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INVESTIGATING STRATEGIES TO IMPROVE CROP GERMINATION WHEN USING SDI

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INTRODUCTION

As the nation's population increases and available irrigation water decreases, new technologies are being developed to maintain or increase production on fewer acres. One of these advancements has been the use of subsurface drip irrigation (SDI) on field crops. Research has shown that SDI is the most efficient in-season water application method available to producers, especially under deficit irrigation (Bordovsky and Porter, 2003; Colaizzi et al., 2009). For certain soils, one of the inherent problems with SDI is seed germination during periods without rainfall. This paper summarizes efforts to improve germination when irrigating with SDI at the agricultural research centers at Halfway, Texas; Bushland, Texas; and Colby, Kansas. These efforts were broadly categorized in terms of soil amendments, drip lateral installation depth and row geometry, and preplant irrigation timing and amounts.

SOIL AMENDMENTS

"Wick" water into the germination zone.

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. Several materials were used in field experiments conducted at the Texas AgriLife Research and Extension Center at Halfway, Texas in 2006 and 2007 in an attempt to promote water movement upward from SDI laterals to the seed germination area in a Pullman clay-loam soil. In 2005, drip laterals were installed on 60-inch centers in an east-west direction using standard drip installation implement and tractor with RTK-GPS 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. SDI emitter spacing was 24 inches and emitter flow rate was 0.16 gph at 10 psi.

The study evaluated four soil amendment treatments compared to an undisturbed soil check and to an excavated soil with no soil amendments. The soil amendment treatments required the excavation of soil and placement of amendments from a depth adjacent to drip laterals up to the seed planting zone. The treatments included polyacrylamide or Pam at 20 lb/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, Texas), 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. Zeba^{TM} is a natural corn starch polymer. The five treatments were replicated four times, resulting in 20 amendment sites. Soil amendments were placed using hand tools in a two dimensional plane from the drip lateral to the crop germination zone. A detailed description of this process is reported by Cranmer et al., 2008. Time domain reflectometry (TDR) soil water measurement probes (Evett and Ruthardt, 2005) were installed at 2, 6, and 12 inch depths in arrays on each side of the SDI lateral (Figure 1). Treatment checks where no amendment or amendment excavation occurred were also established and soil probes installed. The soil probes were used to measure differences in soil volumetric water content (VWC) among the treatments as the soil was wetted with the SDI system. Values for VWC at each probe location and treatment site were acquired daily during the each test cycle.

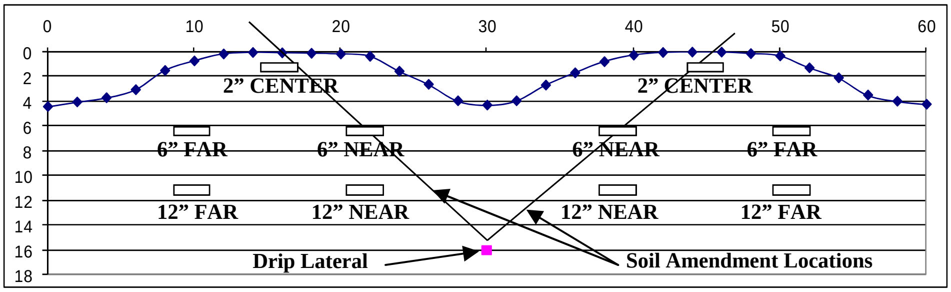

Figure 1. Locations of TDR probes and soil amendments relative to drip laterals and crop rows of treatment sites in the SDI cottonseed germination study at the Texas AgriLife Research Center, Halfway, TX, 2006 and 2007.

To prevent rainfall from masking the effects of irrigation, each site was covered with a small shelter and rain water routed away from treatment sites by modifying crop rows intersecting sheltered areas. 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. Irrigation depth was

0.10 in per application or 0.20 in per day. Without reapplying amendments or reinstalling the TDR probes, the soil wetting cycle was repeated again in 2007. Total irrigation applied was 6.0 and 6.8 inches in 2006 and 2007, respectively.

In both years, VWC was recorded prior to irrigation initiation and continued for 30 days following irrigation termination with the treatment locations under rainout shelters the entire time. Irrigation water reaching probe locations was signified by a marked increase in soil VWC. Within each treatment and year, water reached the probe location closest to the drip lateral (12" Near) first and the top of the seedbed (2" Center), generally, last. The time for irrigation water to reach probes is given in Table 1. 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 Compost and Gypsum treatment in 2006 at 15 days and the Compost treatment at 12 days in 2007. As shown in Table 1, soil amendment treatments failed to substantially decrease the time required for wetting probe locations compared to the treatments where no amendments were applied or in the check areas where probes were installed in the undisturbed soil profile. Time required to wet probe locations was generally less at all locations and all amendment treatments in 2007 than 2006, indicating soil consolidation over this one year time period may have enhanced water movement from the drip lateral to the seed drill location.

Table 1. Number of days from irrigation initiation to evidence of increased volumetric soil water at given TDR probe locations in plots having different soil amendments at Texas AgriLife Research, Halfway, Texas, 2006-2007.

		Check Undisturbed Soil	Excavated, No Amendment	Zeba^{TM}	Pam	Compost	Compost and 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 probe wetting, irrigations were continued and soil water measurements were 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 2. In both years, the highest water contents at the 2" Center location (i.e., intended seed zone location) were in the Check treatments where soil adjacent to drip laterals had not been disturbed resulting in peak soil VWC contents of 0.215 cm^3/cm^3. This was followed by the No Amendment and Compost and Gypsum treatments. The amount of time to reach peak VWC at 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 water content. 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" (data not shown).

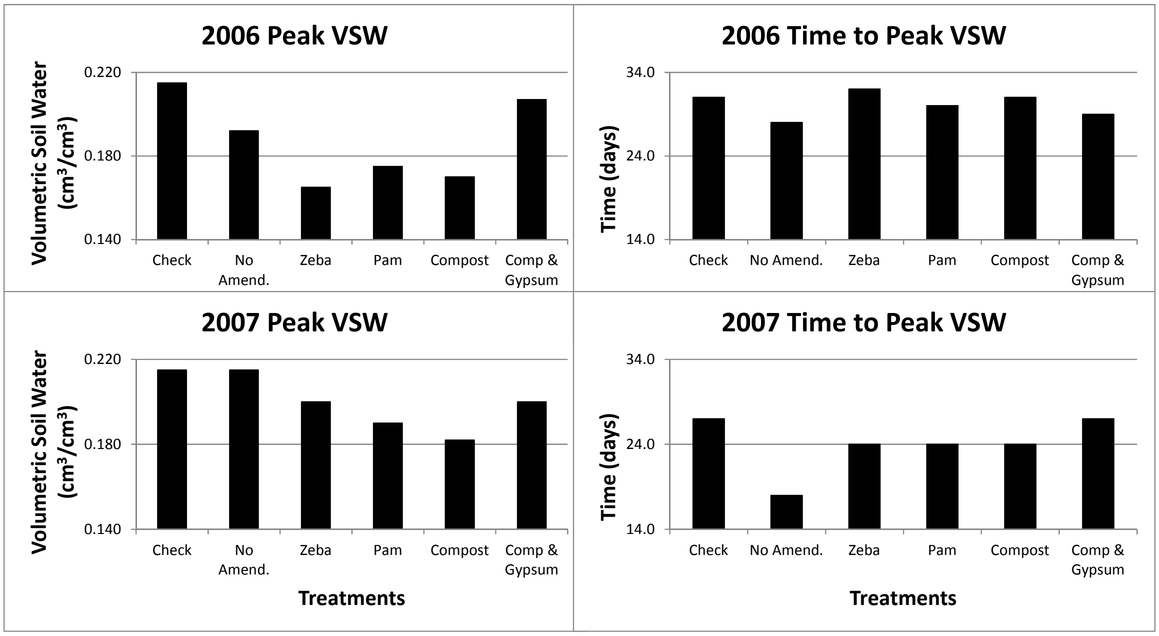

Figure 2. Peak VWC values and the time required to reach peak VWC at the 2" Center location of six soil amendment treatments in the SDI cottonseed germination study at Texas AgriLife Research Center, Halfway, TX, 2006 and 2007.

Although there seems to be little benefit in using these soil amendments to increase soil VWC in the seed germination zone by irrigation with SDI, the Zeba^{TM} treatment appeared to slightly reduce the rate of soil drying following irrigation termination compared to other treatments. In the 2006 test year, rate of soil water loss following irrigation termination ranged from 0.0026 cm^3/cm^3-d for Zeba^{TM} to 0.0043 cm^3/cm^3-d for the Compost treatment. In 2007, water losses ranging from 0.0076 cm^3/cm^3-d for Zeba^{TM} to 0.0089 cm^3/cm^3-d in the Check treatment. These data suggest that the use of the Zeba^{TM} soil amendment in the seed germination zone prior to planting might improve germination by retaining available soil water from rainfall or irrigation longer.

Incorporating polymers near the soil surface to reduce evaporation.

The soil amendment Zeba^{TM} was used in an experiment in 2008 in an attempt to improve cottonseed germination and yield. The field where the experiment was conducted was irrigated by SDI, lateral spacing of 60 inches, emitter spacing of 24 inches, emitter flow of 0.16 g/h at 10 psi, lateral depth of 15 inches below level soil surface, and crop row spacing of 30 inches. On 10 April, the polymer was placed two inches deep in rows where cottonseed would later be planted using an eight row planter with material being metered from insecticide boxes. Treatments included polymer rates of 3.2, 6.9, and 10.8 lbs/ac along with an untreated check, 0.0 lbs/ac. Plots were 2 rows wide by 200 ft long and were replicate eight times. Seasonal irrigation was daily with amounts determined by soil water balance and 100% ET_c replacement. Following planting on 10 May, TDR probes were installed in seedbeds perpendicular to the soil surface directly in the plant row at three locations per plot, and in three replicates of each treatment. The seedbeds were allowed to be wetted by precipitation events. Volumetric soil water content was measured from May through September.

The average volumetric soil water content for each treatment through the growing season is shown in Figure 3. All treatments followed the same pattern of change in soil water content and were not drastically affected by the quantity of polymer applied. In terms of cotton lint yield, the untreated check produced 1576 lbs/acre and was not significantly different than the yields of 1456, 1681, and 1701 lbs/acre from the 3.2, 6.9, and 10.8 lb/acre Zeba^{TM} treatments, respectively (Figure 4).

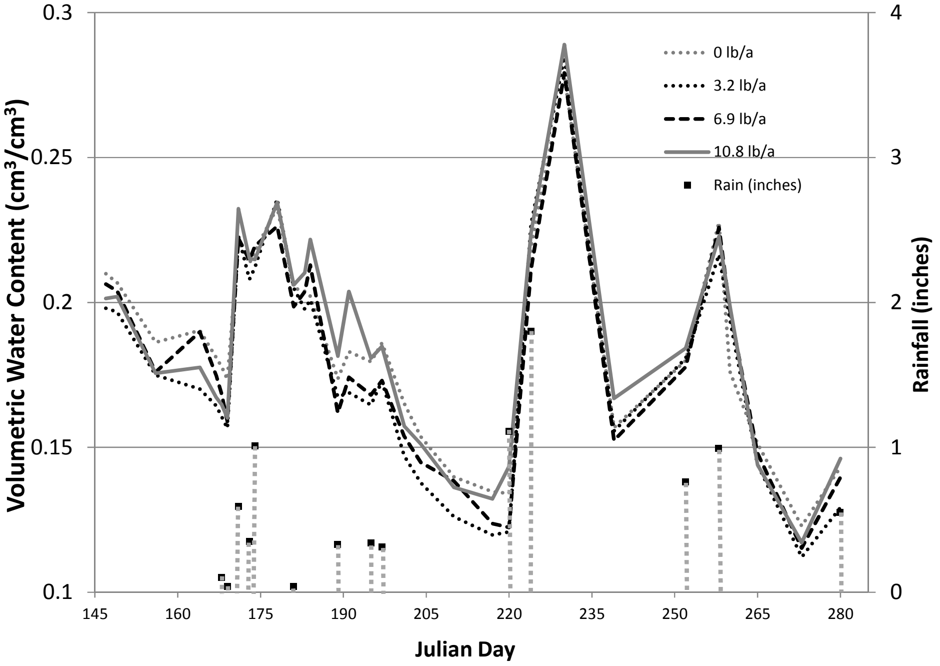

Figure 3. Volumetric soil water content resulting from three rates of Zeba^{TM} polymer applied in the seed drill and determined by TDR probes placed in seedbeds near the soil surface at Texas AgriLife Research Center, Halfway, TX., 2008.

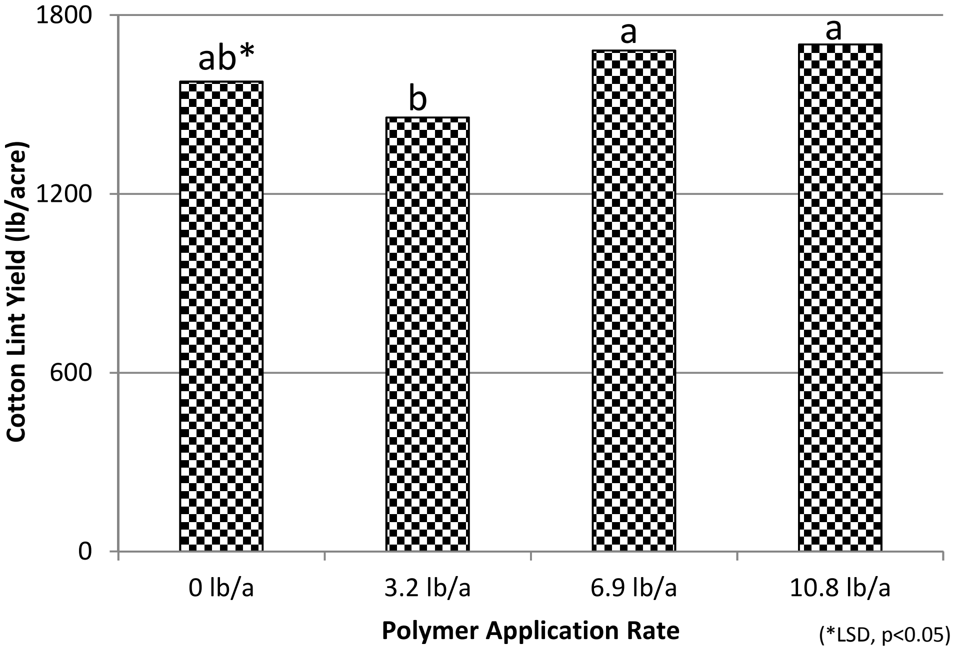

Figure 4. Effects of pre-plant Zeba^{TM} application rates on cotton lint yield, at Texas AgriLife Research Center, Halfway, TX., 2008.

DRIP LATERAL INSTALLATION DEPTH AND ROW GEOMETRY

Bushland Studies

At the USDA Agricultural Research Service Conservation and Production Research Laboratory in Bushland, Texas, scientists evaluated emergence and grain yield with SDI laterals installed in wide beds containing two seed rows and compared this with laterals installed in alternate furrows and in every bed. Drip laterals are commonly installed in alternate furrows because installing laterals in every bed for low value crops is typically uneconomical (Enciso et al., 2005). The wide bed, or twin row design has been used successfully throughout the world for a wide variety of crops (Figure 5). This design has the same number of SDI laterals and plant rows per unit area as standard beds with laterals in alternate furrows, but the seed bed is much closer to the lateral, motivating the hypothesis that better crop establishment and yield would result.

Crop germination can also be influenced by lateral installation depth. Shallow laterals result in greater near-surface wetted soil areas compared with deeper laterals, which may result in more uniform seed germination. However, shallow laterals carry greater risk of mechanical (i.e., tillage operations) and animal (i.e., rodent) damage, engender greater soil water evaporation losses, and may reduce early season seed bed temperatures.

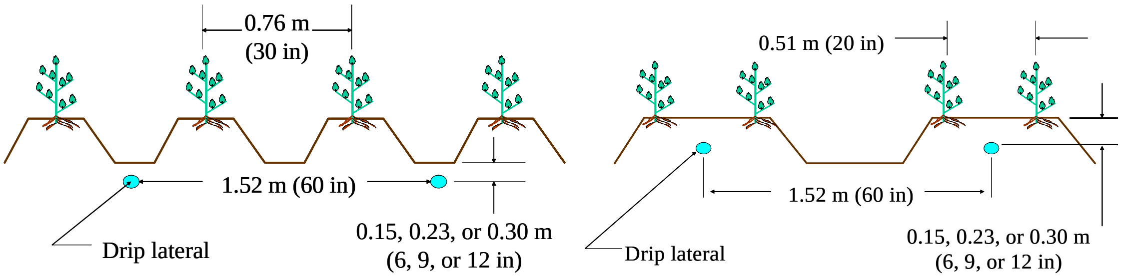

Figure 5. Standard bed design with SDI laterals in alternate furrows (left) and wide bed-twin row design with SDI laterals centered in each bed (right).

Crop yield and plant population were evaluated for each bed design and lateral depth at irrigation rates of 33, 66, and 100% of the full crop water requirement designated as I-33, I-66, and I-100, respectively. The crops were late-planted soybean in 2005 and corn (Pioneer 33B541) seeded at 32,000 plants/acre during the 2006, 2007, and 2008 seasons.

Soybean

Although the wide bed design generally resulted in greater plant emergence early in the season than that for standard beds (with SDI laterals installed in alternate furrows), bed designs and lateral installation depths usually did not result in significant differences in final grain yield (Figure 6). For the I33 and I100 treatments, grain yield was numerically greater for the wide beds, with the exception of the wide-bed I33 treatment with the 9-in lateral installation depth, for which grain yield was significantly less than that for the 12-in lateral depth. For the I66 treatment, grain yield was similar between the wide and standard bed designs, although early season plant emergence was often significantly less for the standard beds. Soybean is a crop that can compensate for sparse stands to some degree through larger plants and more pod set per plant, so the similarity in yields is not surprising. No consistent correlation between lateral installation depth and final yield was observed for the single season of data reported here.

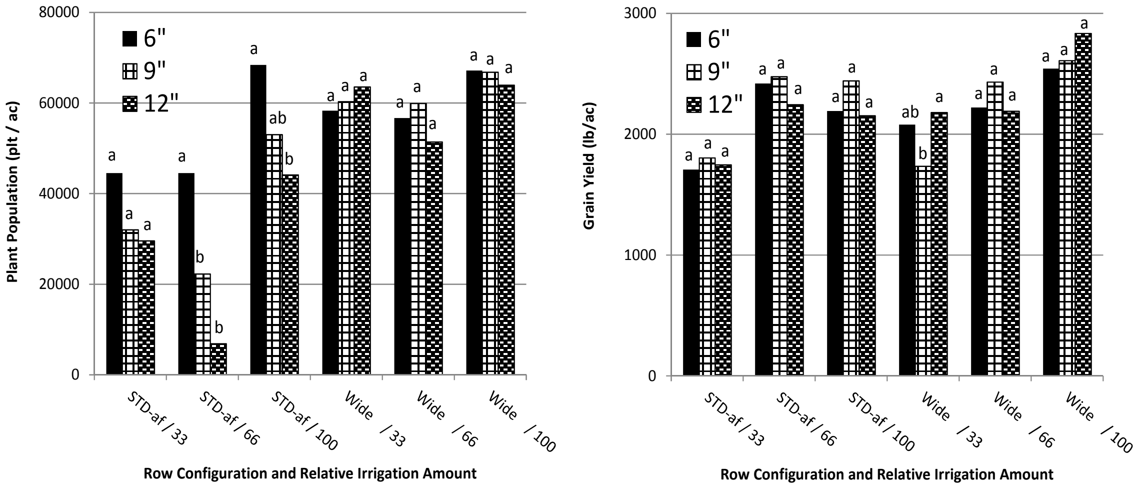

Figure 6. Plant population and soybean grain yield resulting from seed bed configurations, SDI lateral depths (6, 9 or 12 inches), and irrigation levels, Bushland, TX, 2005.

<u>Corn</u>

Early season precipitation and growing conditions were favorable from 2006 to 2008, making evaluation of crop germination response to alternative SDI designs difficult. Grain yield was most responsive to irrigation rate; nonetheless, some differences in grain yield and yield components were observed for bed design and lateral depths among irrigation rates (Table 2). Overall, the 9-inch lateral depth performed best for the standard bed design (except for the I-33 irrigation rate where grain yield for the 9- and 12-inch lateral depth were nearly equal), whereas the 12-inch lateral depth performed best for the wide bed design. The grain yield differences appeared mostly related to numerical differences in final plant population and kernel mass (I-66 and I-100 irrigation rates), or the number of kernels per ear (I-33 irrigation rate). The 12-inch lateral depth likely reduced evaporative losses of near-surface soil water, which was advantageous for the wide bed design. However, for the standard bed design, the 12-inch lateral depth resulted in reduced germination (and hence plant population) compared with shallower lateral depths.

The optimal lateral depth appeared to depend on the choice of bed design, where the 9- and 12-inch lateral depths performed best for the standard and wide bed designs, respectively. This was likely due to the relative influence of germination, soil water evaporation, and early season seed bed temperatures. In drier years, the deeper lateral depth for the wide bed design might reduce evaporative losses and improve yields, as seems to be the case here.

Table 2. Crop response to irrigation rate, bed geometry, and lateral depth, Bushland, Texas, 2006-2008.

Irrigation Rate	Bed Geometry	Irrigation Applied (inches)	Seasonal water use (inches)	Lateral Depth (inches)	Yield 15.5% wb (bu ac^{-1})	Plant Population (plants ac^{-1})	Kernel mass (g)	Kernels per ear
I-33	Standard	8.0	20.1	6	82.6 a	31,804 a	0.281 ab	247 b
				9	103.5 a	30,544 a	0.285 ab	305 ab
				12	103.7 a	30,004 a	0.275 ab	316 ab
	Wide	7.9	19.8	6	93.2 a	29,330 a	0.274 ab	300 ab
				9	91.9 a	29,734 a	0.266 b	321 ab
				12	111.6 a	29,510 a	0.303 a	335 a
I-66	Standard	14.4	26.2	6	237.0 ab	30,904 a	0.353 a	505 a
				9	246.2 a	31,309 a	0.354 a	513 a
				12	221.3 ab	30,724 a	0.350 a	482 a
	Wide	14.2	26.8	6	219.7 ab	29,240 a	0.342 a	514 a
				9	204.5 b	28,835 a	0.336 a	493 a
				12	233.6 ab	30,634 a	0.346 a	522 a
I-100	Standard	20.0	31.3	6	264.1 a	32,074 a	0.352 a	566 a
				9	266.2 a	32,883 a	0.355 a	541 a
				12	248.1 a	32,119 a	0.346 a	534 a
	Wide	20.3	33.6	6	245.8 a	29,510 a	0.358 a	564 a
				9	244.5 a	29,240 a	0.354 a	575 a
				12	253.3 a	30,859 a	0.358 a	549 a

Colby Study

A four-year yield study (1999-2002) was conducted to examine the effect of dripline depth on subsurface drip-irrigated field corn on the deep silt loam soils of western Kansas (Lamm and Trooien, 2005). Although crop germination and establishment were not examined in the study, soil water measurements taken within the study may provide some insight concerning the effect of dripline depth on movement of water towards the crop seed zone. The treatments were five dripline depths of 8, 12, 16, 20 or 24 inches replicated four times in a complete randomized block design. Low flow (0.22 gpm/100 ft) dripline with a 12 inch emitter spacing and 7/8 inch inside diameter was installed with a 5-ft dripline spacing with a shank type injector at the specified treatment depths.

During the study period, the Central Great Plains experienced a severe drought, beginning in the year 2000 and extending through the remaining duration of the study. Available soil water at the crop row (15 inches horizontally from the nearest dripline) was measured periodically during the growing season in 1-foot increments to a depth of 8 ft. During drier periods there was increased soil water availability in the top foot of the profile for the shallower dripline depths as shown in the seasonal progression of soil water from 2000 (Figure 7). The 8 and 12 inch depth showed considerably greater available soil water than the 16, 18, and 24 inch dripline depths for the majority of the season.

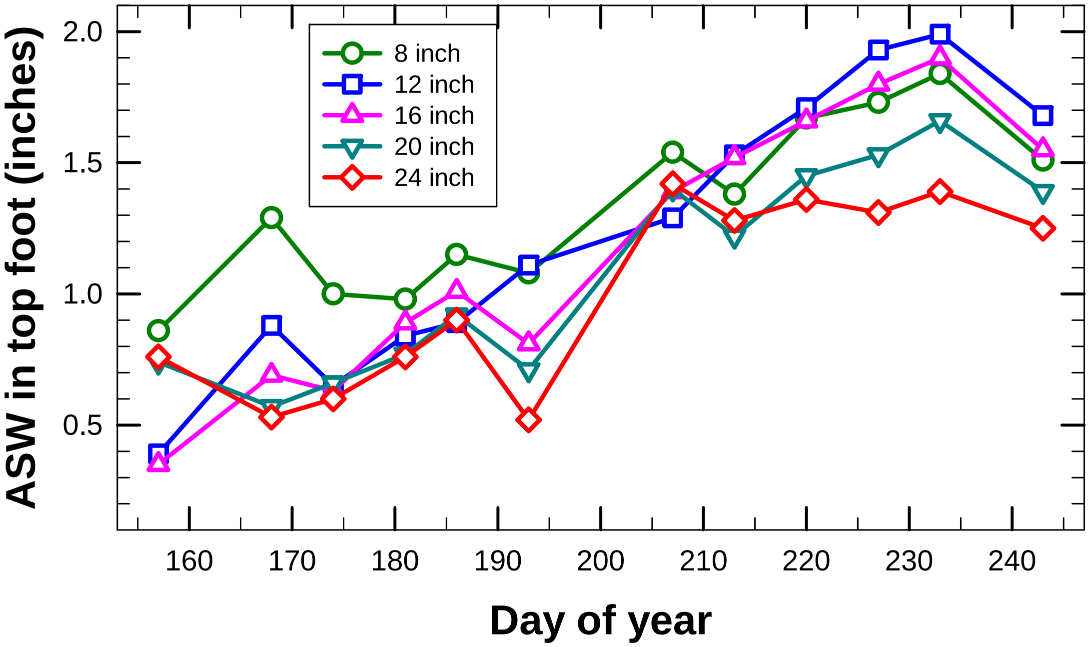

Figure 7. Seasonal progression of available soil water in the top foot of the profile at the crop row as affected by dripline depths ranging from 8 to 24 inches, Colby, KS, 2000.

PREPLANT IRRIGATION TIMING AND AMOUNTS

Pulsing water through SDI emitters verses continuous emitter flow, has been suggested as a possible solution to wetting the seed zone at planting. The theory is that the intermittent irrigation allows time for upward capillary movement of water in non-confined soil profiles and reduces the effects of saturated gravity flow in the downward direction. Although considerable research and theory to support this technique for improved wetting patterns are available for surface drip irrigation (Zur, 1976; Levin and van Rooyen, 1977; Levin et al., 1979), little research and few operational guidelines exist for SDI.

Halfway Study

A field experiment was conducted in 2011 at Halfway to evaluate preplant irrigation sequences in terms of cotton lint yield. The test area contained nine 1.2-acre zones irrigated by SDI laterals spaced at 60 inches. Crop rows were spaced 30 inches apart with two rows planted on single 60 inch beds. All tillage and seedbed shaping occurred immediately following the 2010 harvest, therefore, the seedbeds were undisturbed from December 2010 until cotton planting in May 2011. Rain occurring during this period totaled 1.44 inches.

Irrigation treatments were applied from 8 April to 2 May and totaled 5.0 inches in all plots. Three irrigation sequences replicated three times in a complete randomized block design were included in the experiment. The sequences included irrigating 0.2 in/d until significant rain or until total irrigation had reached 5.0 inches (T1); applying a large early irrigation, 2.5 in, delaying for any rainfall that might occur, then reinitiating irrigation at 0.2 in/d until reaching 5.0 inches (T2); and waiting to initiate irrigations until just prior to planting, then applying 5.0 inches (T3). Irrigation sequences and depths are shown in Figure 8. Additional treatments within each of the three sequences included removing dry soil from the planting bed surface with disks in front of planter units in an attempt to place seed into wetted soil (deep planting). Planting occurred on 11 May. Due to high temperatures, high wind speeds, and the lack of rainfall, irrigations continued in all treatments following preplant irrigation, from 3 May to 1 June, at 0.1 in/d in an attempt to germinate additional cottonseed.

Final plant establishment was extremely low and erratic in all treatments with final plant stands at less than 25% of initial seed drop. All treatments were identically irrigated through the growing season at approximately 40% ET_c. In-season rain was extremely low at 1.5 inches. The entire plot (~0.6 acres) of each treatment and replicate were harvested by traditional methods.

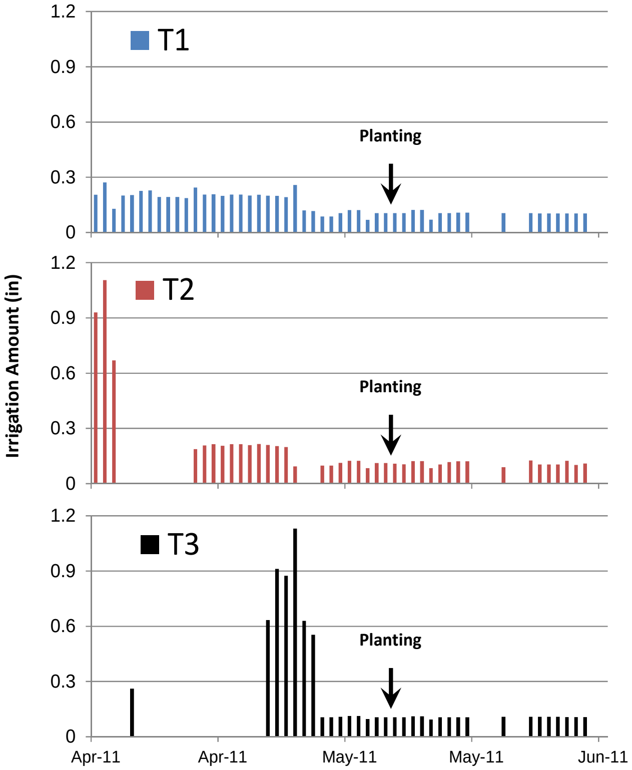

Figure 8. Pre-plant and early season irrigation sequences in a germination study at the Texas AgriLife Research Center, Halfway, TX, 2011.

Although plant stands were extremely poor, cotton lint yield of all treatments averaged 859 lb/ac (Figure 9). Removing dry soil in front of the planter failed to improve germination, failed to consistently improve yield, and would have caused additional germination problems if significant rain had occurred. When considering normal planting methods, applying a large preplant irrigation immediately prior to planting (T3) resulted in significantly less yield than applying a sequence of smaller irrigations (T1 and T2). The 2011 growing season was extremely hot, dry, and windy, particularly during the early stages. As such, these single year test results may not represent those of a more typical growing season.

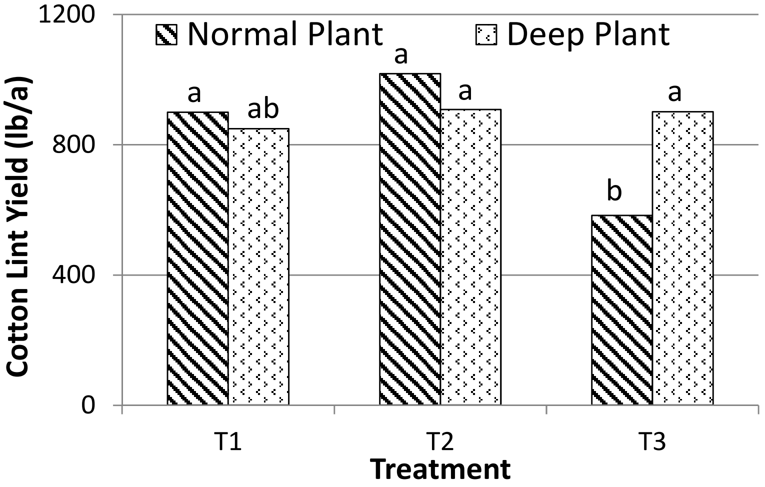

Figure 9. Cotton lint yield resulting from pre-plant irrigation sequences of 0.2 in/d for 25 days (T1), 2.5 inch plus 0.2 in/d for 12 days (T2), and 5.0 inch immediately prior to plant (T3). Cotton was planted with normal planter settings and also following the removal of some dry soil or "deep planting" at the Texas AgriLife Research Center, Halfway, TX, 2011.

Colby Study

A study was conducted on a deep silt loam soil at the KSU Northwest Research-Extension Center in the fall fallow periods of 1999, 2000 and 2001 to examine the effect of intermittent pulsing of irrigation events on soil water redistribution at the crop row. The studies were conducted in the fall because of reduced precipitation probabilities as compared to the spring and summer months. Soil water was measured gravimetrically (0 to 4, 4 to 8, 8 to 12, 12 to 18 and 18 to 24 inch increments) in the crop location which is at a horizontal distance of 15 inches perpendicular to the dripline (16-18 inch depth). Sampling was done prior and after the irrigation events. For brevity, only the results from 0 to 12 inch depth increments will be discussed in this report. The three irrigation treatments (4 replications in randomized complete block design) were a single 32-hour irrigation event, sixteen 2-hour events with 4-hour pauses in between, and eight 4-hour events with 8-hour pauses in between. The application intensity for these 5-ft spaced driplines with 12-inch emitter spacing was 0.048 inches/hour. Minor adjustments were made to the pressures in each plot so as to closely match application intensity. The overall irrigation amount was 1.54 inches. The irrigation events were staged so that the ending of all events were at the same time, thus soil water redistribution before the final soil water gravimetric sampling was for similar periods. In 1999, the study was conducted after the fall bedding tillage operation, so the surface soils were loosely consolidated, but in 2000 and 2001, fall tillage was delayed until after the final soil water sampling.

There was very little change in available soil water between the initial and final gravimetric samplings for the 0 to 4, 4 to 8 and 8 to12 inch soil depth increments in any of the three years (Figure 10). In many cases, at the crop location there was actually slight losses of soil water between the sampling events, although 1.5 inches of water had been applied by the 16-18 inch deep dripline. There were also no significant changes in soil water amounts attributable to the different irrigation strategies.

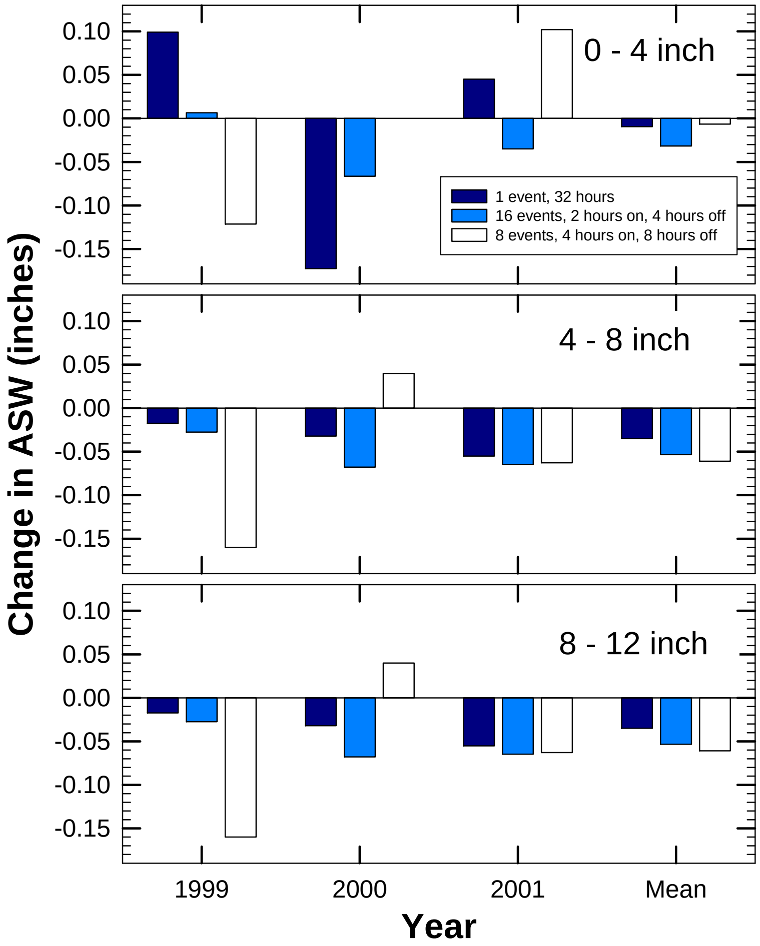

Figure 10. Change in available soil water for various depth increments at the crop row location as affected by timing strategy of irrigation events, Colby, KS, 1999-2001.

The results from the Colby study suggest that pulsing of SDI does not increase redistribution of soil water toward the crop seed zones. These results are similar to simulation and field study results reported by Skaggs et al. (2010) who found no differences in pulsed irrigation treatments. They concluded soil texture and antecedent soil water conditions play larger roles in soil water redistribution with SDI.

RESEARCH SUMMARY

The various experiments conducted at Halfway, Bushland and Colby did not result in procedures to ensure acceptable crop germination with alternate furrow SDI during dry periods. None of the soil amendment treatments improved soil wetting in the seed germination zone over the untreated checks under the conditions of these experiments. Alternate row geometries did not consistently provide significant differences in germination and yield in soybean and corn at Bushland. Shallow dripline depths, such as 8 to 9 inches, may improve soil water availability in the crop seed zone, but results will likely depend on the severity of the drought, soil texture and the amount of soil consolidation above the dripline. None of the three pre-plant irrigation sequences resulted in an acceptable stand of cotton in the hot, dry conditions encountered in 2011 at Halfway. Pulsing of irrigation events did not increase seed zone soil water on silt loam soils in northwest Kansas. Although there appears to be no "silver bullet" to ensure crop germination, the following section outlines general information used at the research centers to improve germination under challenging conditions.

STRATEGIES THAT SEEM TO HELP

Dry overwinter conditions which are prevalent in the semi-arid Great Plains region can result in inadequate near surface soil water for crop germination. Soil conditions such as excessively loose soil above the dripline can exacerbate the problem of water movement into the seedzone. When tillage is necessary or desired, it is best to complete the tillage operations as soon as practical following the previous year’s crop, so that any winter precipitation that does occur can help settle soil in the tillage zone allowing for better capillary movement of applied subsurface drip irrigation water. Minimizing the number of field operations that might disturb the seed zone near the time of planting can help reduce unnecessary drying of the soil. Whenever possible, fertilizers or pesticides that need incorporation into the soil should be done early or in a manner leaving an undisturbed seed zone (e.g. knife application of fertilizer parallel and to the side of the seed zone).

Similarly, excessively compacted soil above the dripline can cause crop establishment problems. Establishment of cotton was poor adjacent to driplines installed at a depth of 8 or 12 inches in wheel-tracked furrows as compared to cotton adjacent to non-tracked furrows (Enciso et al., 2005). They attributed the stand differences to possible flattening of the dripline (i.e., reducing the flow rate) or to reducing soil water redistribution into the seed zone (i.e., decreased soil hydraulic conductivity). Tillage above the wheel tracks following harvest and eliminating wheel tracks from the dripline furrow in a subsequent year eliminated the row-to row differences in establishment and cotton lint yield.

Seed beds that facilitate two crop rows (e.g., two 30-inch spaced rows on 60-inch crop bed centered on 60-inch dripline spacing) can be rebuilt in the fall after harvest and rolled to help with soil settling. Modifications of crop row spacing to reduce the perpendicular, horizontal distance that SDI applied water must travel can also help with crop establishment. For example, corn row spacing can be adjusted to 28 inches between corn rows centered on the dripline with a 32-inch spacing between adjacent crop row pairs. This planting arrangement can be harvested with a normal corn picker head spaced at 30 inches without any modification.

If the upper portions of the soil profile are very dry to a considerable depth, preseason irrigation during the early spring may reduce the amount of spring precipitation required to reconnect wet and dry zones within the profile. This preseason irrigation can also help fill the soil profile with water, and increase the soil hydraulic conductivity between the SDI lateral location and the seed zone area. Hot, windy and dry conditions can also dry adequately moist seed zones, so preseason irrigation can reduce the amount of precipitation required to rewet near surface soil layers. When applied subsurface drip irrigation does not move into the loosely consolidated soil surface layers in a bed cropping system, the dry soil can be removed to the traffic furrow, thus exposing wetter and firmer soils for crop establishment. This same technique could also be utilized through a listing operation on a flat-planted field, but would be more risky due to the possibility of severe crusting should heavy precipitation occur after planting.

Construction or reshaping of beds should be done in such a manner so that the number and size of soil voids and cracks within the bed are minimized. Soil voids can be reduced in the bedding operation itself such as with a roto-tilling operation or by rolling the beds with a cultipacking operation.

Maintenance of greater crop residue on the surface can enhance storage precipitation, through reduced runoff and soil water evaporative losses during fallow periods for both dryland and irrigated production systems, and increase crop water productivity (e.g., Unger and Cassel, 1991; Weise et al., 1998). Both permanent beds and reduced tillage would also reduce the risk of mechanical damage to shallow laterals. Unfortunately, the greater amounts of residue near the surface create a more favorable habitat for mice and other rodents that can damage SDI laterals during relatively dry winters.

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