SEEDING RATE AND WINTER COVER CROP EFFECTS ON MATURITY AND YIELD OF MID-SOUTH COTTON

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Abstract

Winter cover crops contribute to soil and water conservation, and they protect cotton seedlings against wind and blowing sand damage. Cotton producers in the Mid-South increasingly include winter cover crops, such as broadcast cereal rye, as a cultural control tactic in weed integrated pest management (IPM) programs. With adoption of new cover crop practices, cotton management questions emerge, including the costly decision on whether to increase cotton seeding rates. There also is uncertainty about when to kill the cover crop. To address those questions, we conducted an on-farm experiment near Manila, Arkansas in 2018, to evaluate cotton performance with three cotton seeding rates (high, recommended, or low), planted in four different winter cover crop treatments (broadcast cereal rye, banded cereal rye, banded wheat, or winter fallow check) which were terminated at two different times (burn-down herbicides applied at the time of cotton planting or 6 weeks earlier). There was extensive in-season monitoring of plants, soil moisture, and arthropod pests. We also used georeferenced yield monitor data and soil EC measures 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 examined costs and economic returns using the University of Arkansas Cooperative Extension Service Budget Generator.

Early termination of winter cover crops was advantageous, and 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). 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 that for cover crop choice (i.e. banded vs broadcast and species mix), producers should choose the least expensive option that results in fewest cotton stand establishment problems AND fits their management objectives and needs for wind protection, weed IPM, and soil & water conservation.

Introduction

Crop management practices that increase efficiency and reduce production input costs are needed to improve profitability and sustainability of USA cotton. Given that current prices for treated, transgenic seed typically are around $100/acre for standard, recommended rates, producers can reduce production costs substantially if they can reduce seeding rates without significant yield penalties. In our previous on-farm work in NE Arkansas, we compared cotton performance with seeding rates of 4.5, 3, or 1.5 seeds per ft of row on 38-inch beds (55,1760, 41,3820, or 20,6910 seeds/acre) and observed similar levels of cotton lint yield (Benson et al. 2015, 2016, 2017). In those studies, we worked in farm fields managed with conventional tillage or with terminated wheat winter cover crops banded between rows. Producers in the production region commonly use banded, terminated cereal cover crops to protect cotton seedlings from blowing sand and wind, but there is strong interest by growers to modify cover crop practices to assist in weed control. The high residue typically associated with broadcast cereal rye can result in weed suppression and is an effective cultural control tactic for management of herbicide-tolerant weeds (Dabney et al 2007). High residue cover crops also can provide advantageous soil and water conservation benefits (Aryl et al 2018). Despite these advantages, cotton production in dense cover crop residues present practical questions regarding cotton stand establishment. Use of cover crops also increases production costs.

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). There were 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 this 2018 research, we repeated the seeding rate and cover crop treatments but added an evaluation of cover crop termination timing. Our research questions for 2018 were: Should cotton seeding rates be modified upward in systems that incorporate winter cover crops? Does it matter when the cover crop is killed – at planting or earlier? Are there different cotton yield or plant maturity responses with changes in cotton seeding rate and cover crop management across different soil textures, and if so, are there practical opportunities for site-specific management variable rate seeding that could reduce costs and improve profitability?

Materials and Methods

The 4*2*3 factorial experiment was arranged in a split plot design with 3 replications (Figure 1). Winter cover crop treatments were considered main plots. The four cover crop treatments were: 1) banded wheat (20 lb/ac), 2) banded cereal rye (variety Elbon) (20 lb/ac), 3) broadcast cereal rye (54 lb/ac), and 4) winter fallow (no cover crop check). Seeding rate and cover crop termination timing treatments were considered sub-plots. Seeding rates were 1.5, 3, and 4.5 seeds per ft of row. The cover crops were terminated at the time of cotton planting or 6 weeks prior to planting. Sub-plots were 12 rows wide and 100 ft long.

The experiment was conducted in a commercial field located at the Manila, AR Airport Complex. Research plots were provided via a cooperative agreement between the University of Arkansas Division of Agriculture, the city of Manila in Mississippi County, and cooperating producers from Wildy Family Farms (WFF). For the experiment, we had access to WFF equipment for planting (12 row variable rate planter) and harvest (6-row cotton picker with yield monitor). Other than the cover crop treatments and cotton seeding rates, all other production practices including land preparation, fertilizer application, irrigation, and pest control were performed by the cooperating producers following their standard management regime and using their equipment. Production inputs and timing are listed in Table 1.

In November 2017, the entire field was re-bedded, and where appropriate cover crops seeded with a Gandy Orbit air seeder (Gandy Company, Owtonna, MN). The cereal rye was the regionally adapted variety, Elbon. A broad-leaf selective herbicide application was made in early March 2017 across all plots. Cover crops were terminated with herbicides either early April or mid-May, one day after cotton planting.

Cultivar DP1518 B2XF planted 15 May using a 12-row variable rate planter which applied the seeding rate prescription for 1.5, 3, or 4.5 seeds per foot of row in appropriate plot locations (Figure 2). The raised beds were spaced at 38 inches. Seed bed conditions were dry at planting, and the producer ran a do-all, seedbed finisher in front of the planter. On the day following planting, the final burndown herbicide was applied across the entire field. A synthetic pyrethroid. insecticide was included in the tank mix.

Soils were classified as Routon-Dundee-Crevasse complex (Typic Endoqualfs). Site selection for plant, soil moisture, and insect pest monitoring activities within the 100ft long, 12-row plots included consideration of soil texture. Sample points for soil moisture monitoring using Watermark sensors were identified and referenced with GPS coordinates based on Soil EC categories set from measurements using a Veris 3150 dual-depth EC Surveyor instrument® (Veris Technologies, Inc., Salina, KS). These were positioned in rows 9 & 10 in selected plots in sample sites categorized as coarse sand (shallow measures and EC< 9 mS/M) or loamy sand (EC< 9 mS/M). Approximately 40% of the field was considered in the coarse sand category.

Winter Cover Crop	
1)	Banded cereal rye 20 lb/ac
2)	Banded wheat 20 lb/ac
3)	Broadcast cereal rye 1 bu/ac
4)	Winter fallow

Cover Crop Termination Timing	
1)	at planting
2)	6 weeks prior to planting

Cotton - Seeding Rate	
1)	1.5 seed per ft of row
2)	3 seed per ft of row
3)	4.5 seed per ft of row

Winter Cover Crop * Termintation Timing * Cotton Seeding Rate

replication	1	1	1	1	2	2	2	2	3	3	3	3
cover crop	2	3	4	1	4	1	3	2	1	3	4	2
termination	2	1	2	1	2	2	2	1	2	2	2	1
seeding rate	1	2	2	1	3	2	1	3	3	2	3	1
plot number	106	112	118	124	206	212	218	224	306	312	318	324
replication	1	1	1	1	2	2	2	2	3	3	3	3
cover crop	2	3	4	1	4	1	3	2	1	3	4	2
termination	2	2	1	2	1	1	2	1	1	2	2	2
seeding rate	2	2	2	3	3	1	2	1	3	1	2	1
plot number	105	111	117	123	205	211	217	223	305	311	317	323
replication	1	1	1	1	2	2	2	2	3	3	3	3
cover crop	2	3	4	1	4	1	3	2	1	3	4	2
termination	1	1	2	2	1	2	1	1	2	1	2	1
seeding rate	2	3	3	2	1	1	3	2	2	1	1	3
plot number	104	110	116	122	204	210	216	222	304	310	316	322
replication	1	1	1	1	2	2	2	2	3	3	3	3
cover crop	2	3	4	1	4	1	3	2	1	3	4	2
termination	2	2	1	2	2	2	2	2	2	2	1	1
seeding rate	3	3	3	1	2	3	3	3	1	3	3	2
plot number	103	109	115	121	203	209	215	221	303	309	315	321
replication	1	1	1	1	2	2	2	2	3	3	3	3
cover crop	2	3	4	1	4	1	3	2	1	3	4	2
termination	1	1	2	1	1	1	1	2	1	1	1	2
seeding rate	1	1	1	3	2	3	2	1	2	3	2	3
plot number	102	108	114	120	202	208	214	220	302	308	314	320
replication	1	1	1	1	2	2	2	2	3	3	3	3
cover crop	2	3	4	1	4	1	3	2	1	3	4	2
termination	1	2	1	1	2	1	1	2	1	1	1	2
seeding rate	3	1	1	2	1	2	1	2	1	2	1	2
plot number	101	107	113	119	201	207	213	219	301	307	313	319

Sub-plots: 100 ft long &12 rows wide with 10 ft alleys

Figure 1. Field plan and treatment lists for 2018 cover crop*termination*seeding rate trial – Manila, AR.

Table 1. Dates of planting, irrigation, pesticide applications* (labeled rates of insecticide, herbicide & harvest aids) and harvest for the 2018 cover crop*termination*seeding rate trial – Manila, AR.

Operation	Date	Days after planting
Field re-bedded & cover crops seeded	22 November 2017	-174
Cover crop termination (early or at-planting)	4 April ***or*** 16 May 2018 (paraquat)	-41 or 1
Selective burndown - broadleaf weeds	10 April (dicamba, thifensulfuron-methyl, tribenuron-methyl)	-35
Cotton planted (Cultivar DP1518B@XF)	15 May	0
Stand counts	21 & 29 May, 5 June	6, 15, 21
Producer-applied foliar insecticides	16 May (cypermethrin); 9 June 25 June & 11 July, (sulfoxaflor); 26 Jul (acephate + »-cyhalothrin)	1, 25, 41, 57, 72, 84
Furrow irrigation	61 June, 5, 12, 20, 26 July, 8 Aug	32, 51, 58, 66, 72, 86
Harvest aids	14, 30 Sept	122, 139
Machine harvest	30 Oct	168

*additional in-season applications of herbicides were made during the production season as well as the plant growth regulator, mepiquat chloride; these were made uniformly across all plots and are not listed here.

Stand counts were made using line-transect sampling with counts of plants per 3 ft in two transects across each 12-row plot. Stand counts were made at 6, 14 and 21 days after planting (DAP). Weekly 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 methods (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 field data collections 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).

Figure 2. Terminated and green banded cover crop treatments are shown.

Arthropod pests: Scouts made weekly inspections for cutworms and other "green bridge" associated seedling pests during stand counts. Thrips assessments were made 2 and 3 weeks after planting using whole plant alcohol washes with 10 plants collected per plot. These same plant samples also were used for leaf area and plant biomass assessments (above ground plant material only). Leaf area index (LAI) measurements were made with a LI-3100C Area Meter (LI-COR, Lincoln, NE, US). Tarnished plant bug numbers (*Lygus lineolaris*) were monitored weekly starting in the first week of squaring (34 DAP) and extending through physiological cutout (NAWF=5). Sampling included use of sweep nets (preflower) and drop cloths (full season).

Yield assessments were based on 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. A four-way factorial structure was used for analysis of the yield monitor measured yield with seeding rate, cover crop, termination timing, and block effect; soil EC classifications were also included as a co-variate. All monitoring data were analyzed using SAS 9.4, PROC MIXED (SAS Institute; Cary, NC).

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

Risk of physical damage to seedling cotton from blowing sand hinders winter fallow production in large fields with sandy soils in the NE Arkansas and SE Missouri cotton production region. In our study, the strip plot design obscured blowing sand protection benefits from cover crops, and therefore we did not observe differences in wind-related damage among treatments. Rainfall amounts during the season were slightly below average in May, June, July and early August (Table 2). The field was irrigated 6 times (Table 1).

Table 2. Monthly precipitation (inches) measured at the study site for the 2018 season compared with 30-year average for the county -- 2018 cover crop*termination*seeding rate trial – Manila, AR.

Mean per month	30-year Average	2018 Rainfall	Departure
		---------------------inches---------------------	
May	5.37	4.00	-1.37
June	3.99	3.61	-0.38
July	4.04	1.34	-2.7
August	2.36	8.12	5.76
Total Season	15.76	17.07	1.31

Plant Stand Density: Results from stand counts showed that delayed cover crop termination delayed stand establishment (*P*=0.01). Reduced soil moisture in plots where cotton was planted in green cover crops likely slowed cotton germination rates. In assessments made at 6 days after planting (DAP), plant stands were >90 % of target where cover crops had been terminated 5 weeks before planting but were < 60% where termination was delayed (Figure 3). Following a 1.4-inch rain event at 5 DAP, soil moisture was sufficient for germination. By 21 DAP, all treatments reached at least 85% of target stand.

Leaf Area and Biomass: Delayed plant emergence was reflected in results from plant leaf area index (LAI) assessments made at 14 and 21 DAP. There was reduced LAI and biomass for plants where cover crop termination was delayed until planting (*P*=0.01) (Figure 4). There also were significant interactions with cover crop and termination timing treatments; termination timing had little effect on biomass and LAI of plants in the winter fallow treatment.

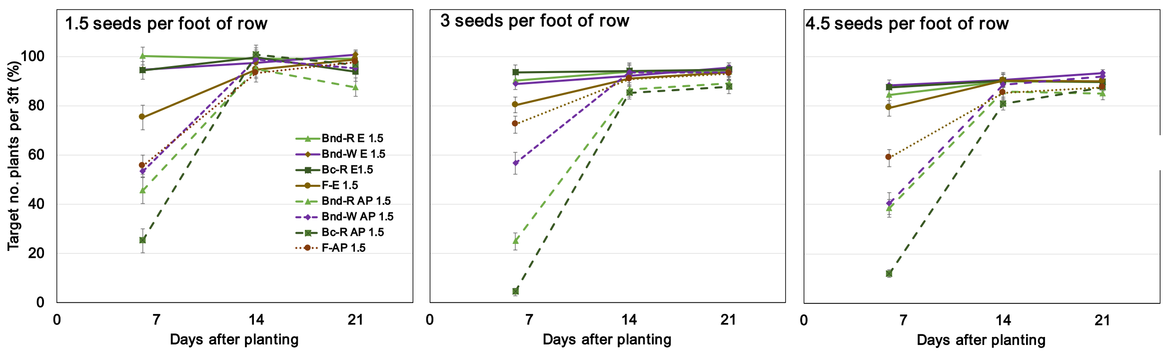

Figure 3. Mean (±SEM) plant stand density as a percentage of target stand (1.5, 3 or 4.5 seeds per ft of row), measured in two, 3-ft transects across the 12-row plots for early and at planting termination timing (E, AP) for banded cereal rye (Bnd-R), banded wheat (Bnd-W), broadcast cereal rye (Bc-R), and winter fallow (F) on 21, 29 May and 5 June (6, 14 & 21 DAP) – 2018 cover crop*termination*seeding rate trial – Manila, AR.

Arthropod Pests: Seedling pests were inconsequential in 2018. Thrips infestation levels were consistently low and below threshold (Figure 4). There were no significant differences for cover crop or termination effects (P>0.20). Reduced thrips numbers have been associated with terminated cover crops in our previous research (Kelly et al. 2013) and in other US cotton production areas (e.g. Toews et al 2010). 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.

Tarnished plant bug numbers were low season-long, with peak abundance 41 and 69 DAP (Figure 5). There generally were no differences in bug numbers associated with cover crop, termination timing or seeding rate effects. Highest numbers were spatially associated with field areas adjacent to favorable overwintering habitat near the field border. The habitat also provided early spring plant hosts for first generation tarnished plant bugs. Plant bug dispersion patterns were like those we have seen previously at the field site. Plant bug feeding injury is typically reflected in pre-flower stage cotton by square retention rates. COTMAN plant monitoring results showed that first position square shed levels generally were low and exhibited similar spatial patterns as the plant bug infestations (Figure 5). No differences in insect feeding injury were associated with cover crop, termination, or seeding rate treatments.

Low pest densities also were related to insecticide applications made through the season for thrips and plant bugs (Table 1). Because our cooperating grower used tank-mix sprays of plant growth regulator and/or herbicides that included an insecticide, it was not practical to withhold insecticide sprays in our portion of the commercial field.

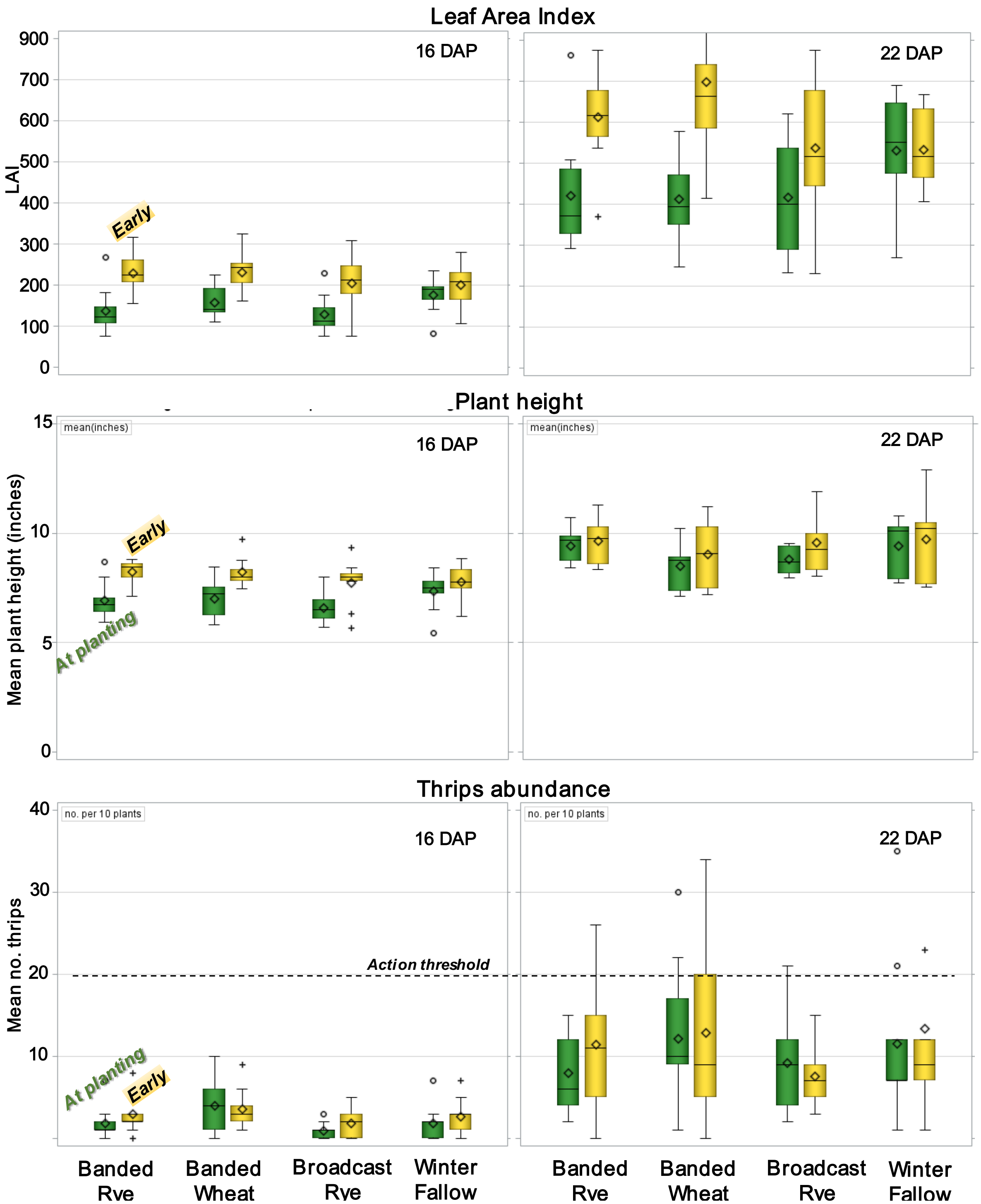

Figure 4. Plant height, LAI, and thrips observations among cover crop and termination treatments at 16 and 22 DAP. Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value – 2018 cover crop*termination*seeding rate trial – Manila, AR.

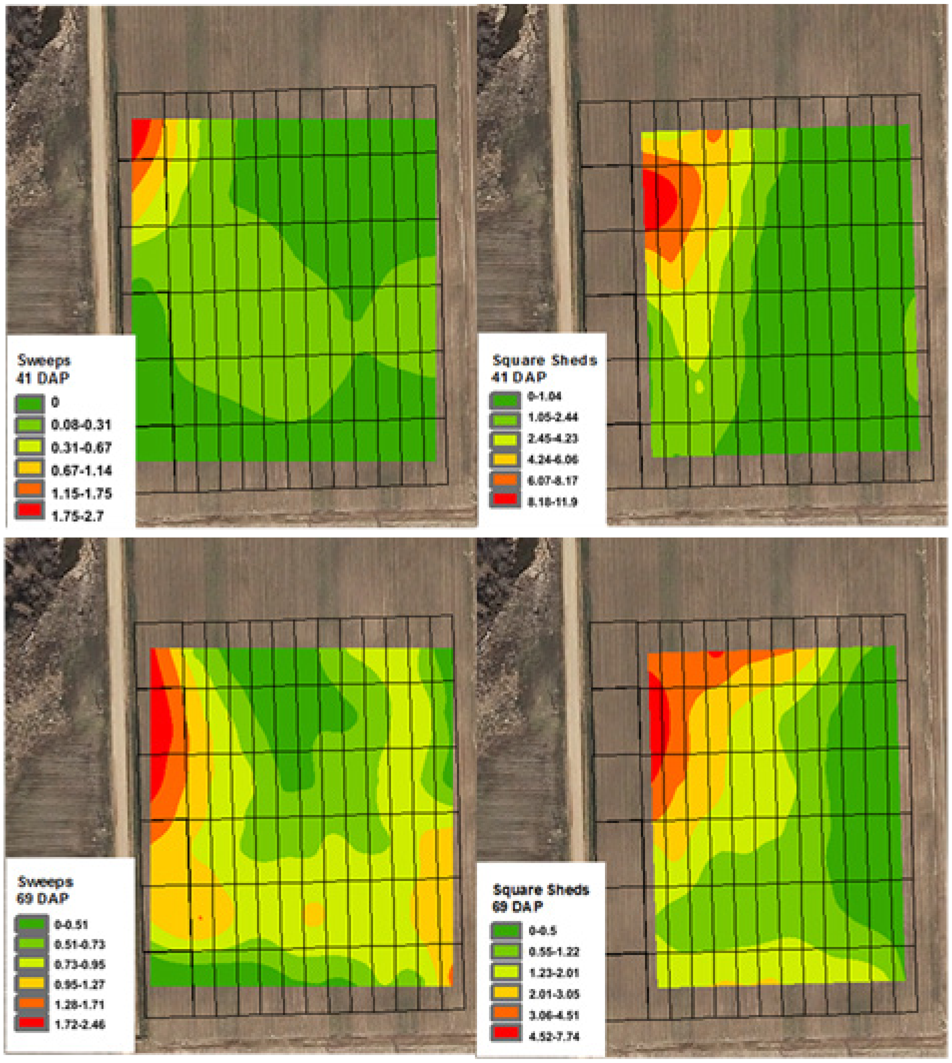

Figure 5. Spatial representation of tarnished plant bug numbers and square shed for 41 and 69 DAP samples across the 2018 cover crop*seeding rate*termination field trial - Mania, AR. Maps were produced using localized polynomial interpolation in ArcGIS 10.3.1.

COTMAN Growth Curves: The pace of pre-flower plant nodal development, depicted in COTMAN growth curves, differed among plants with different cover crop termination timing. Growth curves for plants from late terminated cover crops show that pace of plant nodal development was delayed compared to those plants with early cover crop termination (preflower). There were no termination timing effects noted for plants in the winter fallow check. First flowers were observed by 55 DAP in the winter fallow, banded wheat and banded cereal rye cover crop treatments. First flowers were not observed until 62 DAP if termination of broadcast rye was delayed until planting. During effective flowering, slope of growth curves (NAWF decline) were very similar among treatments. In the COTMAN system, physiological cutout (NAWF=5) is considered the flowering date of the last effective boll population. Mean no. days from planting to physiological cutout (days to cutout) ranged from 71 to 82 DAP among seeding rate and cover crop treatments. There was significant cover crop*termination*seeding rate interaction (P=0.01) with latest maturity associated with late terminated, banded and broadcast cereal rye, at 1.5 and 3 seeds per ft of row (Figure 6). No differences in days to cutout were noted with banded wheat or winter fallow treatments.

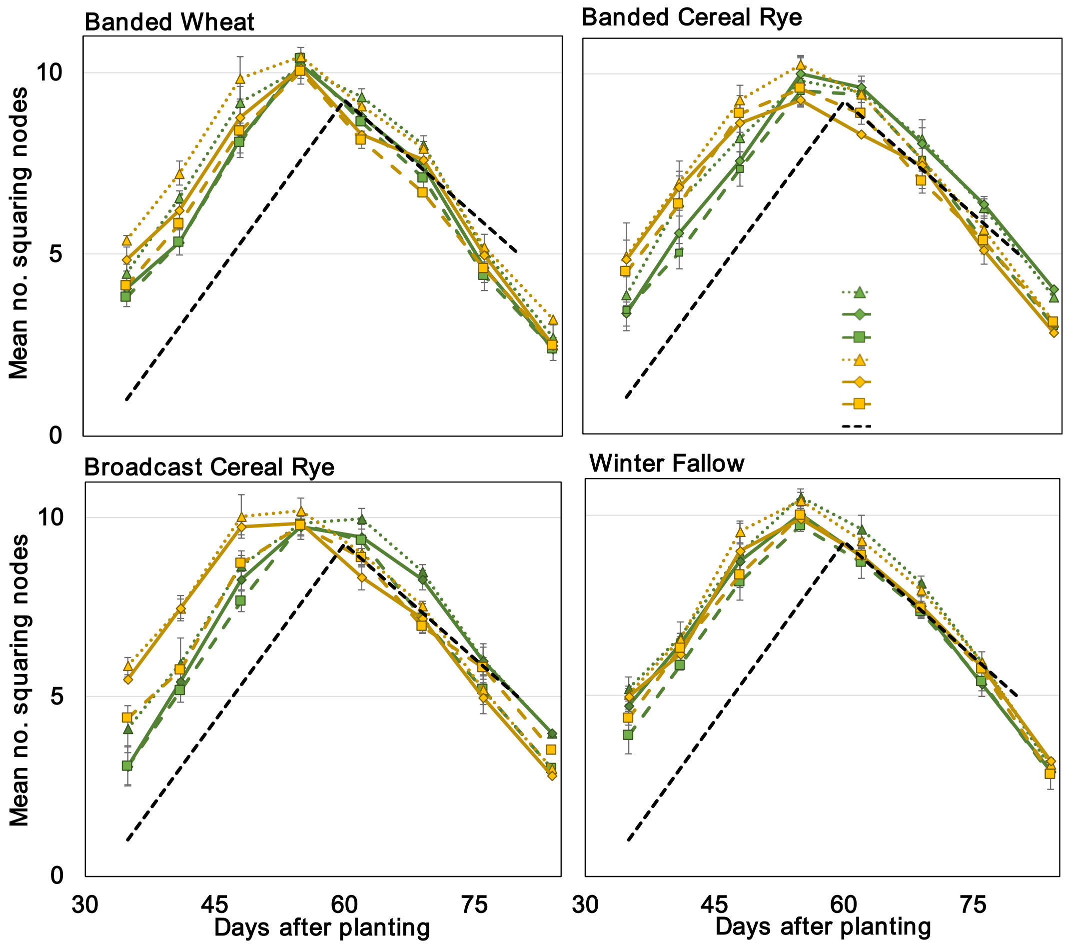

Figure 6. COTMAN growth curves for plants in each of the four cover crop treatments with two different termination timing (Early and At-planting) for the three seeding rates (1.5, 3, and 4.5 seeds per ft of row) – 2018 cover crop*termination*seeding rate trial – Manila, AR.

Soil Moisture Monitoring: Readings from Watermark sensors (positioned at 6 and 12 inches below the soil surface between plants at the top of beds) generally showed great variability among seeding rate, termination timings and cover crop treatments. Only a portion of our 2018 soil moisture data are presented. Variability is a common problem with Watermark sensors in sandy soils and especially with the alluvial soils and sand blows common in that production region. Reduced infiltration due to soil surface sealing in water furrows also was a challenge at the study site.

Soil moisture charts are presented Figure 7 for coarse sand and loamy sand sample sites with similar termination and cover crop treatments. There was adequate rainfall to provide soil moisture through seedling stage and early squaring stage. A prolonged drying period followed, with weekly irrigations, and there were some trends related to differences in irrigation infiltration and soil water holding capacity. Irrigation events registered more frequently with sensors located in coarse sands and for broadcast cereal rye treatments. For example, the first irrigation event was apparent in Watermark sensor measurements at both the 6 and 12-inch depths for both soil textures for broadcast cereal rye and in the coarse sand treatment for banded wheat; however, response was not apparent in sensor readings in the winter fallow or in banded cereal rye treatments. We interpret these measurements as an indication of increased infiltration in the cereal rye compared to the other treatments.

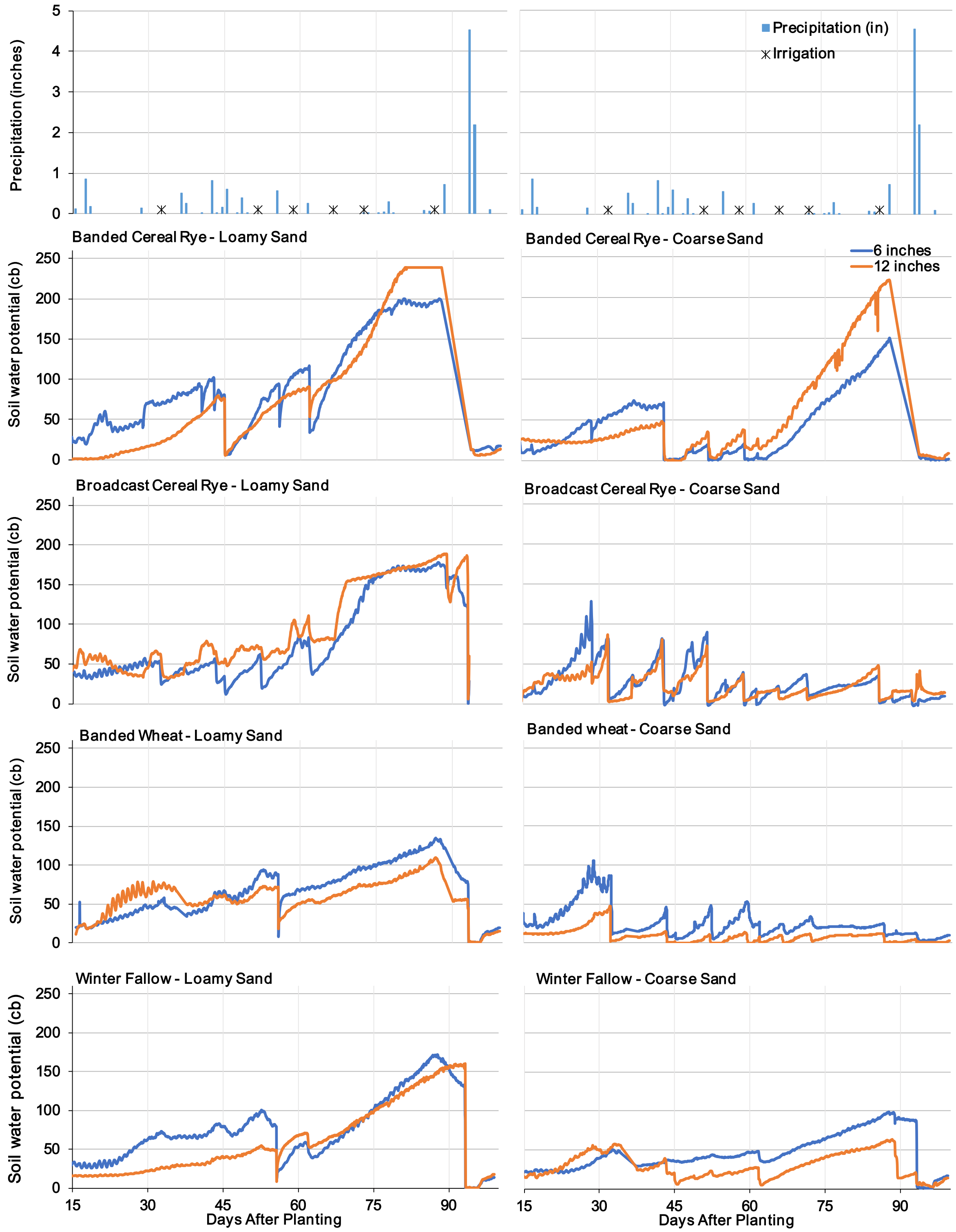

Figure 7. Precipitation, irrigation timing, and soil moisture measures (mean of 3 Watermark sensors per station) at 6 and 12-inch depths positioned at points in different soil textures placed based on soil EC measures in different cover crop treatments.

Yield: Both cover crop termination timing and seeding rate sub-plot significantly affected yields; however, there were significant interactions among factors tested (Table 3). Yield monitor measured yields (Figure 8) showed early termination timing of cover crops was advantageous. There were yield penalties for "planting green" (Figure 9). No differences in yield were noted for winter fallow termination timing (there was minimal weedy vegetation because of early spring overspray of herbicides for broadleaf weeds). Lowest yields were associated with coarse sand, the areas of the field with lowest soil EC values (EC< 9 mS/M) compared to loamy sand areas of the field (Figure 9). The coarse sand class encompassed 40% of the field (Figure 8). Seeding rate response was inconsistent in cover crop treatment combinations with interactions of cover crops*termination timing*seeding rate and soil texture.

Table 3. Results from lint yield analysis using PROC MIXED; shown are fixed effects for Cover crops (CC), cover crop termination timing (Term), cotton seeding rate (SR) and soil textures based on soil EC class (EC-Bin).

Effect	Num DF	Den DF	F Value	Pr > F
CC	3	6	0.83	0.5258
Term	1	1719	149.91	<0.0001
CC*Term	3	1719	37	<0.0001
SR	2	1719	12.04	<0.0001
CC*SR	6	1719	10.7	<0.0001
Term*SR	2	1719	2.2	0.1114
CC*Term*SR	6	1719	5.2	<0.0001
EC_BIN	1	2	4.08	0.1807
CC*EC_BIN	3	1719	19.08	<0.0001
Term*EC_BIN	1	1719	0	0.979
CC*Term*EC_BIN	3	1719	5.51	0.0009
SR*EC_BIN	2	1719	13.55	<0.0001
CC*SR*EC_BIN	6	1719	5.56	<0.0001
Term*SR*EC_BIN	2	1719	2.69	0.0683
CC*Term*SR*EC_BIN	5	1719	1.33	0.2487

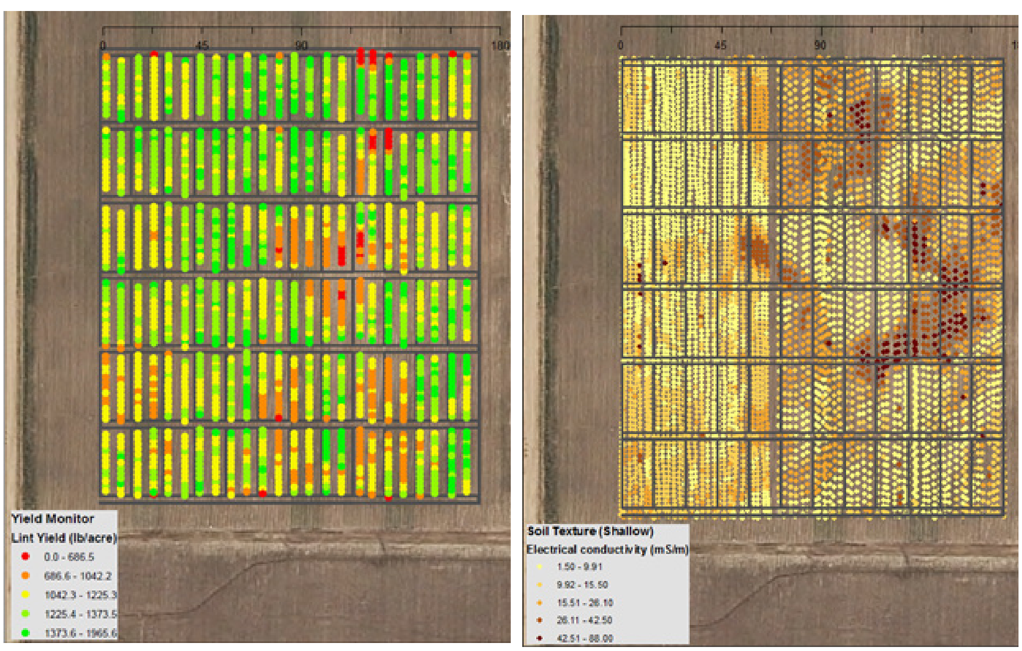

Figure 8. Yield map (left) and soil EC map (right) for 2018 cover crop*termination*seeding rate trial, Manila, AR.

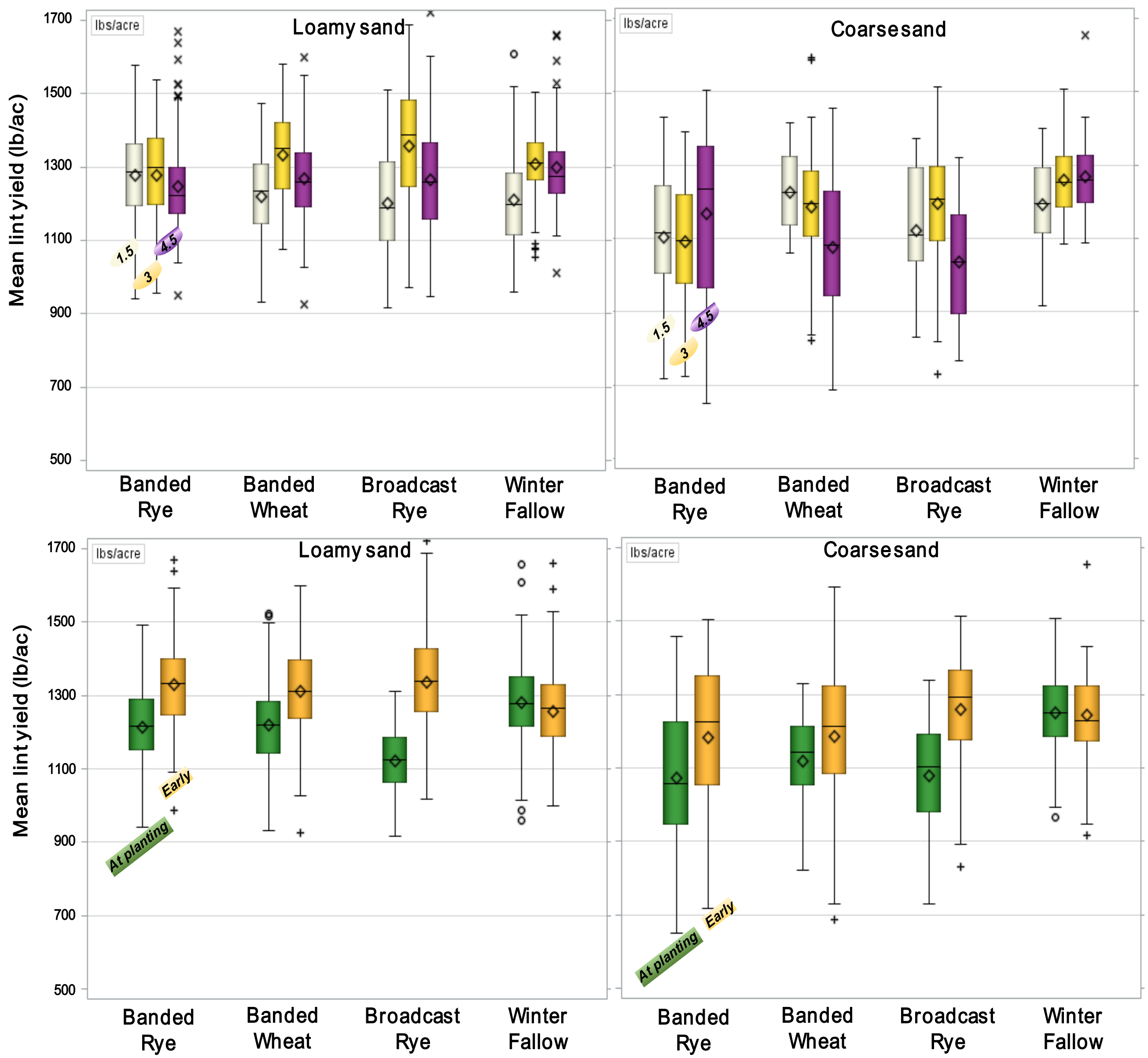

Figure 9. Lint yields for seeding rate and soil texture effects derived from calibrated yield monitor data (above) and for termination timing of cover crops are shown. Boxes represent 50% quartile; diamonds within the box depict means, and the line is the median value—2017, Manila, AR.

Partial Budget Analysis: Returns to operating expenses (variable costs) were calculated using the University of Arkansas Cooperative Extension Service Cotton Enterprise budgets. Net returns for mean yields were based on $0.70 per lb price and a 25% share for land rent. Fiber quality discounts were not considered. Seed costs for cover crops and seeding rates were based on grower cost (Table 4). Capital recovery & fixed costs were estimated at $162.3 per acre but were not included in net returns shown.

For loamy sand soils (~60% of the field), yields and net profit were highest with broadcast rye cover crop and seeding rate of 3 seeds per ft of row (mean lint yield 1433 lb/ac). Low seeding rates (1.5 seeds per ft of row) with banded cereal rye and banded wheat also produced >$200/ac net returns (Table 5). Lowest net returns in loamy sand ($28/ac) were observed with broadcast rye, terminated at planting, with seeding rate of 4.5 seeds per ft of row. In coarse sand soils (40% of field area), highest net returns ($273/ac) were observed with banded wheat, terminated early, and cotton seeded at 1.5 seeds per ft of row (mean yield 1396 lb/ac). Lowest net returns ($-19 and $-15/ acre) were observed with banded wheat and broadcast cereal rye, terminated at planting, with cotton seeding rate of 4.5 seeds per ft of row (mean yields 1008- 1028 lb/acre).

Table 4. Variable seed costs for cotton and cover crops for 2018 cover crop*termination*seeding rate trial – Manila, AR.

		Cotton seeding rate cost ($/acre)		
		1.5 per ft	3 per ft	4.5 per ft
Treatment		$46	$92	$138
Cover Crop seed cost ($/acre)		Treatment combinations ($/acre)		
Winter Fallow	$ 0.0	$46	$92	$138
Banded Wheat	$ 4.40	$50	$96	$142
Banded Rye	$ 7.00	$53	$99	$145
Broadcast Rye	$13.60	$60	$106	$152

Table 5. Mean lint yields and calculated net returns per acre for cover crop*seeding rate*termination timing treatments in loamy sand and coarse sand textures in 2018 Manila field study.

Treatment		**Lint Yield**				**Net Returns per acre**			
Soil texture & cov crop termination	**Seeding rate** no. per ft	**Banded rye**	**Banded wheat**	**Brdcast rye**	**Winter fallow**	**Banded rye**	**Banded wheat**	**Brdcast rye**	**Winter fallow**
		lb per acre				*$ per acre*			
Loamy Sand									
At planting	1.5	1250	1154	1105	1237	$197	$150	$116	$197
	3	1202	1285	1181	1320	$126	$171	$108	$193
	4.5	1188	1246	1113	1295	$73	$105	$28	$134
Early	1.5	1306	1283	1294	1185	**$225**	**$216**	**$211**	$170
	3	1356	1372	1433	1297	**$204**	**$215**	**$236**	$181
	4.5	1318	1304	1314	1301	$139	$135	$130	$137
Coarse sand									
At planting	1.5	1126	1187	1073	1213	$133	$167	$100	$184
	3	1075	1102	1129	1271	$61	$78	$82	$168
	4.5	1008	.	1028	1249	-$19		-$15	$111
Early	1.5	1077	1396	1209	1165	$108	**$273**	$168	$160
	3	1112	1262	1316	1247	$80	$159	$177	$156
	4.5	1311	1075	1097	1290	$135	$18	$19	$131

Discussion

Midsouth cotton growers typically plant winter cover crops for weed suppression and/or crop protection from blowing sand and wind. Enhanced weed suppression typically results when the spring growth of the cover crop is extended, and there is increased cover crop residue. Greater residue also may serve to conserve soil water later the season; however, if spring rainfall is limited, prolonging cover crop growth may deplete soil moisture. The soil may be too dry at planting and adversely affect establishment of the main crop (Dabney et al. 2007). A delay in cover crop termination also can exacerbate risks from allelopathic effects of the terminated cover crop, reducing cotton seedling growth and plant vigor (McClure et al 2017; Robertson and Barber 2018). There was evidence of one or both these negative effects in our delayed termination treatments in 2018. No arthropod or other pest feeding related injury was measured in our experiment in association with delayed termination, so we do not attribute delayed stand establishment, reduced early season seeding growth, and reduced yield to "green bridge" effects in 2018.

Wind and sand protection at our study site did not appear to impact seedling plant vigor in 2018; however, in most years, risks of damage from blowing sand make winter fallow production an impractical agronomic choice for sandy fields in Northeast Arkansas and Southeast Missouri. Banded cover crops provide wind protection, and most cotton producers who farm those soils have adopted this practice. Broadcast cereal rye provides wind protection, weed control benefits, and can improve soil physical/chemical properties. This option also was the most expensive cover crop treatment. If not terminated several weeks before cotton planting, our 2018 results and results from 2017 (Teague et al 2018), indicate that at planting termination of broadcast cereal rye reduced cotton yields compared to winter fallow or banded cereal crops.

Cover crops can lessen negative effects of soil compaction and sealing soils and act to improve water infiltration and soil water holding capacity (Dabney et al. 2007). Some Midsouth cotton producers plant winter cover crops in expectation of positive impacts on soil physical properties that result in increased irrigation efficiency. In our 2018 study, we did observe positive changes in soil moisture availability in mid-season with cover crops compared to observations from winter fallow treatment plots.

Given the high costs for treated, transgenic cotton seed, producers can lower production costs substantially if they reduce seeding rates. Our results show that there were no significant yield penalties associated with lower plant stand densities if cotton was seeded into cover crops which had been terminated 5 weeks prior to planting. The study site was a spatially variable field with heterogeneous soils, and ca. 40% of the field was classified as coarse sand. We measured a strong relationship with lint yield associated with soil texture. For the typically lower yielding, coarse sand areas of the field, highest net revenue (over $200/acre) was observed with lowest seeding rates with banded wheat cover crop. In loamy sand areas of the field, there were six cover crop and seeding rate treatment combinations (three with 1.5 seeds per ft of row & three with 3 seeds per ft of row) that produced over $200/ac net revenue.

In addition to positive effects on crop protection and soil properties, cover crops can provide other significant benefits including environmental protection related to improved nutrient management. In on-going research in the NE Arkansas region with edge-of-field water quality monitoring, Aryal et al. 2018 reported that use of cover crops in commercial cotton fields reduced nutrient and sediment loss in runoff water compared to no cover crops. These WQ benefits support the expanded USDA-NRCS programs in Arkansas established through the Mississippi River Healthy Water Initiative (NRCS 2017) which provides cost-share support to producers who include winter cover crops in their conservation practices.

Key Findings & Practical Application

Our cover crop research findings support the following general guidelines for the northern Midsouth production area. 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/or* soil & water conservation. Managers should target early October for seeding cereal cover crops and terminate cover crops one month before planting cotton. Desiccation of the winter cover crop should be complete at least two weeks before planting cotton to avoid providing a "green bridge" that allows pests to survive on the growing cover crop, to minimize allelopathic effects on cotton seedlings, and to conserve soil moisture for planting.

Variable rate seeding approaches should be considered when there is extreme within-field soil variability, if equipment is already available, and if site-specific management costs for prescriptions are minimal. For 2018 and in previous research in NE Arkansas (Benson et al 2014, 2015, 2016), lowest cotton seeding rates in coarse sand produced best economic returns. In loamy sand, low and medium seeding rates produced best economic returns. For site-specific prescriptions in fields that include clay soils or crusting soils with significant stand establishment challenges, a medium seeding rate (standard Cooperative Extension recommendation) is suggested.

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