ON-FARM EVALUATION OF REDUCED COTTON SEEDING RATES IN A MID-SOUTH SYSTEM INCORPORATING A WINTER COVER CROP WITH TWO TERMINATION TIMES

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Abstract

An on-farm experiment located near Manila, Arkansas was conducted in 2019 to evaluate cotton performance with four cotton seeding rates (high, recommended, or low), planted in a cereal rye, winter cover crop which was terminated at two different times (burn-down herbicides applied at the time of cotton planting or 2 weeks earlier). There was extensive in-season monitoring of plants, soil moisture, and arthropod pests. For yield assessments, we used georeferenced yield monitor data coupled with measures of apparent soil conductivity (EC_a) to consider how within-field variability in soil textures could interact with cover crop and seeding rate factors. Soils were classified as Routon-Dundee-Crevasse complex and were dominated by coarse sand to loamy sand soil textures. Information regarding soil texture interactions can inform decision-makers on applicability of employing site-specific, variable rate seeding. We determined costs and economic returns using the University of Arkansas System Division of Agriculture Cotton Enterprise budgets.

Early termination timing of cereal rye winter cover crops offered no advantages over at-planting termination. In field areas dominated by coarse sand soil texture, cotton seeding rates of 2 seeds per ft of row (38-inch rows) produced highest yield and best economic returns. In areas with loamy sand, recommended seeding rates (3 seeds per ft of row) and lower (2 seeds/ft of row) produced highest yield; however best economic returns were observed with 1 seed per ft of row. Arthropod pest densities were low, and pest related injury resulted in no measurable impact on maturity or yields. Based on these findings and previous work, we suggest producers should choose the least expensive seeding rate option that results in an acceptable stand of at least one plant per ft of row.

Introduction

Sustainable crop production practices that increase efficiency and reduce production input costs are needed to improve **profitability** of US cotton. Because one of the costliest production inputs is treated, transgenic seed, our research in the past 5 years has included field studies to evaluate effects of reduced seeding rates. We have reported that reducing cotton seeding rate from 4.5 down to 1.5 seeds per ft of row (55,176 to 20,691 seeds per acre) had no significant effect on cotton lint yield (Benson et al. 2015, 2016, 2017). An expanded 2018 field trial included cotton seeding rate evaluations in cover crop systems with different termination timing and in a spatially variable field with heterogeneous soil (Teague et al. 2019). Early termination of winter cover crops was advantageous; there were significant maturity and yield penalties for "planting green". In field areas dominated by coarse sand soil texture, low cotton seeding rates (1.5 seeds per ft of row on 38-inch rows) produced best economic returns. In areas with loamy sand, low and recommended seeding rates (1.5 and 3 seeds per ft of row) produced best economic returns compared to high rates (4.5 seeds per ft of row). In 2019, we continued our evaluations of cotton seeding rates and interactions with cover crop termination timing in a commercial field with spatially heterogeneous soils.

We initiated expanded on-farm studies in 2017 with different cotton seeding rates in cover crop systems that included both banded and broadcast seeded cereal rye (Teague et al 2018). Termination timing for cover crops was at planting, and we observed significant yield penalties if cotton was planted into “green” broadcast cereal rye compared to banded wheat or no cover crop (winter fallow). Highest seeding rates were required for highest yields in the high residue broadcast rye treatment. In our 2018 experiment, we compared seeding rates in combination with early compared to at-planting termination of cover crops. We found that early termination of winter cover crops was advantageous compared to “planting green”. With dry 2018 spring conditions, cotton emergence was delayed where cover crops were allowed to grow resulting in significant maturity and yield penalties. Soil spatial variability was an important factor in profitability. In field areas dominated by coarse sand soil texture, low cotton seeding rates (1.5 seeds per ft of row on 38-inch rows) produced best economic returns. In areas with loamy sand, low and recommended seeding rates (1.5 and 3 seeds per ft of row) produced best economic returns compared to high rates (4.5 seeds per ft of row).

In this paper, we report results from a 2019 study where we continued evaluation of seeding rates and cereal rye winter cover crop termination timing. Research questions were: Should cotton seeding rates be modified for cropping systems that incorporate banded cereal rye winter cover crops? Does it matter when the cover crop is killed – at planting or earlier? Because heterogenous soils are common in the production area, we continued to include consideration of soil texture in our experiment to examine cotton crop response to cotton seeding rate and cover crop management across different soil textures. These findings will help inform crop managers on practical utility of variable rate seeding for site-specific management in order to reduce costs and improve profitability.

Materials and Methods

The experiment was conducted in a commercial field located at Wildy Family Farms in Manila in Mississippi County Arkansas (35°51'32.2"N 90°14'53.0"W). The experiment was designed as a 2*4 factorial arranged in a split plot design with winter cover crop termination timing designated as main plots and & seeding rate factors as sub-plots (Figure 1). Sampling in sub-plots was stratified across different soil texture classifications – coarse sand and loamy sand.

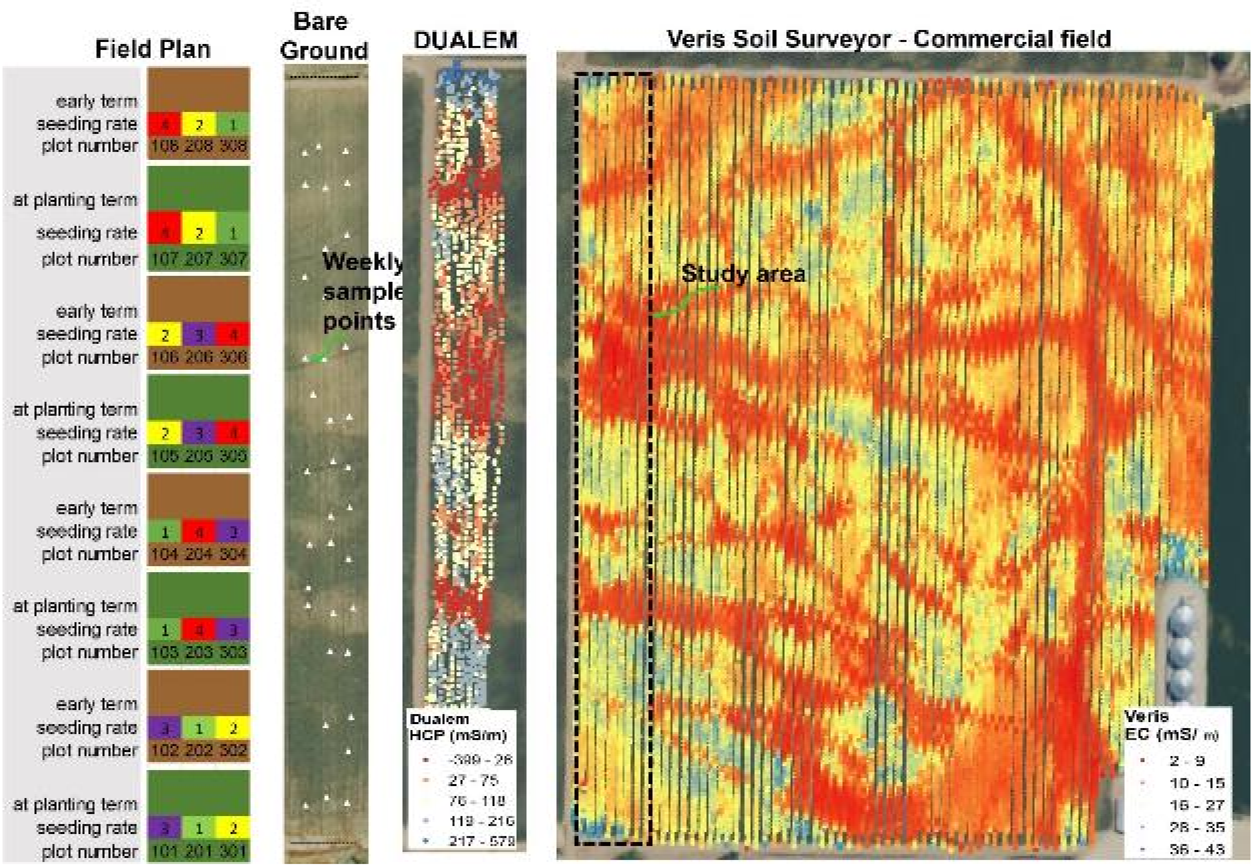

Figure 1. Field plan plus treatment list (left), bare ground map showing weekly sample points, and Soil EC_a maps (right) generated from readings using either a DUALEM or a Veris Soil Surveyor. Red color on maps denotes coarse sand areas of the field - 2019 cover crop termination*seeding rate trial – Manila, AR.

To establish the winter cover crop, the entire field was re-bedded in October 2018, and cereal rye (var. Elbon) was seeded with a Gandy Orbit air seeder (Gandy Company, Owtonna, MN) (Figure 2). A broad-leaf selective herbicide application was made in early March 2019 across all plots. The aim of this application was for weed control but also to reduce risks of arthropod and mollusk (slugs) pest numbers building to damaging levels and consequently moving to cotton seedlings (green bridge). To further explore the green bridge risk, we compared termination timing of the cover crop. Burndown herbicides were applied either 2-weeks prior (early) or one day after cotton planting (at-planting).

Figure 2. Cereal rye (var. Elbon) was air seeded in fall 2018 when beds were re-shaped (left). The cover crop was terminated either 2 weeks prior to or just after cotton planting in spring 2019 (center). A 12-row variable rate planter was used to apply the seeding rate prescription (right).

Cultivar Stoneville 5471 GLTP was planted 29 April 2019 using 12-row variable rate planter which applied the seeding rate prescription for 1, 2, 3, or 4 seeds per foot of row in appropriate plot locations (Figure 2). The raised beds were spaced at 38 inches. On the day following planting, the final burndown herbicide was applied across the entire field. A synthetic pyrethroid insecticide was included in the final burndown tank mix. All production activities including land preparation, fertilizer application, irrigation, and pest control were performed by the cooperating producers following their standard management practices and using their equipment. Production inputs and timing are listed in Table 1.

Table 1. Dates of planting, irrigation, pesticide applications* (labeled rates of insecticide, herbicide & harvest aids) and harvest for the 2019 cover crop termination*seeding rate trial – Manila, AR.

Operation	Date	Days after planting
Cover crops seeded	Fall 2018	-159
Selective burndown- broadleaf weeds	19 Mar	-42
Cover crop termination	16 Apr or 29 Apr	-13 or 0
Date of cotton planting	29 Apr	0
Stand counts	7,13,20 May	8,14,21
Thrips assessments	21,28 May	22,29
Lygus sweep net sampling	10,17,24 Jun	42,49,56
Lygus drop cloth sampling	1,8,17,22,29 Jul;6 Aug	63,70, 79, 84, 92
COTMAN plant monitoring	12,17,24 Jun;1,8,17,22,29Jul;6 Aug	44,49,56, 63,70,79,84,91,99
COTMAP final mapping	26 Sep	150
Foliar insecticides	30 Apr;1,9,19Jul; 5,12 Aug	1,63,71,81,98,105
Center pivot irrigation dates	21,27Jun; 3,24 Jul; 2,14,20 Aug	53,59,65,86,95,107,113
Harvest aids – defoliation	13 Sep	137
Hand harvest	27 Sep	151
Machine harvest	1 Oct	155

Sample site selection for plant, soil moisture, and insect pest monitoring activities within the 160ft long, 12-row plots included consideration of soil texture. Soils were classified as Routon-Dundee-Crevasse complex (Typic Endoqualfs). We included soil texture in our experimental design, sampling protocols, and analysis because of heterogeneous soils in the spatially variable field (alluvial soils plus historic seismic activity). Points were selected based on indirect measures of soil EC_a (Figure 3). Spatial variation of ECa within a field is the consequence of soil formation and meteorological processes as well as anthropogenic influences (Corbin and Scudiero 2016). Sample sites were positioned in field areas categorized as coarse sand (shallow measures and EC< 15 mS/M) or loamy sand (EC≥ 15 mS/M) in each sub-plot based on measures using a DUALEM-1H (DUALEM Inc., Milton, ON, Canada). The DUALEM is non-invasive EMI instrument, and with it, we were able set sample points after crop emergence. Sample points for weekly in-season plant and pest monitoring were set 7 days after planting (DAP), and this included selection of 10ft plot lengths selected for hand-harvest. The harvest row included buffer rows on either side in rows 3-6 within the 12-row sub-plot (165 ft long) – scouts avoided touching these plants through the season. Not all subplots included both soil texture classes (coarse sand dominated some field areas compared to others), and so there was unbalanced sample sizes for some treatment combinations in the plant monitoring and hand-harvest data sets.

Figure 3. Sample points for different soil textures were set after cotton planting using a non-invasive DUALEM-1H (left). Classification of soil textures for yield analysis were made following harvest using a Veris Soil Surveyor (right).

Stand counts were made using line-transect sampling. Samplers counted plants per 3 ft in two transects across each 12- row plot at 8, 14, and 21 DAP (Figure 4). Stand count data were gauged by comparing seedling counts to the seeding rate target.

Figure 4. Stand counts were made at weekly intervals using transect sampling across the 12-row sub-plots. Shown above are images representing the 4 seeding rates recorded 14 days after planting.

We monitored soil moisture through the season using Watermark sensors. Sample points for sensing stations were identified and referenced with GPS coordinates in coarse sand and loamy sand locations based on Soil EC_a classification from the DUALEM. Sensors were positioned at 6- and 12-inch depths in the top of beds between plants. There were 4 sensors at each sample site in subplots with similar cover crop termination and seeding rate. Sensors were positioned in row 4 of 12-row plot to control for possible soil compaction effects related to previous cotton harvest activities. Data were recorded using Irrometer 900M-O Watermark Monitors (https://www.irrometer.com/).

COTMAN plant monitoring activities were initiated at first square and included evaluations of plant main-stem nodal development, height, and first position square and boll retention using standard COTMAN® sampling protocols (Oosterhuis and Bourland 2008). Monitoring continued through the effective squaring and flowering periods (Teague 2016). Efficient plant monitoring requires a standard with which to compare actual plant growth. In the COTMAN system, growth curves are generated from plant mapping (counts of main-stem sympodial nodes and retention of first position fruiting forms) and consist of squaring nodes plotted against days after planting. Growth curves are compared to the COTMAN target development curve, a standard curve, which is assumed to represent an optimum combination of early maturity and high yield (Bourland et al 2008). The standard curve shows main stem squaring nodes through a season, ascending at a pace of one node each 2.7 days through first flower at 60 days after planting, and then descending to physiological cutout at 80 days. The rate of squaring node development after first flower declines in response to an increasing boll load. This post-flower decline in terminal growth is measured as NAWF (nodes above white flower). Physiological cutout was defined as the flowering date of the last effective boll population. Research in Arkansas has shown that the field or management unit is at physiological cutout when the sampled plant population reaches an average of NAWF = 5 (Oosterhuis and Bourland 2008).

Arthropod pests were monitored in weekly inspections. During stand counts, samplers scouted for cutworms (Lepidoptera: Noctuidae) and other seedling pests that could be associated with green bridge effects and the cover crop. Thrips (Thysanoptera: Thripidae) assessments were made 2 and 3 weeks after planting using whole plant alcohol washes with 10 plants collected per plot. Plant samples used for thrips monitoring also were used for leaf area and plant biomass assessments (above ground plant material only). Leaf area measurements were made with a LI-3100C Area Meter (LI-COR, Lincoln, NE, US). Tarnished plant bugs (*Lygus lineolaris* (Palisot de Beauvois)) were monitored weekly starting in the first week of squaring (~35 DAP) through physiological cutout (NAWF=5). Sampling included use of sweep nets (preflower) and drop cloths (full season).

Yield assessments were based on hand harvests in the 10-ft harvest plots as well as data collected from the cooperating producer's John Deere 7600 cotton picker equipped with calibrated yield monitor with GPS receiver to attain site-specific lint yield. Prior to analysis, the yield monitor data were "cleaned" using Yield Editor (ver 2.0.7 https://data.nal.usda.gov/dataset/yield-editor-207).

Soil EC_a measurements from the Veris Soil Surveyor were obtained following harvest after stalks were cut. Data (5m shallow) were stratified into two classes -- coarse sand (<15 mS m-1) and loamy sand (≥ 15mS m-1). Approximately 40% of the commercial field was classified in the coarse sand category (Figure 1). Class categories were based on previous experience at the farm site, analysis of historical yield, and plant monitoring data. Georeferenced data layers from the yield monitor and from Veris Soil Surveyor (5 m -shallow) were joined using ArcGIS (ESRI; ver10.7) to enable inclusion of soil texture as a covariate in yield analysis. A factorial structure was used for analysis of the yield monitor measured yield data with seeding rate, cover crop termination timing, and block effect; soil ECa classifications were used as a co-variate. Statistical analyses were performed using SAS 9.4 (SAS Institute). Analysis of variance was conducted using mixed model procedures (Proc Mixed & Proc GLIMMIX). Mean comparisons were made using LSMEANS procedure with the Tukey adjustment ($P \leq 0.05$).

Fiber quality was evaluated using a 40-boll sub-sample of the 10ft hand harvest (40 bolls harvested throughout plants including both upper and lower canopy bolls). Samples were ginned on laboratory gin, and fiber set to the Texas Tech Fiber and Biopolymer Research Institute for HVI evaluations.

A partial budget analysis was performed to calculate returns to operating expenses (variable costs) using the University of Arkansas System Division of Agriculture Cotton Enterprise budgets (https://www.uaex.edu/farm-ranch/economics-marketing/farm-planning/budgets/docs/budgets2016/Budget_Manuscript_2019.pdf). Net returns for mean yields were based on $0.70 per lb price with land rent included as 25% share rent. Capital recovery & fixed costs were estimated at $162.3 per acre but were not included in the results.

Results

Rainfall amounts during the season were above average in May, June, July and early August (Table 2). The field was irrigated 7 times (Table 1).

Table 2. Monthly precipitation (inches) measured at the study site for the 2019 season compared with 30-year average for the county -- 2019 cover crop termination*seeding rate trial – Manila, AR.

Mean per month	30-year Average	2019 Rainfall	Departure
	----------------------	inches	----------------------
May	5.37	9.00	3.63
June	3.99	5.22	1.23
July	4.04	9.26	5.22
August	2.36	6.41	4.05
Total Season	15.76	29.89	14.13

Plant stand density was not affected by **c**over crop termination timing in stand counts made at 8 DAP (*P*=0.41). Seedling emergence was delayed in the loamy sand compared to coarse sand (*P*<0.001) (Figure 5). Seeding rate treatments reached at least 85% of target stand by 14 DAP in coarse sand. Stand counts for all treatments were above 80% of target by 21 DAP.

Arthropod pests were inconsequential in the 2019 study. Thrips infestation levels (primarily tobacco thrips) were consistently low and below threshold (data not shown). There were no significant differences for cover crop or termination effects (P>0.20). During plant stand counts as well as for thrips collections, scouts made note of any pests associated with *green bridge* effects (arthropod, mollusks, etc.), and there were none observed. Overall, insect pest pressure was low in the production region during the 2019 crop season; in addition, low pest densities observed in our study were related to insecticide applications made through the season (Table 1).

There was non-insect related seedling loss associated with damping-off and injury from blowing sand. Seedling mortality associated with damping-off symptoms was highest in field areas with loamy sand texture. Saltation (blowing sand) also contributed to seedling mortality and appeared to be greater in coarse sand areas of the field. Biomass of cereal rye growing in coarse sand measured at the time cotton was planted, was ca. 1/3 of that in loamy sand; however, blowing sand was somewhat problematic throughout the field because, with banded cover crops, the tops of beds were not entirely protected from destructive winds and sand bombardment.

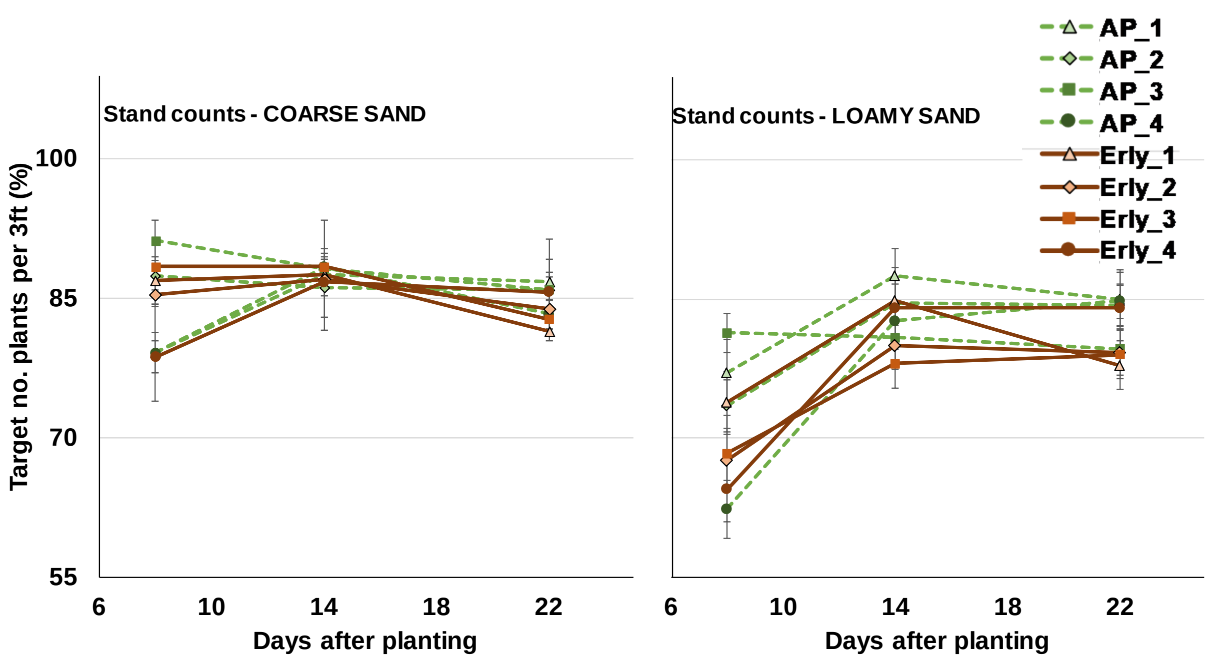

Figure 5. Mean (±SEM) plant stand density as a percentage of target stand (1, 2, 3 or 4 seeds per ft of row), for at planting (AP) and early terminated (Erly) cover crop termination treatments, measured in two, 3-ft transects across the 12-row plots for coarse sand and loamy sand soil textural classes on 7, 13, and 20 May (8, 14 and 21 DAP) – 2019 cover crop termination*seeding rate trial – Manila, AR.

Cotton leaf area and biomass assessments were made 22, 29, and 37 DAP with 10 plant samples measuring of total leaf area and shoot dry weight. Plants grown in loamy sand areas of the field had significantly higher measures compared to those from coarse sand. These data were interpreted as an indicator of increased early season, plant vigor. There were no significant effects from seeding rate or termination. (Figure 6).

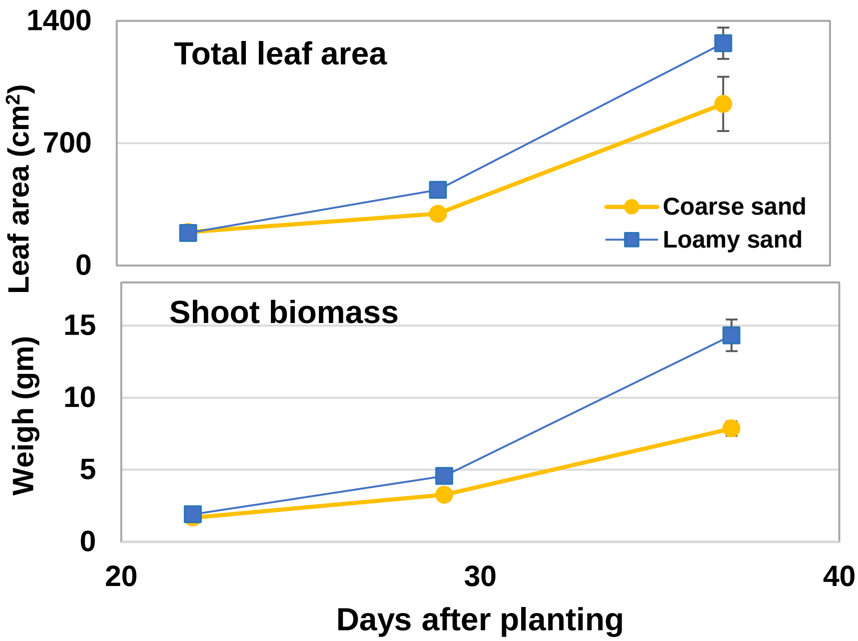

Figure 6. Total leaf area and shoot dry weight of cotton plants collected at 22, 29, and 37 DAP from sample sites in loamy sand and coarse sand soil textural classes – 2019 cover crop termination*seeding rate trial – Manila, AR.

COTMAN growth curves reflected effects of cool spring weather conditions after planting. There was delayed onset of squaring relative to the expected first squaring node by 35 DAP. The pace of pre-flower main-stem sympodial nodal development (squaring nodes) lagged behind the standard COTMAN Target Development Curve (Figure 7). For plants in coarse sand, a faster pace of nodal development was observed in the lower seeding rates compared to more dense stands; differences nodal development rate of plants in loamy sand were not as apparent. First flowers were observed at 63 DAP. Mean no. squaring nodes at first flowers were highest for plants in lowest seeding rate in both coarse sand and loamy sand. COTMAN plant monitoring results showed that first position square shed levels generally were extremely low. Square retention on 1st position, main-stem sympodia during the week of first flowers ranged from 95 to 99%, indicating very low levels of tarnished plant bug feeding activity (data not shown).

Cloudy, rainy, and overcast weather conditions affected crop development during the effective flower stage, starting at around 67 DAP and extending through 78 DAP. Those overcast conditions resulted in plant maturity delay across all treatments and was reflected in changes of slope of COTMAN growth curves starting at 79 DAP. The rate of squaring node production should decline during the effective flowering period as boll load increases (i.e. NAWF values decline); however, in our experiment, growth curves flattened during flowering indicating boll load was less than projected in the target development curve. Overcast conditions likely resulted in increased small boll shed and delayed boll fill. Reduced solar radiation resulting from prolonged overcast conditions during effective flowering will limit yield potential (Zhao and Oosterhuis, 1998, 2000). It is not uncommon in the Midsouth and Southeast US to have overcast conditions during the effective flowering and boll filling crop development stages, and there have been research efforts focused on development of a solar radiation stress index for cotton (Reba and Teague, 2013).

Results from plant monitoring indicated that, on average, plants reached physiological cutout (NAWF=5) by 92 DAP, which is 12 days later than expected when compared to the COTMAN standard of 80 DAP (Figure 7). Among seeding rate treatments, mean no. days to physiological cutout was 96 days for the lowest seeding rate (1 seed/ft), compared to the earliest observed cutout date of 90 DAP observed for plants in the high seeding rate treatment. Plants growing in coarse sand areas of the field reached cutout 3 days earlier than those in loamy sand (91 compared to 94 days). There were no significant interactions and no statistical differences in days to cutout noted with cover crop termination timing.

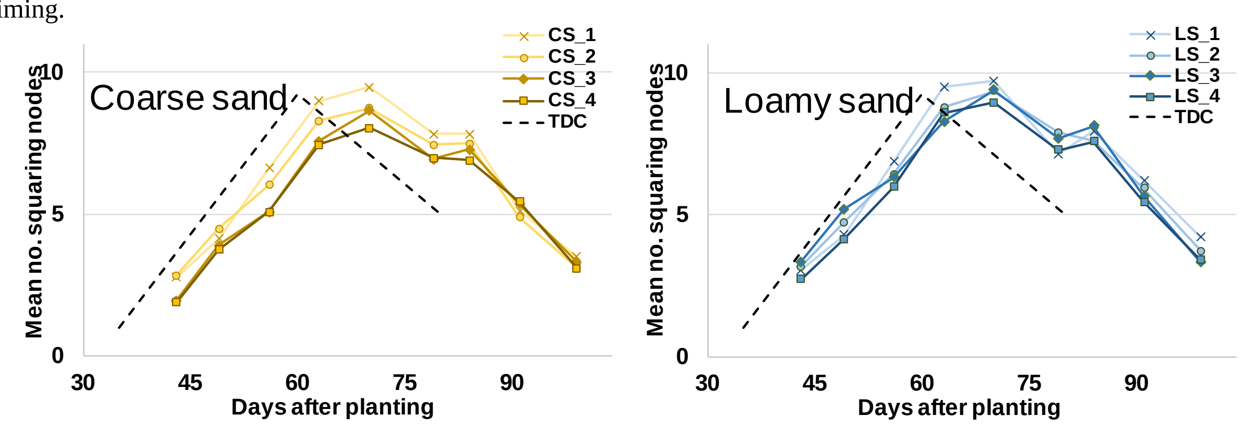

Figure 7. COTMAN growth curves for plants in each of the four seeding rate treatments for the two soil textural classes – 2019 cover crop termination*seeding rate trial – Manila, AR.

Soil moisture monitoring readings from Watermark sensors generally showed variability in soil moisture measures among soil textures. Soil moisture charts are presented for coarse sand and loamy sand sample sites with similar seeding rate and cover crop termination treatments (Figure 8). There was adequate rainfall to provide soil moisture through seedling stage and early squaring stage. A drying period followed, and with weekly irrigations were applied. Differential response in early season between coarse sand and loamy sand were interpreted as variation in infiltration rate between the two soil textures We have observed similar variability in previous years working with these soils. It is challenging to interpret data from Watermark sensors in sandy soils, and it is especially problematic with the alluvial soils and sand blows common in the study area. Our data from this and previous studies, show that irrigation triggers should not be based solely on soil moisture monitoring data (Teague et al 2018). Decision makers should also consider crop status, crop water use (i.e. Evapotranspiration), and irrigation effectiveness when scheduling irrigation.

Yields varied across the heterogeneous soils. For hand-harvest, lint yield from plants in different soil texture classes and seeding rates ranged from 1407 lb/ac in loamy sand with seeding rate of 2 seeds per ft of row down to 983 lb in coarse sand with seeding rate of 4 seeds per ft of row (Figure 9). There were no significant interactions among factors tested (Table 3). For yield monitor measured yields, lowest lint yields also were associated with coarse sand (EC_a <15 mS/M) compared to loamy sand areas of the field. The coarse sand class encompassed 40% of the field (Figure 1). Cover crop termination timing did not significantly impact yield. (Table 4). Seeding rate response was inconsistent in cover crop treatment combinations with interactions of cover crop termination timing, seeding rate, and soil texture. Seeding rates of 2 to 3 seeds per ft of row had highest mean yields for coarse and loamy sand soils, respectively.

Plant measurements and yield data collected at sampling points set in early season using the DUALEM corresponded well with the post-harvest measurements using the Veris soil surveyor. Points set based on DUALEM measurements typically represented extremes in soil textures compared to the field scale measures using the Veris. We made no complex geospatial EC_a comparisons of the two soil EC_a survey methods; our aim was to ensure that hand harvests as well as in-season monitoring activities roughly corresponded to the same soil texture classifications used for field scale analysis of yield monitoring data.

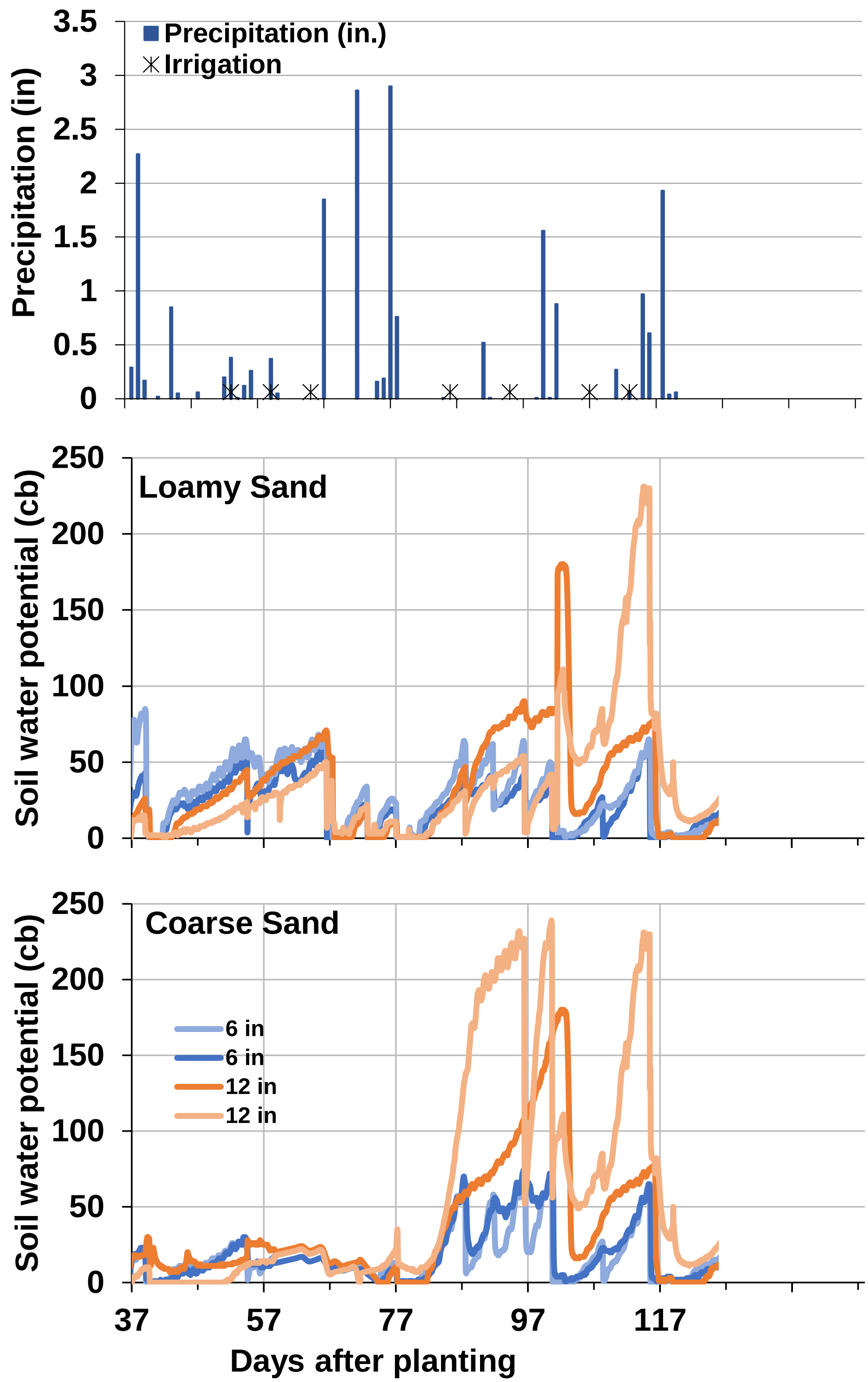

Figure 8. Precipitation, irrigation timing, and soil moisture measures (2 Watermark sensors per station) at 6 and 12-inch depths positioned at points in different soil textures placed based on soil ECa measures in different cover crop treatments.

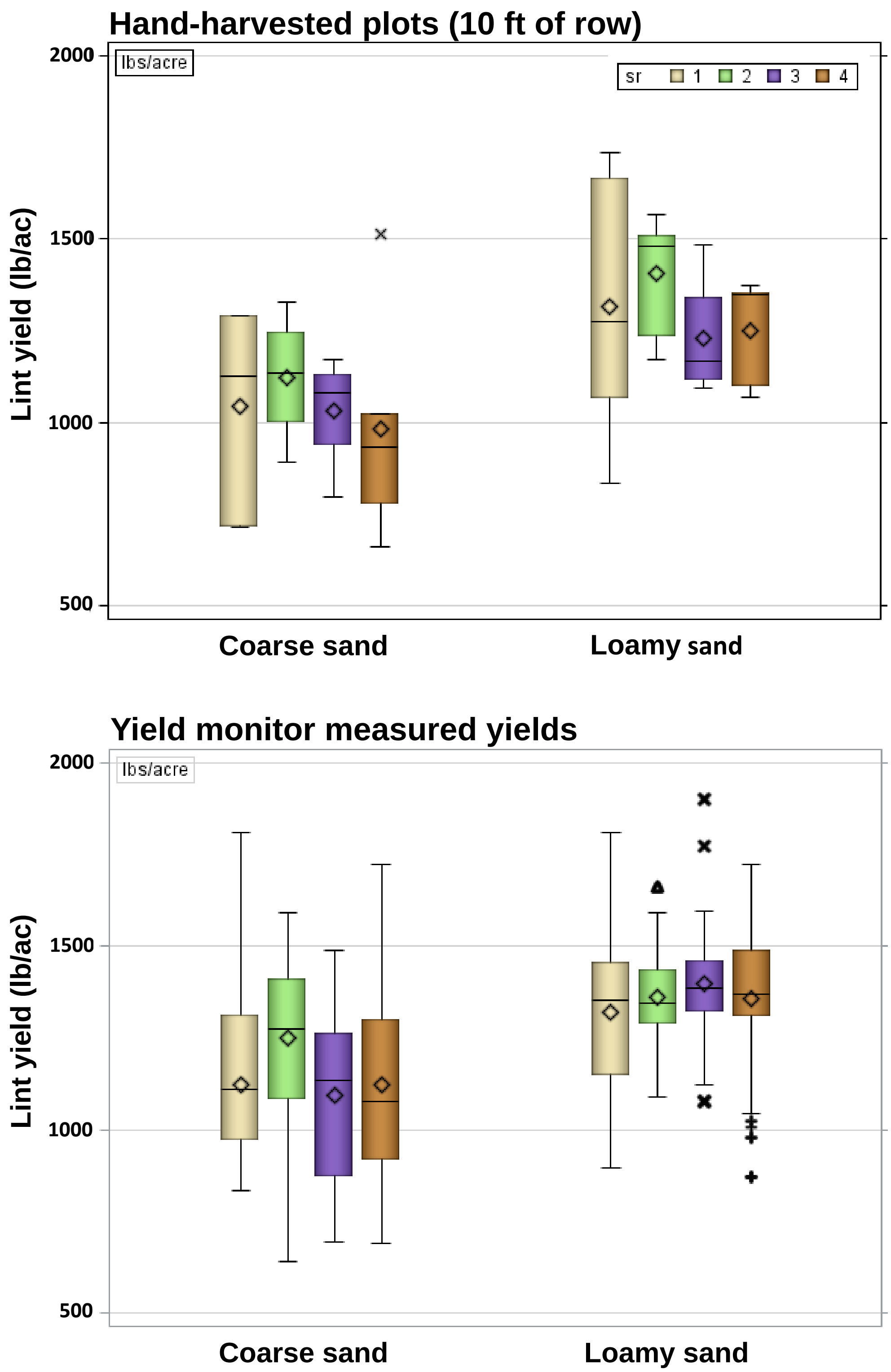

Figure 9. Yield for hand harvest and yield monitor measured yields for coarse sand and loamy sand areas of the field with seeding rates (sr) of either 1, 2, 3 or 4 seeds per ft of row (38-in rows) in the cover crop termination*seeding rate trial, Manila, AR. Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value.

Table 3. Hand harvest measured yield analysis from PROC MIXED-Fixed Effects of cover crop termination timing (Term), cotton seeding rate (SR) and soil texture (Tex) based on soil texture classification.

Effect	Num DF	Den DF	F Value	*P* > F
SR	3	16	1.09	0.3807
Tex	1	16	15.48	0.0012
SR*Tex	3	16	0.19	0.8995
Term	1	2	0.1	0.7845
SR*Term	3	16	0.89	0.4693
Term*Tex	1	16	2.55	0.1298
SR*Term*Tex	3	16	0.36	0.7809

Table 4. Yield monitor measured yield analysis results from PROC MIXED-Fixed Effects of cover crop termination timing (Term), cotton seeding rate (SR) and soil texture (Tex) based on soil texture classification.

Effect	Num DF	Den DF	F Value	*P* > F
SR	3	1514	25.81	<.0001
Tex	1	2	59.49	0.0161
SR*Tex	3	1514	12.42	<.0001
Term	1	1514	0.17	0.7212
SR*Term	3	1514	25.25	<.0001
Term*Tex	1	1514	14.74	0.0015
SR*Term*Tex	3	1514	5.43	<.0001

Partial budget analysis was performed using the University of Arkansas System Division of Agriculture Cotton Enterprise budgets. Results were used to estimate returns to operating expenses (variable costs). Net returns were based on $0.70 per lb price and a 25% share for land rent. Seed costs were based on grower cost (Table 5). Fiber quality discounts were not considered. Capital recovery and fixed costs were estimated at $162 per acre but were not included in net returns shown.

Mean yields for treatments were calculated from yield monitor measured yield, and those values were used for calculation of net revenue for each treatment combination. Net revenue was highest in loamy sand areas of the field and was above $200 per acre for all seeding rates except the 4 seed per ft of row seeding rate. Lowest net returns ($64/ac) were observed with a seeding rate of 4 seeds per ft of row in coarse sand soils (Table 6).

Table 5. Seed costs for treated, transgenic seed used in the 2019 seeding rate trial (based on cooperating producer costs in spring 2019[a]).

Seeding rate (per ft of row,	No. seeds (per acre)	Seed cost ($ per acre)
1	13,756	$32
2	27,512	$65
3	41,267	$97
4	55,023	$130

[a]Cotton seed costs were based on 50 lb bag cost of $530, with 225,000 seeds per bag, and an estimated cost per seed of $0.0024.

Would there be an economic advantage to variable rate planting in the study field? Assuming mean yields and net returns shown in Table 6, a uniform seeding rate in this variable commercial field would return $218, $215, 195, and $128 per acre for the 1, 2, 3, and 4 seeding rates, respectively. When a variable rate planting option was considered using two management zones (coarse sand and loamy sand), each seeded at "optimal" rate, average net return was estimated to be $217. Differences in weighted average net return between variable rate vs broadcast planting was a $1 to $2 per acre advantage. It should be noted that our variable rate net return estimate did not include additional management and capital equipment costs required for variable rate planting.

Table 6. Mean lint yields from yield monitor measurements and calculated net returns per acre for seeding rate treatments in loamy sand and coarse sand textures in 2019 Manila field study.

Soil texture classification	Seeding rate *no. per ft of row*	No. seeds *per acre*	Lint yield[a] *lb per acre*	Net returns *$ per acre*
Loamy sand	1	13,756	1313 B	$249
	2	27,512	1370 AB	$245
	3	41,267	1414 A	$234
	4	55,023	1350 B	$169
Coarse sand	1	13,756	1136 D	$159
	2	27,512	1220 C	$169
	3	41,267	1127 D	$136
	4	55,023	1143 D	$64

Tukey-Kramer Grouping for seeding rate*soil texture; Least Squares Means (Alpha=0.05) for yield with the same letter are not significantly different.

Fiber Quality assessments (HVI) from 40 boll hand-picked samples indicated no significant differences in fiber quality parameters associated with soil texture, termination timing, or seeding rate treatments (Table 7).

Table 7. Mean boll size and fiber quality assessments (HVI[a]) for 40-boll collections made in each sub-plot –soil texture effects shown -- 2019, Manila, AR.

Soil texture classification	Boll weight *g*	Micronaire *unit*	Length *in.*	Uniformity *UI*	Strength *g/tex*	Elongation
Coarse sand	4.9	4.96	1.15	84.72	33.68	6.89
Loamy sand	4.8	4.77	1.19	85.18	34.73	6.94
P>F	*0.35*	*0.13*	*0.13*	*0.65*	*0.31*	*0.54*

[a] HVI assessments made at the Fiber & Biopolymer Research Institute, Texas Tech University, Lubbock.

Discussion

In our 2019 evaluations with termination timing for a banded cereal rye winter cover crop, we found early termination timing offered no advantage over at-planting termination. Unlike our findings in 2018, there were no yield penalties for "planting green". In 2019 there was above-average precipitation at the time of planting. Delayed termination in the drier 2108 planting season resulted in depleted soil moisture at planting, which stalled cotton seed germination. Thrips numbers also were very low in 2019, and no significant arthropod pests of cotton were associated with the green cereal rye. Application of a selective broadleaf herbicide in early spring also resulted in reduced arthropod pest risk associated with the *green bridge*.

The 2019 results and our findings from previous years of on-farm research show that cotton seeding rates can be reduced in systems with a banded, cereal rye winter cover crop. When seeding rates of costly transgenic cotton seed were reduced to 2 seeds per ft of row (27,512 seeds per acre) in comparison to the current prescribed Extension cotton seeding rate recommendation of 3 to 4 seeds per foot of row (38-in rows; 41,267 to 55,023 seeds per acre), we recorded savings of at least $32 to over $100 per acre without loss in lint yield, quality, or earliness.

Lint yield fluctuated across soil textures in the spatially variable field. Seeding rates of 2 seeds per ft of row produced highest yield and best economic returns in the coarse sand areas of the field (40% of commercial field). In loamy sand, best economic returns were associated with the 1 seed per ft of row rate; however, there was less than $4 per acre difference in net profit between 1 and 2 seeds per ft of row for production in loamy sand. When considering production risk, a seeding rate of 2 compared to 1 seed per ft of row reduces the likelihood of stand failure and would be a rational management choice considering the soils typical in the cotton production region. Higher seeding rates may be appropriate in production areas where soils are prone to crusting.

Based on these findings and previous work in the NE Arkansas cotton production area, our results do not support the additional management and capital equipment costs required to implement variable rate planting. Specific cases where variable rate seeding approaches should be considered include 1) when there is extreme within-field soil variability with some soils prone to crusting, 2) if equipment is already available, and 3) if management costs for building site-specific prescriptions are minimal.

Cotton producers in NE Arkansas and SE Missouri who farm on sandy soils commonly use banded wheat, oats, or cereal rye as winter cover crops to provide cotton seedlings protection from winds and blowing sand. Other benefits from winter cover crops include reductions in negative effects of soil compaction and sealing soils and improvements water infiltration and soil water holding capacity (Dabney et al. 2007). Midsouth cotton producers also plant winter cover crops in expectation of positive impacts on weed suppression (Korres and Norsworthy 2015). In addition, cover crops can provide significant environmental benefits including enhanced nutrient management to improve runoff water quality (Aryal et al. 2018).

Our cover crop research findings support the following general guidelines for the northern Midsouth cotton production areas. Producers should consider low cost cover crop systems that result in fewest cotton stand establishment problems. We recommend cereal cover crop species that fit a producer’s specific management goals for wind protection, weed suppression, and soil & water conservation. Managers should target early October for seeding cereal cover crops. Broadleaf weeds should be selectively killed at least one month before sowing cotton to avoid providing a “green bridge” that allows pests to survive. Early cover crop termination is also advised to reduce risks of allelopathic effects on cotton seedlings and to conserve soil moisture for planting.

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