Sub-surface drip fertigation for precision management of cotton

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Abstract

A subsurface drip fertigation study in north Alabama evaluated four fertigation timing scenarios over seven years. Replicated treatments included 40-inch rows with drip tape between every other row of cotton. All treatments received 135# of N and K_2O, 20# of S, and 1.0# of B. Phosphorus was surface-applied to maintain high P soil levels. Treatments were: (1) Non-fertigated control - 60#N pre-plant surface, remainder side-dressed, (2) Pre-plant 20#N surface, remainder drip to bloom+25 days, (3) 100% fertigated (bloom + 25 days) - drip 20#N at planting, (4) 100% fertigated (bloom + 40 days) - drip 20#N at planting, (5) Pre-plant 40#N surface, remainder drip to bloom (50 days). Water was not a limiting factor with adequate irrigation provided to all treatments. Treatments (2) and (5), the two fertigation treatments with the highest amount of pre-plant surface N, had significantly higher yields in four out of seven years. These two treatments out-yielded the non-fertigated control (1) indicating the effectiveness of pre-plant surface N in conjunction with drip fertigation in cotton.

Keywords. Drip irrigation, fertigation, cotton production

Introduction

Subsurface drip irrigation (SDI) systems can have a long economic life when properly designed, installed, and managed. The profitability of drip irrigation is impacted by design life of the system, crop and climate, placement of laterals, and method by which irrigation and fertilization is scheduled and applied. As energy and corresponding pumping costs continue to increase and longer SDI operational life is documented, lower pressure SDI systems have become an alternative to higher pressure center pivot irrigation systems. In many fields in Alabama, SDI is becoming a viable option for producers as they become more familiar with installation and operational technology. SDI fertigation through chemical injection of nutrients is an option that can reduce field travel and input costs.

In an SDI system, improved profitability and reduced environmental contamination is possible because of the ability to manage small applications of water and N fertilizer as needed by the crop (Camp et al., 1997). Application of fertilizer nutrients through irrigation systems (fertigation) has been found to increase seed cotton yield, water use efficiency, and nutrient uptake by researchers in Syria (Janat and Somi 2001a, 2001b; Janat**,** 2004), Texas (Enciso-Medina et al., 2007), and India (Thind et al., 2008). Irrigation systems permit multiple small dose fertilizer injections at different intervals, reducing the risk of leaching compared to fertilizers applied in a single application. Notwithstanding, Hunt et al. (1998) near Florence, South Carolina found that N fertigation using a single drip-application produced the highest seed cotton yield compared with five split drip-applications. Similar results were reported by Hou et al. (2007) for N applied at the beginning of the irrigation cycle rather than in more frequent, smaller doses throughout the irrigation cycle. Alternatively, Bauer et al. (1997) determined that N application method (single versus five split drip-applications) through SDI had no significant effect on cotton yield. The present study follows closely on these studies to evaluate the effectiveness of varied fertigation timing treatments on cotton yield in northern Alabama.

Methods

This research compares four SDI fertigation management treatments with one conventional side-dress treatment for nitrogen, potassium and phosphorus delivery. The study uses an automated nutrient delivery system to provide in-season fertilizer injection as prescribed by four SDI fertigation treatments. The response to all treatments (four sub-surface fertigation and one conventional surface fertilization) is quantified by measuring seed cotton yield. The focus of the seven-year study is to evaluate the timeliness, precision, and effectiveness of several fertigation treatments. A pressure-compensating SDI tape product was installed at approximately 12-inch depth using a tractor auto-guidance system to ensure all tape runs were precisely located parallel and 80 inches apart between every other row of 40-inch cotton. The resulting experimental plots consist of four replications of five eight-row treatments. An automated tracking (auto-guidance) system was also used to accurately plant cotton rows each season in relation to the SDI tape. All subsequent field operations were completed using an auto-guidance systems to ensure proper equipment traverse across each plot, each year.

Experiment Design

The SDI fertigation study was initiated in 2006 at the Alabama Agricultural Experiment Station's Tennessee Valley Research and Extension Center (TVREC) in Belle Mina, AL (86 ˚ 52' 30" W, 34 ˚ 41', 00" N) on a Decatur silt loam (fine, kaolinitic, thermic, Rhodic Paleudult). The treatment design is a randomized complete block (r=4) with five fertilizer application methods (one conventional surface-fertilization vs. four fertigation treatments). The dimension of each harvested treatment plot is 80 inches x 345 feet making up the middle two rows of an eight-row treatment plot. At the outboard edge of each treatment one irrigated buffer or “guard” row is provided to minimize interference between fertilizer/fertigation treatments. Irrigation was provided equally to all treatments ensuring that water was not a limiting factor in this study.

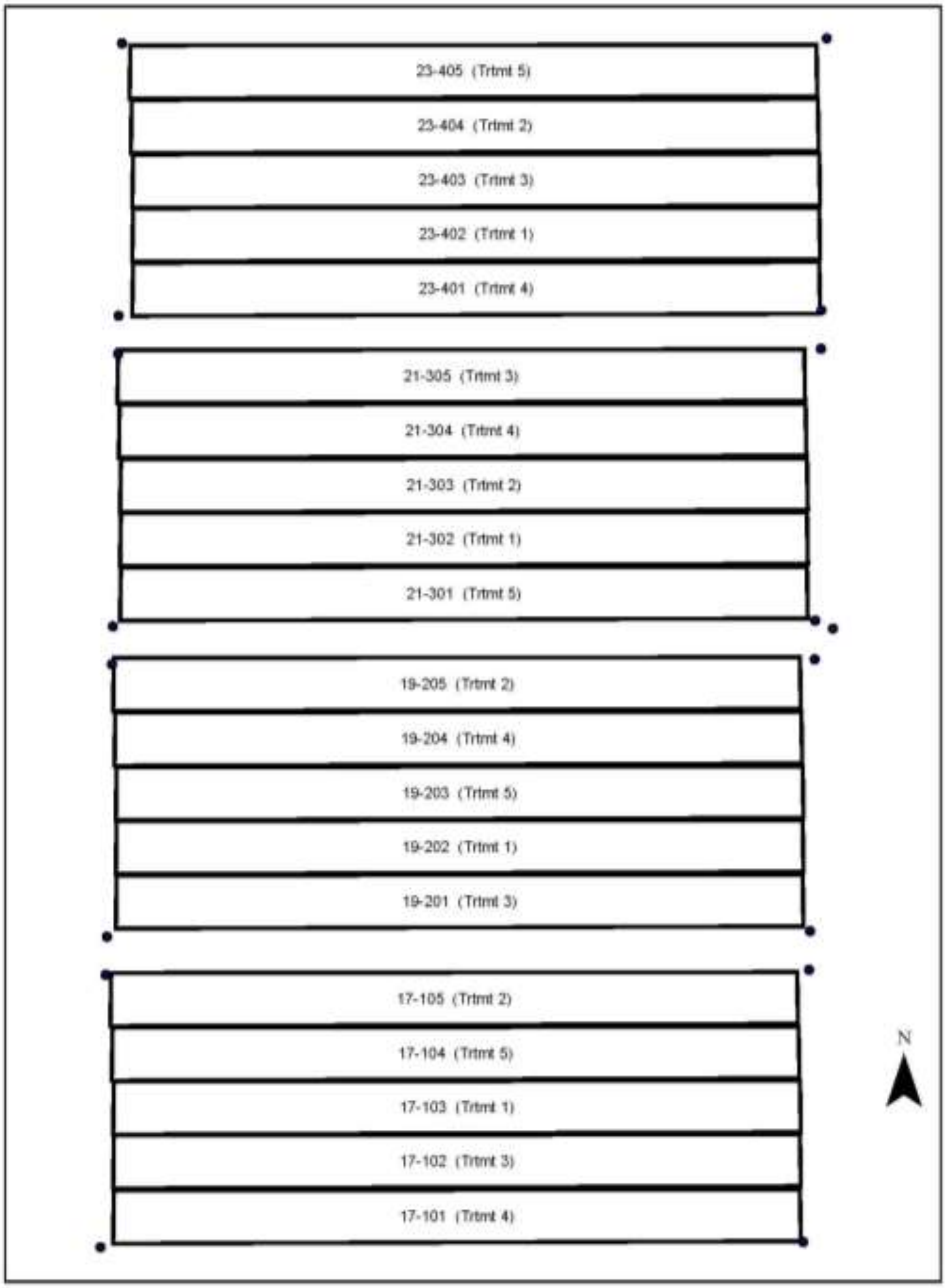

Fig. 1. Five randomized treatments (r=4) making up SDI fertigation study, 2006-2012, Belle Mina, AL. Each treatment plot is made up of eight rows of cotton 360 feet long in 40-inch rows with two irrigated guard (buffer) rows between each treatment plot. The middle two rows of each treatment plot (80"x345') were harvested for yield response.

Irrigation and scheduling

The irrigation system was installed in fall of 2005 before cotton planting in spring 2006. Subsurface drip tape (0.874" ID) was installed between 10 and 14 inches deep using a heat-treated shank with installation tube on the backside (Andros Engineering, Paso Robles, CA) mounted on a standard toolbar behind a 130 hp agricultural tractor. The toolbar assembly was equipped with an integrated reel carrier and platform for handling the self-feeding reels. During the study, the irrigation system operated at a nominal pressure of 10 psi with individual emitter flows (24" spacing) at 0.24 gph.

Daily pan evaporation was accessed from the Alabama Weather Information Service (AWIS). The daily irrigation requirement, ET, was calculated using the following equation;

$$ET = 0.90 \times PAN \times CC,$$

where evapotranspiration, ET (in day^{-1}) was calculated from 90% pan evaporation, PAN (in day^{-1}) adjusted for fractional canopy cover, CC. Canopy cover was determined weekly by measuring the open canopy distance (in) between rows with a tape measure. Fractional canopy cover was calculated using the following formula; (row width - open canopy distance)/row width. Canopy closure measurements were a critical component used in this study to estimate the daily amount of irrigation water as a function of calculated daily pan evaporation.

Crop

Cotton was planted in the second or third week of April each year using a 4-row planter with a 40-inch row spacing and a seeding rate of 4-5 seeds ft^{-1}. Plots were end-trimmed by 3 ft to eliminate edge effects just before picking. The two center rows of each plot were harvested with a 2-row cotton picker and weighed using a boll buggy equipped with electronic load cells to measure accumulated seed cotton yield per plot. Average post-harvest turnout from the gin was used to determine lint yield for subsequent economic analysis. Average lint turnout for the study as a percentage of seed cotton was approximately 41%.

Fertilization treatments

Approximately 7,500 feet of SDI tape, supply and flush lines, control valves, air-vacuum release, and fertilizer injection equipment was installed on four replicated test plots. Four positive displacement liquid fertilizer injectors (Neptune, USA) were installed to supply four replications of five nutrient timing treatments including four fertigated treatments and one non-fertigated control (Table 1). Treatment 1 served as the irrigated control providing conventional surface side-dressing of nutrients. Treatments 3 and 4 provided "spoonfed" fertigation scenarios with 100% of nutrient mix provided through SDI injection. Treatments 2 and 5 provided a combination of pre-plant surface-applied nutrients along with in-season fertigation. All treatments received 135 pounds per acre of nitrogen and potassium (K_2O), 20 pounds per acre of sulfur, and l.0 pound per acre of boron. Phosphorus fertilizer was surface-applied to maintain P at high soil test levels. Drip fertilizer was 8-0-8-1.2S-0.06B made using 32% liquid N, potassium thiosulfate, fertilizer grade KCL, solubor, and water. Nurse tank and injection pumps were mounted on a concrete pad located in the middle of treatment plots (Fig. 2). Sand filtration was provided ahead of nutrient injection. Drip tape was flushed twice yearly, at beginning and end of each season using a separate positive displacement pump with injection nurse tank for water/acid/water flushing.

Table 1. Treatment description, fertigation management trials, 2006-20127.

Treatment	Description
1. Control - drip irrigated, but all fertilizers are surface applied.	*Preplant* - N and K @ 60 pounds per acre. *Post-Plant* N (75lb/A) sidedressed at early square.
2. Timing 1 – with surface preplant	*Preplant* - 20 pounds of N and K (surface). *Drip* 40 pounds N,K –square to bloom (25 days) *Drip* 75 pounds N,K – bloom to 25 days
3. Drip timing 1 – no preplant	*Planting Drip* - 20 pounds N,K *Drip* 40 pounds N,K –square to bloom (25 days) *Drip* 75 pounds N,K – bloom to 25 days
4. Drip timing 2 – no preplant "spoon-fed"	*Planting Drip* - 20 pounds N,K *Drip* 40 pounds N,K square to bloom (25 days) *Drip* 75 pounds N,K – bloom to 40 days
5. Timing 2 – with surface preplant	*Preplant* - 40 pounds of N and K (surface). *Drip* 95 pounds N,K –square through bloom (50 days)

All treatments received 135 pounds per acre of nitrogen and potassium (K_2O), 20 pounds per acre of sulfur, and l.0 pound per acre of boron. Phosphorus fertilizer was surface-applied to maintain P at high soil test levels. Drip fertilizer was 8-0-8-1.2S-0.06B made using 32% liquid N, potassium thiosulfate, fertilizer grade KCL, solubor, and water.

Fig. 2. Fertigation mixing tank, chemical injection pumps, and injection header for five replicated SDI fertilizer treatments and two irrigated buffer (guard) rows, Belle Mina, AL

Results and discussion

Observed yields indicated significant differences between treatment means during five out of seven years of this study. Table 2 indicates that treatments 2 and 5, the two fertigation treatments with pre-plant side-dressed N had significantly higher yields in 2008, 2010, 2011, and 2012. In 2006, treatments 2 and 5 were also the highest yielding treatments, but only treatment 2 was significantly higher than the other treatments. During 2007 and 2009, there were no statistical differences observed between treatments.

Seed cotton yields for the first two years of the study, 2006 and 2007 occurred during two of the driest consecutive years on record at TVREC and still yielded an average 3.0 and 2.9 bales of cotton, respectively. In 2007 and 2008, although the non-fertigated control (treatment 1) was the highest yielding treatment it was not significantly different from the two highest fertigated treatments (treatments 2 and 5). Though not significant, the three highest yielding treatments in 2007 and 2008 received at least 20 pounds of surface-applied, preplant nitrogen and potassium (K_2O). When averaged across the seven years of this study, the three highest ranking treatments (1, 2, and 5) verify the conclusions of previous researchers (Hunt et al., 1998; Hou et al., 2007) regarding the importance of early N applications versus continuous or "spoon-fed" applications throughout the growing season.

Table 2. Summary of mean seed cotton yield by fertilizer treatment and year, lb/A.

trt	2006	2007	2008	2009	2010	2011	2012	ave.
1	3167[c]	3636[nd]	4649[a]	2071[nd]	4092[b]	2329[c]	3618[a,b]	**3366**
2	3788[a]	3328[nd]	4226[a,b]	2370[nd]	4338[a,b]	3142[a]	3996[a]	**3598**
3	3536[b]	3164[nd]	4038[b]	2395[nd]	4136[b]	2726[b]	3519[b]	**3359**
4	3437[b]	3266[nd]	4008[b]	2389[nd]	4226[b]	2510[b,c]	3232[b]	**3295**
5	3614[b]	3333[nd]	4596[a]	2282[nd]	4626[a]	2787[ab]	3989[a]	**3604**
ave.	**3508**	**3345**	**4303**	**2301**	**4284**	**2699**	**3671**	**3445**
Rain†, in	6.63	6.06	11.27	12.39	8.34	12.69	9.24	**11.49**
Temp‡, F	82	85	77	77	82	80	78	

[a] superscript denotes significant difference between treatment means within an individual year (α=0.05).
[nd] denotes no significant difference between treatment means within an individual year (α=0.05).
† Total June through August rainfall. Average represents 83-year total June-August rainfall.
‡ Average June through August temperature.
1. Surface applied N-P-K with drip irrigation (control). 2. Preplant 20# N-K surface with 2 N-K drip timings. 3. 20# N-K drip at planting with 2 N-K drip timings (to 25 days after bloom). 4. 20# N-K at planting with 2 N-K drip timings (to 40 days after bloom). 5. Preplant 40# N-K surface with 1 N-K drip timing (square through bloom).

The higher response of the non-fertigated control treatment in the second year of the study, 2007, was thought due to beneficial downward movement of surface-applied fertilizer early in the season as a result of 4.55" of rain between May and July. A comparable number of storm events in 2006 delivered only 2.87" of rain over the same May through July period. As a result, in spite of nearly equal and unusually low total seasonal rainfall in the 2006 and 2007 growing seasons (6.6” and 6.1”, respectively), higher early season rainfall in 2007 may have facilitated delivery of surface-applied nutrients, increasing yield. Several large convectional storms later in the 2007 season may have advantageously moved surface-applied nutrients into the soil horizon, while concurrently leaching fustigated nutrients farther out of reach of roots. In both 2006 and 2007, plant tissue nutrients (not shown) were generally higher in the highest yielding treatments, with plant tissue boron, manganese, and sodium generally lower in the surface-applied control treatment (treatment 1). Similarly, during the 2008 growing season 2.57 inches of rain fell on one day June, potentially moving surface-applied nutrients downward and highlighting the importance of rainfall or surface irrigation as a relevant factor.

Summary

A subsurface drip irrigation study was installed at the Tennessee Valley Research and Extension Center (TVREC), in Belle Mina, Alabama in 2005 to evaluate four precision fertigation management (i.e., fertilizer timing) scenarios. Approximately 7,500 feet of SDI tape and four positive displacement liquid fertilizer injectors were installed on five nutrient timing treatments with four replications in RCB design. The resulting twenty treatment plots were made up of eight, 345-foot rows of cotton on 40-inch row spacing, with drip tape between every other row of cotton. All treatments received 135 pounds per acre of nitrogen and potassium (K_2O), 20 pounds per acre of sulfur, and 1.0 pound per acre of boron. Phosphorus fertilizer was surface-applied to maintain P at high soil test levels. Treatments were as follows: (1) Non-fertigated control - 60#N pre-plant surface, remainder side-dressed at early square, (2) Pre-plant 20#N (surface), remainder drip at square and bloom + 25 days, (3) 100% fertigated (bloom + 25 days) - drip 20#N at planting, remainder drip at square and bloom, (4) 100% fertigated (bloom + 40 days) - drip 20#N at planting, remainder drip at square and bloom, (5) Pre-plant 40#N (surface), remainder drip at square through bloom (50 days). Drip fertilizer was 8-0-8-1.2S-0.06B made using 32% liquid N, potassium thiosulfate, fertilizer CL, solubor, and water. Although growing season rainfall varied considerably across the seven-year study, water was not a limiting nutrient as irrigation was consistently applied to all treatments using an adjusted pan evaporation method. Treatment yield response across all seven years of this study revealed significantly higher yields in treatments (2) and (5) in four out of seven years, the two fertigation treatments receiving the highest amount of pre-plant nitrogen (20# and 40#, respectively). These two fertigated treatments out-yielded, on average, the non-fertigated control (1) which had 60# of pre-plant nitrogen surface applied. Results indicate the effectiveness of drip fertigation in conjunction with pre-plant surface application of nitrogen to boost cotton yields in the Tennessee Valley.

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