant N application should be knifed in the bed on the wet furrow side of the seed row. The balance of the N fertilizer can be injected through the fertilizer system. In most situations, we encourage avoiding N fertilizer pre-plant or at planting, as it is far less efficient than in-season fertigation. Since most irrigation systems start up in June close to first square, N fertilization should start at this time. After first square, however, biomass growth and N accumulation increase rapidly, making this the best time for N fertilization.

Current research by Texas A&M and Texas Tech University is testing timing of N, source of N and spectral reflectance-based N fertigation management in cotton (Table 1). Preliminary results show no difference in 5 or 8 week injection periods of 32-0-0 and no affect of 28-0-0 5S compared to 32-0-0. Spectral reflectance-based N management has potential to reduce N fertilizer applications compared to soil test-based 32-0-0 management, without hurting cotton yields (Table 1, Yabaji et al., 2006, and Chua et al. 2003).

PHOSPHORUS

Phosphorus (P) management, like N management, starts with soil testing. A 6-inch sample will suffice for P analysis. Phosphorus soil testing is only needed every 2-3 years, and the same P fertilization program should be followed between soil tests. Since P fertilizer is often band applied, it is important to take the soil subsamples for P in all positions of the field, i.e. bottom of furrow, side of bed, top of bed, and composite them before analysis.

There is a lot of interest in injecting P fertilizer through SDI (and center pivot) systems. This can be done, but several points need to be made. First of all, banding P fertilizer (either dry or liquid) close to planting 2 to 4 inches off the seed row and 2 to 4 inches deep has long been the best P fertilizer management practice. The P band in the bed will take care of early season growth and encourage rooting. It is possible that the large mass of young, active roots that are present near the emitters in the wet furrow after first bloom have trouble accessing a P band in the bed, which may be in dry soil. For this reason, Texas A&M University researchers compared banded P fertilizer (10-25-0) with phosphoric acid injections in an SDI system in Glasscock county. They found no difference between these two modes of P fertilization (Fig. 1), however, the response to added P relative to the zero-P treatment was not significant.

Producers with SDI systems may want to consider a second P fertilizer band in the bottom of the wet furrow (applied at the same time as the P band in the bed). This would be highly effective, and definitely take care of the concern of some that the P near the emitter will "run-out". This is not likely if a P band (several hundred ppm P) applied with a ground rig is only a few inches away in the same wet zone, as mass flow and diffusion will rapidly replenish soil solution P as the roots take it up. Injecting P fertilizer through the SDI system could be done during the season, but a several warnings are in order. First, 10-34-0-0 is the fertilizer source with the strongest tendency to precipitate (salt) out in hard irrigation water. It is necessary to increase the acidification program to adjust the pH of the irrigation water to pH 6.0 to prevent precipitation and emitter clogging. Another factor with 10-34-0 use is that this source is out of balance with plant needs, i.e. the cotton plants need more N than P. Therefore, additional N from 32-0-0 is needed to be pumped and injected into the system as well. Phosphoric acid (0-54-0) injection is another possibility to supply in-season P to SDI cotton. Some disadvantages of phosphoric acid (H_3PO_4) include: 1) it is hazardous to handle, 2) it is more costly per unit of P than 10-34-0, 3) calcium phosphate precipitates can form and clog the system, and 4) it does not supply as much plant available P in alkaline and calcareous soils as 10-34-0 does (Hopkins and Ellsworth, 2004).

Many producers will find it desirable to inject multiple products at once into a SDI system, for e.g. N-pHURIC and 32-0-0. It is important that the same injection pump not be used for more than one product, unless it is a dual head pump (separate inlets and outlets). This is because precipitation will likely occur when two or more products are injected together. Even with a dual head pump, the two products should go into the irrigation line at least three feet apart. A cheaper alternative to injecting multiple products besides buying additional pumps is a Venturi system, which relies on creating a pressure differential. Local SDI suppliers can provide the parts and more details on setting up a Venturi system for injecting fertilizers and acids.

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Table 1. First open boll biomass, N accumulation, N fertilizer recovery efficiency, seed and lint yields as affected by nitrogen management in a subsurface drip irrigation system, Lubbock, TX, 2005 (Yabaji et al., 2006).

N source	N timing	N fertilizer injected	Total N uptake	Recovery efficiency	Biomass	Seed yield	Lint yield
		--------- lb N/ac ------		%	-------------- lb/ac ------------------		
28-0-0-5	Early bloom[1]	90	-	-	-	2611 a	1865 a
28-0-0-5	Peak bloom[2]	90	-	-	-	2598 a	1829 a
32-0-0	Early bloom[1]	90	-	-	-	2629 a	1879 a
32-0-0	Peak bloom[2]	90	160 a	63 a	9647 a	2549 a	1812 a
32-0-0	Reflectance-based[2]	65	143 a	62 a	9164 a	2511 a	1817 a
Zero-N	N/A	0	103 b	-	8047 b	2072 b	1620 b

[1] Injected from 20 June to 22 July
[2] Injected from 20 June to 12 Aug

Fig. 1. Cotton lint yields as affected by band applications of ammonium polyphosphate (10-25-0) and injection of phosphoric acid (0-55-0) in a subsurface drip irrigation system, Glasscock County, TX, 2005