SOIL AMENDMENT AND TILLAGE EVALUATIONS TO IMPROVE GERMINATION WITH SUBSURFACE DRIP IRRIGATION

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Abstract

Achieving uniform cottonseed germination during planting periods of low rainfall and high air temperatures and wind speeds has been a major challenge when using subsurface drip irrigation (SDI) in the Texas High Plains. A field experiment having different soil amendments placed in pathways from near SDI laterals to seed germination zones was conducted in an attempt to improve soil surface wetting and germination in 2006 and 2007. A second experiment with similar objectives using different tillage treatments was conducted in 2008. All work was performed at the Texas AgriLife Research and Extension Center at Halfway, TX on a Pullman clay loam soil. Soil amendment treatments included the starch-based polymers Pam and Zeba™ each applied at 20 lb/acre, composted cow manure at 400 lb/acre, a combination of composted cow manure plus gypsum at 400 lb/acre each, and a "no amendment" treatment where soil was disturbed as if an amendment were applied, but no amendments were used. Tillage treatments included strip-tillage and the combination of sub soiling (Paratill® Bigham Brothers, Inc., Lubbock, TX) and strip-tillage. Under the conditions of these experiments, neither the soil amendment nor the tillage treatments improved soil wetting in the seed germination zone over untreated checks. There was evidence that tillage alone could improve seed zone wetting and that the soil amendment Zeba™ might reduce soil surface evaporation maintaining available planting moisture for longer periods of time compared to non-treated areas. Finding methods to improve germination with SDI may help producers adopt more efficient irrigation systems and conserve water.

Introduction

Irrigated agriculture plays a very important role in the state of Texas with over 4 million acres of irrigated cropland (TASS, 2005). Most of these 4 million acres are located in the Texas High Plains over the Ogallala Aquifer and account for approximately 15 percent of the total irrigated acreage in the U.S. (Segarra et al., 1999). As the state population increases and available irrigation water decreases, new technologies are being developed to maintain or increase production on fewer acres. One of these advancements is the use of subsurface drip irrigation (SDI) on lower valued field crops. Research has shown that SDI is the most efficient in-season water application method available to producers in the Texas High Plains (Bordovsky and Porter, 2003).

An estimated 250,000 acres of irrigated cotton are being grown using SDI in the Texas High Plains (McMichael et al., 2006). Other than water use efficiency, the benefits of SDI over other irrigation methods include precision control of quantities and amounts, unique chemigation potential, irrigation while conducting normal field operations, and decreased annual weeds. Although SDI has many benefits, its use also presents challenges such as consistent, uniform seed germination. Timely upward movement of irrigation water from buried drip laterals to the seed planting zone can be difficult depending on the condition of the soil profile including soil texture, density, organic matter and soil layering. This process is further aggravated by dry, windy conditions that can occur in the Texas High Plains during cotton planting and early crop development periods from late April through May. Daily evaporation from free water surfaces can exceed available irrigation rates during this critical period.

Soil amendments and/or soil conditioners have been used for years to improve soil physical properties in the hope of improving crop production or reducing erosion. Adding organic matter improves soil structure and water holding capacity. Although a large portion of the organic carbon is lost in composting and the value of organics for soil improvement comes mainly from carbohydrates (Lax and Garcia-Orenes, 1993), composting cow manure pasteurizes the organic material killing pathogens and weed seeds, provides a more uniform material for field application than raw organic matter, and is commonly available. Advantages of gypsum include greater stability of soil organic matter, more stable soil aggregates, improved water penetration into soil, reduced crusting, improved hydraulic conductivity, decreased compaction and reduced bulk density (Sumner and Miller, 1992; Shainberg et al., 1989). There are many water soluble polymers and some are used to enhance pore space in soils (Wallace and Wallace, 1986). Pam is a water soluble polymer that can aid in the stabilization of soil aggregates to improve the ability of the water to penetrate and improve water infiltration on some soils (Wallace and Wallace, 1995). Zeba^{TM} (Absorbent Technologies Inc., Beaverton, Oregon) is a superabsorbent polymer derived from natural cornstarch, will absorb 400 times its original weight in water, and has been used as a seed coating as well as soil amendment in vegetable production according to commercial literature.

The goal of this project was to evaluate options that might lead to increase cottonseed germination in fields irrigated with SDI in the Texas High Plains. Two experiments were conducted, the first using different soil amendments as treatments, in the second, methods of tillage were treatments. The ability to consistently germinate cottonseed in a timely fashion is the first crucial step to achieving a productive cotton crop and high irrigation water use efficiency.

Materials and Methods

Field experiments were conducted at the Texas AgriLife Research and Extension Center at Halfway, TX from 2006 to 2008. The research site was at the Helms Research Farm, 2 miles south of Halfway. In 2005, a 1-acre SDI system was installed in a Pullman clay-loam soil having less than 0.2% slope from west to east and that had not been in production for 6 years. Drip laterals were installed on 60-inch centers in an east-west direction using standard drip installation implement and tractor with RTK guidance. Drip lateral depth averaged 14 inches below the leveled soil surface. Thirty-inch wide rows were formed with each lateral serving two crop rows, the area was bordered and flood irrigated to settle soil around drip laterals. SDI emitters spacing was 24 inches and emitter flow rate was 0.16 gph at 10 psi. Irrigation water was from a local domestic well capable of delivering 25 gpm at 30 psi. Pressure regulation, filtration, and flow control was provided at the head of the irrigation system.

In June 2006, soil amendments were placed at multiple sites within the test area. The soil amendment treatments required the excavation of soil and placement of amendments adjacent to drip laterals up to the seed planting zone. The treatments included polyacrylimide or Pam at 20 1b/acre, (Earth Chem., Inc., Scottsbluff, Nebraska), Zeba^{TM} at 20 lb/acre (Absorbent Technologies, Inc., Beaverton, Oregon), composted cow manure at 400 lb/acre (Back to Nature, Lubbock, TX), a mixture of composted cow manure and gypsum at 400 lb/acre each, and a “no amendment” treatment where soil was excavated as if an amendment were applied, but no amendments were used. The five treatments were replicated four times, resulting in 20 amendment sites. Excavations were by hand using shovels. Soil was removed to form a “V” shaped trench with the drip lateral exposed at the bottom of the “V” and the tops of the “V” located at the top-center of the 30-inch wide seed beds (Figure 1). Each trench was 6 ft long and accommodated two of the 20 amendment sites (Figure 2). The soil amendment for a site was mixed with approximately 0.5 ft^3 of soil removed from the trench. This mixture was evenly applied by hand along one wall of the trench using small amounts of sprayed water for adhesion. A second soil amendment was applied in similar fashion on the opposite trench wall creating a second treatment site. The locations of SDI emitters at these sites were marked, the trenches backfilled, the profile soil consolidated with hand tools, and the beds reshaped to their original form.

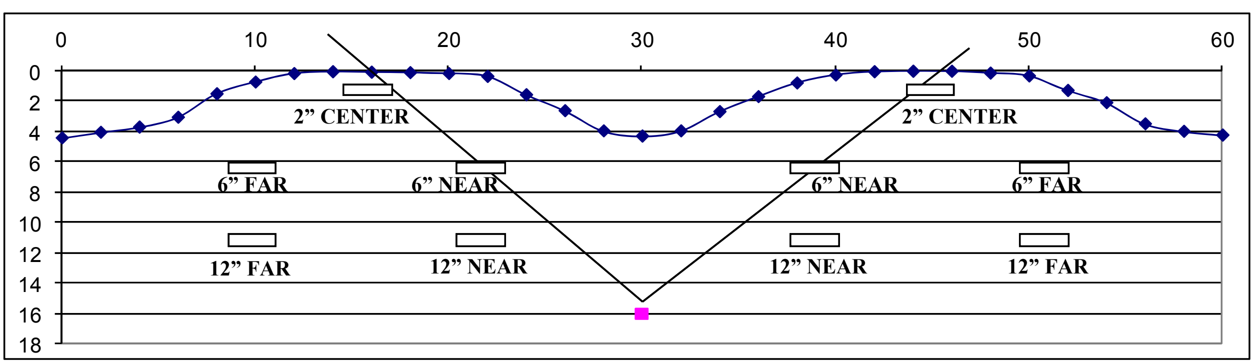

Figure 1. Locations of TDR sensors and soil amendments relative to drip laterals and crop rows of two adjacent treatment sites in the SDI cottonseed germination study at the Texas AgriLife Research Center, Halfway, TX, 2006 and 2007.

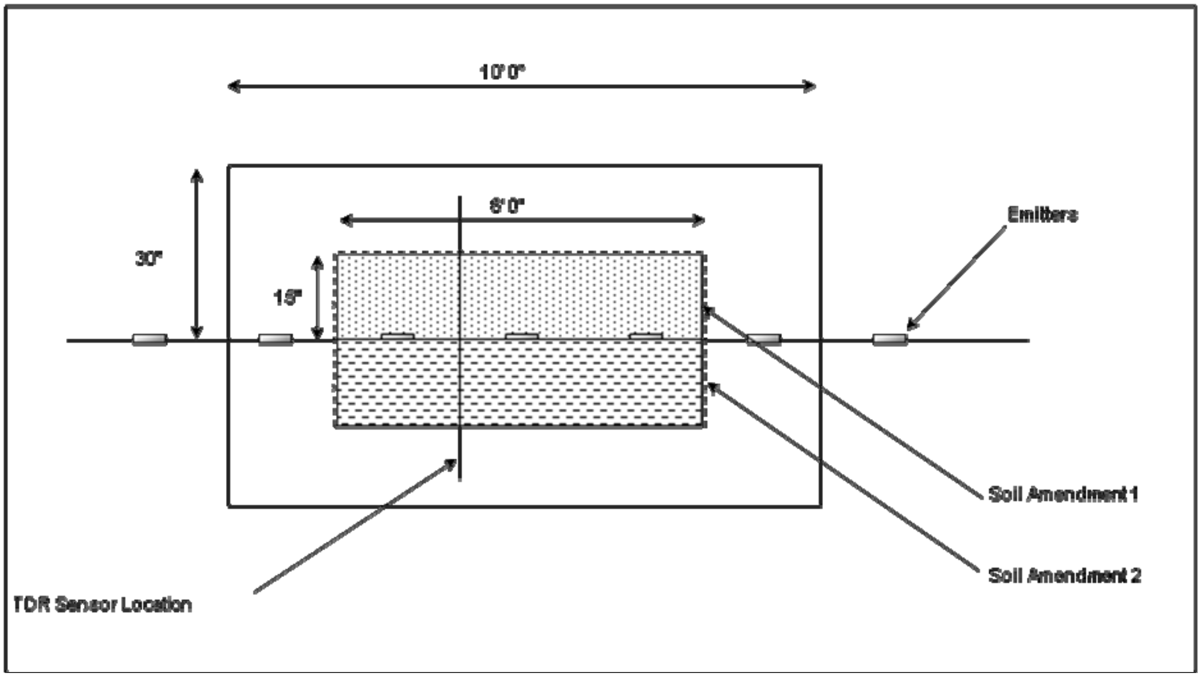

Figure 2. Schematic diagram of adjacent treatment sites in the SDI cottonseed germination study at the Texas AgriLife Research Center, Halfway, TX, 2006 and 2007.

After amendment placement the SDI area was cultivated to create uniform seed beds, corn planted at 75,000 plants per acre, and the area flood irrigated to resettle the "V" trenched areas. The rapid growth and high transpiration of young corn plants dried the treatment sites for controlled rewetting with the SDI system at a later time. Immediately following corn germination, ten time domain reflectometry (TDR) moisture sensors (Evett and Ruthardt, 2005) were installed at three depths at each pair of sites (Figure 1). After careful excavation of narrow trenches oriented perpendicular to the drip lateral, TDR sensors were pressed horizontally into the consolidated soil profiles with the center of each sensor located equidistant from adjacent buried SDI emitters at 2, 6, and 12 inches below the top of the seed beds (Figure 2). Soil was again backfilled and manually consolidated. Treatment checks where no amendment or amendment excavation had occurred were also established at an additional pair of sites and soil sensors installed. The TDR sensors were used to measure differences in soil volumetric water content (VWC) among by treatments as the soil was wetted with the SDI system.

To prevent rainfall from masking the effects of irrigation, each pair of sites were covered with a small shelter and rain water routed away from treatment sites by modifying crop rows intersecting sheltered areas. The domed-shaped shelters covered 10 ft x 10 ft surface areas and were constructed of clear plastic greenhouse film (Hummert International, Springfield, MO.) fastened to frames constructed of PVC pipe. The frames were built so the covers were one foot above the crop rows allowing air to move under the shelter and over soil surfaces.

Data was collected from the soil sensors using a mobile TDR100 (Campbell Scientific, Logan, Utah) and field computer (Panasonic Toughbook, Secaucus, NJ). Raw data was collected daily prior to and during the irrigation portion of the field trial and processed using TDR Data Acquisition (TACQ) software (Evett, 1998). This process resulted in values for VWC at each sensor location and treatment site every day data was acquired. Periods of irrigation and data acquisition, irrigation intervals, and total irrigation amounts for the three years are shown in Table 1. In 2006, drip irrigation was started on 31 July and ended on 30 August. Daily irrigation run time was 7 hrs over two periods, 10:00 AM to 1:30 PM and 10:00 PM to 1:30 AM. As noted in Table 1, VWC was measured prior to and following irrigation periods.

Table 1. Irrigation periods, intervals, frequency, annual amount, and data collection periods during seed germination experiments with subsurface drip irritation at Texas AgriLife Research, Halfway, 2006-2008.

	2006	2007	2008
Start Date (calendar / julian)	Jul 31 (212)	July 10 (191)	Aug 13 (225)
End Date (calendar / julian)	Aug 30 (242)	Aug 13 (225)	Sept 8 (251)
Interval (hrs)	12	12	12
Quantity per Irrigation (in)	0.1	0.1	0.1
Total Quantity (in)	6.0	6.8	5.2
Data Acquisition Start (calendar / julian)	July 11 (192)	Jan 4 (4)	July 25 (206)
Data Acquisition End (calendar / julian)	Dec 12 (346)	Sept 13 (256)	Oct 7 (280)

From the Sept. 2006 until June 2007, shelters were removed, however, treatment sites were left undisturbed and soil sensors remained in the 2006 locations. The entire treatment area was planted in wheat in October 2006. The soil water content of all test sites was reduced due to transpiration of the wheat plants. By June 2007 all vegetation was chemically terminated and wheat residue removed. The sites were again covered with the rainout shelters and the 2006 wetting cycle was repeated again in 2007 (Table 1).

Due to the results seen in 2006 and 2007, a different experiment was conducted in 2008. The previous treatments were altered to examine tillage effects on seed zone wetting. The three treatments were the use of strip tillage (ST), the combination of a Paratill™ (PT) (Bigham Brothers, Lubbock, TX) then strip tillage (ST), and a non-treated check (Figure 3). The treatment areas were shifted from the 2006-2007 areas to an area that had been in wheat in 2007 and chemically fallowed since that time. All treatments were contained in each of four blocks resulting in 12 plots. Twelve days after the plots were tilled with the appropriate implement, TDR sensors were installed at each treatment site. Sensors were placed at seed-drill locations in the top-center of the 30-in beds at depths of 2 and 6 inches below the soil surface (Figure 3). Again, the 10 ft x 10 ft rainout shelters were placed over each treatment area, irrigations were initiated, and soil VWC's for each treatment were determined (Table 1).

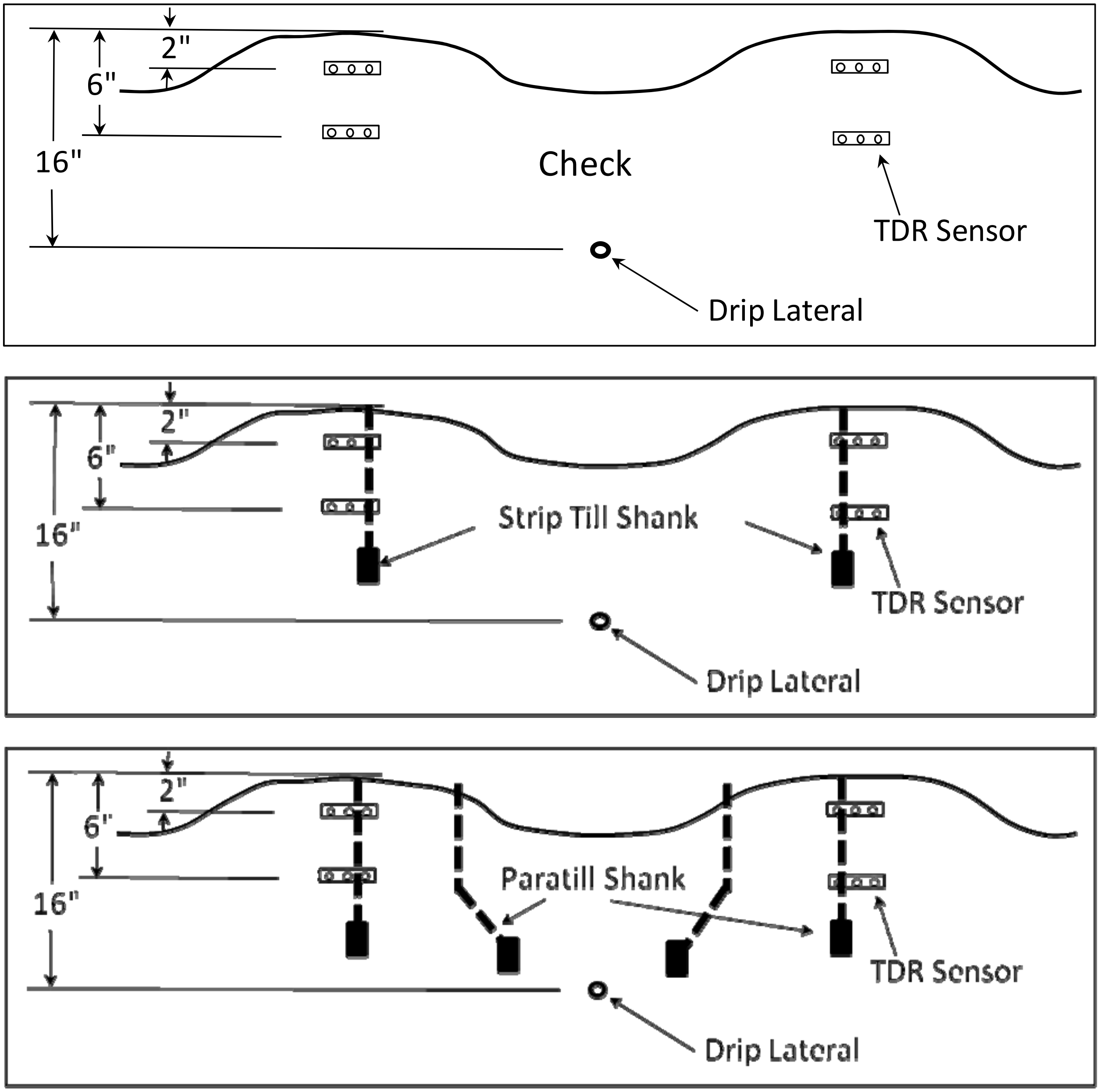

Figure 3. Locations of TDR sensors and tillage tools relative to drip laterals and crop rows for Check, Strip-Till, and Para-till plus Strip Till treatments in the SDI cottonseed germination study at the Texas AgriLife Research Center, Halfway, TX, 2008.

Results

Changes in soil volumetric water content of the five amendment treatments and treatment checks during the test periods in 2006 and 2007 are shown in Figure 4. Individual graphs show results of the five TDR sensor locations with each graph point representing an average of replicated soil water quantities for that time, treatment, and sensor location. The beginning time of each graph starts prior to the irrigation initiation and continues for at least 30 days fallowing irrigation termination with the entire time under the rainout shelters. Irrigation water reaching sensor locations were signified by a marked increase in soil VWC. Within each treatment and year, water reached the sensor location closest to the drip lateral (12” Near) first and the top of the seedbed (2” Center), generally, last. Soil VWC at the 2” Center location in all treatments failed to reach the levels of the deeper locations, with soil locations at 12” depths generally wetter than those at 6” (Figure 4).

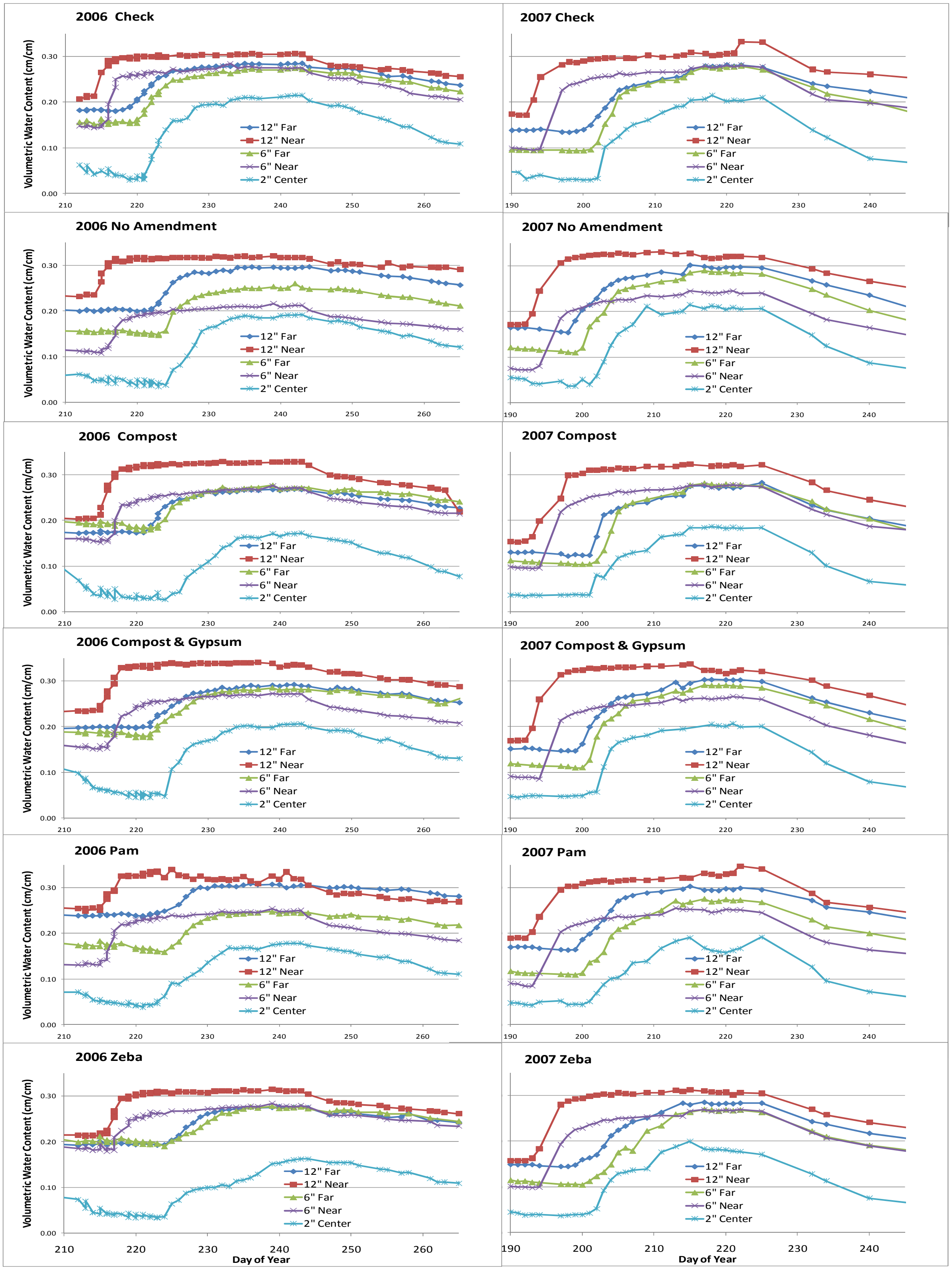

Figure 4. Soil VWC measured by TDR sensors at five locations adjacent to drip laterals in six treatments during irrigation and drying cycles in the SDI cottonseed germination study at Texas AgriLife Research Center, Halfway, TX, 2006 and 2007.

The time for irrigation water to reach sensors is given in Table 2. The average time for water to reach the 2” Center location, or the seed drill location, was 12.5 days in 2006 and 11.2 days in 2007. Of the soil amendments, the Pam treatment resulted in slightly quicker seed drill wetting at 11 and 10 days in 2006 and 2007, respectively, than the other treatments. The treatment that took the longest to wet was the Comp. & Gypsum treatment in 2006 at 15 days and the Compost treatment at 12 days in 2007. As shown in Table 2, treatment with any of the soil amendments failed to substantially decrease the time required for wetting sensor locations compared to the treatments where no amendments were applied or in the check areas where sensors were installed in the undisturbed soil profile. Time required to wet sensor locations were generally less at all locations and all amendment treatments in 2007 than 2006, indicating soil consolidation over this one year time period tended to enhance water movement from the drip lateral to the seed drill location.

Table 2. Number of days from irrigation initiation to evidence of increase volumetric soil water at given TDR sensors locations in plots having different soil amendents at Texas AgriLife Research, Halfway, TX, 2006-2007.

		Check	No Amend.	Zeba	Pam	Compost	Comp & Gypsum	Avg.
2006	2" Center	10.0	13.0	13.0	11.0	13.0	15.0	12.5
	6" Far	8.0	13.0	13.0	12.0	10.0	11.0	11.2
	12" Far	7.0	10.0	13.0	13.0	9.0	9.0	10.2
	6" Near	3.5	4.0	5.0	5.0	5.0	5.0	4.6
	12" Near	3.0	3.0	4.0	4.0	4.0	3.0	3.5
	Avg.	6.3	8.6	9.6	9.0	8.2	8.6	8.4
2007	2" Center	12.0	11.0	11.0	10.0	12.0	11.0	11.2
	6" Far	11.0	9.0	10.0	10.0	10.0	11.0	10.2
	12" Far	9.0	8.0	9.0	9.0	9.0	11.0	9.2
	6" Near	4.0	3.0	4.0	3.0	3.0	4.0	3.5
	12" Near	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Avg.	7.6	6.6	7.2	6.8	7.2	7.8	7.2

Following initial sensor wetting, irrigations were continued and soil water measurements taken to document peak soil VWC at the seed drill position. Peak VWC and times to reach peak VWC of 2006 and 2007 treatments are contained in Figure 5. In both years, the highest water contents at the 2” Center location were in the Check treatments where soil adjacent to drip tape laterals had not been disturbed resulting in peak soil VWC contents of 0.215 cm/cm. This was followed by the No Amendment and Comp. & Gypsum treatments, then the Zeba™, Pam, and Compost treatments with lower water contents. The times to reach peak VWC of the 2” Center locations of the No Amendment treatments were 28 days in 2006 and 18 days in 2007. All other treatments required 24 to 32 days to reach peak soil VWC’s.

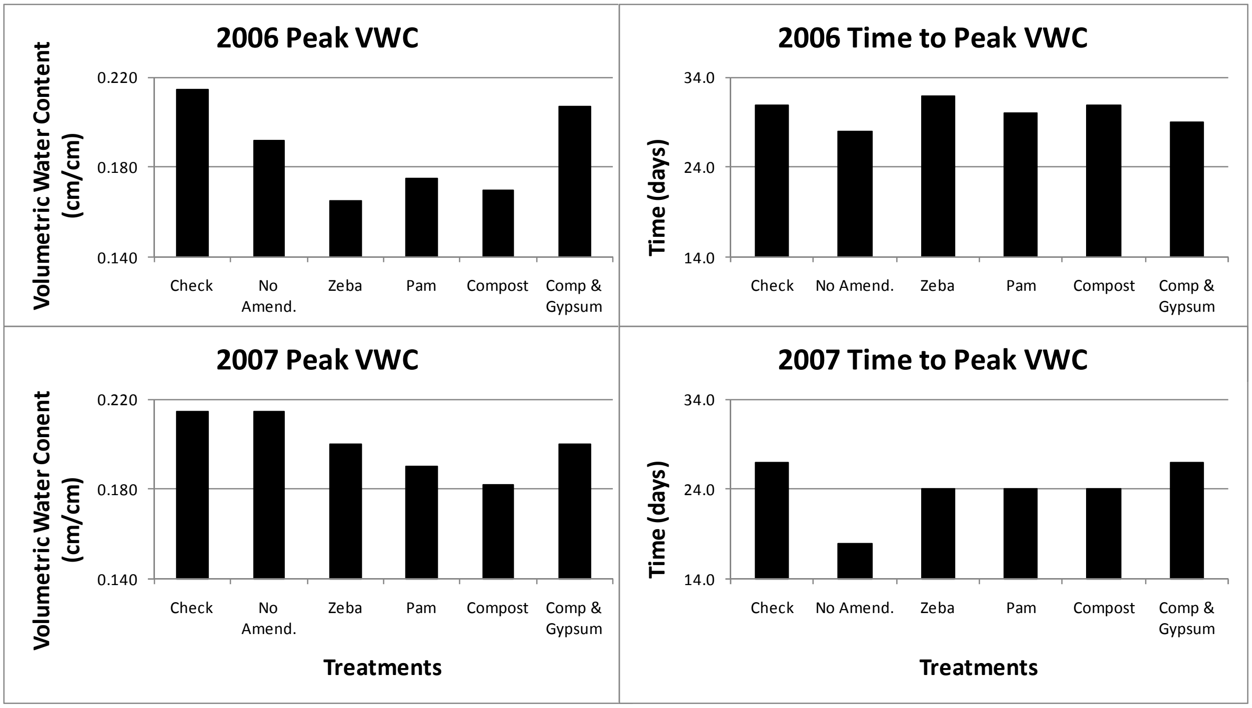

Figure 5. Peak VWC values and the time required to reach peak VWC at the 2” Center location of six soil amendment treatments in the SDI cottonseed germination study at Texas AgriLife Research Center, Halfway, TX, 2006 and 2007.

Although there seems to be little benefit in using these soil amendments to increase soil VWC in the seed germination zone, the Zeba^{TM} treatment appeared to slightly reduce the rate of soil drying following irrigation termination compared to other treatments. The change in VWC of areas while under rainout shelters following irrigation termination is given in Figure 6. In the 2006 test year, rate of soil water loss ranged from 0.0026 cm/cm-d for Zeba^{TM} to 0.0043 cm/cm-d for the Compost treatment. In 2007, all water losses were much greater than in the previous year ranging from 0.0076 cm/cm-d for Zeba^{TM} to 0.0089 cm/cm-d in the Check treatment. Differences in rates between years were thought to be due to different evaporative conditions during the respective test periods. However, this data supports the theory that the use of concentrated soil amendments in the seed germination zone prior to planting may improve germination by improving retention of any moisture available during this time of the year.

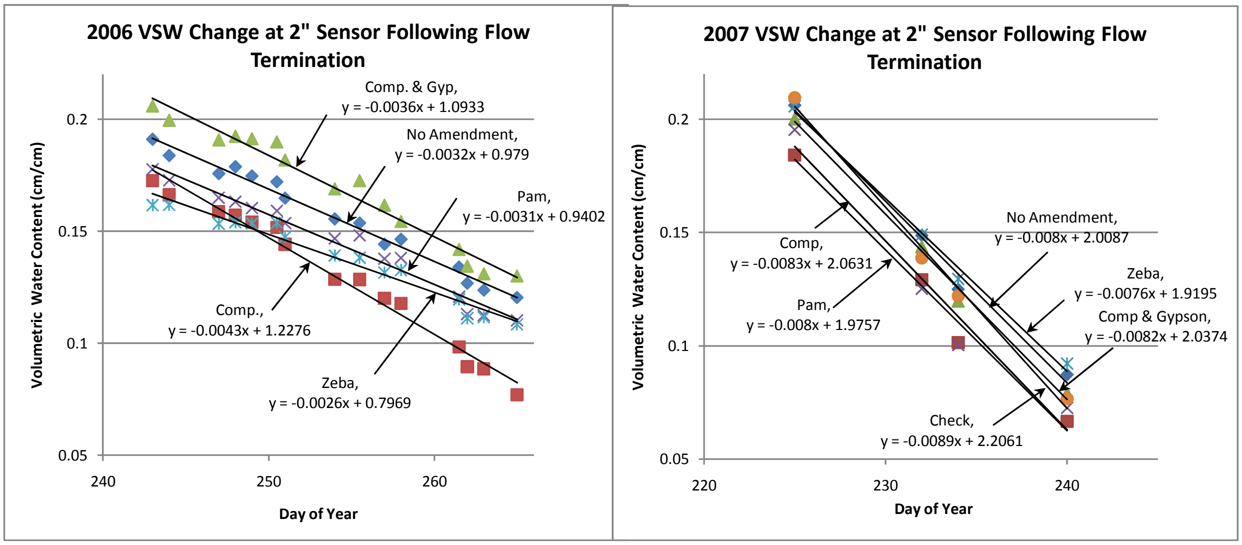

Figure 6. Change in VWC at the 2” Center locations of six soil amendment treatments following irrigation termination in the SDI cottonseed germination study at Texas AgriLife Research Center, Halfway, TX, 2006 and 2007.

In 2008, neither the strip tillage (ST) nor the Para-till plus strip tillage (PT&ST) treatment result in faster wetting of the seed germination area than did the non-tilled Check treatment. The time to wet soil sensors from irrigation initiation, the average VWC from sensor wetting to irrigation termination, and the increase in VWC due to irrigation at TDR locations is in Table 3. Each treatment wetted the seed germination zones very rapidly, within a 3-day period. At the 2” sensor location, the increase in measured soil VWC over the irrigation period was much larger for the Check treatment at 0.14 cm/cm than the ST and PT&ST treatments at 0.063 and 0.051 cm/cm, respectively. Also the average VWC after irrigation was much higher for the Check treatment at 0.240 cm/cm the than ST and PT&ST treatments at 0.13 cm/cm and 0.125 cm/cm, respectively. These results were partially due to poorer soil to sensor contact in the tillage treatments compared to the Check treatment.

Table 3. Time required to wet sensors from irrigation initiation, average VWC from sensor wetting to irrigation termination, and the increase in VWC due to irrigation at given TDR sensors locations in plots at Texas AgriLife Research, Halfway, TX, 2008.

	Sensor Depth	Check	Strip Till	Para & Strip Till	Average
Time to Wet Sensor (days)	2"	3.0	3.0	3.0	3.0
	6"	3.0	3.0	3.0	3.0
		3.0	3.0	3.0	
Average VWC during irrigation, day 233 to 252 (cm/cm)	2"	0.240	0.130	0.125	0.165
	6"	0.260	0.135	0.170	0.188
		0.250	0.133	0.148	
Increase in measured VWC due to irrigation (cm/cm)	2"	0.140	0.063	0.051	0.085
	6"	0.090	0.061	0.050	0.067
		0.115	0.062	0.051	

Conclusions

The results from these experiments were somewhat disappointing, but followed trends seen in unpublished laboratory experiments conducted in 2005. Neither the soil amendment nor the tillage treatments improved soil wetting in the seed germination zone over the untreated checks under the conditions of the experiment. Also, in all test years, untreated check plots wetted much faster and at higher water content than what is typically observed at planting in dry years. Differences in these tests compared to dry year field observations may be due to being unable to simulate the early May, dry environment using the rainout shelters, the time of the year that the tests were conducted, and possible differences in soil texture and cropping history of the test area compared to production SDI fields. On a positive note, in the first year of treatment, the rate of soil water loss from near the seed germination zone following the termination of SDI irrigation appeared to be reduced by the Zeba™ treatment.

Continued efforts to improve cotton germination in dry years with SDI will include applications of different levels of concentrated soil amendments in the seed germination zone in an attempt to maintain available water for germination. Also experiments using combinations of small irrigations, tillage, and light seedbed compaction during the off season will be tried at field scale.

Acknowledgements

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