Crop Yield, Tube Longevity, and Economics with Shallow Subsurface Drip Irrigation (S3DI)

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Abstract. *The objectives were to determine crop yield, drip tube longevity, and economics when using S3DI with conventional, strip- and no-till regimes. Drip tubing was buried about 3-cm in 2006 and left in the field for 5 years for strip- and no-till areas and removed, stored, and reinstalled in conventional tilled. Crop rotation was cotton (Gossypium hirsutum), corn (Zea mays, 3 years), and peanut (Arachis hypogaea). There was no difference in cotton lint yield within tillage treatment. Irrigated lint yield was 2.4 times greater than non-irrigated. There was no difference in irrigated corn grain yield due to tillage practices or time (years). Irrigated corn yield was 5.8 times greater than nonirrigated yield. Irrigated peanut yield was not different across tillage treatments but was 2.6 times greater compared with non-irrigated yields. For tube longevity, conventional tilled areas had less tube repairs compared with either strip- or no-tilled regimes. Thinner wall tubing had 3.5 times more holes compared with the thicker wall tubing. The "cost to repair" versus "cost to replace" tubing indicates replacement at about 5.8 years. There was less production expenses for strip- and no- till compared with conventional tillage. Strip- and no- till practices seem to be the most economical for S3DI.*

Keywords: drip irrigation, crop yield, strip tillage, no-tillage,

Drip irrigation has been used to irrigate vegetables and high value crops for many years due to its simplicity of design (Bucks et al., 1974; Hanson et al., 1997). Drip irrigation can precisely deliver water, nutrients, and chemicals to the crop root zone. Previous research has shown that surface drip irrigation (SDI) can be installed with low initial investment and labor, used on a variety of crops, and can increase crop yield compared with nonirrigated areas (Sorensen et al., 2008; Sorensen et al., 2009). Burying the drip tubing 5-cm below the soil surface (shallow subsurface drip irrigation – S3DI) can significantly reduce rodent damage (Sorensen et al., 2007). Yield potential of irrigated crops using S3DI was over 2, 3, and 7 times greater than nonirrigated crops of peanut, cotton, and corn, respectively, depending on yearly precipitation timing and amount (Sorensen et al., 2010). The increased yield and eventual gross revenue was great enough in the installation year to cover the cost of the in-field portion of the S3DI system expenses compared with the nonirrigated revenue (Sorensen et al., 2010).

Conventional tillage consists of mixing or burying plant residue into the soil for quicker decomposition and in some cases may be critical for pest control for the upcoming crop (Boyle, 1956). Tillage not only buries plant debris but also levels the soil surface in preparation for other tillage operations and the comfort of the equipment operator. Conventional or clean tillage provides a clean, smooth, soil surface conducive for ease of operation during planting, pesticide applications, and eventual harvest. Conventional tillage may have benefits for the operator's comfort and ease of other operations but has added expense for fuel, labor, equipment, and time. Tillage also has the added problem of increased soil moisture loss that may be critical for crop emergence in drought situations.

Strip-till is a form of conservation tillage that only disturbs a small strip of soil where the crop is planted (Johnson et al., 2001) and can be an effective management tool to reduce crop production expenses. However, the acceptance of strip-till, especially in peanut, has been slow due to grower concerns of increased plant or soil-borne diseases and ultimately loss of yield. The loss of peanut yield to *Sclerotium rolfsii* (stem rot) and the recommendation to bury plant debris (which acts as a pathogen host when left on the soil surface) has become traditional with growers since the late 1950's (Boyle, 1956).

No-till is another form of soil conservation where a crop is planted in the existing debris of the previous crop. No-till as the name implies, does not have any tillage investment costs. Depending on the amount of crop debris, additional row cleaners or cutting coulters may be installed on a planter in order to sow the new crop. Both strip- and no-till operations may be less expensive as management tools but may not always be cost effective due to possible lower yields and possible cost of additional herbicides to control troublesome weeds.

Subsurface and surface drip irrigation on crop rotations in the southeast has been effective in increasing crop yield when compared with nonirrigated crop production (Sorensen et al., 2000; Sorensen et al., 2008; Sorensen et al., 2009; Sorensen et al., 2010). The use of S3DI with conservation tillage techniques on agronomic crops and rotations could be of major interest in conserving water, reducing agronomic inputs, and possibly increasing on-farm revenue that would benefit the agricultural community.

If a grower implemented a conservation tillage technique, either strip- or no-till, then S3DI could be installed and maintained for multiple years which would be economical than removing the tubing on a yearly basis as describe previously (Sorensen et al., 2010). If tubing can be left in the field for multiple years and if crop yield increased as described above, then using S3DI may be economically feasible for traditional row crops in the southeastern U.S. This type of drip irrigation system would also be of interest to growers with small, irregular shaped fields where irrigation water from small domestic deep wells may be available, such as old homesteads. However, the crop yield response to S3DI along with strip- or no-till is unknown. Additionally, the useful life of the drip tubing installed near the soil surface (S3DI) where it is vulnerable to biological and mechanical damage is unknown. Similarly, the economic cost or benefit of using a more expensive, i.e., thicker wall tubing in these tillage situations has not been determined. The objectives of this research were to determine: 1) crop yield when using S3DI in conjunction with conventional, strip and no tillage, 2) longevity of drip tubing with various wall thicknesses to biological or mechanical damage, and 3) economic viability of S3DI with conservation tillage techniques.

Land Preparation and Crop Management

This research was conducted at the USDA-ARS Multi-crop Irrigation Research Farm in Shellman, GA during the 2006 through the 2010 growing seasons on a Faceville fine sandy loam (fine, kaolinitic, thermic Typic Kandiudults) with up to 3% slope.

The field for this research was 57 m wide by 61 m long. Crop rotation was cotton, corn (three years), and peanut. The field was separated into three sub-fields/plots for the tillage treatments of conventional, strip till and no till. Each sub-plot was 16.5 m wide by 61 m long. Each sub plot was divided into smaller sub-sub plots that consisted of drip tube wall thickness. Three tube wall thicknesses were tested within each tillage system replicated three times. Tubing wall thickness variables were 0.2, 0.25 and 0.38 mm. The irrigation system, drip tube laterals, and tube thickness will be described later.

In the first year, the whole field was prepared in the fall (2005) using the following tillage operations, disk harrowed, chiseled, row bedded and cultivated following fertilizer and herbicide application. A winter cover crop of wheat (*Triticum aestivum*) was planted across the entire field. The wheat crop was killed in early spring using glyphosate herbicides at recommended rate and timing.

Conventional tillage consisted of the following practices in order after the first year described above: 1) disk harrow (fall), 2) chisel plow (fall), 3) row bedding (spring), and 4) field cultivate (spring) to incorporate fertilizer and/or pre-plant herbicides. Drip tubing was installed on the conventionally tilled area immediately following plant emergence. Following cotton and corn harvest, drip tubing in the conventional tilled area was removed from the soil, rolled, and stored on spools using experimental equipment. Following drip tube removal in the conventional plot area, all crop residues were mowed at 20 cm height with a rotary mower and plant stalks were pulled with a stalk puller (Arizona Drip Systems, Coolidge, AZ). In early spring, the conservational tillage part of the project was strip tilled (Brown Manufacturing Corp., Ozark, AL 36360) creating a 20-cm wide planting bed. Nothing was done with the no-till area prior to planting.

At the end of the project, just prior to peanut harvest, all drip tubing was removed using experimental equipment (USDA-ARS-National Peanut Research Laboratory) that lifted the tubing from the soil and laid it on the soil surface for evaluation. Following tube evaluation (described later), the drip tube laterals were rolled for disposal.

All crops were planted with the same planter in all years. The planter had attached row cleaners used for strip- and no-till type conditions (Monosem, Inc. Edwardsville, KS and Yetter Manufacturing Company, Colchester, IL). Prior to planting cotton, 22 kg N ha^{-1} of dry fertilizer was applied along with other recommended fertilizer (phosphorus, potassium, and sulfur) as determined by soil test. Cotton was planted and harvested 2006. Cotton cultivar DPL555BR was planted at a density of 106,300 seeds ha^{-1}. A total of 60 kg N ha^{-1} (yearly total 82 kg N/ha) was applied to the soil surface in three split applications using 28-0-0-5 liquid fertilizer. Nitrogen fertilizer was applied prior to either an irrigation or precipitation event. Herbicides were applied as recommended by field scouting. Cotton was picked using a 2-row spindle picker. The picker was modified to collect cotton in a large mesh bag. The sample was weighed and a small subsample (0.3 kg) was used to determine lint out-turn on a table top gin. A 0.2 kg sub-sample was collected from each ginned sample to determine lint quality. Gross revenue was determined using the average price received for lint cotton each year cotton was grown. The price used to determine gross revenue was \$1.473 kg^{-1} (7).

Corn was planted in 2007, 2008, and 2009. Corn (DeKalb 6972RR) was planted at a density of about 79,000 seeds ha^{-1}. Prior to strip tillage and planting, 22 kg N ha^{-1} of dry fertilizer and the recommended rate of other fertilizers (phosphorus, potassium, and sulfur) were applied as determined by soil test. Liquid fertilizer, 28-0-0-5, was applied on the soil surface in three split applications for a total of 225 kg N ha^{-1} (yearly total 245 kg N ha^{-1}). Fertilizer was applied prior to an irrigation or precipitation event to aid in nitrogen movement into the soil. Herbicides were applied at recommended timing and rates determine by field scouting. Corn was harvested with a 4-row combine. Each sample was discharged from the combine into a weigh buggy. After weighing, a 2-kg subsample was collected from the weigh buggy and tested for moisture and test weight. Gross revenue was determined using the average price received for corn grain across the 2008 and 2009 cropping season of \$0.181 kg^{-1} (7).

Peanut was planted in 2010. Peanut cultivar, Georgia 06G, was planted in a single row seeding pattern with a density of 20 seeds m^{-1} as recommended for reducing the risk of Tomato Spotted Wilt Virus (TSWV) (2, 3). Aldicarb (2-methyl-2-(methylthio)-O-((methylamino)carbonyl) oxime) was applied in each crop row at recommended rates. Boron was applied to foliage twice each season for a total of 0.56 kg B ha^{-1}. Fungicides, insecticides, and herbicides were applied at recommended rates and timing as determined by field scouting during the growing season for disease, insect, and weed control. Peanut maturity was determined by the hull scrape method (Williams and Drexler, 1981). Yield rows were dug with a 2-row inverter, allowed to field dry, and harvested with a two row field combine. Pod yield, farmer stock grade, and kernel size distribution were determined after being mechanically dried, weighed, and adjusted to 7% moisture (wet basis) and using screens specified in USDA grading procedures (USDA, 1993). Gross revenue was determined using the average market price for 2010 of \$0.45 kg^{-1} (http://www.nass.usda.gov/Publications/Todays_Reports/reports/pnpr4310.pdf).

Irrigation System Design and Management

Irrigation water was supplied through a series of 5 cm diameter flexible hose (Sun-Flow Layflat SFAF2-300V; Jain Irrigation, Inc. Fresno, CA) with drip tubing connected to the flexible hose using plastic barb adapters (Agricultural Products, Inc., Ontario, CA, Model 400B-06-LS). The drip tubing was 16 mm diameter with wall thickness of 0.2, 0.25 and 0.38-mm (Netafim USA, Fresno, CA). All drip tubing had the same flow rate per emitter. All drip tube laterals were spaced in alternate row middles, 1.83-m apart. Drip tubing was buried an average of 3-cm soil depth. The irrigation water was from a deep well, filtered using a manually cleaned 120 mesh (130 micron) disk filter (Netafim USA, Fresno, CA) and received no chemical amendments during any irrigation events to begin or end the season. Operating pressure was regulated at 100 kPa (Senninger Irrigation, Inc., Clermont, FL, Model PR-HF-15) at the head of the field (200 kPa at the pump) and water flow rate and total water applied (liters/min and total liters) was measured with a mechanical water meter.

Irrigation events for cotton, corn, and peanut were determined by soil moisture sensor data in association with IrrigatorPro® (Davidson et al., 1990; Davidson et al., 1991; Lamb et al., 1993). The average total water applied at each irrigation event was about 3 to 3.5-cm. Meteorological data were collected with an electronic weather station with precipitation being verified with an onsite manual gauge. A nonirrigated conventional and/or strip-tilled plot was maintained as a control.

In the conventional tillage area, drip tubing was removed following crop harvest and stored. Tubing was reinstalled following planting and crop emergence. In the conservation tilled areas, the drip tubing was left in the field throughout the entire project. Each spring, after planting, the irrigation system was activated and the laterals checked for leaks. Repairs were made by cutting out the section of thin wall tubing with the hole using scissors, then inserting thick walled tubing (1.2 mm wall thickness) inside the thin wall tubing, and clamping each end with stainless steel wire ties (Sorensen et al., 2007). The number of repairs was to be documented to identify the number of hole/repairs made during each growing season. However, various personnel were used to make repairs within and across years such that yearly repair activities were not adequately documented. The following procedure was used to document tube longevity. Prior to peanut harvest, each tillage treatment was separated into four equal lengths of 15.25 m. Each drip lateral was evaluated within these smaller field lengths to document total number of repairs and total number of existing holes. Splitting the field into four equal distances would document if the was an “edge effect” of biological damage, i.e., rodents moving in from the edge of the field and causing damage compared with rodent damage in the middle of the field (Sorensen et al., 2007).

The expense to repair drip tubing was documented in previous research (Sorensen et al., 2007) at \$0.67/repair and was used to calculate tubing repair costs in this research. We recognize that labor expense, along with repair equipment has increased in cost and may be higher than previously documented.

Treatment Expenses

Table 1 shows the expenses for various tillage operations, infield irrigation system, and tubing removal and installation. All management practices for seed rate, irrigation amount, pest control, fertility, and harvest procedures were the same across tillage and irrigation treatments. Table 1 shows expenses for conventional, strip- and no-till operations were different from each other. We see that no-till treatments had the lowest expenses attribute to tillage, followed by strip-till, with the greatest expense in the conventional tilled treatments. Conventional tilled expenses were over 16 times more expensive compared with no-till treatment. Strip-till treatment was 4 times more expensive compared with the no-till treatments.

In 2006 the initial irrigation system was installed. Material expenses needed to install the infield irrigation system was \$377 ha^{-1} for drip tubing, \$32 ha^{-1} for barbed adapters, and \$26 ha^{-1} for flexible hose for a total of \$435 ha^{-1}. The expenses for irrigation conveyance system to the field, filters, electronic controls, irrigation pump, valves, water meters, and pressure regulators were not included with the installation cost.

The cost of removing and installing the drip tubing in the conventional tilled plots was assumed to be the same across all years. There was not a cost assigned for tubing storage. There was also not a cost assigned for equipment since the equipment is experimental and has no commercial value. Tubing retrieval and installation involved the use of a tractor, specialized equipment for retrieval and installation (both experimental), and a minimum of two people. The retrieval and installation equipment was only designed to handle one drip tube lateral at a time. Commercial drip tube installers and retrievers will typically handle multiple rows decreasing time and energy across the field. For this research, the use of one row equipment was utilized, and the expenses modified to simulate multiple (3-lateral) equipment. The approximate time to install or retrieve the tubing in the spring or fall, respectively, was about 0.75 hr on the conventionally tilled treatment. The estimated time with "three lateral equipment" would be about 0.25 hr for an estimated time of 2.5 hrs ha^{-1} or a total of 5 hr ha^{-1} for both installation and retrieval per year. We used a labor expense of \$10 hr^{-1} and an estimated fuel consumption of 3.1 L hr^{-1} (fuel cost = \$1.00 L^{-1}). Total estimated expense of fuel and manpower to retrieve and install tubing was about \$66 ha^{-1} yr^{-1}.

The expense to repair drip tubing was documented in previous research (Sorensen et al., 2007). They showed an approximate cost of \$0.67 per repair. In 2006 labor expense was about \$8/hr; however, we valued labor expenses closer to \$10 which would increase the cost of tubing repair. However, calculations for tubing repairs were kept at the \$0.67 per repair.

Crop yield, tillage type, gross revenue, net revenue and interactions of tillage by yield, gross, and net revenue were analyzed by crop year using a general analysis of variance procedure (Statistix9, Tallahassee, FL). The drip tube laterals were analyzed by tube thickness for tillage, field location (edge or middle), holes and repairs, and total expense. Tukey's mean separation range test was used to show differences between means ($P \leq 0.05$) when *ANOVA F*-test showed significance. Total net income for each tillage treatment was totaled across years and tillage treatment to identify best economic benefit.

Crop Yield Analysis

Each crop will be discussed independently. Cotton in 2006 received 394 mm of rainfall and 322 mm of irrigation (Table 3). There was no cotton lint yield difference within irrigation or by tillage treatment (Table 4). Irrigated cotton lint yield was greater than the non-irrigated cotton yield by an average 2.4 times. Within the nonirrigated regimen, the non-irrigated strip-tilled treatment had higher lint yield than the non-irrigated conventionally tilled treatments by almost double (1.8 times). These data are consistent with other research using subsurface drip irrigation (SSDI). Texas data shows that conventionally tilled cotton had the same yield as that with no-tilled (cotton planted in rye) two out of three years. The three year average showed no difference between conventional and no-till systems when irrigated using SSDI with laterals spaced 1 or 2-m distance (Sij et al., 2010).

Corn was raised in 2007 to 2009 inclusive. Rainfall data show that 2009 had double and almost triple the rainfall in 2008 or 2007, respectively. The effect of rainfall is directly shown in the nonirrigated treatments where there were no corn yield recorded for 2007 or 2008 in any tillage treatment. In 2009 within the non-irrigated regime, only the conventional tilled treatment was planted and crop yield was

1976 kg ha^{-1} which was much lower than the irrigated treatments. Within the irrigated treatments, there was no corn yield difference between tillage practices. The average corn yield across all three years was 11490 kg ha^{-1}. These data are similar to current agronomic yield values in GA that suggest conservation tillage practices (strip- or slit- tilled) are equal to or slightly better than those with conventionally tilled treatments and yield from no-tilled treatments was lower than either conventional or conservational tilled practices (Lee, 2010).

In 2010, there was no peanut yield difference due to tillage treatments. Irrigated peanut yield was 2.6 times greater than the non-irrigated peanut yield. Peanut grade values show that both the strip and no-tilled treatments had higher grade values (Total Sound Mature Kernels - TSMK) compared with the conventionally tilled treatment. These data agree with previous research which showed that peanut production with strip-tilled treatments using various crop covers did not have any clear yield advantage over conventionally tilled treatments (Grichar, 1998; Prostko, 2001; Sorensen et al., 2010), but strip-tilled treatments has been found to reduce yield losses from some diseases (Grichar, 1998; Johnson et al., 2001).

Drip Tube Longevity

The analysis of repairs and holes counted prior to peanut harvest is shown in Table 5. These probability values indicate there were different amounts of repairs when comparing tillage treatments, tubing wall thicknesses, and tillage by wall thickness interactions but with field location (edge versus middle of the field). The number of repairs within the tillage treatments show significantly less repairs in the conventionally tilled treatment compared with either strip- or no-tilled treatment. This was probably due to the time of “infield exposure” where the conventionally tilled area had the tubing removed resulting in less time available for biological or mechanical damage. Thus, tubing repair costs for the conventional tillage was a third less when compared with either strip or no-tilled practices.

The thinner wall thickness (0.20-mm) had 3.5 times more holes/repairs compared with the other thicker wall drip tubing. Consequently, the thinner wall thickness had higher associated repair costs compared with the other thicker wall tubing. Thinner wall thickness having more repairs or holes is just opposite of previous research (Sorensen et al., 2007) which showed fewer holes with thinner tubing compared with thicker tubing.

Tillage by wall thickness interaction shows that most repairs occurred with the thinner walled tubing in the strip- and no-tilled treatments and not in the conventional treatment. Again more holes or repairs in strip- or no-tilled treatments can be explained by “field exposure” but does not explain why the thicker walled tubing with the same time exposure had less damage than the thinner walled tubing. Another possible reason for more damage in the thinner walled tubing could be from mechanical mowing (commonly called “bush-hogging”) of corn and cotton stalks. During mechanical mowing events, it was notice that an “air vacuum” occurs under the equipment with the rotating blade lifting plant debris and soil from the soil surface and in some areas removing enough soil to expose the drip tubing. At this time, fast moving plant debris could pierce the thinner walled drip tubing but not the thicker walled tubing. It is unknown if this occurred, however, it was noticed by personnel, small pin-like holes in the thinner tubing following a mechanical mowing. More data would need to be collected to determine if more holes occur in tubing with mechanical mowing in which case the tubing would need to be buried deeper or the tractor operator should not have the mower deck close to the soil surface.

Table 6 shows the total number of repairs and holes per hectare counted over the 5-yr life of the project. Previous research indicated that the “break even” point for the cost to repair holes versus replacement cost of drip tubing was about 500 holes ha^{-1} (Sorensen et al., 2007). The total number of holes in the conventionally tilled treatment averaged across all wall thickness was 58 holes yr^{-1} with a projected life to replace lateral at 8.6 years. The no-till treatment averaged 98 holes yr^{-1} or about 5.1 years and strip-till treatment averaged 136 holes yr^{-1} or 3.7 years before tubing cost to repair was greater than the cost to replace. The average time for tube replacement across all tillage regimes and wall thickness was about 5.8 years. It would seem plausible that 5-yrs would be a good time to replace tubing, depending on management as noted above with mechanical mowing or other mechanical type tillage practices used in the field. With good management in keeping the tubing buried (or remove and re-install), the drip tubing could last up to 8 years before replacement is needed.

Partial Net Revenue

Since there was no difference in crop yield by year or tillage treatment, there was also no difference in gross revenue within crop specie (year) or tillage treatment. There were large differences between irrigated and non-irrigated gross revenues by year. This was especially true in corn where yields were zero in 2007 and 2008 due to drought and gross revenue in those same years was also zero.

The total gross revenue over the life of the project averaged over all the irrigated treatments was \$10313 ha^{-1}. Numerically, conventional tillage had greater gross revenue, followed by strip- till, then followed by no-till. When subtracting expenses due to irrigation, tillage, tubing repair and tubing removal and re-installation (conventional tillage only), the numerical order changed such that the no-till had higher dollar value return per area (\$9372 ha^{-1}), followed by strip-till (\$9350 ha^{-1}), then followed by conventional till (\$8897; Table 7).

The cost of tillage was significantly greater for the conventionally tilled treatments compared with strip- or no-tilled treatments. The cost of drip tube repairs was 2.5 times greater for both strip- and no- tilled treatments compared with conventionally tilled treatment. The cost of tillage may have been less for strip- and no-till treatments, but the extra cost of tubing repairs brought the total expenditure to values similar to conventional tillage. Conversely, the yearly cost of tubing removal and installation with the conventionally tilled treatments decreased the net returns below that of strip- or no-till treatments. Overall, there was less expense with strip- and no-till treatments with S3DI compared with conventionally tilled treatments and the yearly removing and reinstalling drip tubing.

As to which tillage regime is recommended for S3DI, strip- and no-till seem to be the most economical, however, the final decision should be left to the grower due to his personal preferences for tillage equipment and style of management. Each tillage type has its own unique challenges, conditions, expenses and results and must be evaluated by the grower.

Conclusions

There was no yield difference within irrigation or tillage treatment for cotton, corn, or peanut. Yield in all three crops were greater with irrigation compared with non-irrigation in all treatments tested.

There were significantly less repairs in the conventional tillage treatment than other treatments probably due to less exposure time in the field. There were more repairs in the thinner wall tubing than thicker tubing probably due to mechanical damage from mowing crop debris and operator error of lowering the “bush-hog” too close to the soil surface.

The cost of tillage was significantly greater for the conventional tillage compared with strip tillage or no tillage. The cost of tillage may have been less for strip and no tillage but the extra cost of tubing repairs brought the total expenditure to values similar to conventional tillage. The cost of yearly tubing removal and installation was greater for conventional tillage such that the partial net return to the grower was numerically less compared with strip or no tillage operation system. Overall, there was less expense with strip and no tillage with S3DI compared with conventional tillage with the yearly removing and reinstalling the same drip tubing.

Overall, the use of S3DI is recommended for strip and no till situations with cotton, corn and peanut for best yields and economic returns. The average time for tube replacement across all tillage regimes with a cotton-corn-peanut rotation would be about 6 years provided cotton and corn was raised in the first 5 years and peanut in the last year of the rotation.

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Table 1. Expenses documented or simulated for various management techniques of conventional and conservation tillage, drip irrigation installation and retrieval. Operations that were the same for all tillage treatments are not shown. In fall 2005 all plots were prepared the same with winter wheat being planted across all plots. CT= conventional tillage, ST = strip tillage, and NT = no tillage.

Treatment	**CT**	**ST**	**NT**
		$/ha	
Disk harrow[†]	20	--	--
Chisel plow	19	--	--
Row bedding	25	--	--
field cultivate	22	--	--
Strip tillage	--	28	--
Spray – spring	--	9	9
Tubing removal	33	--	--
Tubing install	33	--	--
Yearly total	152	37	9
5-year total	760	185	45

[†] Expense values determined from University of Georgia crop budgets with $10/hour labor and $1.0/L fuel costs. www.ces.uga.edu/Agriculture/agecon/budgets/budgetsexcel.htm

Table 2. Crop, year, irrigation, rainfall, and time period of rainfall measured during the growing year for 2006 to 2010.

Crop	Year	Irrigation	Rainfall	Time period
		--------- mm	--------	
Cotton	2006	322	394	01May - 15 Oct
Corn	2007	480	276	15 Mar-15 Aug
Corn	2008	380	388	15 Mar-15 Aug
Corn	2009	314	766	15 Mar-15 Aug
Peanut	2010	224	451	01 May - 01 Oct

Table 3. Crop yield measured by year for irrigated and nonirrigated tillage treatments. CT= conventional till, ST = strip-till, and NT = no-till.

Treatment		**2006**	**2007**	**2008**	**2009**	**2010**
		Cotton	**Corn**	**Corn**	**Corn**	**Peanut**
irrigated				**yield – kg ha^{-1}**		
	CT	1769a	11452a	11889a	10963a	3854a
	ST	1775a	11001a	12343a	11059a	3079a
	NT	1718a	11571a	12392a	10744a	3307a
nonirrigated						
	CT	515b	0	0	1976	1288
	ST	957b	0	0	--†	--

Means within column and treatment followed by the same lower-case letter are not significantly different (p=0.05).

† = Not planted

Table 4. Gross revenue received by crop and by year for irrigated and non-irrigated tillage treatments and total gross revenue for the copping system. CT= conventional till, ST = strip-till, and NT = no-till.

Treatment	Cotton	Corn	Corn	Corn	Peanut	Total
irrigated			**$ ha^{-1}**			
CT	2605a	2027a	2152a	1984a	1734	10503
ST	2615a	2048a	223a4	2002a	1386	10284
NT	2530a	1947a	224a3	1945a	1488	10153
nonirrigated						
CT	758	0	0	358	580	1696
ST	1409	0	0	--†	--	1409

Means within the same column and treatment with the same lower-case letter are not significantly different (p=0.05).
† = Not planted

Table 5. Probability values for holes and repairs by tillage (T), wall thickness (W), and field location (L) of drip tubing in the field.

Source	DF	Holes P value	Repairs P value
Tillage (T)	2	0.3863	0.0059
Wall (W)	2	0.1548	0.0000
Location (L)	3	0.9542	0.2117
T*W	4	0.2131	0.0494
T*L	6	0.1125	0.3192
W*L	6	0.7694	0.7092
T*M*L	12	0.3902	0.4982

Table 6. Number of repairs, holes, and total repairs and holes counted at the end of the project by tillage treatment and tube thickness. CT= conventional till, ST = strip-till, and NT = no-till.

Tillage treatment	**Tube thickness**	**Repairs**	**Holes**	**Total**	**Average holes**
	mm	**------------ ha^{-1}**		**--------------**	**yr^{-1} ha^{-1}**
ST	0.20	987a	239a	1226	245
NT	0.20	837ab	120a	957	191
CT	0.20	269c	150a	419	84
NT	0.25	299bc	0a	299	60
CT	0.25	240c	150a	389	78
ST	0.25	209c	329a	538	108
NT	0.38	209c	0a	209	42
ST	0.38	209c	60a	269	54
CT	0.38	0c	60a	60	12

Means in the same column followed by the same lower-case letter are not significantly different (p=0.05).

Table 7. Total gross revenue, tillage expense, irrigation expense, tubing repair expense, and partial net revenue compared with tillage treatment over the life of the project. CT= conventional till, ST = strip-till, and NT = no-till.

Tillage treatment	**Total gross revenue**	**Tillage expense**	**Irrigation expense**	**Repair expense**	**Partial Net revenue**
			$/ha		
CT	10503	760	732†	114	8897
ST	10284	185	435	314	9350
NT	10153	45	435	301	9372

† $435 initial S3DI installation plus $297 for estimated total yearly cost to install and remove tubing in conventionally tilled treatments.