Summaries of Arkansas Cotton Research 2019

Cotton seedlings protected by winter cover crop

Edited by Fred Bourland

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Cover Photo: Newly emerged cotton seedlings are protected from wind and blowing sand by the residue of a terminated winter cover crop. Cover crops provide soil erosion, protection, and weed suppression. They also can improve soil conditions and protect water quality by reducing loss of nutrients and sediment. Photograph by Tina Teague, University of Arkansas System Division of Agriculture.

Layout by Christina Jamieson
Technical editing and cover design by Gail Halleck

Arkansas Agricultural Experiment Station (AAES), University of Arkansas System Division of Agriculture, Fayetteville. Mark J. Cochran, Vice President for Agriculture. Jean-François Meullenet, AAES Director and Senior Associate Vice-President for Agriculture–Research.
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Summaries of Arkansas Cotton Research 2019

Fred Bourland, Editor

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Fayetteville, Arkansas 72704

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Agronomy

Cotton Incorporated and the Arkansas State Support Committee

The *Summaries of Arkansas Cotton Research 2019* is published with funds supplied by the Arkansas State Support Committee through Cotton Incorporated.

Cotton Incorporated's mission is to increase the demand for cotton and improve the profitability of cotton production through promotion and research. The Arkansas State Support Committee is composed of the Arkansas directors and alternates of the Cotton Board and the Cotton Incorporated Board, and others whom they invite, including representatives of certified producer organizations in Arkansas. Advisors to the committee include staff members of the University of Arkansas System Division of Agriculture, the Cotton Board, and Cotton Incorporated. Seven and one-half percent of the grower contributions to the Cotton Incorporated budget is allocated to the State Support Committees of cotton-producing states. The sum given to Arkansas is proportional to the states' contribution to the total U.S. production and value of cotton fiber over the past five years.

The Cotton Research and Promotion Act is a federal marketing law. The Cotton Board, based in Memphis, Tennessee, administers the act, and contracts implementation of the program with Cotton Incorporated, a private company with its world headquarters in Cary, North Carolina. Cotton Incorporated also maintains offices in New York City, Mexico City, Osaka, Hong Kong, and Shanghai. Both the Cotton Board and Cotton Incorporated are not-for-profit companies with elected boards. Cotton Incorporated's board is composed of cotton growers, while that of the Cotton Board is composed of both cotton importers and growers. The budgets of both organizations are reviewed annually by the U.S. Secretary of Agriculture.

Cotton production research in Arkansas is supported partly by Cotton Incorporated directly from its national research budget and by funding from the Arkansas State Support Committee from its formula funds (Table 1). Several of the projects described in this series of research publications are supported wholly or partly by these means.

Table 1. Arkansas Cotton State Support Committee Cotton Incorporated Funding 2019.

		2018	2019
New Funds		$161,000	$154,000
Previous Undesignated		$42,929	$40,302
Total		$203,929	$194,302
Researcher	**Short Title**	**2018**	**2019**
Robertson	Cotton Research Verification/Applied Research	$50,000	$50,000
Bourland	Breeding	$26,000	$26,000
Roberston	Soil Health - No Till	$12,074	$20,000
Barber	New Herbicide Tech	$25,000	$0
Adviento-Borbe	Tillage Practices and Water Quality	$5,000	$5,000
Robertson	Target Leaf Spot Integrated Pest Management	$15,000	$15,000
Robertson	Cereal Rye Termination Timing	$27,000	$27,000
Lorenz	Official Variety Test Thrips Tolerance	$5,000	$0
Barber	Integrated Pest Management for Weeds	$0	$20,000
Uncommitted		$40,302	$31,302
Total		**$205,376**	**$194,302**

Acknowledgments

The organizing committee would like to express appreciation to Christina Jamieson for help in typing this special report and formatting it for publication.

Disclaimer

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the US Department of Agriculture, an equal opportunity provider and employer.

Summaries of
Arkansas Cotton Research
— 2019 —

Review of the 2019 Arkansas Cotton Crop

Overview

Statewide, temperatures and precipitation were mostly above average (https://www.weather.gov/lzk/cli2019atxt.htm). The 2019 season was the wettest since 2015, and the 7th wettest on record. The wettest month was May, and the driest month was September. By average temperature, the coldest month was January, and the warmest month was August. Considering departures from normal, the most significant warmth occurred in September, which was 7.0 degrees above average.

Many fields were muddy or underwater, given a lot of rain early in the year, and extensive river flooding (including the historic Arkansas River flood). It was far too wet in some areas of the state for any planting during the beginning of the growing season. In August, The United States Department of Agriculture (USDA) released a report stating that Arkansas had 38,068 acres of cotton unplanted (or prevented) (https://www.fsa.usda.gov/news-room/news-releases/2019/report-farmers-prevented-from-planting-crops-on-more-than-19-million-acres). Arkansas producers harvested 610,000 acres of cotton in 2019, up 27% from 2018 (https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Releases/Annual_Summary/2019/arannsum19.pdf). The yield is expected to average 1102 pounds per harvested acre, down 31 pounds from last year. Production is estimated at 1.40 million bales, up 24% from 2018.

In the last five years, cotton acreage in Arkansas has steadily increased from an all-time low of 210,000 acres in 2015 to 610,000 planted acres in 2019. One reason for the increase can be attributed to a downturn in prices received by producers for commodities such as corn and soybean, which compete for acres with cotton. This increase of acres continues to push our ginning capacity of 28 gins in 2018 and on-farm picker capacity to the limit. Arkansas producers have averaged 1124 lb lint/ac over the last five years producing an average of 860,000 bales per year. Total average value of Arkansas cotton to the Arkansas economy has been over 284 million dollars per year. Each of the last five years has yields that rank historically in the top 7 of all time. Arkansas currently ranks fourth in 2019 cotton production behind Texas, Georgia, and Mississippi.

Planting

Virtually 100% of cotton varieties planted in 2019 contained traits for enhanced insect and weed control. Reports released by Agricultural Marketing Service (https://www.ams.usda.gov/mnreports/cnavar.pdf) estimated 86% of the cotton varieties planted in 2019 contained XtendFlex® herbicide-tolerant traits (XF), up from 84% in 2018, 70% in 2017 and 58% in 2016. Plantings of varieties containing the Enlist™ weed control system traits (FE) was estimated at 5% down from 8% in 2018. The remaining 9% of the cotton acres were planted to cotton with traits for herbicide tolerance to only glyphosate and glufosinate. Varieties containing two-gene *Bt* traits (B2-84% and T-1%) accounted for 85% of the acres statewide. The remaining 15% of the acres were planted to three-gene *Bt* traited varieties (B3-2%, TP-8%, and W3 5%). The two most widely planted varieties DP 1646 B2XF and DP 1518 B2XF accounted for 36% and 24% of planted acres, respectively.

The early planting window, which we generally have in April, never materialized as we only planted about 5% of our crop in April (https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Releases/Crop_Production_Monthly/2019/index.php). Conditions did not become favorable for cotton planting until the last few days of April. Planting progress got off to a slow start and trailed behind the five-year average to the very end of planting. We were only 50% planted at Memorial Day weekend (25 May) compared to the five-year average of 80% for the same period. It was surprising that we exceeded 600,000 planted acres. While not planned, some producers' planting windows extended into June.

Fruiting and Harvest

The condition of most of the crop was good to excellent all season long. Reports by the United States Department of Agriculture National Agricultural Statistics Service (https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Progress_&_Condition/2019/) indicate the percentage of the acres statewide receiving a rating of excellent never dropped to less than 36% once the crop started flowering. The percent of the crop rated good and excellent was greater than 80% the entire season.

Progress of squaring did not fall behind that of last year or the five-year average, as did our planting progress. As expected, squaring started slow but by the time half of our crop was squaring, we were only slightly behind the five-year average. Flowering followed the same trend. However, flowering exceeded our five-year average two to three weeks into the flowering period. The progress of the 2019 crop in catching up to the five-year averages reflects the favorable season with timely

rainfall. In 2019, it was not uncommon to visit with producers who unrolled polypipe but never had to irrigate fields. As a result of very timely rainfall values, nodes above white flower (NAWF) were near our goal of 9 to 10 NAWF at first flower. The warm September conditions promoted the maturity and yield of the late-planted cotton.

Harvest progress started well ahead of last year and the five-year average. Rainfall during harvest impacted this trend after the middle of October. After this, harvest progress trailed progress of the previous year and the five-year average. Approximately 25% of the crop was not harvested as we reached our target harvest completion date of 1 November. Harvest for some fields did not finish until mid- to late-November.

Inputs

In our 2019 Cotton Research Verification Sustainability Program (CRVSP), operating expenses per acre averaged $555.40 per acre across all fields. Our greatest operating expenses were seed, pesticides, and fertilizers. Seed and related fees averaged $123.37 per acre, pesticides averaged $195.36 per acre, and fertilizer products, $72.28 per acre. These accounted for over 70% of our total operating expenses per acre.

Plant bugs and Palmer pigweed continue to be our key pests. Fields in our CRVSP were treated an average of 3.6 times for plant bugs in 2019. Each field had an average of 1.9 burndown and 3.0 in-season herbicide applications. All fields averaged 1.1 treatments for moths/worms. Average costs for herbicides and insecticides were $75.23/ac and $91.82/ac, respectively.

The average yield in the 2019 CRVSP was 1455 lb lint/ac. Average fixed costs were $163.82, which led to average total costs of $719.22/ac. Total specified costs averaged $0.50/lb lint. With a crop-share rental agreement of 20% crop and no cost share, the producer specified-cost average would increase to approximately $0.63/lb. The Arkansas annual average price for the 2019 production year was $0.70/lb lint. This leaves only $0.07/lb to contribute to management and overhead with this rental scenario.

Yield and Quality

The NASS August Crop Production report projected that Arkansas producers would harvest 1151 lb lint/ac. Their estimates decreased to 1102 lb lint/ac in September and remained at that level when the final report for 2019 was initially released (https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Releases/Annual_Summary/2019/arannsum19.pdf).

Fiber quality was perhaps the most significant thing that set the 2019 crop apart from last year. In 2019, 89.6% of bales classed for Arkansas was tenderable compared to 70.4% in 2018 (https://www.ams.usda.gov/mnreports/cnwwqs.pdf). Even with rain delays, color grades were very good, with 40.4% of bales receiving color grades of 31 or better, and 90.3% of bales classed received a color grade of 41 or better. Micronaire averaged 4.5, with 93.2% of Arkansas cotton classed having micronaire in our target value range of 3.5 to 4.9. Staple averaged 37.16, with 45.6% of the bales classed having a staple 38 or greater. Leaf was less of an issue in 2019, with 82.4% of the bales classed receiving a leaf of 4 or less compared to 77.7 in 2018. Leaf values for the 2019 crop averaged 3.64 for the season.

Summary

Arkansas ended the 2019 season ranked 4th nationally in harvested acres (610,000 acres), 6th in lint yield (1102 lb/ac), and 4th in total production (1,400,000 bales). The string of consecutive years with good yields is helping to drive the increase in cotton acres. Harvest and ginning capacity are major limiting factors for acre expansion. Cotton planting intentions for 2020 are relatively flat from 2019. This continues to push our ginning capacity of 29 gins in 2019 and on-farm picker capacity to the limit. Total average value of Arkansas cotton to the Arkansas economy has been over 284 million dollars per year for the last five years.

Bill Robertson
Professor, Cotton Extension Agronomist
Newport Extension Center, Newport

2019 Northeast Research and Extension Center: Overview of Cotton Research

A. Beach,[1] E. Brown,[1] and F.M. Bourland[1]

Background

The University of Arkansas System Division of Agriculture initiated cotton research at Keiser in 1957. The Keiser station includes 750 acres (about 650 in research plots) and is located between Keiser and Interstate 55. Through the years, cotton research has spanned all disciplines with particular focus on breeding, variety testing, control of insects, diseases, and weeds, soil fertility, irrigation, and agricultural engineering (Table 1). Innovative practices evaluated at Keiser have included narrow row culture, mechanical harvest (pickers, strippers and the cotton combine), and the cotton caddy (forerunner to cotton module system). The Sharkey clay soil at Keiser is not a dominant cotton soil type in Arkansas. Still, it provides an environment with a soil type that contrasts our other cotton stations and one that has a very low incidence of Verticillium wilt. Since cotton typically does not require the application of mepiquat chloride on this soil type, plants develop unaltered heights at this station.

Table 1. List of 2019 cotton research at Northeast Research and Extension Center, Keiser.

Project Leader	Discipline	Title
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (transgenic test, 50 entries and conventional test, 15 entries)
Fred Bourland	Cotton Breeding	National Cotton Variety Test (10 entries), Regional High Quality Strain Test (19 entries) and Regional Breeders' Network Test (24 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests (6 tests evaluating a total of 120 entries)
Fred Bourland	Cotton Breeding	Cotton Industry Strain Test (evaluating 24 entries)
Fred Bourland	Cotton Breeding	Cotton Breeding Trials (including crosses, F_2, F_3, F_4 populations, F_5 and F_6 progenies, and seed increases, plus greenhouse and laboratory tests)
Jason Norsworthy	Weed Science	Evaluation of Factors Contributing to the Off-Target Movement of Dicamba
Glenn Studebaker	Entomology	Tarnished Plant Bug in Cotton: Resistance in *Bt* Cultivars, Resistance in Conventional Cultivars, Insecticide Spray Intervals, Experimental Insecticides, Rate Efficacy, and Tank Mix Evaluation (6 tests)
Glenn Studebaker	Entomology	Bollworm in Cotton: Evaluation of Damage In Different *Bt* Technologies
Glenn Studebaker Gus Lorenz	Entomology	Thrips in Cotton: Seed Treatment Combinations, Experimental Seed Treatments and Experimental Foliar Insecticides (3 tests)

[1] Program Technician, Program Technician, and Professor, respectively, University of Arkansas System Division of Agriculture, Northeast Research and Extension Center, Keiser.

2019 Conditions and Observations

Similar to conditions in 2018, rainfall in April delayed land preparation at Keiser (Fig. 1). Planting of cotton plots was completed until late May. Adequate moisture and suitable soil temperatures resulted in good stands in most plots. Except for August and early September, frequent rains caused fields to be relatively wet throughout the season. Some fields suffered nitrogen deficiency due to the loss of nitrogen to heavy rainfall in May. Seasonal rainfall (May through October) was 48% higher than average, while August rainfall was less than half as expected (Table 2). Total Degree-Day 60 (DD60s) accumulated from May through October in 2019 was 22% higher than the historical average (Table 2). The DD60 accumulations were greater than historical averages for each month from May through October with greatest deviations occurring in April, May, September, and October. Despite the high heat unit accumulations for the season, temperatures never exceeded 100°F and exceeded 95 °F on only 11 days. Ten of the 11 days exceeding 95 °F occurred in September and October. Both insect and disease incidences were low at Keiser in 2019. Defoliants were applied on time using ground application. Harvest was completed before multiple rain events that began on October 6 and continued through much of the 2019-2020 winter months.

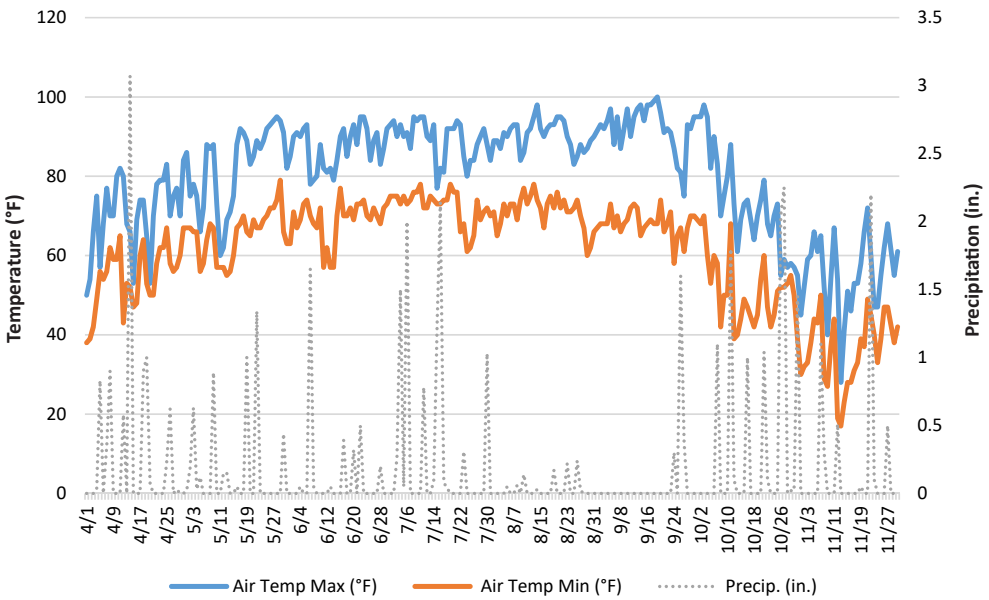

Fig. 1. 2019 Northeast Research and Extension Center, Keiser, temperature and precipitation.

Table 2. Weather conditions at Northeast Research and Extension Center, Keiser.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2019	142	434	545	646	644	607	161	3177
Historical avg. DD60s[a]	49	293	522	634	552	348	57	2612
Rainfall (in.) 2019	8.6	5.0	3.2	9.5	0.9	2.3	10.9	40.5
Hist. avg. rainfall (in.)[b]	4.8	5.4	4.0	4.0	2.4	3.2	4.0	27.4

[a] 30-year average of data collected in Mississippi County 1986–2015; Degree-Day 60 (DD60); www.dd60.uaex.edu
[b] 30-year average of data collected at the Keiser Station 1981–2010; www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgments

The authors would like to thank Mike Duren, Resident Director and Charles Wilson, Center Director of the Northeast Research and Extension Center. Support also provided by the University of Arkansas System Division of Agriculture.

2019 Judd Hill Cooperative Research Station: Overview of Cotton Research

E. Brown,[1] A. Beach,[1] and F.M. Bourland[1]

Background

The University of Arkansas System Division of Agriculture and Arkansas State University initiated a cooperative research agreement with the Judd Hill Foundation in 2005 to conduct small-plot cotton research on a 35-acre block of land on the Judd Hill Plantation. In addition, the Judd Hill Foundation generously permits scientists from Arkansas State University and the Division of Agriculture to conduct research on other property belonging to the Foundation. Judd Hill is located about 5 miles south of Trumann and 8 miles northwest of Marked Tree. Research at the Judd Hill site has been conducted annually since 2005. The primary soil type at the Judd Hill station is a Dundee silt loam (fine-silty, mixed, active, thermic Typic Endoaqualfs). Furrow irrigation is available on the entire 35-acre block.

Table 1. List of 2019 cotton research at Judd Hill Cooperative Research Station.

Project Leader(s)	Discipline	Title
Arlene Adviento-Borbe, Michelle Reba, Tina Teague	Multi-disciplinary	Influence of Tillage Practices on Water Quality of Irrigation Runoff and Total N Loss in a Cotton Production
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Test (transgenic test with 50 entries and conventional test with 15 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests (6 tests evaluating a total of 120 entries)
Fred Bourland	Cotton Breeding	Cotton Industry Strain Tests (9 tests with a total of 564 plots)
Morteza Mozaffari	Soil Fertility	Effect of Phosphorus and Potassium Rates on Seedcotton Yield
Alejandro Rojas, Scott Winters	Plant Pathology	2019 National Cottonseed Treatment (NCST) Test

2019 Conditions and Observations

Wet and warm conditions occurred throughout most of the 2019 growing season at Judd Hill. With adequate moisture and suitable soil temperatures in 2019, most plots at Judd Hill achieved excellent stands. The plants grew well and established exceptional boll loads. Insect pressure was light throughout the season. There was a moderate to high incidence of Verticillium wilt in 2019. Daily high temperatures exceeded 95°F on 16 days (11 of these in September and October), but never exceeded 98 °F during the season (Fig. 1). Accumulative Degree-Day 60 (DD60s) over the season were 26% higher than the historical average but near normal in June and July. Total rainfall in August through October of 2019 was 49% greater than the historical average rainfall (Table 2). Other than relatively dry conditions in August and September, monthly rainfall accumulations exceeded the historical averages each month. The excessive late-season rainfall hampered harvest. Harvest was completed between major rain events in October.

[1] Program Technician, Program Technician, and Professor, respectively, University of Arkansas System Division of Agriculture, Northeast Research and Extension Center, Keiser.

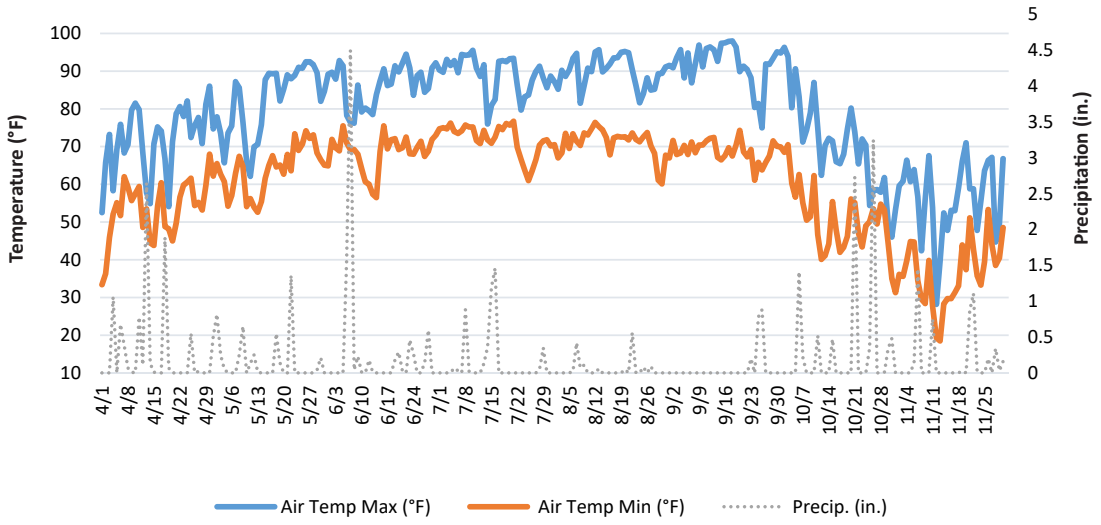

Fig. 1. 2019 Judd Hill temperature and precipitation.

Table 2. Weather conditions at Judd Hill Cooperative Research Station.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2019	136	400	524	639	634	611	147	3090
Historical avg. DD60s[a]	49	293	522	634	552	348	57	2455
Rainfall (in.) 2019	8.4	5.2	8.6	4.5	1.5	1.9	9.8	39.8
Hist. avg. rainfall (in.)[b]	5.0	4.6	3.8	3.5	2.5	3.0	4.3	26.7

[a] 30-year average of data collected at the Keiser Station 1986–2015; Degree-Day 60 (DD60); www.dd60.uaex.edu
[b] 30-year average of data collected at the Jonesboro Municipal Airport 1981–2010; https://www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgments

We are indebted to Mike Gibson and the Judd Hill Foundation for their generous support and assistance. Cooperative efforts provided by Marty White (producer) and Mike Duren (Resident Director Northeast Research and Extension Center) are greatly appreciated. Support was also provided by the University of Arkansas System Division of Agriculture.

2019 Manila Airport Cotton Research Station: Overview of Cotton Research

F.M. Bourland[1] and R. Benson[2]

Background

A Memorandum of Agreement (MOA) was initiated in 2014 between the City of Manila, Costner and Sons Farm, and the University of Arkansas System Division of Agriculture to conduct cotton research on a 30-acre block of land at the Manila Airport. This research was initiated in response to local demand for cotton research on a dominant cotton soil (Routon-Dundee-Crevasse complex) in northeast Arkansas. The MOA was amended in 2016 by substituting Wildy Farms for Costner and Sons Farm. Fields in this area of the state often exhibit soil texture variations ranging from coarse sand to areas of silt loam and clay. Soil textural variations within individual fields confound management decisions, especially with regards to irrigation and fertility. Infiltration of irrigation water to the rooting zone is a major concern in the area and varies across the different soil textures. Consequently, timing the frequency of irrigation events is challenging, and warrants dedicated research activities. One long-term research objective at this location is to determine ways to improve irrigation water use

Table 1. List of 2019 cotton research at Manila Airport.

Project Leader	Discipline	Title
Tina Gray Teague	Multi-disciplinary	Seeding Rate, Cover Crop, and Cover Crop Termination Timing Effects on Maturity and Yield of Mid-South Cotton
Fred Bourland	Cotton Breeding	Arkansas Transgenic Cotton Variety Test (50 entries)
Bill Robertson	Agronomy	Impact of Cover Crop Termination on Soil Health and Lint Yield of Cotton
Bill Robertson	Agronomy	Integrated Management of Target Leaf Spot in Cotton
Bill Robertson	Agronomy	Evaluation of Cotton in Large-Plot On-Farm Variety Testing

2019 Conditions and Observations

Wet conditions delayed the planting of plots at Manila until 30 May. Adequate moisture and suitable soil temperatures resulted in good stands in most plots. Weather conditions in the area were wetter than usual throughout the season. Evapotranspiration (Reference ET) was calculated daily from local weather station recordings during the season. Reference ET was used to estimate daily water use and help time irrigation applications. Irrigation events, however, were generally initiated based on the cooperating producer's standard production practices (Fig. 1)

Evapotranspiration (ET) gauge readings were collected weekly and used to estimate and track field moisture status during the season. From planting through August, precipitation averaged approximately 0.2 inches per day, which reduced requirements for irrigation applications. Additionally, temperatures were generally moderate during the majority of the growing season. Daily average high temperatures ranged from 87, 89, and 89 degrees for June, July, and August, respectively.

Insect pressure was generally light in 2019. The incidence of bacterial blight and target spot diseases was very weak. Harvest was completed by early November. Despite the late planting date, average lint yield obtained in the 2019 Arkansas Cotton Variety Test at the Manila Airport was the third highest that we have achieved since we began conducting the test at

[1] Professor, University of Arkansas System Division of Agriculture, Northeast Research and Extension Center, Keiser.
[2] County Cooperative Extension Agent, University of Arkansas System Division of Agriculture, Cooperative Extension Service, Blytheville.

Manila Airport in 2014. Warmer than normal temperatures during September extended the growing season beyond what is typical for northeast Arkansas. As a result of warm temperatures in September, flowers set later than the average cutout date for the region and accumulated sufficient heat units to develop into bolls that contributed to the crop's final yield.

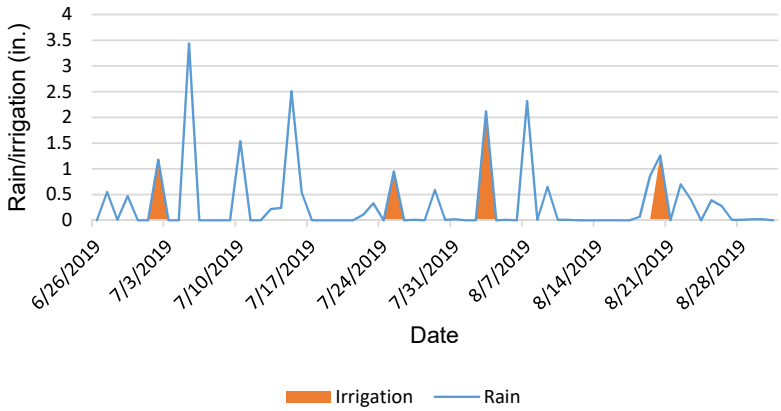

Fig. 1. Rainfall and irrigation events on a pivot irrigated large plot variety test at Manila Airport in 2019.

Weather Data

Weather at Manila Airport would be similar to the weather reported for Keiser Research Station and Judd Hill Cooperative Research Station. Manila Airport is located about 15 miles northwest of Keiser and about 28 miles northeast of Judd Hill.

Acknowledgments

The authors thank the City of Manila, Mayor Wayne Wagner, Wildy Farms (David Wildy and professional staff), and Mississippi County Cooperative Extension Service (Ray Benson) for their support of this work. Additionally, the authors thank Mike Duren, Resident Director of the Northeast Research and Extension Center. Support was also provided by the University of Arkansas System Division of Agriculture.

2019 Lon Mann Cotton Research Station: Overview of Cotton Research

C. Kennedy[1] and F.M. Bourland[2]

Background

The Lon Mann Cotton Research Station (LMCRS) began in 1927 as one of the first three off-campus research stations established by the University of Arkansas System Division of Agriculture, and was known as the Cotton Branch Experiment Station until 2005. Cotton research has always been the primary focus of the station. The station includes 655 acres (about 640 allocated for research) and is located in Lee County on Arkansas Highway 1 just south of Marianna with its eastern edge bordering Crowley's Ridge and the Mississippi River. The primary soil types at LMCRS are Loring silty loam (fine-silty, mixed, thermic Typic Fragiudalfs) and Calloway silt loam (fine-silty, mixed, thermic Glossaquic Fragiudalfs). The silt loam soils at Marianna have long been associated with cotton production in eastern Arkansas. Cotton research at the station has included breeding, variety testing, pest control (insects, diseases, and weeds), soil fertility, plant physiology, and irrigation.

Table 1. List of 2019 cotton research at Lon Mann Cotton Research Station.

Project Leader	Discipline	Title
Tom Barber	Weed Science	Control of Weeds Using Various Cotton Herbicides and Programs, Including New Xtend and Enlist Technologies
Tom Barber	Weed Science	Evaluation of Cotton Herbicide Efficacy and Weed Control Systems
Tom Barber	Weed Science	Evaluation of Cover Crop Species and Termination Timing for Optimum Weed Control Benefit and Cotton Emergence
Tom Barber	Weed Science	Evaluating Multiple Integrated Weed Management Tactics for Optimum Control of Palmer Amaranth in Cotton
Fred Bourland	Cotton Breeding	Cotton Strain Tests (6 tests evaluating a total of 120 entries)
Fred Bourland	Cotton Breeding	Cotton Industry Strain Test (total of 280 plots)
Fred Bourland	Cotton Breeding	Cotton Breeding Trial of 240 Advanced F_6 Progenies
Fred Bourland	Cotton Breeding	Cotton Observation Plots of 960 F_5 Preliminary Progenies
Fred Bourland	Cotton Breeding	Cotton Leaf Roll Dwarf Virus (CLRDV) Sentinel Plots
Gus Lorenz	Entomology	Thrips Efficacy Trials (5 trials, 44 total treatments)
Gus Lorenz	Entomology	Thrips Variety Trials (2 trials; *Bt*, 20 entries; conventional, 20 entries)
Gus Lorenz	Entomology	Plant Bug Efficacy Trials (6 trials, 74 treatments, 296 plots)
Gus Lorenz	Entomology	Plant Bug Transgenic Trials (3 trials, 42 treatments, 168 plots)
Morteza Mozaffari	Soil Fertility	Improving Potassium and Phosphorous Soil Test Calibration for Cotton
Jason Norsworthy	Weed Science	HPPD Cotton Tolerance to Herbicide
Jason Norsworthy	Weed Science	Long-Term Evaluation of Integrated Weed Management Strategies in Cotton
Jason Norsworthy	Weed Science	Residual Control of Weeds in Cotton with Isoxaflutole

[1] Resident Director, University of Arkansas System Division of Agriculture, Lon Mann Cotton Research Station, Marianna.
[2] Professor, University of Arkansas System Division of Agriculture, Northeast Research and Extension Center, Keiser.

2019 Conditions and Observations

The Lon Mann Cotton Research Station experienced frequent rains and relatively mild temperatures through most of the 2019 growing season (Fig. 1). Abnormally high rainfall in April (Table 1) delayed land preparation and planting on the station, but most cotton plots were planted before mid-May. Adequate moisture, good soil temperatures, and low degree of soil crusting resulted in good stands in most plots. In some fields (including the variety test), cereal rye was used as a cover crop. The cereal rye cover crop aided weed control, particularly pigweed. Weather conditions were generally good throughout the season. Heat units [Degree-Day 60 (DD60s)] accumulated from April through October were 14% higher than expected, but were normal (within 10% of the historical averages) in June, July, and August. Rainfall during the same period was 79% higher than the historical average, with the greatest deviations occurring in April (before planting) and in October (after harvest). The relatively warm and dry September promoted maturation of the crop and facilitated a timely harvest. Plots were furrow-irrigated as needed. Mepiquat chloride (Pix) to control internode elongation and plant height was required at normal rates. Insect pressure was relatively light, with the primary insect pest being plant bugs. Harvest was completed in early October.

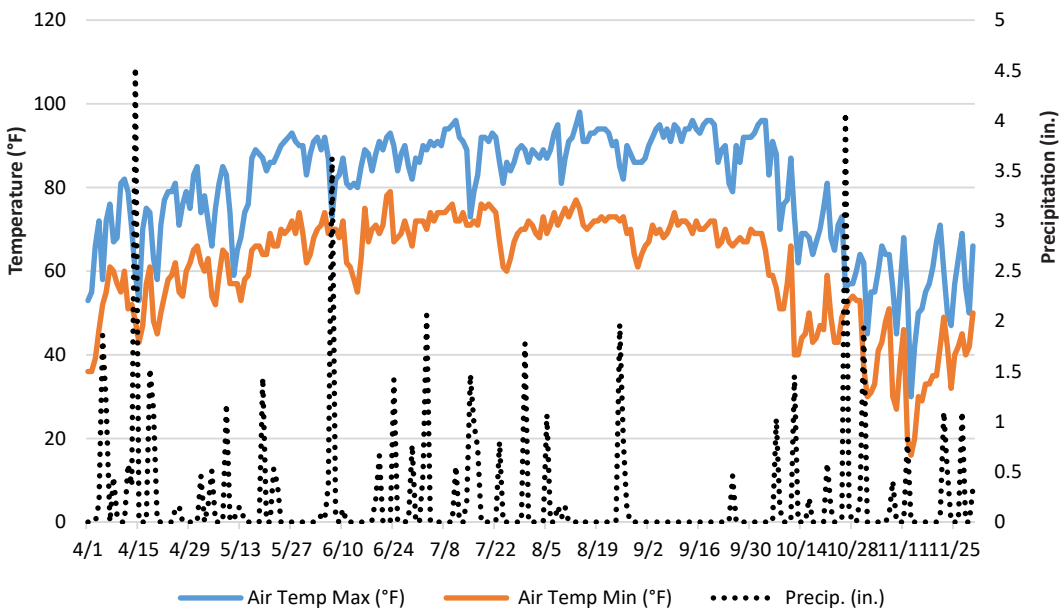

Fig. 1. 2019 Marianna temperature and precipitation.

Table 2. Weather conditions at Marianna.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2019	132	391	525	621	638	614	163	3081
Historical avg.	87	339	548	650	594	398	98	2714
Rainfall (in.) 2019	12.2	5.0	7.4	9.1	4.3	0.5	10.0	48.4
Hist. avg. rainfall	5.0	5.1	3.9	3.8	2.6	2.5	4.1	27.0

[a] 30-year average of data collected in Lee County 1986–2015; Degree-Day 60 (DD60); www.dd60.uaex.edu
[b] 30-year average of data collected at the Marianna Station 1981–2010; www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgments

We thank the staff at the Lon Mann Cotton Research Station for their assistance in performing research at this station. Support was also provided by the University of Arkansas System Division of Agriculture.

2019 Rohwer Research Station: Overview of Cotton Research

L. Martin[1] and M. Young[1]

Background

Cotton research has always been a primary focus at the Rohwer Research Station that began operations in 1958. The station includes 826 acres (about 630 allocated to research) and is located on Arkansas Highway 1 in Desha County, 15 miles northeast of McGehee. Soil types at the Rohwer Research Station include Perry clay (very-fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts), Desha silty clay (very-fine, smectitic, thermic Vertic Hapludolls), and Hebert silt loam (fine-silty, mixed, active, thermic Aeric Epiaqualfs) with cotton grown primarily on the latter. Cotton research at the station has primarily focused on breeding, variety testing, pest control (insects, diseases, and weeds), soil fertility, plant physiology, and irrigation. Cotton research projects conducted at Rohwer in 2019 are listed in Table 1.

Table 1. List of 2019 cotton research at Rohwer Research Station.

Project Leader	Discipline	Title
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (transgenic, 50 entries and conventional, 15 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests (6 tests evaluating a total of 120 entries)
Fred Bourland	Cotton Breeding	Cotton Breeding Trial of 240 Advanced F_6 Progenies
Fred Bourland	Cotton Breeding	Cotton Observation Plots of 960 F_5 Preliminary Progenies
Trent Roberts	Soil Fertility	Corteva Agriscience Cotton Research

2019 Conditions and Observations

Research trials at Rohwer were planted during the first week of May. Low temperatures and excessive rainfall occurred within a few days after planting (Fig. 1). Consequently, seedling diseases were problematic during the first month of cotton growth. Stands in a few plots were lost, and undesirable skips occurred in some other plots. Heavy rainfall after planting hindered the effectiveness of weed control of early season grass and broadleaf species. Post emergent applications were effective in controlling grass and broadleaf species, including Palmer amaranth. Extensive hand weeding was essential to control escaped Palmer amaranth in some areas. Four irrigations were applied to maintain adequate moisture (2 inches allowable deficient) with the last occurring during the final week of July. Insect pests met threshold levels three times during the season and required applications of insecticides. Termination timings for plant bugs, worms, and irrigations were late-July to mid-August. Harvest was completed in one day during dry conditions.

Except for high temperatures in September, temperatures experienced in 2019, as indicated by monthly Degree-Day 60 (DD60s) accumulations, were very similar to historical averages (Table 2). Only nine days at Rohwer had temperatures exceeding 95 °F, with six of these occurring in September and October. The absence of extremely high temperatures and the occurrence of relatively high rainfall provided excellent growing conditions through most of the season. The unusually warm September promoted plant development in later maturity lines.

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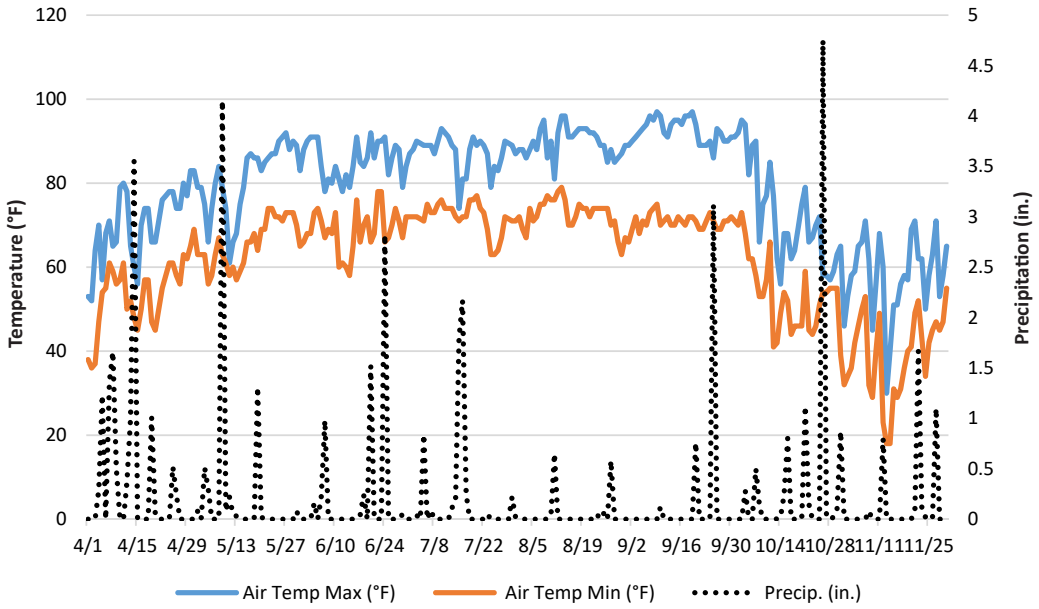

Fig. 1. 2019 Rohwer temperature and precipitation.

Table 2. Weather conditions at Rohwer in 2019.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2019	123	420	514	608	657	650	167	3138
Historical avg. DD60s[a]	100	354	551	661	618	415	167	2866
Rainfall (in.) 2019	11.8	6.8	6.0	5.8	1.4	4.0	9.0	44.8
Hist. avg. rainfall (in.)[b]	4.8	4.9	3.6	3.7	2.6	3.0	3.4	26.1

[a] 30-year average of data collected in Desha County 1986–2015; Degree-Day 60 (DD60); www.dd60.uaex.edu
[b] 30-year average of data collected at the Rohwer Station 1981–2010; www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgments

The authors would like to thank Larry Earnest, Director, and the staff of the Rohwer Research Station. Support was provided by the University of Arkansas System Division of Agriculture.

Cotton Research Verification Sustainability Program: Sustainability Report

A. Free,[1] M. Fryer,[2] B. Robertson,[1] M. Daniels,[3] and B. Watkins[4]

Abstract

Production practices that lead to improved soil health often improve both profitability and sustainability, having a positive impact on a field's environmental footprint. The objectives of this project were to evaluate the use of cover crops to improve efficiency specifically regarding irrigation water use, improve soil health, and to document differences between farmer standard tillage and a modified production system no-till cover crops through the utilization of the Fieldprint Calculator. All fields were monitored for inputs which were entered into the Fieldprint Calculator and used to calculate expenses. The growing season of 2019 was wet, with many fields receiving only 2 to 3 irrigations compared to normally 5 to 7 irrigations. The yield on no-till cover crop increased an average of 1.7% but was $0.03 per pound of lint more expensive to produce than farmer standard tillage no cover crop. The metrics from the Fieldprint calculator favored no-till cover crop with regard to improving irrigation water use by 21.0%, soil conservation or erosion, which was reduced by 73.2%, energy use reduced by 7.7%, and greenhouse gas emissions decreased by 4.7%. The use of no-till and cover crops in this study resulted in several improvements in yield and a smaller, more sustainable environmental footprint which the supply chain desires.

Introduction

As production costs continue to increase, the key for producers to maintain and increase profitability is to continuously introduce technologies that will improve efficiency. Cotton producers utilize many different production practices to improve efficiency and profitability but not any one practice will benefit all producers. Producers are often hesitant when adopting cover crops as a new technology due to its associated costs, as well as concerns about irrigation efficiency. Producers newly entering a no-till cover crop system are also reluctant to reduce inputs until they become more comfortable with the newly adapted production system.

The University of Arkansas System Division of Agriculture has been conducting the Cotton Research Verification Program (CRVP) since 1980 with the objective of demonstrating the profitability of production recommendations. In 2019, the Cotton Research Verification Sustainability Program (CRVSP) conducted research on six comparison sites where fields were divided in half for observation of two operating systems—a farmer standard no cover crop and a modified production system using no-till with cover crop.

The Fieldprint Calculator is a relatively new tool developed by Field to Market: The Alliance for Sustainable Agriculture (www.fieldtomarket.org). The Fieldprint Calculator was designed to help educate producers on how adjustments in management affect environmental factors. Utilization of the calculator assists producers by making estimates over eight sustainability factors: land use, soil conservation, soil carbon, irrigation water use, energy use, greenhouse gas, water quality, and biodiversity. Fieldprint Calculator estimates fields' performance and compares results to national and state averages. Calculated summaries give producers insight into the ability areas for improved management on their farm. The objectives of this continuing project are to 1) improve efficiency: specifically regarding irrigation water use, 2) Improve soil health, and 3) document differences in farmer standard tillage fields to that of a modified production system no-till cover crop through the utilization of the Fieldprint Calculator.

Procedures

In each 2019 CRVSP field, a farmer standard tillage system was compared to a modified production system utilizing no-till cover crop in an effort to improve efficiency, profitability, sustainability, and soil health. 'Elbon' cereal rye, broadcast at a rate of 56 pounds per acre, was the cover crop used in all no-till cover crop fields. The fields averaged approximately 40 acres in size, with each system comprising half of the field. Throughout the study, all producers' inputs

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were recorded providing the information used to calculate costs. These data were entered into the Fieldprint Calculator. Periodically throughout the growing season, holes were dug and examined for the presence of earthworms. Plots were machine harvested, grab samples were collected, and ginned on a tabletop gin to determine turnout.

Results and Discussion

Concern that water would not flow well down the row in no-till with cover crop fields was alleviated after the first irrigation. After large rainfall events, we observed that water infiltrated quickly in a no-till cover crop system, which decreased runoff when compared to a stale seedbed re-hipped with a cover crop. Furrow-irrigated no-till with cover crop fields on flat rows had one tillage operation using FurrowRunner compared to multiple tillage operations in farmer standard tillage. The FurrowRunner provided a narrow trench in the middle of the row, which assisted water movement through the field while leaving all cover crop residue on the sides of the furrow and top of the row. Producers in Clay and Mississippi County fields elected to run tillage equipment to flatten the tops of rows for planting. Water movement slowed as water worked its way through stubble, allowing for better water infiltration and less runoff. Visually across all fields, soil structure seems to be improving with several noticeable earthworm channels.

Due to increased soil health, no-till cover crop fields had a 1.72% increased yield over the farmers' standard fields (Table 1). Improvements were also observed with regard to sustainability metrics with an established no-till cover crop production system compared to a farmer standard tillage practice. The sustainability metrics shown in Table 1 include: land use (a function of yield), soil conservation (amount of soil loss from both wind and water erosion), irrigation water use (increase in yield over dry land production), energy use (actual embedded energy from field operations), and greenhouse gas emissions (gas given off from production inputs). The environmental footprint calculated by Fieldprint Calculator showed a smaller, more sustainable footprint in no-till cover crop. The footprint is a shaded area of a field's performance on a spidergram; the smaller the footprint, the more sustainable the field. Footprints are compared to state and national averages (Fig. 1).

Practical Applications

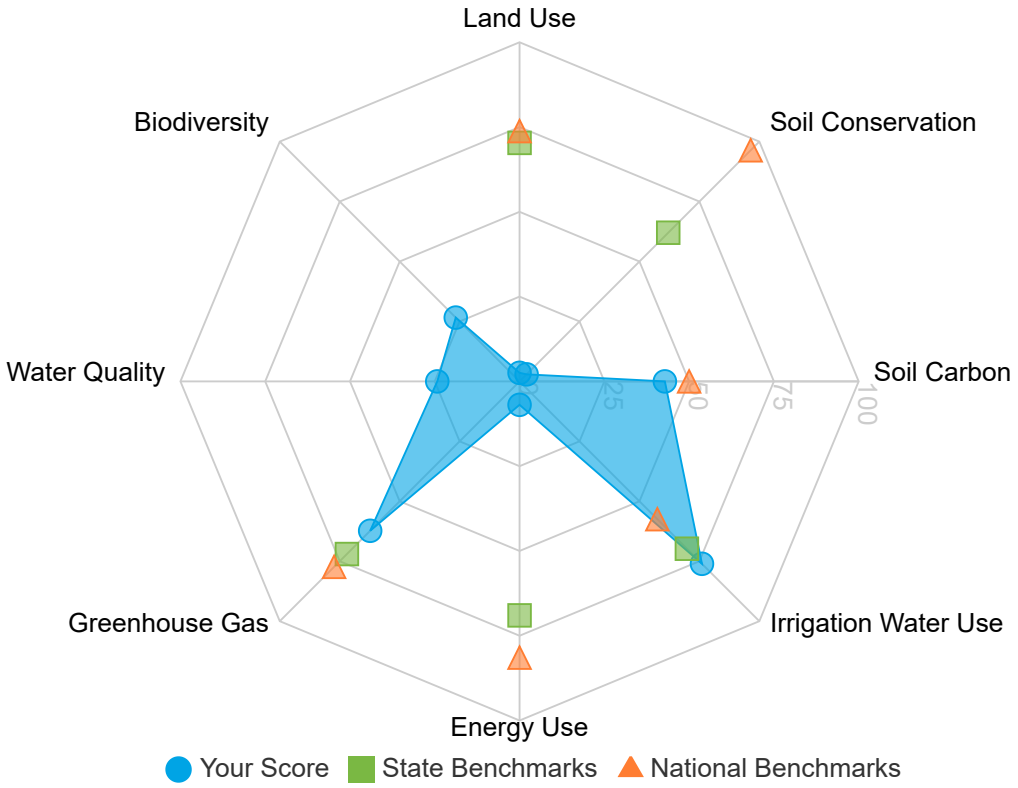
In the study, a no-till with cover crop system increased water use efficiency requiring 21% less water to produce a pound of cotton. Slower water movement through the cover crop fields resulted in better water infiltration and less runoff than in standard tilled fields. Lint yield did not differ between no-till cover crop and farmer standard practice. Additional research is needed to evaluate further how profitability, irrigation water use efficiency, size of environmental footprint, soil health, and continuous improvement are related.

Acknowledgments

The authors would like to acknowledge Cotton Incorporated for their support of this project. The authors would also like to thank producers, county extension agents, and consultants for their interest and support of this study.

Table 1. Lint yield, operating expenses and metrics used to evaluate sustainability as affected by tillage and cover crops in the 2019 Arkansas Cotton Research Verification Program.

Parameters	No-till Cover	Till No-Cover	% Change No-till vs. Till
Yield (lb lint /ac)	1515	1489	1.72%
Operating Expenses ($/ac)	563.46	542.16	3.78%
Operating Expenses ($/lb lint harvested)	0.393	0.365	7.20%
Land Use (ac/lb)	0.00067	0.00069	-2.99%
Soil Conservation (ton/ac/year)	3.58	6.20	-73.18%
Irrigation Water Use (ac-in./lb)	0.0317	0.0384	-21.01%
Energy Use (BTU/lb)	4014	4324	-7.72%
Greenhouse Gas Emissions (lb CO_2eq/lb)	1.48	1.55	-4.73%



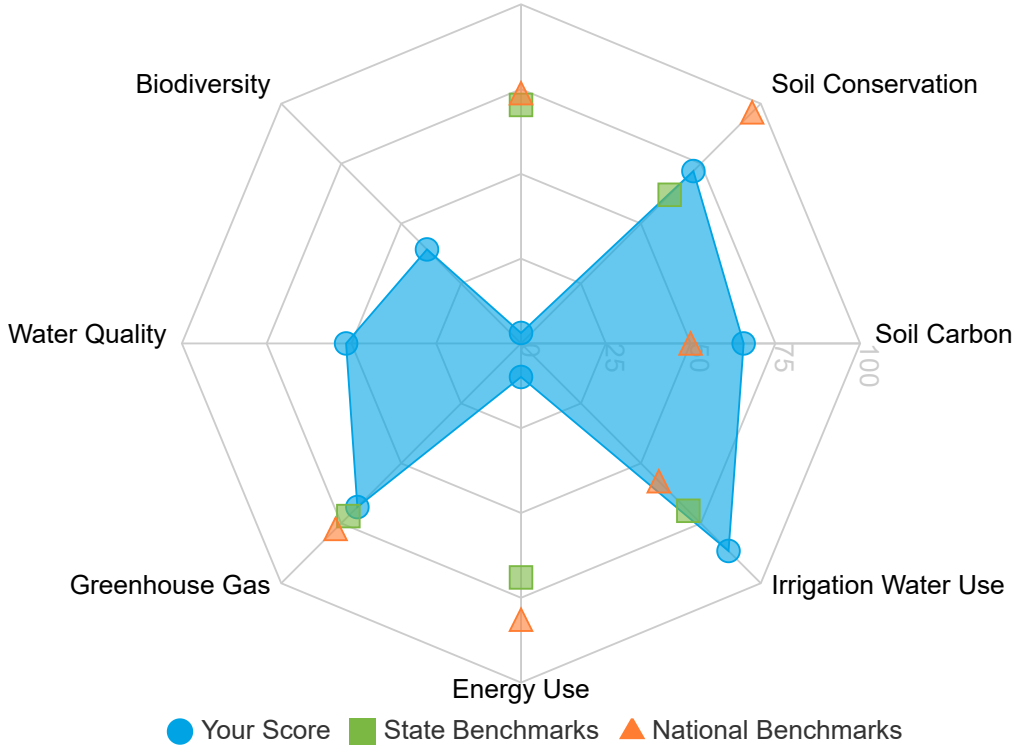


Fig. 1. Field to Markets: Fieldprint Calculator's Field Footprint for 2019 East Weaver field comparing no-till cover crop (top) to till no-cover crop (bottom) in the 2019 Arkansas Cotton Research Verification Sustainability Program. The footprint is a shaded area in the spidergram; the smaller the footprint, the more sustainable the field.

Cotton Research Verification Sustainability Program: 2019 Economic Report

A. Free,[1] B. Robertson,[1] and B. Watkins[2]

Abstract

The University of Arkansas System Division of Agriculture's Cotton Research Verification Sustainability Program (CRVSP) works with producers to grow cotton more efficiently to improve profitability. As costs of production continue to increase, producers are searching for ways to make modifications to their practices in an effort to improve both efficiency and profitability. For cotton to continue being a viable commodity, profitability must be improved.

Introduction

The University of Arkansas System Division of Agriculture has been conducting the Cotton Research Verification Program (CRVP) since 1980. The CRVP is an interdisciplinary effort, in which best recommendation practices and production technologies are applied in a timely manner to a specific farm field. Since the inception of the CRVP in 1980, there have been 321 irrigated fields entering the program. The success of the cotton program spawned verification programs in rice, soybean, wheat, and corn in Arkansas as well as in other mid-South states. In 2014, the CRVP became known as the Cotton Research Verification Sustainability Program (CRVSP). The CRVSP expands beyond that of the traditional verification programs by measuring the producers' environmental footprint for each field and evaluating the connection between profitability and sustainability.

Procedures

The 2019 CRVSP included 14 fields in 4 counties, Desha (8 fields), Clay (2) Mississippi (2), and St. Francis (2). Each field was entered into the Field to Market Fieldprint Calculator (www.fieldtomarket.org). Two fields entered the fifth year of comparing farmer standard tillage with a stale seedbed compared to a modified no-till with cover crop production system. Increasing both efficiency and profitability will continue to be a main part of the program.

The CRVSP has worked with the University of Arkansas System Division of Agriculture's Discovery Farms Program in Southeast Arkansas for 6 of the 14 fields in the program. The main focus of the Discovery Farms Program is to monitor edge-of-field water quality with fields watered in two sets. The split-field arrangement provides the opportunity to compare two production strategies. The farmer standard tillage was compared to a no-till system with cereal rye cover crop. The fields in Clay, Mississippi, and St. Francis Counties could not be irrigated in two sets. In the fall of 2018, all no-till cover fields were broadcast planted with either 'Elbon' or 'Wrenz Albrunzi' cereal rye at a target seeding rate of 56 pounds per acre. Irrigation methods were composed of either furrow or pivot irrigation at all locations. The diversity of the fields in the program reflect cotton production in Arkansas. Field records were maintained and economic analysis was conducted to determine net return per acre for each field in the program.

Results and Discussion

The majority of the 2019 cotton crop in Arkansas was planted from late April to late May. Tarnished plant bug (TPB) numbers increased slightly in the 2019 CRVSP fields (treated an average of 3.57 times) compared to the 2018 CRVSP fields (treated 3.33 times). The TPB pressure was similar across all locations, with the number of treatments varying from three to five times during the growing season. Each 2019 field had an average of 1.86 burndowns and 3.00 herbicide applications. The average number of treatments for moths/worms was 1.14. The average costs for herbicides and insecticides were $75.23 and $91.82, respectively. Pest control represents a significant expense and can impact yields greatly.

Records of field operations on each field provided the basis for estimating expenses. Production data from the 14 fields were applied to determine costs and returns above operating costs, as well as total specified costs. Operating costs and total costs per pound indicate the commodity price needed to meet each cost type. Costs in this report do not include land costs, management, or other expenses and fees not associated with production. Budget summaries for cotton are presented in Table 1. Price received for cotton of $0.70/lb is the estimated Arkansas annual average for the 2019 production year. The average cotton yield for these verification

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fields was 1455 lb lint/ac, which was 354 lb lint/ac greater than the state average.

The average operating cost for cotton was $555.40/ac (Table 1). Chemicals averaged $195.36/ac and were 35% of operating expenses. Seed and associated technology fees averaged $123.37/ac, or 22% of operating expenses and included six fields with a cover crop. Fertilizer and nutrient costs averaged 13% of operating expenses and were $72.28/ac.

With an average yield of 1455 lb lint/ac, average operating costs were $0.39/lb lint (Table 1). Operating costs ranged from a low of $439.44 in the Mississippi County FS/NC field to a high of $703.19 in the Desha Co. S.W. NT/C field. Returns to operating costs averaged $463.25/ac. The range was from a low of $103.95 in the Desha Co. Wellcot FS/NC field to a high of $669.16 in the Desha Co. Weaver NT/C field. Average fixed costs were $163.82, which led to average total costs of $719.22/ac. The average return to total specified costs was $299.43/ac with a low of -$58.83 in the Desha Co. Wellcot FS/NC field to a high of $503.18 in the Desha Co. Weaver NT/C field. Wellcot was the only field in which a negative return was observed. Excluding Desha Co. Wellcot, the Mississippi County NT/C generated the least return to specific expenses at $167.56. The reason for such a low yield in the Desha Co. Wellcot Field is believed to be nematode and soil salinity issues. This field (locked into growing cotton) has had lower yields than others in the past and will be rotated to corn in 2020. Total specified costs averaged $0.50/lb lint. With a land rental agreement of 20%, crop share with no cost share would raise the total specified cost to $0.63/lb lint, which does not include a return to management and overhead.

Practical Applications

The CRVSP has become a vital tool in the educational efforts of the University of Arkansas System Division of Agriculture. It continues to serve a broad base of clientele, including cotton growers, consultants, researchers, and county extension agents. The program strives to meet its goals and provide timely information to the Arkansas cotton community.

Acknowledgments

The authors would like to acknowledge Cotton Incorporated for their support of this project. The authors would also like to thank producers and county extension agents for their interest and support of this study.

Table 1. Summary of revenue and expenses per acre for 2019 Cotton Research Verification Sustainability Program fields comparing farmer standard tillage without a cover crop (FS/NC) to no-till with cover crop (NT/C).

	Field														
Revenue	**Clay, NT/C**	**Clay, FS/NC**	**Desha, Weaver NT/C**	**Desha, Weaver FS/NC**	**Desha, Shop NT/C**	**Desha, Shop FS/NC**	**Desha, S.W. NT/C**	**Desha, S.W. FS/NC**	**Miss., NT/C**	**Miss., FS/NC**	**St. Francis, NT/C**	**St. Francis, FS/NC**	**Desha, Homeplace FS/NC**	**Desha, Wellcot FS/NC**	**Average**
Yield (lb)	1427.00	1525.00	1757.00	1660.00	1516.00	1565.00	1841.00	1708.00	1208.00	1125.00	1340.00	1348.00	1403.00	950.00	1455.21
Price ($/lb)	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Tot. Crop Rev.	**998.90**	**1067.50**	**1229.90**	**1162.00**	**1061.20**	**1095.50**	**1288.70**	**1195.60**	**845.60**	**787.50**	**938.00**	**943.60**	**982.10**	**665.00**	**1018.65**
Cottonseed Value Exp.	**213.91**	**228.60**	**263.37**	**248.83**	**227.25**	**234.59**	**275.97**	**256.03**	**181.08**	**168.64**	**200.87**	**202.07**	**210.31**	**142.41**	**218.14**
Seed	139.48	116.33	117.15	94.00	125.15	121.13	127.70	104.55	184.78	129.30	145.35	134.24	94.00	94.00	123.37
Fert. & Nutrients	55.50	55.50	75.42	75.42	93.63	93.63	85.00	84.99	54.10	54.10	66.89	66.89	75.42	75.42	72.28
Herbicides	64.48	69.43	58.48	60.60	58.48	53.85	137.44	142.01	38.35	38.35	109.53	109.69	58.69	53.85	75.23
Insecticides	61.58	61.58	96.40	89.26	125.26	118.56	132.29	132.29	60.08	60.08	40.25	40.25	144.96	122.66	91.82
Other Chemicals	19.23	25.89	18.44	18.44	21.30	17.16	60.92	60.92	23.86	23.82	34.75	34.75	18.44	18.44	28.31
Custom Applic.	0.00	0.00	40.00	32.00	32.00	40.00	8.00	16.00	0.00	0.00	23.00	23.00	40.00	40.00	21.00
Other Inputs	27.65	29.29	3.88	3.88	3.88	3.88	34.55	32.34	3.88	3.88	22.32	22.46	3.88	3.88	14.26
Diesel Fuel	16.67	16.43	27.62	28.48	27.19	26.46	19.89	21.65	30.65	28.62	15.34	15.02	28.15	28.15	23.59
Irr. Energy Costs	13.29	13.29	27.55	37.35	27.43	35.43	14.76	13.29	8.86	8.86	6.73	6.73	21.29	28.52	18.81
Input Costs	**397.88**	**387.74**	**464.94**	**439.43**	**514.32**	**510.10**	**620.55**	**608.04**	**404.56**	**347.01**	**464.16**	**453.03**	**484.83**	**464.92**	**468.68**
Fees	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41	21.41
Repairs & Maint.[a]	27.02	26.82	30.32	31.48	30.30	30.06	29.93	30.46	32.21	29.78	26.79	26.41	29.79	30.38	29.41
Labor, Field Act.	9.88	9.51	29.06	29.66	29.06	28.14	12.48	13.19	31.04	29.47	7.33	7.14	29.22	29.33	21.04
Production Exp.	**456.19**	**445.48**	**545.73**	**521.98**	**595.09**	**589.71**	**684.37**	**673.10**	**489.22**	**427.67**	**519.69**	**507.99**	**565.25**	**546.04**	**540.54**
Interest	12.54	12.25	15.01	14.35	16.36	16.22	18.82	18.51	13.45	11.76	14.29	13.97	15.54	15.02	14.86
Post Harvest Exp.	213.91	228.60	263.37	248.83	227.25	234.59	275.97	256.03	181.08	168.64	200.87	202.07	210.31	142.41	218.14
Operating Exp.	**468.72**	**457.72**	**560.74**	**536.33**	**611.45**	**605.93**	**703.19**	**691.61**	**502.68**	**439.44**	**534.00**	**521.95**	**580.79**	**561.05**	**555.40**
Returns to Op. Exp.	**530.18**	**609.78**	**669.16**	**625.67**	**449.75**	**489.57**	**585.51**	**503.99**	**342.92**	**348.06**	**404.00**	**421.65**	**401.31**	**103.95**	**463.25**
Cap. Recovery and Fixed Costs	150.88	150.75	165.98	170.49	164.89	160.88	175.65	181.06	175.36	167.06	156.00	151.99	159.75	162.78	163.82
Tot. Specified Exp.[b]	**619.60**	**608.47**	**726.72**	**706.82**	**776.35**	**766.81**	**878.85**	**872.67**	**678.04**	**606.50**	**690.00**	**673.94**	**740.54**	**723.83**	**719.22**
Returns to Spec. Exp.	**379.30**	**459.03**	**503.18**	**455.18**	**284.85**	**328.69**	**409.85**	**322.93**	**167.56**	**181.00**	**248.00**	**269.66**	**241.56**	**-58.83**	**299.43**
Operating Exp./lb	0.33	0.30	0.32	0.32	0.40	0.39	0.38	0.40	0.42	0.39	0.40	0.39	0.41	0.59	0.39
Total Exp./lb	0.43	0.40	0.41	0.43	0.51	0.49	0.48	0.51	0.56	0.54	0.51	0.50	0.53	0.76	0.50

[a] Includes employee labor allocated to repairs and maintenance.

[b] Does not include land costs, management, or other expenses (Exp.) and fees not associated with production.

University of Arkansas Cotton Breeding Program: 2019 Progress Report

F.M. Bourland[1]

Abstract

The University of Arkansas System Division of Agriculture's Cotton Breeding Program attempts to develop cotton genotypes that are improved with respect to yield, yield components, host-plant resistance, fiber quality, and adaptation to Arkansas environments. Such genotypes should provide higher, more consistent yields with fewer inputs. The current program has released almost 100 germplasm lines and varieties. A strong breeding program relies upon continued research to develop techniques that can be used to identify genotypes with favorable genes. Improved lines that possess these favorable genes are subsequently selected and evaluated.

Introduction

Cotton breeding programs have existed at the University of Arkansas System Division of Agriculture for over a century (Bourland, 2018). Throughout this time, the primary emphases of the programs have been to identify and develop lines that are highly adapted to Arkansas environments and that possess good host-plant resistance traits. Bourland has led the program since 1988 and has been responsible for almost 100 germplasm and variety releases. He has established methods for evaluating and selecting several cotton traits. The current program primarily focuses on the development of breeding methods and the release of conventional genotypes (Bourland, 2004; 2013). Conventional genotypes continue to be important to the cotton industry as a germplasm source and alternative to transgenic cultivars. Most transgenic varieties are developed by backcrossing transgenes into advanced conventional genotypes.

Procedures

Breeding lines and strains are annually evaluated at multiple locations in the University of Arkansas System Division of Agriculture's Cotton Breeding Program. During early generations, breeding lines are evaluated in non-replicated tests because seed numbers are limited. Tests of breeding lines include initial crossing of parents, generation advance in F_2 and F_3 generations, individual plant selections from segregating F_4 populations, and evaluation of the 1st year (F_5) and advanced (F_6) progenies derived from individual plant selections. Once segregating populations are established, each sequential test provides screening of genotypes to identify ones with specific host-plant resistance and agronomic performance characteristics. Selected advanced progeny are promoted to strains, which are evaluated in replicated strain tests at multiple Arkansas locations to determine yield, yield components, fiber quality, host-plant resistance and adaptation properties. Superior strains are then evaluated over multiple years and in regional tests. Improved strains are used as parents in the breeding program and/or are released as germplasm lines or varieties.

Results and Discussion

Breeding Lines

The primary objectives of crosses made in 2014 through 2019 (F_1 through F_6 generations evaluated in 2019) included development of enhanced nectariless lines (with the goal of improving resistance to tarnished plant bug), improvement of yield components (how lines achieve yield), and improvement of fiber quality (with specific use of Q-score fiber quality index). Particular attention has been given to combining the fiber quality of UA48 (Bourland and Jones, 2012a) into higher yielding lines. Breeding line development exclusively focuses on conventional cotton lines.

The 24 cross combinations made in 2019 included five crosses made with Ark 0812-87ne (released as UA212ne) and four crosses with another advanced nectariless line (Ark 0921-31ne). Seven of the 24 crosses used lines from Dr. Gerald Myers (LSU AgCenter), and two crosses used lines from Dr. Ted Wallace (Mississippi Agricultural and Forestry Experiment Station) as a parent. Other crosses were between superior UA lines. The F_1 seed of the crosses have been sent to Costa Rica for generation advance in a winter nursery. The 2019 breeding effort also included field evaluation of 24 F_2 populations, 22 F_3 populations, 12 F_4 populations, 888 1st year progeny, and 216 advanced progeny. Bolls were harvested from superior plants in F_2 and F_3 populations and bulked by population. Individual plants (1200) were selected from the F_4 populations. After discarding individual plants for fiber traits, ~920 progenies from the individual plant selections will be evaluated in 2020. From the 1st year progenies in 2019, 192 were advanced to 2020 testing. Out of the 2019 Advanced Progeny, 72 F_6 advanced progenies were

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promoted to strain status. Many of these selected 72 F_6 advanced progeny have either UA48 or UA222 (Bourland and Jones, 2012b) in their pedigrees.

Strain Evaluation

In 2019, a total of 117 strains (72 Preliminary Strains, 18 New Strains, 18 Advanced Strains, and 9 in the 2019 Arkansas Conventional Variety Test) were evaluated in replicated tests at 4 experiment stations in Arkansas. Cotton lines UA222 and UA48 were included as checks in each test. Lint yield of 52 and 82 strains exceeded yields of UA222 and UA48, respectively. Based on Q-score values, 102 and 10 of the 117 strains produced better fiber quality than UA222 and UA48, respectively. Several of the high yielding lines also have excellent fiber quality. Screening for host-plant resistance included evaluation for resistance to seed deterioration, bacterial blight, Verticillium wilt, and tarnished plant bug. Work to improve yield stability by focusing on yield components and to improve fiber quality by reducing bract trichomes continues.

Germplasm Releases

Genetic releases are a major function of public breeding programs. A total of 91 germplasm lines and 8 varieties have been released from this program, including 2 varieties (UA212ne, Bourland and Jones, 2019, and UA248) in 2019. These lines represent unique genetic materials that have demonstrated improved yield, yield components, host-plant resistance and/or fiber quality. The 8 conventional varieties released since 2010 include UA48; UA103 (Bourland and Jones, 2013); UA222; UA107 (Bourland and Jones, 2018a); UA114 (Bourland and Jones, 2018b); UA212ne (Bourland and Jones, 2020); and UA248. All of these varieties have produced high yields, expressed excellent fiber quality, are early maturing, and are resistant to bacterial blight. Cultivar UA48 has set a new industry standard for fiber quality but has a relatively narrow adaptation. Cultivar UA222 has a wide adaptation, a good combination of yield components, and has shown good resistance to tarnished plant bug. Cultivar UA114 is similar to UA222, but usually produces higher yield. Cultivar UA103 is an okra leaf cultivar that has performed in certain areas. Cultivar UA107 is another okra leaf cultivar that has wider adaptation than UA103. Cultivar UA212ne is a nectariless cultivar with wide adaptability and harbors lower populations of tarnished plant bugs. Since nectariless cultivars do not produce nectar that attracts bees, they should be exempt from any restrictions that might be imposed on neonicotinoid insecticides. The fiber quality of UA248 approaches that of UA48 (one of its parents), but usually produces higher yields than UA48. These releases provide germplasm and varieties that possess novel and improved traits and adaptation.

Practical Applications

The University of Arkansas System Division of Agriculture is developing cotton lines possessing enhanced host-plant resistance, improved yield and yield stability, and excellent fiber quality. Improved host-plant resistance should decrease production costs and risks. Selection based on yield components may help to identify and develop lines having improved and more stable yield. Released germplasm lines should be valuable as breeding material to commercial and other public cotton breeders or released as varieties. In either case, Arkansas cotton producers should benefit from having genetic lines that are specifically adapted to their growing conditions.

Acknowledgments

The author extends appreciation to Cotton Incorporated for their support of this program. Assistance of the Directors, Program Technicians and staff at the stations of the University of Arkansas System Division of Agriculture is greatly appreciated. Special thanks to Brittany Hallett and Wendy Allen, Agriculture Lab Technicians, who perform and oversee much of daily work associated with the program.

Literature Cited

Bourland, F.M. 2004. Overview of the University of Arkansas Cotton Breeding Program. pp. 1093-1097. *In:* Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, Texas. 5-9 Jan. National Cotton Council, Memphis, Tenn.

Bourland, F.M. 2013. Novel approaches used in the University of Arkansas cotton breeding program. pp. 409-418. *In:* Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, Texas. 7-10 Jan. National Cotton Council, Memphis, Tenn.

Bourland, F.M. 2018. History of cotton breeding and genetics at the University of Arkansas. J. Cotton Sci. 22:171-182.

Bourland, F.M. and D.C. Jones. 2012a. Registration of 'UA48' cotton cultivar. J. Plant Reg. 6:15-18.

Bourland, F.M. and D.C. Jones. 2012b. Registration of 'UA222' cotton cultivar. J. Plant Reg. 6:259-262.

Bourland, F.M. and D.C. Jones. 2013. Registration of 'UA103' cotton cultivar. J. Plant Reg. 7:135-139.

Bourland, F.M. and D.C. Jones. 2018a. Registration of 'UA107' okra leaf cultivar of cotton. J. Plant Reg. 12:176-180.

Bourland, F.M. and D.C. Jones. 2018b. Registration of 'UA114' cultivar of cotton. J. Plant Reg. 12:181-185.

Bourland, F.M. and D.C. Jones. 2019. UA212ne – A new nectariless cotton variety. pp. 47-52. *In:* Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 8-10 Jan. National Cotton Council, Memphis, Tenn.

Bourland, F.M. and D.C. Jones. 2020. Registration of 'UA212ne' – a nectariless cotton cultivar. J. Plant Reg. 1-7.

Arkansas Cotton Variety Test 2019

F.M. Bourland,[1] A. Beach,[1] E. Brown,[1] C. Kennedy,[2] L. Martin,[3] and B. Robertson[4]

Abstract

Other than variation in transgenic technologies and seed treatment, costs of cotton planting seed are relatively constant. However, choosing the best cotton variety to plant can often determine whether the producer experiences a successful production year. The producer must assume that past performance of varieties is a good predictor of future performance. Generally, the best cotton variety to plant in the forthcoming year is the one that performed best over a wide range of environments. However, specific adaptation to certain soil and pest situations may exist. Varieties that are now available or may soon be available to producers are annually evaluated in small and large plot tests in Arkansas. Results from the small plot tests, which usually include 40 to 60 lines and are mostly conducted on experiment stations, provide information on which lines are best adapted to Arkansas environments. Based on these results, varieties are chosen and evaluated in large plot on-farm tests. These large plot tests represent various growing conditions, grower management, and environments of Arkansas cotton producers. Results from the large plot tests are used to supplement and verify results of small plots. Results from both tests help producers to choose the best varieties for their specific field and farm situations.

Introduction

Variety testing is one of the most visible activities of the University of Arkansas System Division of Agriculture. Data generated by cotton variety testing provide unbiased comparisons of cotton varieties and advanced breeding lines over a range of environments. The continuing release of varieties that possess new technologies has contributed to a rapid turnover of cotton varieties. Our current testing system attempts to offset this rapid turnover by supplementing small plot variety testing at five locations (coordinated by Bourland) with subsequent evaluation in large plot extension plots at multiple sites (coordinated by Robertson). A much greater number of varieties can be evaluated in our small plot tests than in our large plot tests. Results from small plot tests are used to select varieties that are subsequently evaluated in on-farm strip tests.

Procedures

Small Plot Tests

Cotton varieties and advanced strains were evaluated in small plots at Arkansas research sites (Manila, Keiser, Judd Hill, Marianna, and Rohwer) in the 2019 Arkansas Cotton Variety Test. Transgenic and conventional entries were evaluated in separate tests. The 50 entries in the transgenic test included 9 B2XF, 25 B3XF, 13 W3FE and 3 GLTP lines, and were evaluated at all five locations. The conventional test included 15 entries evaluated at all locations except Manila. Reported data include lint yield, lint percentage, maturity (plant height and percent open bolls), yield component variables, fiber properties, leaf pubescence, stem pubescence, and bract trichome density. All entries in the experiments were evaluated for response to tarnished plant bug and bacterial blight in separate tests at Keiser.

The originators of seed supplied seed of their entries treated with their standard fungicides. Prior to planting, all seed were uniformly treated with imidacloprid (Gaucho®) at a rate of 6 oz/100 lb seed. Plots were planted with a constant number of seed (about 4 seed/row ft). All varieties were planted in two-row plots on 38-in. centers and ranging from 40 to 50 ft in length. Experiments were arranged in a randomized complete block. Although exact inputs varied across locations, cultural inputs at each location were generally based on University of Arkansas System Division of Agriculture's Cooperative Extension Service recommendations for cotton production, including COTMAN rules for insecticide termination. Cereal rye was planted in the test plot area at Marianna as a cover crop. Conventional tillage was employed at all other locations. All plots were machine-harvested with 2-row or 4-row cotton pickers modified with load cells for harvesting small plots.

Large Plot Tests

A core group of 11 transgenic varieties was evaluated at 8 locations from Ashley County to Clay County. Three additional locations contained 7 to 10 of the core 11 varieties. Two

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varieties chosen by the seed company were entered for this study: BASF, Bayer, Americot, Dow, and Nutrien. Replicated strips were planted the length of the field and managed according to the remainder of the field in which the study was located in all locations with the exception of Clay County. The Clay County location was not replicated. A full-sized module of each variety was harvested, ginned, and marketed separately for each variety in Clay County. The studies were harvested with the producer's equipment. Grab samples were collected for lint fraction and fiber quality with the exception of Clay county's which were ginned in a commercial gin.

Results and Discussion

Results of the Arkansas Cotton Variety Test (small and large plot tests) are published annually and made available online at https://aaes.uark.edu/variety-testing/

Small Plot Tests

Both heat units and rainfall in 2019 exceeded historical averages at each site. The warm temperatures in May provided excellent conditions for emergence and early growth of seedlings, but wet conditions delayed plantings. Despite the high heat unit accumulations for the season, temperatures exceeding 95 °F were relatively rare—11 days at Keiser, 7 days at Marianna and 9 days at Rohwer. Most of the days exceeding 95 °F occurred in September and October—10 days at Keiser, 5 at Marianna and 6 at Rohwer. The absence of extremely high temperatures and the occurrence of relatively high rainfall provided excellent growing conditions through the season. The unusually warm September promoted plant development in late planted sites and in later maturity lines.

Variety by location interactions in the transgenic test were significant for all parameters except fibers per seed. In the conventional test, interactions occurred for lint percentage, open bolls, seed index, lint index, and length uniformity index. Despite the interactions, several of the top yielding varieties were similar at each site. Parameters measured at only one location included leaf pubescence, bract trichome density, tarnished plant bug damage, and bacterial blight response. Significant variety effects for each of these parameters were found in both tests.

The transgenic varieties included 22 that were evaluated in both 2018 and 2019. The five transgenic varieties producing the highest two-year yield means over all locations were PHY 400 W3FE (in the top four at each location), DP 1725 B2XF (in the top three at Manila, Judd Hill, and Marianna), DG 3520 B3XF (in the top three at Keiser, Judd Hill, and Rohwer), DP 1646 B2XF (in the top three at Marianna and Rohwer), and ST 4550 GLTP (the top yielding line at Manila). Eight conventional lines were evaluated in both 2018 and 2019. The varieties Ark 0822-48 and UA212ne produced the highest two-year yield means over all locations.

Large Plot Tests

On-farm plots were established with a wide range of planting and harvest dates. Acceptable plant stands were achieved at each location. Full-season data, obtained using COTMAN™ Cotton Management Expert System Software (SQUAREMAN AND BOLLMAN), indicated no unexpected stress at any location. Nodes above white flower data were recorded for all varieties to calculate days to cutout. Lint yield was summarized across locations.

Practical Applications

Varieties that perform well over all locations of the Arkansas Cotton Variety Tests possess wide adaptation. Specific adaptation may be found for varieties that do particularly well at Keiser (north Delta, clay soil adapted), Judd Hill (north Delta, Verticillium wilt tolerant), Manila (north Delta, sandy soil adapted), Marianna (applicable to most Arkansas environments), and Rohwer (more southern location may favor late maturing lines). The reported parameters provide information on each variety regarding their specific yield adaptation, how their yields were attained (i.e., yield components), maturity, relative need for growth regulators, fiber quality, plant hairiness, and response to bacterial blight and tarnished plant bug. Results from large plot tests provide more information on specific adaptation of varieties. When choosing a variety, producers should first examine results (yield and fiber quality) of a large plot test that most closely match their geographical and cultural conditions. Second, they should examine results from multiple years of small plots for consistency of performance. Third, variety selection can be fine-tuned by examining pest, yield components, and morphological features from small plot tests. Finally, results from the small plot tests can identify new lines that may be considered.

Acknowledgments

We appreciate the assistance of the Directors, Program Technicians and staff at the stations of the University of Arkansas System Division of Agriculture. We are also grateful to the cotton producers who cooperate with us to perform the large plot tests. Finally, we acknowledge the contributions of seed companies that participate in the Arkansas Cotton Variety Testing.

Literature Cited

Bourland, F., A. Beach, E. Brown, C. Kennedy, L. Martin, and B. Robertson. 2020. Arkansas Cotton Variety Test 2019. Arkansas Agricultural Experiment Station. Research Series 665.

Evaluation of Tavium Use in Cotton Herbicide Programs

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Abstract

A mixture of *S*-metolachlor and dicamba, Tavium, was developed by Syngenta to control broadleaf and grassy weeds in cotton. Using two modes of action simultaneously reduces selection for resistance. A field trial was conducted in Crawfordsville, Arkansas, in 2019, to determine the level and length of residual control with Tavium when compared with dicamba alone. Tavium treatments averaged >97% control of Palmer amaranth, significantly outperforming dicamba with 85% control at 21 days after treatment. Tavium outlasted the residual control of dicamba by 16 days with a threshold of 95% control. These findings lead to the conclusion that Tavium could be a useful tool for cotton farmers looking to add more modes of action to their weed control programs and lengthen residual control of Palmer amaranth.

Introduction

Tavium is a herbicide recently commercialized by Syngenta (Syngenta Group Company, Wilmington, Delaware) to provide postemergence broadleaf and broad spectrum residual control when applied preemergence or postemergence in cotton. Consisting of 1.12 lb/gal of dicamba and 2.26 lb/gal of *S*-metolachlor accompanied by VaporGrip technology, Tavium uses two sites of action to reduce selection for resistance of Palmer amaranth (*Amaranthus palmeri* S. Wats.), the most troublesome weed of mid-South cotton and soybean production (Anonymous, 2019; Ward et al., 2013). Since the release of XtendFlex cotton and Xtend soybean, dicamba has been widely used to control problematic weedy broadleaf species. The premix of dicamba and *S*-metolachlor has potential to provide more residual control than the use of dicamba alone due to the lasting effects of *S*-metolachlor. An experiment was designed with the objective of determining the injury caused by and efficacy of Tavium used as a preemergence and postemergence option when added to common mid-South cotton herbicide programs.

Procedures

The Deltapine variety DP 1518 B2XF cotton was planted 14 May 2019, at 43,000 seeds per acre on 38-inch rows and divided into 4-row by 20-ft plots. Preemergence treatments included the herbicides Caparol (prometryn), Gramoxone (paraquat), Brake (fluridone), Cotoran (fluometuron) and Tavium (dicamba + *S*-metolachlor). Postemergence treatments included varying combinations of XtendiMax (dicamba), RoundUp PowerMax (glyphosate), and Tavium (Table 1). Preemergence applications were made two weeks prior to planting and postemergence applications were made on two leaf cotton using a CO_2-pressurized backpack sprayer applying 15 gal/ac. Visible injury was rated 14 days after postemergence treatment on a 0–100% scale with 0% representing no damage and 100% meaning total crop destruction. Palmer amaranth control ratings were taken every 7 days from the date of the first application to 35 days after treatment utilizing 0–100% scale with 0% meaning no control and 100% representing total control. Means were subjected to analysis of variance and separated using Fisher's protected least significant difference ($\alpha = 0.05$). Multiple ratings were analyzed using regression and fitted with a 3P line in order to analyze residual effects.

Results and Discussion

Injury ratings did not vary among treatments with or without Tavium at 14 days after the postemergence treatment (Table 2). Treatments containing Tavium provided better control of Palmer amaranth at 21 days after application than treatments without Tavium. All treatments using Tavium as a preemergence or postemergence option met or exceeded 97% control while the treatment without Tavium averaged 85%. Residual control of Palmer amaranth using Tavium also exceeded that of treatments without Tavium, with an additional 15 days at a 95% threshold when using Tavium as a postemergence option, 14 days with when used as a preemergence, and 19 days when used with Brake as a preemergence herbicide and Tavium used postemergence (Table 3). When an 80% threshold is used, Tavium treatments averaged 32 days after treatment, while the treatment without Tavium averaged 24 days.

Practical Applications

Data from this trial indicate that not only does Tavium inflict minimal injury to dicamba-resistant cotton, but that the

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herbicide also provides exceptional postemergence Palmer amaranth control as well as residual lasting up to 32 days.

Acknowledgments

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Literature Cited

Anonymous. 2019. Tavium Herbicide Label. Syngenta Crop Protection.

Ward, S.M., T.M. Webster, and L.E. Steckel. 2013. Palmer amaranth (*Amaranthus palmeri*): a review. Weed Tech. 27:12–27.

Table 1. List of herbicide treatments including preemergence- and postemergence-applied herbicides, rates, and timings, Crawfordsville, Arkansas, 2019.

Herbicide Treatments			
Preemergence herbicides†	**Rate (fl oz/ac)**	**Postemergence herbicides‡**	**Rate (fl oz/ac)**
Caparol + Gramoxone	32 + 32	XtendiMax + Roundup PowerMax	22 + 32
Caparol + Gramoxone	32 + 32	Tavium + Roundup PowerMax	56.5 + 32
Brake + Caparol + Gramoxone	16 + 32 + 32	Tavium + Roundup PowerMax	56.5 + 32
Cotoran + Caparol + Gramoxone	16 + 32 + 32	Tavium + Roundup PowerMax	56.5 + 32
Tavium + Caparol + Gramoxone	56.5 + 32 + 32	Tavium + Roundup PowerMax	56.5 + 32

†Preemergence applications: All treatments included 0.25% v/v non-ionic surfactant (NIS).
‡Postemergence applications: All treatments included a drift reduction agent.

Table 2. Injury at 14 days after treatment and Palmer amaranth control at 21 days after postemergence treatment, Crawfordsville, Arkansas, 2019.

	Ratings %	
Herbicide Treatments	**Injury**	**Palmer amaranth control‡**
Caparol + Gramoxone fb† XtendiMax + Roundup PowerMax	0	85b
Caparol + Gramoxone fb Tavium + Roundup PowerMax	4	99a
Brake + Caparol + Gramoxone fb Tavium + Roundup PowerMax	3	99a
Cotoran + Caparol + Gramoxone fb Tavium + Roundup PowerMax	2	99a
Tavium + Caparol + Gramoxone fb Tavium + Roundup PowerMax	1	99a

†fb = followed by.
‡Probability level: means with the same letter are not significantly different.

Table 3. Length of residual Palmer amaranth control of each herbicide program, Crawfordsville, Arkansas, 2019.

	Threshold of Palmer amaranth control			
	95%		80%	
Herbicide Treatment	**Days†**	**C.I.‡**	**Days**	**C.I.**
Caparol + Gramoxone fb XtendiMax + Roundup PowerMax	10	3–17.5	24	22–25
Caparol + Gramoxone fb Tavium + Roundup PowerMax	24	21–27	31	30–31.5
Brake + Caparol + Gramoxone fb Tavium + Roundup PowerMax	29	25.5–32	33	31–35
Cotoran + Caparol + Gramoxone fb Tavium + Roundup PowerMax	25	23–28	31	30–31.4
Tavium + Caparol + Gramoxone fb Tavium + Roundup PowerMax	25	22–28	31	30–31.5

†Days until threshold reached.
‡C.I. = Confidence interval.

Influence of Groundcover and Glufosinate on Dicamba Volatility

M.C. Castner,[1] J.K. Norsworthy,[1] M.L. Zaccaro,[1] G.L. Priess,[1] and C.B. Brabham[1]

Abstract

With the availability of the Engenia™ and XtendiMax™ formulations of dicamba, cotton growers may be provided another effective postemergence (POST) control option for problematic broadleaf weeds such as Palmer amaranth (*Amaranthus palmer* S. Wats.) in XtendFlex™ systems. Despite the known efficacy of dicamba on broadleaf weeds, volatility of dicamba-containing products remains a primary concern in crop production areas due to widespread injury mainly associated with susceptible soybean cultivars (conventional, LibertyLink, Roundup Ready, LibertyLink GT27, and Enlist E3). To investigate dicamba volatility as a function of groundcover and application timing of glufosinate, a low-tunnel experiment was conducted in Fayetteville, Arkansas in 2018 and 2019. Treatments were arranged in a two-factor factorial with three replications, with the first factor being groundcover and the second being application timing of glufosinate. Flats of soil were treated with 4X rates of glufosinate and dicamba to compensate for plot area, with 1X being 0.6 lb ai/ac glufosinate and 1X being 0.5 lb ae/ac dicamba. Each flat was placed into the respective low-tunnel between two rows of soybean, which served as a bioindicator. At both 21 and 28 days after treatment (DAT), all treatments where dicamba and glufosinate were applied in combination demonstrated greater percent injury to soybean regardless of groundcover. At 21 DAT, glufosinate followed by dicamba showed 26% injury, which increased to 43% by 28 DAT. Soybean in treatments where glufosinate and dicamba were applied as a mixture exhibited 35% and 50% injury at the respective ratings, which was significantly more than when glufosinate was applied prior to dicamba. The combination of dicamba and glufosinate yielded greater volatility in comparison to glufosinate followed by dicamba, and the presence of groundcover was not a contributing factor towards dicamba volatility in this experiment.

Introduction

Engenia™ and XtendiMax™ formulations of dicamba may provide cotton growers another effective postemergence (POST) control option for problematic broadleaf weeds such as Palmer amaranth in XtendFlex™ systems. According to the XtendiMax product label, mixing low-volatile formulations of dicamba with glufosinate may lead to further off-target movement of dicamba. Although glufosinate is an effective herbicide for broadleaf weeds, it cannot be mixed with dicamba because of the potential risk for increased dicamba volatility (Anonymous, 2018). The degree of dicamba volatilization also may be largely a function of groundcover and likely to increase with the presence of plant tissue (Behrens and Leuschen, 1979). The objective of this study was to determine if timing of glufosinate and the presence or absence of groundcover influenced dicamba volatility to mitigate off-target movement of dicamba in a production system.

Procedures

To investigate dicamba volatility as a function of groundcover and application timing of glufosinate, a low-tunnel experiment was conducted at the University of Arkansas System Division of Agriculture's Milo J. Shult Agricultural Research and Extension Center in Fayetteville, Arkansas in 2018 and 2019. Treatments were arranged as a two-factor randomized complete block with three replications. A glufosinate-resistant soybean cultivar CDZ 4938 (BASF, Florham Park, N.J.) was planted on 6 June 2018 and 10 June 2019 on 36-in. wide rows into a Captina silt loam soil to serve as a bioindicator to quantify visible injury caused by dicamba. Moist bareground flats (15 by 19 in.) and flats planted to DP 1518 B2XF (Bayer, St. Louis, Missouri) were initiated to simulate the presence or absence of groundcover. The resulting bareground flats and 4-leaf cotton plants were treated with glufosinate 4 days prior to a mixture of dicamba plus glyphosate or treated with a mixture of glufosinate plus dicamba plus glyphosate. All flats were treated with a CO_2-pressurized sprayer at 15 gal/ac using TTI110015 nozzles approximately 0.5 miles from the field where the experiment was conducted to avoid dicamba contamination to the bioindicator soybean. A 1X rate of herbicide covers a 12 by 20 ft plot area; however, all treatments were applied to flats at a 4X rate (1X equating to 0.6 lb ai/ac glufosinate, 0.5, and 0.6 lb ae/ac dicamba and glyphosate, respectively) to achieve the same degree of dicamba volatilization. Two treated flats were placed into the appropriate tunnel (4.5 ft wide × 20 ft long × 4 ft tall) that covered two 30-ft long rows of soybean.

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A single high-volume air sampler was placed between two rows of soybean with one treated flat on either side of the air sampler to measure volatility. Immediately following trial initiation, pH of each spray solution was collected and analyzed. Low-tunnels, flats, and air samplers were removed 48 hours following trial initialization. For data collection, soybean under each tunnel was divided into 8 quadrants where visible injury was assessed at 7, 14, 21, and 28 days after treatment (DAT). Distance to 5% injury was measured at the same weekly intervals from the center of each tunnel in the direction where greater injury was observed, which is typically in the downwind direction from the treated flat. Dicamba volatility data collected from high-volume air samplers are not yet available. All data were subjected to analysis of variance in JMP Pro 14.3 using Fisher's protected least significant difference ($\alpha = 0.05$).

Results and Discussion

The presence of groundcover did not influence dicamba volatility, but an increase in volatility was documented when glufosinate was applied as a mixture with dicamba. Greater maximum visible injury resulted when dicamba was applied in combination with glufosinate at both 21 and 28 DAT, which elicited an increase in dicamba volatility in comparison to treatments where glufosinate preceded a dicamba application (Fig. 1). At 21 DAT, treatments where glufosinate preceded dicamba showed 26% injury 21 DAT, increasing to 43% by 28 DAT. When glufosinate was applied as a mixture with dicamba, soybean exhibited 35% and 50% injury at 21 and 28 DAT, respectively. Following the same trend at 21 DAT, a non-labeled mixture of glufosinate plus dicamba consequently resulted in greater visible injury for a longer distance by approximately 7 ft in the downwind direction independent of groundcover, indicating increased volatility over treatments where glufosinate was applied prior to dicamba (Fig. 2). The presence or absence of vegetation did not influence dicamba volatility, which was not consistent with Behrens and Leuschen (1979) findings.

Practical Applications

Overall, the off-target movement of low-volatile dicamba products has been a major concern in the mid-South due to a multitude of contributing factors. The results from this study are consistent with the XtendiMax product label as mixtures with glufosinate greatly influenced volatility, which suggests that growers need to ensure that dicamba applications are made independent from glufosinate applications. Although the presence or absence of groundcover did not influence dicamba volatility in this study, research shows that dicamba applied to plant tissue increases the risk for volatility. However, the late planting window of cotton relative to the 25 May dicamba cutoff in Arkansas indicates that a limited amount of cotton vegetation would be present for a legal dicamba application, mitigating dicamba volatility from cotton plant tissue.

Acknowledgments

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Literature Cited

Anonymous. 2018 Xtendimax® herbicide product label. Bayer Publication No. 524-617. St. Louis, Missouri: Monsanto Company.

Behrens, R. and W.E. Leuschen. 1979. Dicamba volatility. Weed Sci. 27:486-493.

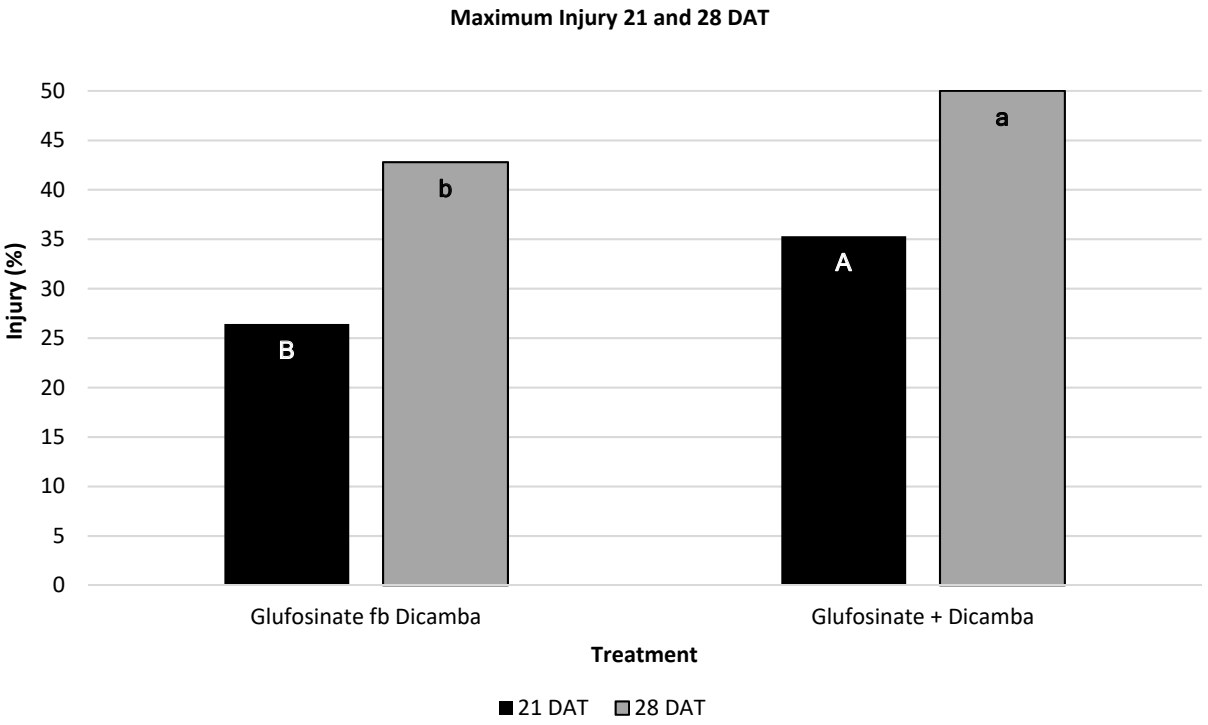

Fig. 1. Comparing the maximum percent injury of soybean 21 and 28 days after treatment (DAT) when a dicamba application is preceded by glufosinate and when glufosinate is combined with dicamba in Fayetteville, Arkansas in 2018 and 2019. Means followed by the same letter are not significantly different (α = 0.05). Abbreviations: fb = followed by.

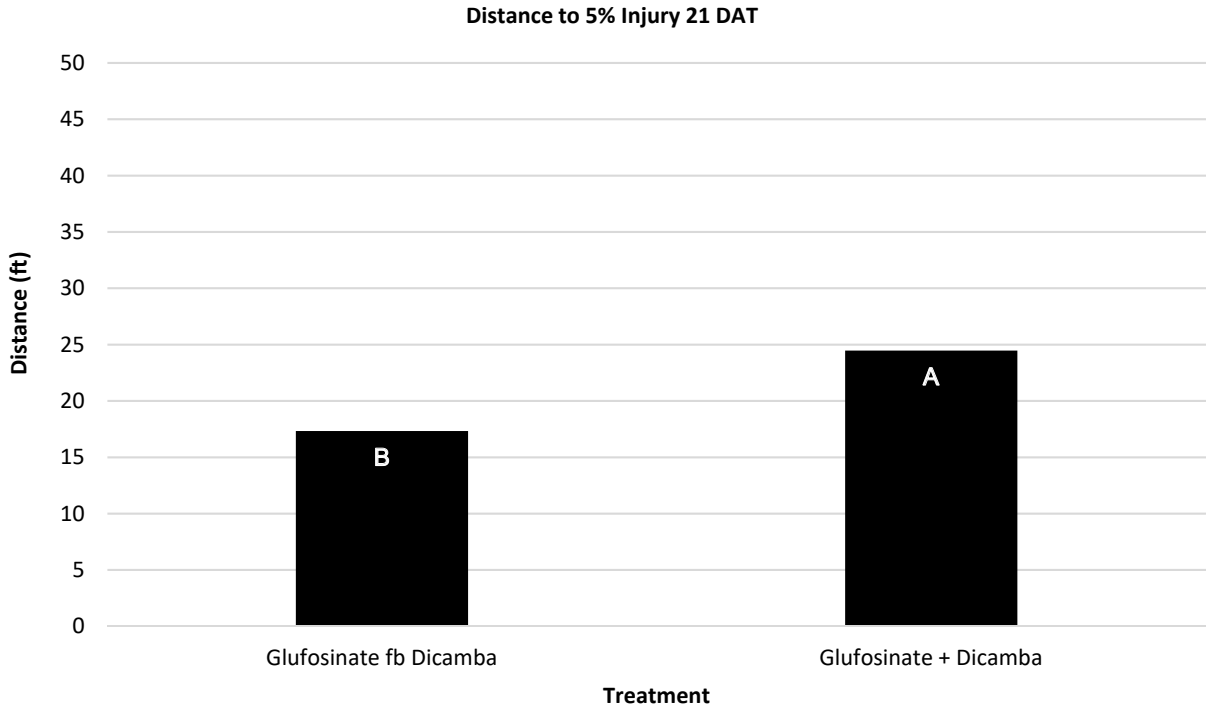

Fig. 2. Comparison of the total distance injured to soybean 21 days after treatment (DAT) when dicamba is preceded by glufosinate and when glufosinate is combined with dicamba until ≤5% dicamba symptomology was observed in Fayetteville, Arkansas in 2018 and 2019. Means followed by the same letter are not significantly different (α = 0.05). Abbreviations: fb = followed by.

Evaluation of Loyant Post-Directed in Arkansas Cotton

R.C. Doherty,[1] T. Barber,[2] L Collie,[2] Z. Hill,[1] and A. Ross[2]

Abstract

Cotton (*Gossypium hirsutum* L.) weed control programs that contain multiple herbicide modes of action and are applied timely are essential in season-long control of Palmer amaranth (*Amaranthus palmeri* S. Wats.). Arkansas cotton growers are in need of new herbicide chemistry and improved methods, to manage this troublesome weed, which has been found resistant to 6 herbicide modes of action in some areas. New technologies such as Enlist™ and XtendFlex™ cotton traits provide opportunity for the use of auxin based herbicide programs. Loyant (florpyrauxifen-benzyl) is a new auxin herbicide labeled in rice and is effective in controlling a range of weed species including Palmer amaranth. Trials were conducted in 2017 at Marianna and Rohwer, Arkansas, and in 2018 and 2019 at Marianna and Tillar, Arkansas, to determine if Loyant would fit in a post-direct program for control of problem weeds at a cotton layby timing and to determine the rate of Loyant necessary to achieve this control. In 2017 and 2018 at both locations and at Tillar in 2019, trials were established in an Enlist™ cultivar. At Marianna in 2019, the trial was established in an XtendFlex™ cultivar. Cotton injury observed from post-directed applications of Loyant was minimal in 2017 and 2018 at both locations, and in 2019 at Tillar. In 2018, Loyant at 8 oz/ac plus Durango (glyphosate) at 32 oz/ac plus Diuron at 32 oz/ac provided 98% or greater control of Palmer amaranth and barnyard grass at both locations in addition to exceptional yields. In 2019, 90% or greater control of Palmer amaranth and barnyard grass was recorded in 8 of the 10 treatments, while causing no visual injury to the cotton at Tillar. Loyant at 5 oz/ac plus MSO (methylated seed oil) at 0.5% v/v at 8 and 10 node cotton only provided 83–87% control of Palmer amaranth, indicating that rates of at least 8 oz of Loyant will be needed for optimum control at this timing. Post-direct applications of Loyant at 8 oz/ac can provide good Palmer control, while causing minimal injury to cotton.

Introduction

Glyphosate, Protoporphyrinogen oxidase inhibitor (PPO), and acetolactate synthase (ALS) resistant Palmer amaranth remain major concerns for cotton growers in Arkansas. Herbicide programs that utilize multiple modes of action applied timely, with residuals are essential in controlling this troublesome weed (Barber et al., 2019). Enlist™ and XtendFlex™ technologies provide an opportunity and the flexibility to use multiple modes of action, over-the-top and post-directed, for control of a wide variety of weeds including Palmer amaranth. The objective in 2017 was to establish potential new programs containing Loyant, and other phenoxy herbicides, applied post-directed in Enlist cotton. In 2018 and 2019, the objective was to establish the appropriate rate of Loyant required for weed control and evaluate crop safety.

Procedures

In 2017, cotton trials were established on 16 May at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station Marianna, Arkansas in a Loring silt loam soil and at the Rohwer Research Station, Rohwer, Arkansas in a Herbert silt loam soil on 24 May 2018 and 15 May 2019. Loyant rate comparison cotton trials were established at Marianna, Arkansas, in a Loring silt loam soil and at Tillar, Arkansas, in a Herbert silt loam soil. Enlist™ varieties, PHY 340 W3FE, PHY 330 W3FE and PHY 350 W3FE were planted in 2017, 2018 and 2019 respectfully. DP 1646 B2XF was established at Marianna in 2019 and represented the only non-Enlist cultivar evaluated.

Trials were arranged in a randomized complete block design with four replications. All treatments received Brake FX preemergence at 40 oz/ac (fluometuron 0.94lb ai/ac + fluridone 0.19 lb ai/ac) followed by Liberty (glufosinate) at 32 oz/ac plus Dual Magnum (s-metolachlor) at 21 oz/ac at 3–4 leaf cotton. Post-directed herbicides evaluated included Valor SX (flumioxazin), MSMA, Diuron, Xtendimax (dicamba), Loyant (florpyrauxifen-benzyl), Starane Ultra (fluroxypyr), and Enlist Duo (2,4-D choline plus glyphosate) (Tables 1–3). Visual weed control ratings of Palmer amaranth, morningglory, barnyardgrass, broadleaf signalgrass, and Southwestern cupgrass were recorded at 20 days after post-direct applications. Studies in 2017 focused more on a program approach to weed control with multiple products. In 2018, treatments were adjusted to determine what rate of Loyant was appropriate in a layby herbicide program. In

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2019, Loyant rates were adjusted again, while making applications to 8 and 10 node cotton to evaluate cotton response.

Results and Discussion

In 2017, all treatments provided 99% control of morningglory, barnyardgrass, and broadleaf signalgrass at both Marianna and Rohwer with minimal injury reported (data not shown). Palmer amaranth control was 99% regardless of treatment at Marianna and 83% to 84% regardless of treatment at Rohwer (data not shown). No visual Enlist cotton injury was caused by any treatment other than Xtendimax at either location in 2017. Cotton yield was impacted significantly by Xtendimax plus Round-Up PowerMax, which was expected and resulted in a yield loss of 552 and 1173 lbs of seedcotton per acre, at Marianna and Rohwer respectively (Fig. 1). All other treatments were statistically equal at the respective locations. The greatest yield at Marianna, 1434 lb of seedcotton per acre, was associated with Enlist Duo at 75 oz/ac plus Liberty 32 oz/ac, while Rohwer was 1462 lb of seedcotton per acre provided by Enlist Duo at 75 oz/ac plus Loyant at 16 oz/ac applied at layby.

In 2018, all treatments provided 99% control of Palmer amaranth, morningglory, barnyardgrass, and Southwestern cupgrass at Tillar (data not shown), while Palmer amaranth control ranged from 88% to 97% and barnyardgrass ranged from 88% to 98% at Marianna (Fig. 2). The highest Palmer amaranth control was achieved with a combination of Loyant, Diuron and Durango. No differences in Loyant rate was observed for Palmer amaranth control. No visual crop injury was caused by any treatment at either location in 2018 (data not shown). Cotton yield was not impacted negatively by any treatment at either Marianna or Tillar in 2018 (Fig. 3). The greatest yield at Marianna was 3945 lb of seedcotton/ac provided by Loyant at 8 oz/ac, while Tillar was 3206 lb of seedcotton/ac provided by Loyant at 8 oz/ac plus Durango at 32 oz/ac.

In 2019, crop injury at Marianna increased as the Loyant rate increased. Visual injury ranged from 2.5% with Loyant at 5 oz/ac to 11.3% with Loyant at 16 oz/ac (Fig. 4). No visual injury was noted, in any Loyant treatment, at Tillar (data not shown). Weed control was not recorded at Marianna. Loyant provided 89–99%, 99%, and 94–99% control of Palmer amaranth, goosegrass, and morningglory respectively, at Tillar 20 days after the 10 node application (Fig. 5). Cotton yield was reduced by 9 of the 10 Loyant treatments at Marianna, while yield was equal to or greater than the weed-free check with all Loyant treatments at Tillar. The highest yield reduction was noted when Loyant was applied at 16 oz/ac to 8 node Xtend™ cotton, while the highest overall yield was provided by Loyant at 5 oz/ac plus Roundup at 32 oz/ac applied to 8 node cotton. (Fig. 6).

Practical Applications

The preliminary evaluation of Loyant herbicide as a potential post-direct or layby option in cotton appears promising. Loyant provided excellent control of Palmer amaranth and other broadleaf weeds in these studies while causing very little injury to Enlist™ cotton. Extra care and more precise application methods may need to be administered while applying Loyant post-direct in XtendFlex™ cotton. This system must also include early season residuals applied preemergence and early-postemergence to ensure complete weed control. Hopefully, these and other data can be used to provide justification for a special use permit for Loyant in cotton, but more research is necessary to fully determine crop sensitivity.

Acknowledgments

The authors would like to thank the University of Arkansas System Division of Agriculture, Research and Extension for support in this research endeavor.

Literature Cited

Barber, T.L., J.W. Boyd, G. Selden, J.K. Norsworthy, N. Burgos and M. Bertucci. 2019. MP44 2020. Recommended chemicals for weed and brush control. University of Arkansas, Division of Agriculture, Research and Extension, Little Rock, Ark.

Table 1. 2017 Post-directed herbicide treatments at Marianna and Rohwer, Arkansas locations.

Herbicide	Rate	Timing
	oz product/ac	
Brake FX	40	Preemergence
Dual Magnum	21	3-4 leaf cotton
Liberty	32	3-4 leaf cotton
Valor SX	2	10 node cotton post-directed
MSMA	43	10 node cotton post-directed
Roundup PowerMax	32	10 node cotton post-directed
Diuron	32	10 node cotton post-directed
Xtendimax	22	10 node cotton post-directed
Loyant 8	8	10 node cotton post-directed
Loyant 16	16	10 node cotton post-directed
Starane Ultra 3.2	6.4	10 node cotton post-directed
Starane Ultra 6.4	3.2	10 node cotton post-directed
Enlist Duo	75	10 node cotton post-directed

Table 2. 2018 Post-directed herbicide treatments at Marianna and Tillar, Arkansas locations.

Herbicide	Rate	Timing
	oz product/ac	
Brake FX	40	Preemergence
Dual Magnum	21	3-4 leaf cotton
Liberty	32	3-4 leaf cotton
Loyant 5.5	5.5	10 node cotton post-directed
Loyant 8.2	8.2	10 node cotton post-directed
Durango DMA	1.27	10 node cotton post-directed
Diuron	32	10 node cotton post-directed
MSMA	32	10 node cotton post-directed

Table 3. 2019 Post-directed herbicide treatments at Marianna and Tillar, Arkansas locations.

Herbicide	Rate	Timing
	oz product/ac	
Brake FX	40	Preemergence
Dual Magnum	21	3-4 leaf cotton
Liberty	32	3-4 leaf cotton
Loyant 5	5	8 and 10 node cotton post-directed
Loyant 8	8	8 and 10 node cotton post-directed
Loyant 16	16	8 and 10 node cotton post-directed
Durango DMA	32	8 and 10 node cotton post-directed
Roundup	32	8 and 10 node cotton post-directed
MSO	0.5 %v/v	8 and 10 node cotton post-directed

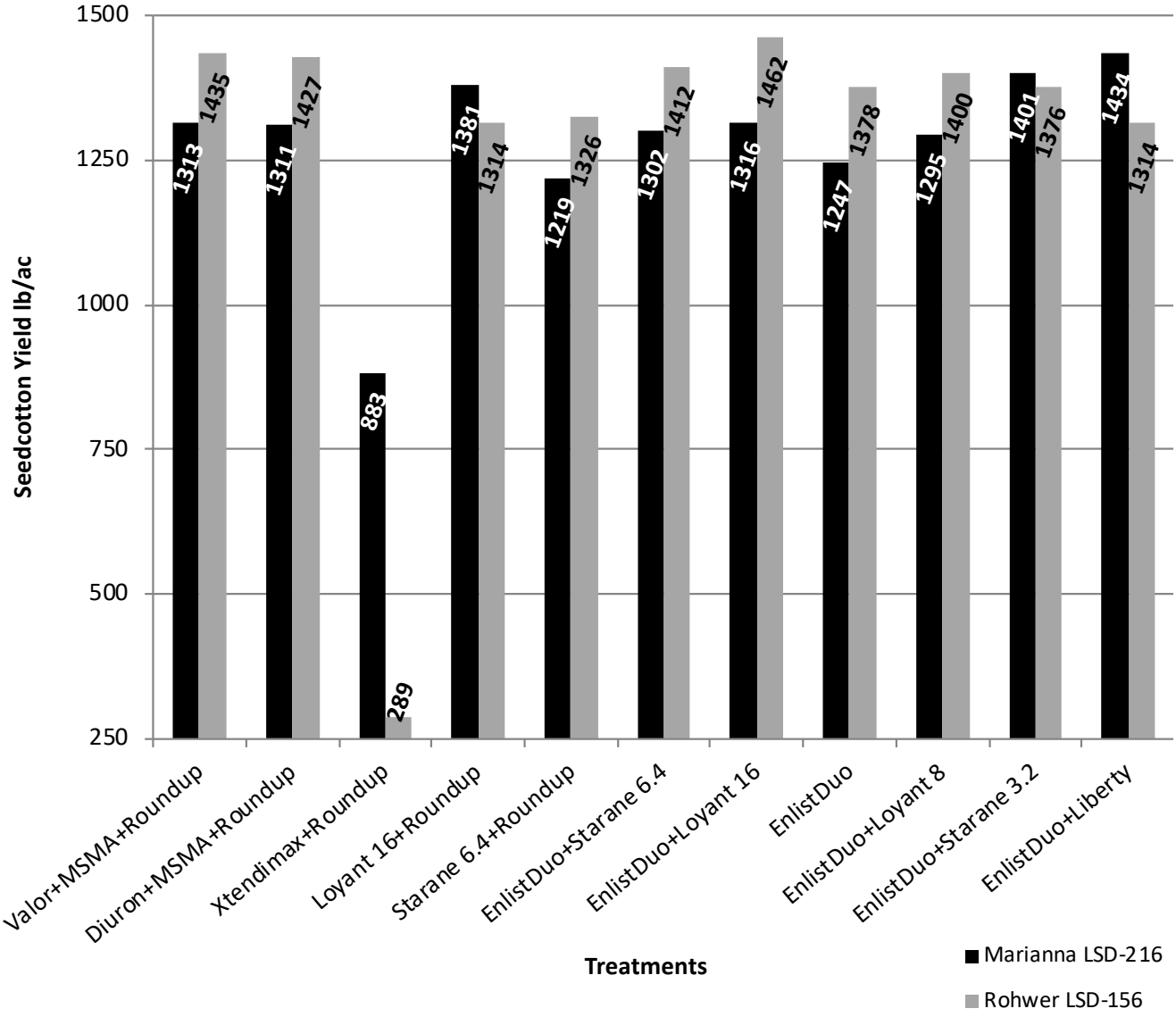

Fig. 1. 2017 seedcotton yield at Marianna and Rohwer Arkansas following various herbicide programs applied at layby. Abbreviations: LSD = least significant difference.

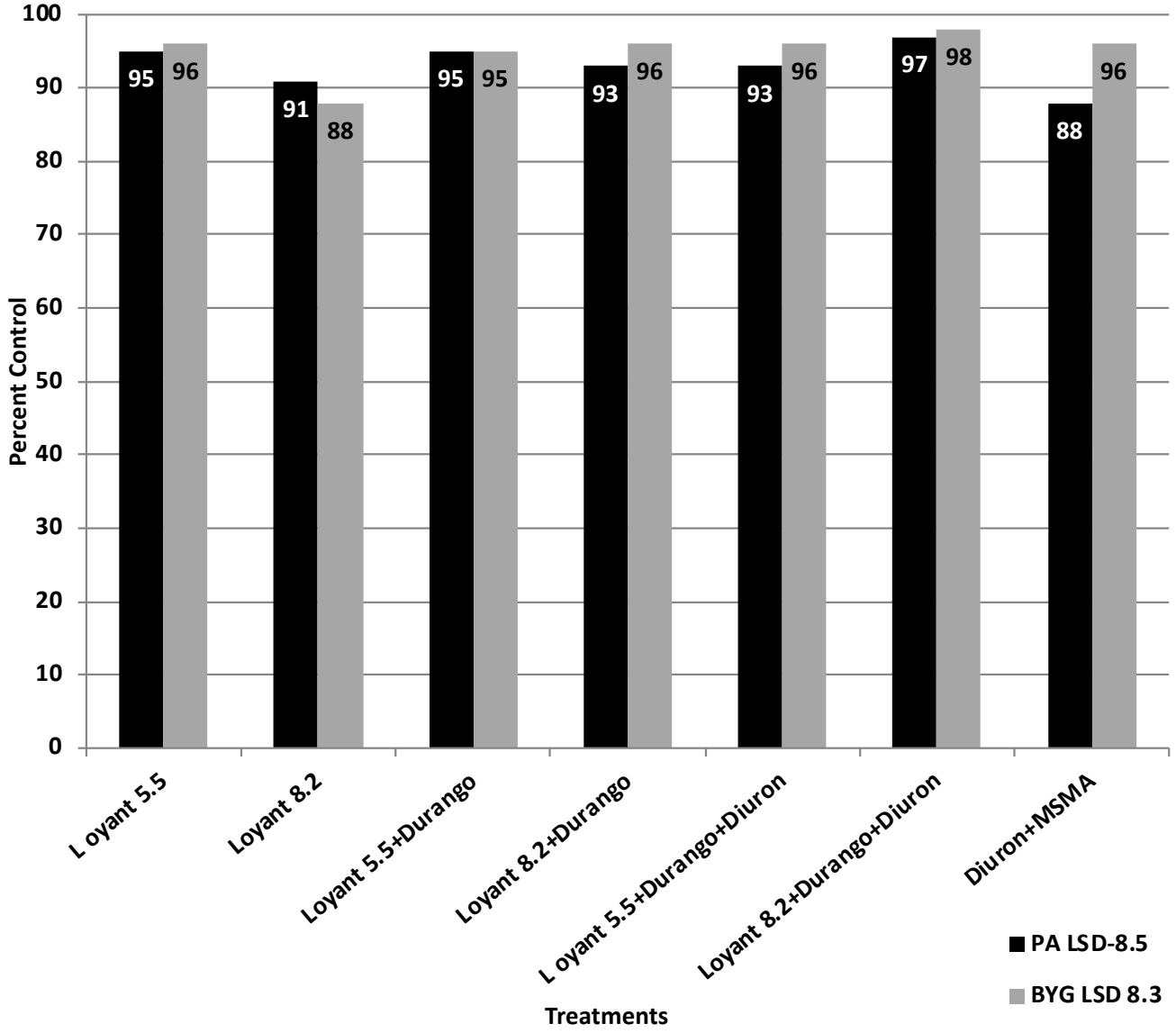

Fig. 2. 2018 weed control 20 days after Layby at Marianna, Arkansas. Abbreviations: PA = Palmer amaranth, BYG = barnyardgrass, LSD = least significant difference.

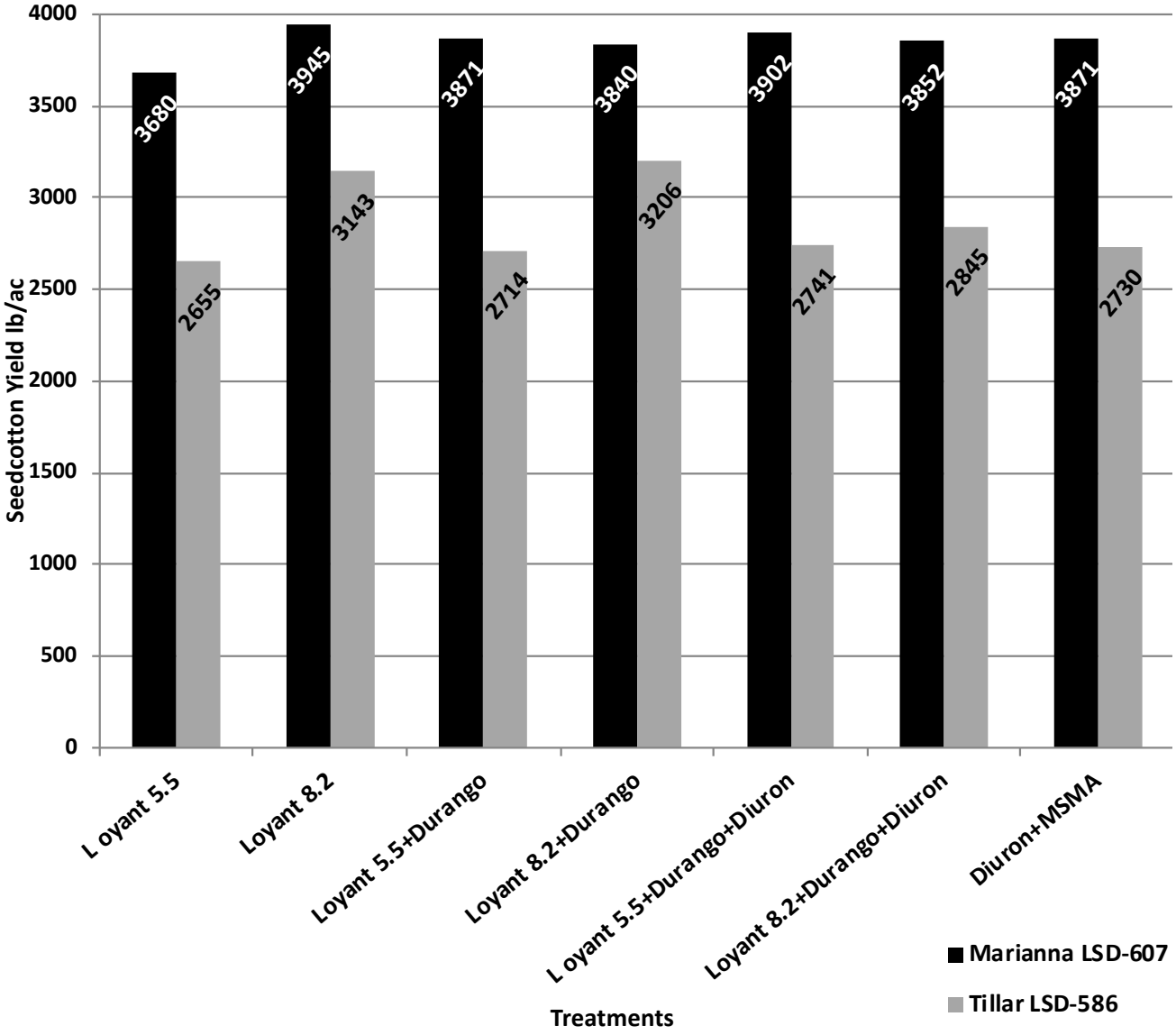

Fig. 3. 2018 seedcotton yield at Marianna and Tillar, Arkansas. Abbreviations: LSD = least significant difference.

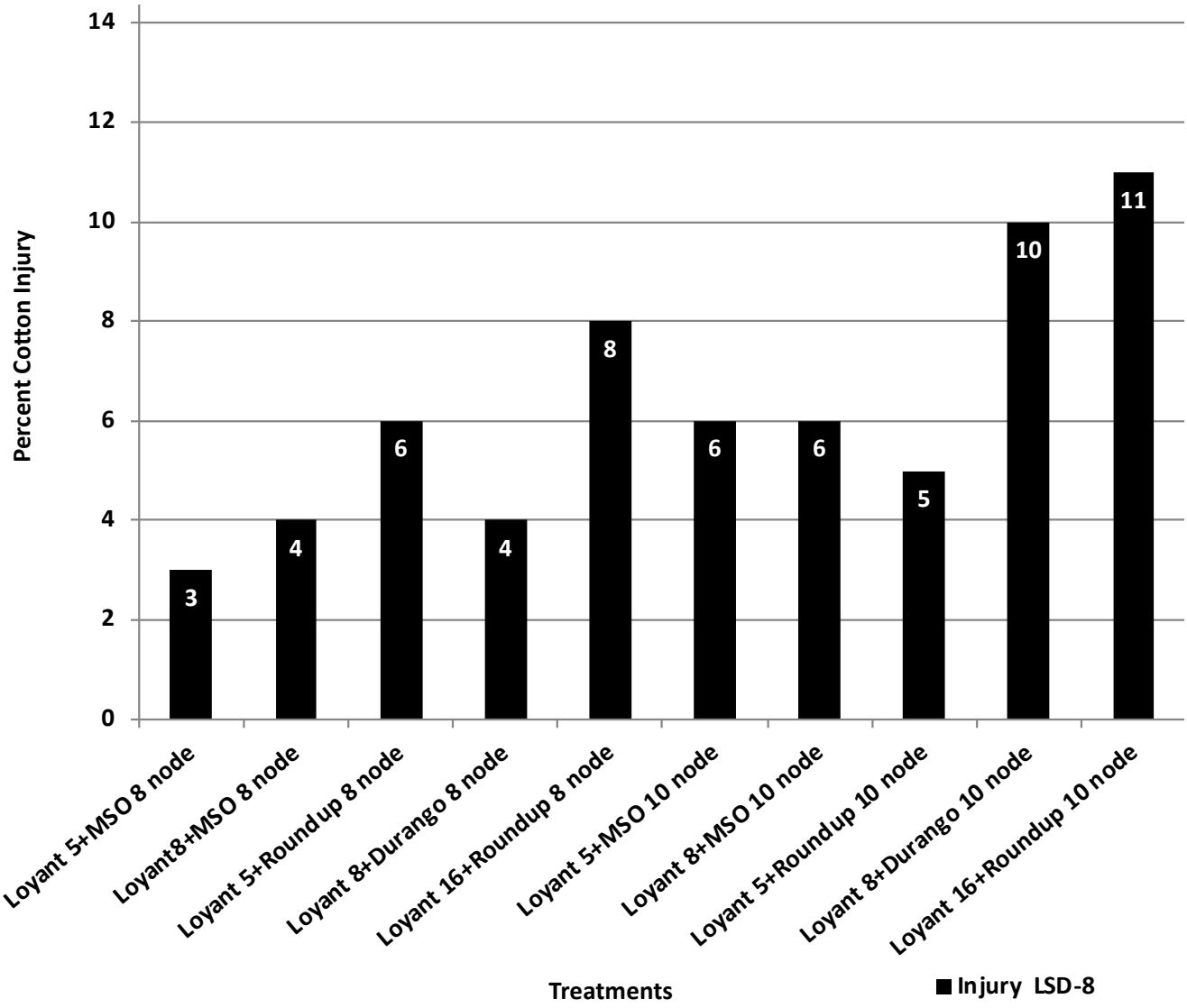

Fig. 4. 2019 visual cotton injury at Marianna, Arkansas. Abbreviations: LSD = least significant difference.

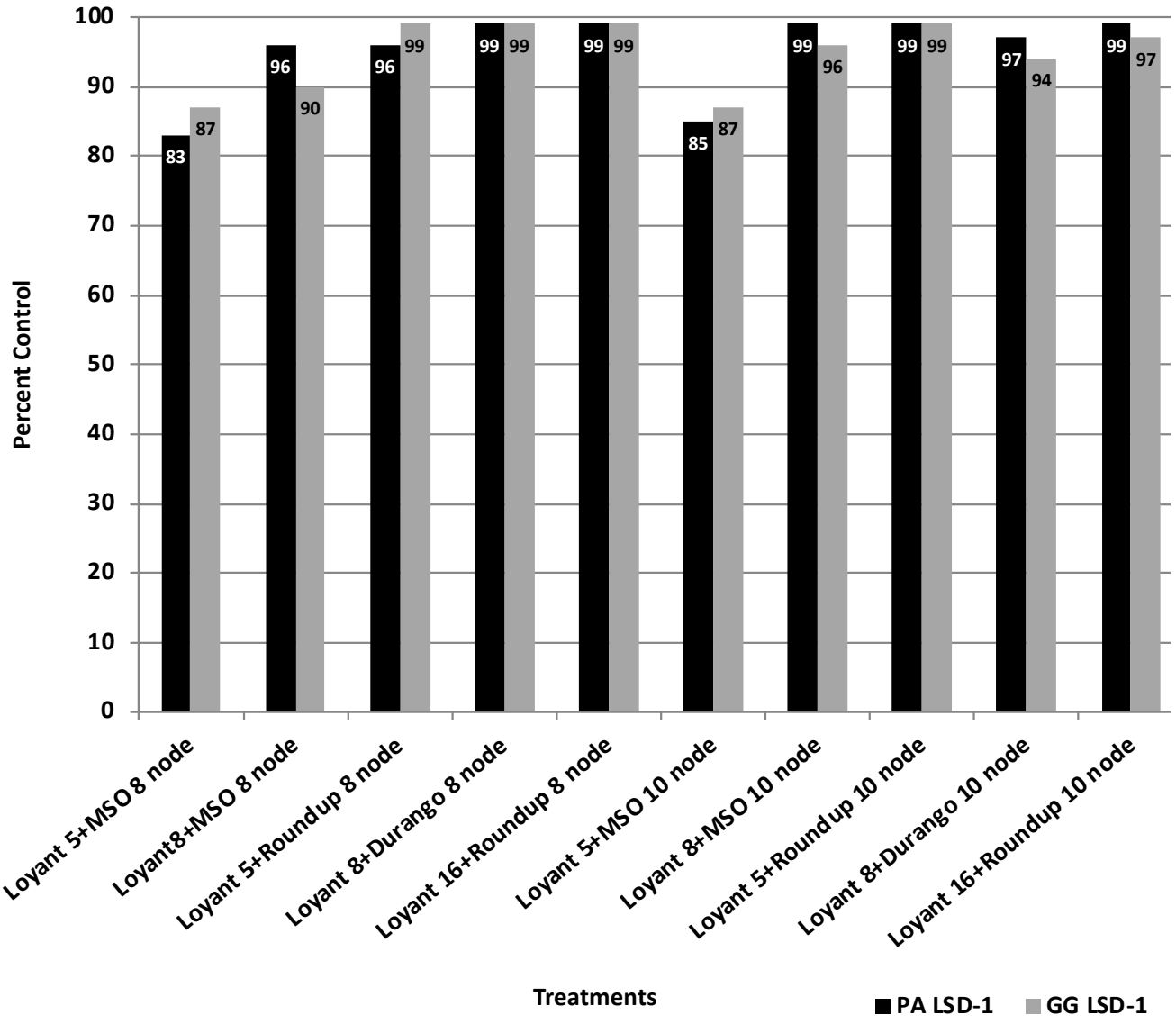

Fig. 5. 2019 weed control 18 days after Layby at Tillar, Arkansas. Abbreviations: PA = Palmer amaranth, GG = goose grass, LSD = least significant difference.

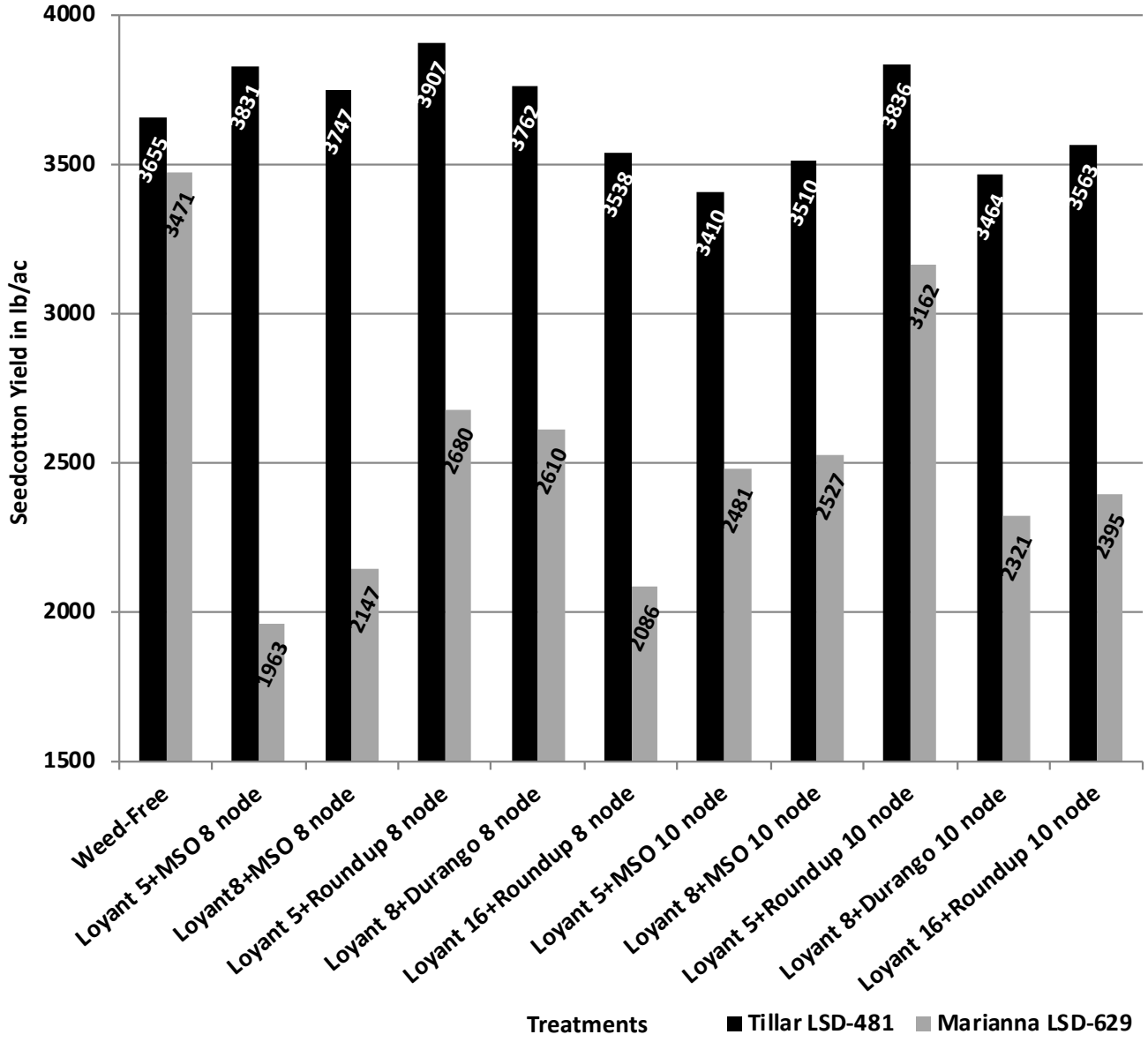

Fig. 6. 2019 seedcotton yield at Tillar and Marianna, Arkansas. Abbreviations: LSD = least significant difference.

Impact of Integrated Weed Management Strategies on Palmer Amaranth in Cotton

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Abstract

Multiple herbicide-resistant weeds have resulted in a need to adopt a multifaceted approach to reduce selection pressure and mitigate the evolution of herbicide resistance. Previous studies have suggested that cover crops, deep tillage, zero-tolerance mechanical weed control, and the use of residual herbicides along with postemergence herbicides can all disrupt the emergence of weeds. A long-term study was initiated in Marianna, Arkansas, during the fall of 2018 to evaluate the influence of a one-time deep tillage, rye cover crop, dicamba- and non-dicamba-based herbicide program, and zero-tolerance weed removal on Palmer amaranth (*Amaranthus palmeri* S. Wats.) emergence and density in the soil seedbank. This study was arranged as a split, split, split-plot with zero-tolerance being the whole-plot factor, deep tillage the sub-plot factor, cover crops the sub-sub-plot factor and herbicide programs the sub-sub-sub-plot factor. Weed densities and emergence were measured in each plot at 21, 42, 63, and 72 days after planting and inflorescence-producing weed counts were taken at harvest. Results from 2019 suggest that the use of deep tillage and zero-tolerance both reduced the amount of weed seed returned to the seedbank. Deep tillage reduced the number of inflorescence-producing weeds at the end of the season by 75%. Zero-tolerance reduced inflorescence-producing Palmer amaranth populations at the end of the season by 63%. Deep tillage also reduced cumulative, in-season Palmer amaranth emergence by 74%. This information will be beneficial in assisting crop producers on how to effectively control and reduce weed populations in an integrated manner.

Introduction

Palmer amaranth has developed resistance to eight different sites of action, limiting the number of effective chemical weed control options in cotton production systems (Heap, 2020). Previous research has found that by layering integrated weed management strategies such as chemical, mechanical, and cultural control methods, the evolution of herbicide resistance and weed populations may be curtailed (Beckie, 2011). Research investigating the utility of integrated practices for Palmer amaranth control found that cover crops and deep tillage were both effective in reducing Palmer amaranth emergence during the season (DeVore et al., 2012). Efforts have also been made in Arkansas to establish a "Zero-tolerance" threshold for Palmer amaranth, where no Palmer amaranth is permitted to reach maturity within a field. Such efforts have been found to be successful even within the first year (Barber et al., 2017). By preventing emergence and seed production, Palmer amaranth seedbanks may rapidly decline to nearly zero within 4 to 5 years (Korres et al., 2018). The objective of this study is to determine best management practices for long-term control of Palmer amaranth in cotton production systems.

Procedures

A long-term experiment was initiated in the fall of 2018 at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna. The experiment was a randomized complete block with a split, split, split-plot arrangement of treatments with four replications. The main plot factor was with or without a one-time hand-weeding event at 77 days after planting to simulate a zero-tolerance program. The sub-plot factor was with or without a one-time deep tillage event to a depth of 6 inches during the fall of 2018. The sub-sub plot factor was with or without cereal rye cover crop, which was planted in November 2018 at 75 lb of seed/ac. The sub-sub-sub plot factor was the use of either a dicamba in-crop (Table 1) or a non-dicamba in-crop (Table 2) herbicide program. The cotton cultivar DP 1518 B2XF was planted at 46,000 seeds/ac on 38-in. wide rows on 15 May 2019. Burndown applications were applied 14 days prior to planting, preemergence (PRE) application at planting, early postemergence (EPOST) application at 21 days after planting, mid-postemergence (MPOST) applications at 42 days after planting, and layby applications at 63 days after planting. Palmer amaranth counts were taken in four random quadrants measuring 2.7 ft^2 in each plot. Counts were taken 21, 42, 63, and 72 days after planting. The number of inflorescence-producing weeds was recorded from each plot immediately prior to harvest. Additionally, the time to hand-weed each plot was recorded to measure variability in time due to differences in weed densities. All data were analyzed using JMP Pro 14.2 and subjected to

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analysis of variance. Means were separated using Fisher's protected LSD ($\alpha = 0.05$).

Results and Discussion

The deep tillage event significantly reduced cumulative emergence of Palmer amaranth through 72 days after planting by 74% when averaged over cover crop and herbicide programs, reducing total emergence from 106,401 Palmer amaranth plants per acre to 25,683 Palmer amaranth/ac (Fig. 1). Deep tillage also reduced the amount of inflorescence-producing Palmer amaranth plants/ac by 75% when averaged over hand-weeding, cover crop, and herbicide programs, reducing the population from 576 plants/ac down to 145 plants/ac (Fig. 2). Hand weeding also significantly impacted the number of inflorescence-producing Palmer amaranth, reducing its density by 63% when averaged over all other factors (Fig. 3). The use of cover crops and either herbicide program was not found to significantly impact the cumulative emergence of Palmer amaranth ($P = 0.448$ and $P = 0.678$, respectively). The use of cover crops or either herbicide program also did not significantly impact the number of inflorescence-producing Palmer amaranth plants during the first year of this long-term study ($P = 0.132$ and $P = 855$ respectively). The lack of a cover crop effect may be the result of late planting of the cereal rye in 2018 which lessened its biomass production. No interactions were found to be significant during the first year of this study.

Practical Applications

When used as part of an integrated weed management system with a layered herbicide program, the use of deep tillage can significantly lower the amount of Palmer amaranth that may compete with cotton during the growing season. The use of deep tillage and a one-time hand-weeding event may both also reduce the number of Palmer amaranth plants that will produce seeds for future growing seasons, especially when used as part of an integrated program. By reducing or eliminating the number of seeds returned to the seedbank, weed populations will decline through continued stewardship.

Acknowledgments

The authors would like to thank Cotton Incorporated and the University of Arkansas System Division of Agriculture for their support of this research.

Literature Cited

Barber, L.T., J.K. Norsworthy, and A.M. Vangilder. 2017. A Community-Based Program for Glyphosate-Resistant Palmer Amaranth Management. University of Arkansas System Division of Agriculture Cooperative Extension. Accessed on 12 February 2020 Available at: https://www.uaex.edu/publications/pdf/FSA2177.pdf

Beckie, H.J. 2011. Herbicide resistant weeds: management tactics and practices. Weed Tech. 20:793-814.

DeVore, J.D., J.K. Norsworthy, and K.R. Brye. 2012. Influence of deep tillage and a rye cover crop on glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) emergence in cotton. Weed Tech. 26:832–838.

Heap, I.M. 2020. International Survey of Herbicide Resistant Weeds. Accessed on 22 January 2020. Available at: http://www.weedscience.org/Summary/Species.aspx?WeedID=14

Korres, N.E., J.K. Norsworthy, B.G. Young, D.B. Reynolds, W.G. Johnson, S.P. Conley, R.J. Smeda, T.C. Mueller, D.J. Spaunhorst, K.L. Gage, M. Loux, G.R. Kruger, and M.V. Bagavathiannan. 2018. Seedbank persistence of Palmer amaranth (*Amaranthus palmeri*) and waterhemp (*Amaranthus tuberculatus*) across diverse geographical regions of the United States. Weed Sci. 66:446-456.

Table 1. Dicamba in-crop herbicide program.

Timing[a]	Herbicide	Rate
		lb ai or ae/ac
Burndown	Roundup PowerMAX	1.1
	Clarity	0.4
PRE	XtendiMax Plus VaporGrip	1.0
	Cotoran	1.0
EPOST	Tavium Plus VaporGrip	0.5+1.0
	Roundup PowerMAX	1.1
	Warrant	1.1
MPOST	Interline	0.6
	Roundup PowerMAX	1.1
	Warrant	1.1
Layby	Valor	0.06
	MSMA	2.0

[a] Abbreviations: PRE = preemergence, EPOST = early-postemergence, MPOST = mid-postemergence.

Table 2. Non-dicamba in-crop herbicide program.

Timing[a]	Herbicide	Rate
		lb ai or ae/ac
Burndown	Roundup PowerMAX	1.1
	Clarity	0.4
PRE	Gramoxone	0.6
	Cotoran	1.0
EPOST	Interline	0.6
	Roundup PowerMAX	1.1
	Warrant	1.1
MPOST	Interline	0.6
	Roundup PowerMAX	1.1
	Warrant	1.1
Layby	Valor	0.06
	MSMA	2.0

[a] Abbreviations: PRE = preemergence, EPOST = early-postemergence, MPOST = mid-postemergence.

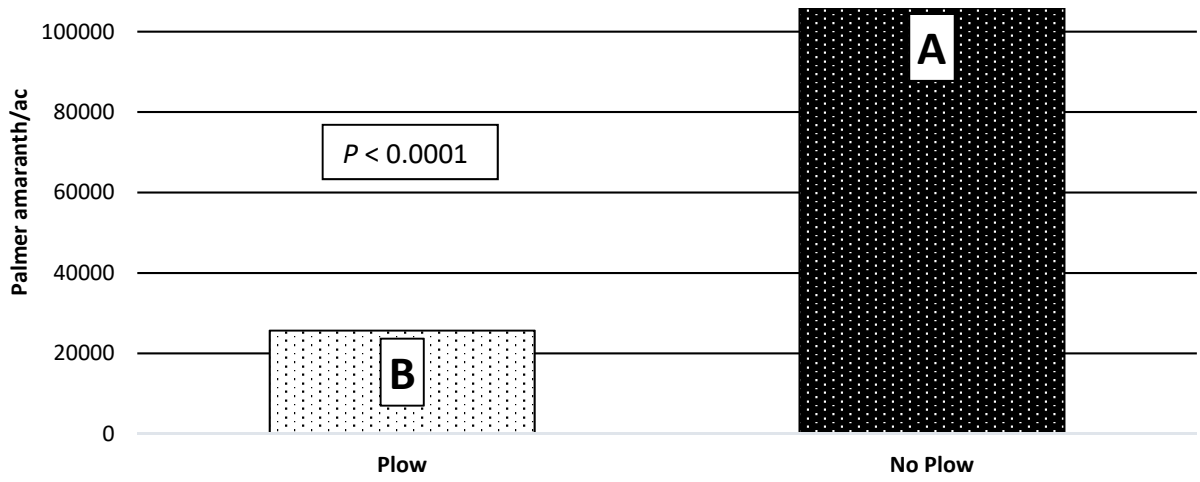

Fig. 1. Cumulative Palmer amaranth emergence by tillage program (moldboard plow presence or absence) averaged over herbicide program, cover crop, and zero-tolerance at Marianna, Arkansas in 2019. Means with the same letter are not statistically different (α = 0.05). The use of a one-time deep-tillage event significantly reduced cumulative emergence of Palmer amaranth by 76%.

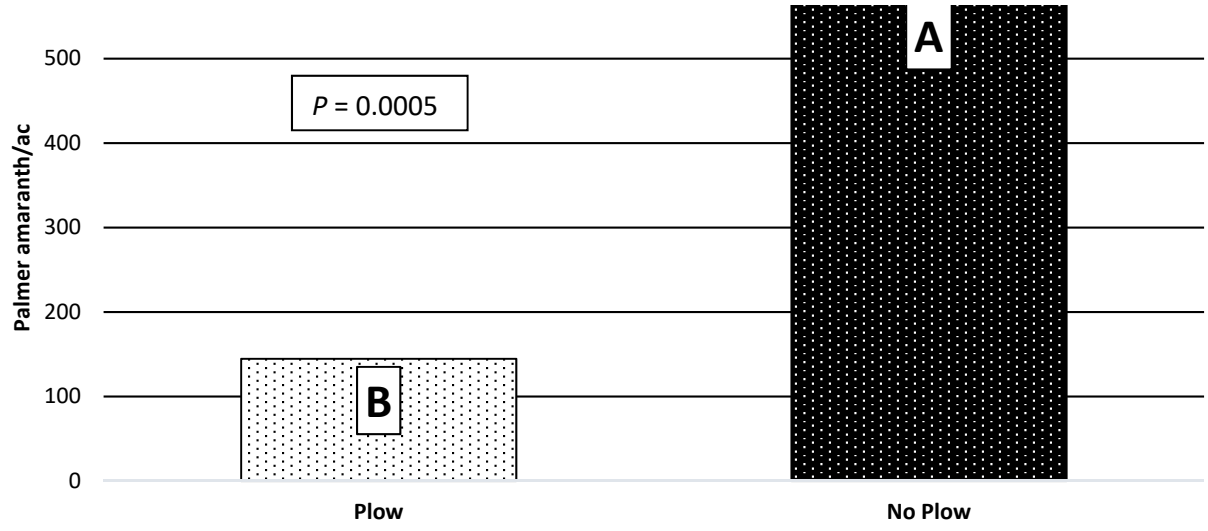

Fig. 2. Inflorescence-producing Palmer amaranth at harvest by tillage (moldboard plow presence or absence) averaged over herbicide program, cover crop, and zero tolerance at Marianna, Arkansas in 2019. Means with the same letter are not statistically different (α = 0.05). The use of a one-time deep-tillage event reduced inflorescence-producing Palmer amaranth by 75%.

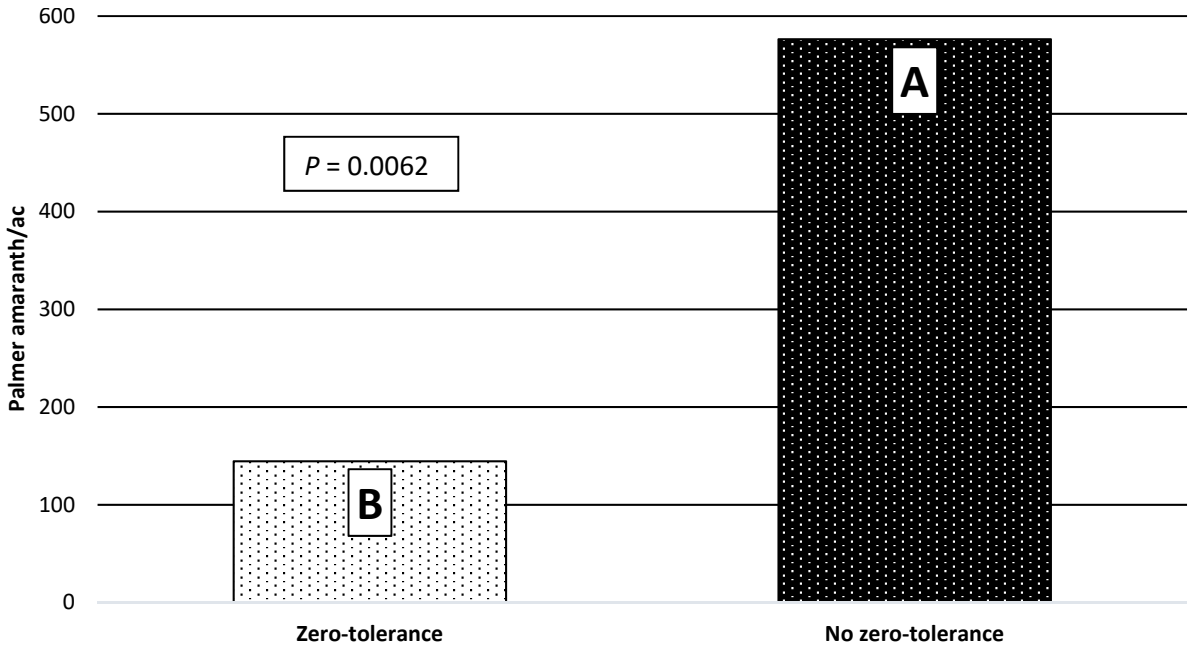

Fig. 3. Inflorescence-producing Palmer amaranth at harvest by zero-tolerance (with or without) program averaged over herbicide program, cover crop, and tillage at Marianna, Arkansas in 2019. Means with the same letter are not statistically different (α = 0.05). Zero-tolerance reduced the number of inflorescence-producing Palmer amaranth by 63%.

Evaluation of Multiple Brake Tank-Mixes for Residual Herbicide Efficacy With and Without Pre-Plant Incorporated Valor

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Abstract

As weed accessions with multiple resistance, such as Palmer amaranth (*Amaranthus palmeri* S. Watson), become more prevalent, the use of weed control programs with multiple sites of action is paramount. This trial compares the weed control efficacy of various cotton-compatible residual herbicides, including fluridone, fluometuron, prometryn, acetochlor, and *S*-metolachlor, with and without the addition of pre-plant incorporated (PPI) flumioxazin. Percent control ratings of Palmer amaranth, tall morningglory (*Ipomoea purpurea*), and barnyardgrass (*Echinochloa crus-galli*) were taken weekly, with an average of 9% greater control of Palmer amaranth achieved in plots receiving flumioxazin PPI versus those that did not. Tall morningglory saw an average of 18% greater control for plots receiving flumioxazin PPI compared to plots not receiving flumioxazin. For plots receiving fluridone preemergence (PRE), Palmer amaranth control was increased over plots not receiving fluridone. Plots receiving acetochlor as a PRE application had consistently greater weed control when compared with plots not receiving acetochlor. Yield data were not taken in this trial.

Introduction

The challenge of multiple-resistant weed accessions has put increasing pressure on producers to maintain quantity and quality of harvested yield. With the evolution of glyphosate-resistant species, weed control with a single site of action is becoming increasingly unsustainable. Sosnoskie and Culpepper (2014) indicated that reliance on flumioxazin and fomesafen for weed control increased 10-fold following the introduction of glyphosate-resistant weeds. While relying on herbicide-resistant traits in cotton is predominant and efficacious, including multiple sites of action can slow the evolution of multiple resistance and is a more sustainable approach to weed management. Flumioxazin, formulated as Valor®, is a protoporphyrinogen oxidase inhibitor with both residual and contact weed control capability. It is currently labeled as a postemergence (POST)-directed and layby application in cotton but has not been evaluated for pre-plant incorporated (PPI) efficacy in a cotton production system. In a study by Askew et al. (2002) where flumioxazin was applied pre-plant, but not incorporated, both Palmer amaranth and tall morningglory were completely controlled at 4 weeks after application. Fluridone, formulated as Brake®, is a phytoene desaturase inhibitor with capability for residual weed control and is labeled for use in cotton as a PPI or preemergence (PRE) application. Fluridone contains a unique site of action; therefore, evaluation of this herbicide may reveal an effective addition to weed control programs in cotton. The objective of this research was to determine the weed control of various cotton-compatible residual herbicides with and without the addition of PPI flumioxazin in herbicide programs utilizing glufosinate-resistant cotton.

Procedures

A bare-ground field experiment was conducted in 2019 at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna on a Memphis silt-loam soil with 1.61% organic matter and a pH of 7.2. Plots were 6.1 m long by 2 m wide with a 1.5-m alley. The trial included 4 replications and was arranged as a 2-factor factorial with factor A being herbicide program and factor B as presence of flumioxazin (with or without) applied 30-days PPI (refer to Table 1 for a list of treatments). Factor A included various combinations of fluridone, fluometuron, prometryn, acetochlor, and *S*-metolachlor. The experiment was initiated on a tilled, bare-ground field with PPL treatments applied on 5 June, PRE on 3 July, and POST on 30 July. All herbicides were applied using a CO_2-pressurized backpack sprayer calibrated to deliver 15 gal/ac at 276 kPa using AIXR 110015 spray tips. The trial was rated at 2 weeks after the POST application for visible weed control of Palmer amaranth, barnyardgrass, and tall morningglory on a scale of 0 (no control) to 100 (complete control) weekly following the PRE application timing.

Results and Discussion

Both herbicide combination and use of flumioxazin affected Palmer amaranth control 2 weeks after the POST herbicide application (Table 2). The absence of interactions between the factors indicated that there was not a synergistic or antagonistic effect for herbicides evaluated. Treatments with herbicide programs containing fluridone (treatments 2–9) had greater Palmer amaranth control than treatments with herbicide programs not containing fluridone (treatments 10 and

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11; Table 3). In addition, treatments containing acetochlor PRE (treatments 8 and 9) had greater control of Palmer amaranth than treatments containing fluometuron and prometryn (treatments 10 and 11), and numerically greater control than all other treatments. Similar results were reported by Cahoon et al. (2015) where acetochlor PRE applied alone provided greater control of Palmer amaranth than pendimethalin, fluometuron, diuron, or fomesafen applied alone. Treatments containing only prometryn and fluometuron PRE (treatments 10 and 11) achieved 39% control of Palmer amaranth, which was less control than any other treatment (Table 3). Treatments containing flumioxazin (treatments 3, 5, 6, 7, 9, and 11) also had greater Palmer amaranth control than those without (treatments 1, 2, 3, 5, 8, and 10; Table 4). According to control ratings of barnyardgrass and of morningglory taken 2 weeks after the POST herbicide application, there was a significant main effect of presence of flumioxazin. Treatments containing flumioxazin had greater barnyardgrass and morningglory control than those without flumioxazin.

Practical Applications

Among herbicide programs evaluated, treatments containing fluridone PRE had greater control of Palmer amaranth and barnyardgrass. Only presence of flumioxazin increased control of tall morningglory. Adaptation of fluridone into a weed control program utilizing herbicide-resistant technology in cotton could increase weed control and slow the evolution of herbicide-resistant weeds. Since flumioxazin applied PPL was associated with greater control of all weed species evaluated, addition of flumioxazin as a PPL treatment into weed management programs in cotton could reduce weed emergence, aiding crop yield, quality, and reducing weed seed returned to the soil seedbank.

Literature Cited

Askew, S.D., J.W. Wilcut, and J.R. Cranmer. 2002. Cotton (*Gossypium hirsutum*) and weed response to flumioxazin applied preplant and postemergence directed. Weed Tech. 16:184-190.

Cahoon, C.W., A.C. York, D.L. Jordan, W.J. Everman, R.W. Seagroves, L.R. Braswell, and K.M. Jennings. 2015. Weed control in cotton by combinations of microencapsulated acetochlor and various residual herbicides applied preemergence. Weed Tech. 29:740-750.

Sosnoskie, L.M. and A.S. Culpepper. 2014. Glyphosate-resistant Palmer amaranth (*Amaranthus palmeri*) increases herbicide use, tillage, and hand-weeding in Georgia cotton. Weed Sci. 62:393-402.

Table 1. List of treatments comparing the weed control efficacy of various cotton-compatible residual herbicides for the trial conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Arkansas, in 2019.

Treatment	Valor SX (flumioxazin) PPL†	Brake (fluridone) PRE†	Cotoran (fluometuron) PRE†	Warrant (acetochlor) PRE†	Caparol (prometryn) PRE†	Liberty (glufosinate) POST†	Dual Magnum, (*S*-metolachlor) POST†
	---- lb/ac ----	---------- gal/ac ----------					
1	0‡	0§	0	0	0	0	0
2		0.125				0.25	0.125
3	0.125	0.125				0.25	0.125
4		0.125	0.125			0.25	0.125
5	0.125	0.125	0.125			0.25	0.125
6		0.125	0.1875			0.25	0.125
7	0.125	0.125	0.1875			0.25	0.125
8		0.125		0.25		0.25	0.125
9	0.125	0.125		0.25		0.25	0.125
10			0.25		0.25	0.25	0.125
11	0.125		0.25		0.25	0.25	0.125

†PPL = pre-plant incorporated; PRE = preemergence; POST = postemergence.
‡Rates provided in lb/ac.
§Rates provided in gal/ac.

Table 2. Results of the analysis of variance (ANOVA) for the factorial experiment conducted for control of Palmer amaranth, barnyardgrass, and tall morningglory at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Arkansas, in 2019.

Factors	Palmer amaranth control	Barnyardgrass control	Tall morningglory control
	---*P*-values---		
Herbicide Program	<0.0001†	0.0989	0.2214
Presence of Flumioxazin	0.0207	0.0004	0.0247
Herbicide Program by Presence of Flumioxazin	0.5498	0.8799	0.6594

†*P*-values at or smaller than 0.05 level considered significantly different from the mean.

Table 3. Control of Palmer amaranth, barnyardgrass, and tall morningglory by herbicide programs, averaged over presence or absence of flumioxazin at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Arkansas, in 2019. See Table 1 for the list of treatments.

Treatment No.	Palmer amaranth control	Barnyardgrass control	Tall morningglory control
Treatments 2 and 3	69 a†	80 ab	59 a
Treatments 4 and 5	75 a	85 ab	71 a
Treatments 6 and 7	78 a	86 a	72 a
Treatments 8 and 9	80 a	88 a	72 a
Treatments 10 and 11	39 b	75 b	54 a

†Means followed by the same letter are not significantly different.

Table 4. Control of Palmer amaranth, barnyardgrass, and tall morningglory with and without flumioxazin averaged over other evaluated herbicides at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Arkansas, in 2019. See Table 1 for list of treatments.

	Palmer amaranth control	Barnyardgrass control	Tall morningglory control
With flumioxazin	73 a†	89 a	73 a
Without flumioxazin	63 b	77 b	58 b

†Means followed by the same letter are not significantly different.

Optimizing Postemergence Options in XtendFlex® Systems Using Dicamba, Glufosinate and Glyphosate

J.A. Patterson,[1] J.K. Norsworthy,[1] G.L. Priess,[1] and R.B. Farr[1]

Abstract

Palmer amaranth (*Amaranthus palmeri* S. Wats.) is one of the most problematic and troublesome weeds in mid-South cotton. Resistance to many herbicide sites of action (SOA) poses the need for further research to find ways to effectively control Palmer amaranth. In 2019, two field experiments were conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas, and at an on-farm site near Crawfordsville, Arkansas. The experiments were implemented as one-factor randomized complete block designs with four replications. The objective of the experiments was to determine if the timing of sequential applications of dicamba and glufosinate and the addition of glyphosate can be optimized to provide better Palmer amaranth control than dicamba or glufosinate alone. Single application treatments included these herbicides: Xtendimax (dicamba), Xtendimax + Roundup (glyphosate), Liberty (glufosinate), Liberty + Xtendimax, and Liberty + Xtendimax + Roundup. Sequential application treatments included Xtendimax followed by (fb) Liberty at 4 hours after and 14 days after, Xtendimax + Roundup fb Liberty at 4 hours after and 14 days after, and Liberty fb Xtendimax or Xtendimax + Roundup at 4 hours after and 14 days after. In Crawfordsville, four weeks after the sequential applications, treatments containing sequential applications of dicamba, fb glufosinate or glufosinate fb dicamba 14 days after provided >90% Palmer amaranth control and were the most effective treatments. In Marianna, four weeks after the sequential applications, treatments containing sequential applications of dicamba fb glufosinate, dicamba + glyphosate fb glufosinate, and glufosinate fb dicamba + glyphosate 14 days later all provided >95% Palmer amaranth control. Overall, dicamba fb glufosinate at the 14-day interval provided comparable or better control than all other treatments. These results suggest that the use of two effective SOA for postemergence control of Palmer amaranth will aid in providing some safety against the evolution of target site herbicide resistance.

Introduction

Palmer amaranth is one of the most common, troublesome, and economically damaging agronomic weeds throughout the southern United States (Ward et al., 2013). Because of Palmer amaranth's resilient nature, and its capacity to evolve resistance to many commonly used herbicides, it is imperative that management decisions are focused on preventing Palmer amaranth from reaching reproductive maturity. Overreliance on a single site of action (SOA) has facilitated the evolution of resistance to many herbicides and has become commonplace (Norsworthy et al., 2012). Present-day producers are tasked with managing Palmer amaranth with multiple resistance to seven SOA (Heap, 2020). One of the most effective tactics for combating herbicide resistance evolution is the use of multiple effective SOA for season-long weed control (Norsworthy et al., 2012). XtendFlex® cotton is resistant to dicamba, glufosinate, and glyphosate. These resistance traits allow mid-South cotton producers to broaden their postemergence herbicide options to combat herbicide resistance. However, due to label restrictions in Arkansas, dicamba, glufosinate, and glyphosate cannot be legally mixed. Therefore, it is imperative that research is conducted to evaluate how postemergence sequential applications of dicamba, glufosinate, and glyphosate can be optimized to effectively control Palmer amaranth.

Procedures

In 2019, two field experiments were conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas and at an on-farm site near Crawfordsville, Arkansas. The experiments were implemented as one-factor randomized complete block designs with four replications. The herbicides used in the experiments were Xtendimax (dicamba), Liberty (glufosinate), and Roundup (glyphosate), and were applied alone, sequentially, or in various combinations. To inhibit further weed emergence, a broadcast application of Dual Magnum (*S*-metolachlor) at 21 fl oz/ac was made at the time of experiment initiation. Additionally, to keep the experiments free of gramineous weed species, applications of Select Max (clethodim) were made as needed. A complete list of treatments can be found in Table 1. In Marianna, applications were made to 8- to 10-in. Palmer amaranth at a density of 64 plants/yd^2. The first applications were made

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on 15 May followed by sequential applications at either 4 hours after or 14 days after. In Crawfordsville, applications were made to 2- to 4-in. tall Palmer amaranth at a density of 985 plants/yd^2. The first applications were made on 13 May followed by sequential applications at either 4 hours after or 14 days after. Experimental plots measured 6.3 ft wide (2-rows) by 20 ft long. All herbicide applications were made utilizing a CO_2-pressurized backpack calibrated to deliver 15 gallons per acre (GPA). Visible Palmer amaranth control assessments were collected 28 days after the final application for each treatment. The Marianna and Crawfordsville locations were analyzed separately due to the differences in Palmer amaranth size and density present. All data were analyzed using JMP Pro 14.2 and subjected to analysis of variance. Means were separated using Fisher's protected least significant difference ($\alpha = 0.05$).

Results and Discussion

For the Crawfordsville location, there was a significant herbicide treatment effect ($P < 0.0001$) at 28 days after the sequential applications. Treatments containing sequential applications of Xtendimax followed by (fb) Liberty (14 days after) or Liberty fb dicamba (14 days after) provided >90% Palmer amaranth control and were the most effective treatments (Table 2). For the Marianna location, there was a significant herbicide treatment effect ($P < 0.0001$) at 28 days after the sequential applications. Treatments containing sequential applications of Xtendimax fb Liberty (14 days after), Xtendimax + Roundup fb Liberty (14 days after), and Liberty fb Xtendimax + Roundup (14 days after) provided >95% Palmer amaranth control. Overall, Xtendimax fb Liberty at the 14-day interval provided comparable or better control than all other treatments. These findings indicate that the use of timely sequential applications of Xtendimax and Liberty with or without the addition of Roundup can optimize postemergence control of Palmer amaranth. Additionally, the use of two effective SOA will aid in providing some safety against the evolution of herbicide resistance.

Practical Applications

Resistance management practices such as the use of multiple effective SOA should be implemented to alleviate the risk for the evolution of herbicide resistance. Current label restrictions in Arkansas do not allow dicamba, glufosinate, and glyphosate to be legally mixed for Palmer amaranth control in XtendFlex® cotton. Consequently, these herbicides must be applied separately. If sequential applications of dicamba and glufosinate are made in a timely manner, optimal control of Palmer amaranth can be achieved.

Acknowledgments

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Literature Cited

Heap, I.M. 2020. International survey of herbicide resistant weeds. Weed Science Society of America. Accessed on 3 March 2020. Available at: www.weedscience.org

Norsworthy, J.K., S.M. Ward, D.R. Shaw, R. Llewellyn, R.L. Nichols, T.M. Webster, K. W. Bradley, G. Frisvold, S.B. Powles, N.R. Burgos, W. Witt, and M. Barrett. 2012. Reducing the risks of herbicide resistance: Best management practices and recommendations. Weed Sci. 60 (SI I):31–62.

Ward, S.M., T.M. Webster, and L.E. Steckel. 2013. Palmer amaranth (Amaranthus palmeri): a review. Weed Tech. 27:12–27.

Table 1. List of herbicide treatments, sequential application timings, and rates used in Palmer amaranth tests at Marianna and Crawfordsville, Arkansas in 2019.

Herbicide Treatment†	Sequential Application Interval‡	Rate
		(fl oz/ac)
Nontreated	--	--
Liberty	--	32
Xtendimax	--	22
Xtendimax + Roundup	--	22 + 32
Liberty + Xtendimax	--	32 + 22
Xtendimax + Roundup + Liberty	--	22 + 32 + 32
Liberty fb Xtendimax	4 hours after	32 22
Liberty fb Xtendimax	14 days after	32 22
Liberty fb Xtendimax + Roundup	4 hours after	32 22 + 32
Liberty fb Xtendimax + Roundup	14 days after	32 22 + 32
Xtendimax fb Liberty	4 hours after	22 32
Xtendimax fb Liberty	14 days after	22 32
Xtendimax + Roundup fb Liberty	4 hours after	22 + 32 32
Xtendimax + Roundup fb Liberty	14 days after	22 + 32 32

†Abbreviations: fb = followed by.
‡Time interval between sequential applications.

Table 2. Visible Palmer amaranth control assessments 28 days after sequential applications near Crawfordsville and Marianna in 2019. See Table 1 for explanation of herbicide treatments.

	Palmer amaranth Control 28 DAT†	
Herbicide Treatment (sequential application interval)‡	**Crawfordsville**	**Marianna**
	----------%----------	
Nontreated	--	--
Liberty	55 gh§	61 d
Xtendimax	59 fgh	76 c
Xtendimax + Roundup	83 bcd	74 c
Liberty + Xtendimax	59 fgh	60 de
Xtendimax + Roundup + Liberty	79 de	43 f
Liberty fb Xtendimax (4 hours after)	58 fgh	60 de
Liberty fb Xtendimax (14 days after)	95 ab	86 b
Liberty fb Xtendimax + Roundup (4 hours after)	70 def	56 de
Liberty fb Xtendimax + Roundup (14 days after)	80 cd	98 a
Xtendimax fb Liberty (4 hours after)	48 h	51 ef
Xtendimax fb Liberty (14 days after)	93 abc	100 a
Xtendimax + Roundup fb Liberty (4 hours after)	65 efg	60 de
Xtendimax + Roundup fb Liberty (14 days after)	98 a	100 a

†days after treatment (DAT).
‡Abbreviations: fb = followed by.
§Letters within a column are used to separate means. Data with the same letters are not significantly different.

Optimizing Timing Between Sequential Applications of Dicamba and Glufosinate

G.L. Priess,[1] J.K. Norsworthy,[1] L.T. Barber,[2] and M.C. Castner[1]

Abstract

Fexapan®, Xtendimax® with VaporGrip®, and Engenia® labels do not allow for dicamba and glufosinate to be applied in mixture over-the-top of XtendFlex™ cotton. Field experiments were conducted in 2019, in Crawfordsville, Marianna, and Keiser, Arkansas, to evaluate the efficacy of dicamba followed by glufosinate and glufosinate followed by dicamba when applied at 0.2- (3 hours), 3-, 7-, 14-, and 21-day intervals from the initial application on native Palmer amaranth populations. Field experiments were conducted to assess if the interval between sequential applications could be optimized to improve weed control when compared to dicamba and glufosinate postemergence (POST) herbicide programs. In two of the three experiments where Palmer amaranth weed size was greater than 5 inches at application, dicamba followed by glufosinate at the 14-day interval provided consistently greater control than either sequence of dicamba and glufosinate at 0.2-, 3- and 7-day intervals. Overall, dicamba followed by glufosinate at the 14-day interval provided equal or greater control than dicamba followed by dicamba or glufosinate followed by glufosinate at any interval. The addition of two effective modes of action for POST control of Palmer amaranth will mitigate the evolution of target-site herbicide resistance and aid in preservation of currently available technologies.

Introduction

The commercial launch and wide adoption of XtendFlex™ cotton, resistant to dicamba, glufosinate, and glyphosate, enables producers to use these herbicides in season. In the past, overreliance on a single site of action (SOA) perpetuated the evolution of herbicide resistance (Norsworthy et al., 2012). Now producers are faced with troublesome weeds like Palmer amaranth with multiple resistance to eight SOA (Heap, 2020). Prior research has shown that utilizing two effective SOA in mixture or rotation will reduce the likelihood of the evolution of target-site herbicide resistance (Norsworthy et al., 2012). Some interactions between dicamba and glufosinate have been evaluated such as glufosinate in mixture with dicamba (Chahal and Johnson, 2012; Vann et al., 2017). The results in the literature mentioned above were variable and exclusive to individual weed species. However, the label restrictions prohibit the mixture of dicamba and glufosinate (Anonymous, 2018). Therefore, additional research is needed to understand how to optimize the efficacy of dicamba and glufosinate when applied sequentially.

Procedures

Field experiments were conducted in 2019, utilizing the treatment list in Table 1. In 2019, this experiment was conducted at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center at Keiser, at a grower's field near Crawfordsville, and at the Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Arkansas. Treatments were initiated, without a crop present, to native Palmer amaranth populations at each location. Plot size at all locations was 6.33 ft wide and 20 ft long with four replications. Applications of each herbicide were made with separate hand-held CO_2-pressurized backpack sprayers calibrated to deliver 15 gal/ac of spray solution at 3 mph, to avoid any herbicide contamination. Dicamba applications were made with TTI 110015-VP (TeeJet, Springfield, Ill.) to abide by the label requirement of an ultra-course droplet (Anonymous, 2018). Glufosinate applications were made with an AIXR 110015-VP (TeeJet, Springfield, Ill.) to attempt to maximize glufosinate efficacy while minimizing drift across plots. The mixture of dicamba + glufosinate was made with a TTI 110015-VP nozzle. Prior to the first herbicide applications, a broadcast application of either dimethenamid-P or *S*-metolachlor was made to inhibit any Palmer amaranth emergence. Dimethenamid-P or *S*-metolachlor was reapplied on a biweekly interval until all assessments were finished. Palmer amaranth control was rated 28 days after the final application in each treatment.

Data were subjected to an analysis of variance in JMP 14.1 (SAS Institute, Inc., Cary, N.C.) and site years were analyzed separately due to varying weed size at each location (Crawfordsville, 3-in. tall Palmer amaranth; Keiser, 7-in. tall Palmer amaranth; Marianna, 8-in. tall Palmer amaranth). Means were separated using Fisher's least significant difference ($\alpha = 0.05$).

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Results and Discussion

Sequential applications of dicamba and glufosinate can be effective if timed properly. When glufosinate was applied 4 hours prior to dicamba, Palmer amaranth efficacy ranged from 41% to 72% (data not shown), thus this treatment is not a viable option for Palmer amaranth control. Overall, when the time interval between sequential applications of dicamba and glufosinate was increased to 14 days, Palmer amaranth efficacy was generally optimized (Figs. 1–3). The sequential application of dicamba followed by glufosinate 14 days later provided equal or greater control than the dicamba or glufosinate system alone and provided greater control than glufosinate followed by dicamba at all time intervals.

Practical Applications

Dicamba and glufosinate should not be applied in sequence of one another in time periods shorter than 14 days. To increase Palmer amaranth efficacy and utilize two effective SOA, dicamba should be applied 14 days prior to a glufosinate application. One-hundred percent control was observed only when dicamba followed by glufosinate at the 14 day interval was applied to 3-in. tall Palmer amaranth. Timing of postemergence herbicide applications in the XtendFlex system is still of the utmost importance.

Acknowledgments

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Literature Cited

Anonymous. 2018. XtendiMax® with VaporGrip® herbicide label. Monsanto Publication 35008S7-05 St. Louis, Missouri.

Heap, I.M. 2020. International survey of herbicide resistant weeds. Weed Science Society of America. Accessed March 2019. Available at: www.weedscience.org

Norsworthy, J.K., S.M. Ward, D.R. Shaw, R. Llewellyn, R.L. Nichols, T.M. Webster, K.W. Bradley, G. Frisvold, S.B. Powles, N.R. Burgos, W. Witt, and M. Barrett. 2012. Reducing the risks of herbicide resistance: Best management practices and recommendations. Weed Sci. 60 (Special Issue I):31–62.

Chahal, G.S. and W.G. Johnson. 2012. Influence of glyphosate or glufosinate combinations with growth regulator herbicides and other agrochemicals in controlling glyphosate-resistant weeds. Weed Tech. 26:638–643.

Vann, R.A., A.C. York, C.W. Cahoon, C.B. Buck, M.C. Askew, and R.W. Seagroves. 2017. Glufosinate plus dicamba for rescue Palmer amaranth control in XtendFlex™ cotton. Weed Tech. 31:666–674.

Table 1. Experimental treatments, including herbicides, herbicide rate, and the time interval between the sequential herbicide applications.

Herbicide	Rate	Time interval between sequential applications
Nontreated	-	-
Dicamba	0.5 lb ae/ac	-
Glufosinate	0.59 lb ai/ac	-
Dicamba + glufosinate	0.5 lb ae/ac + 0.59 lb ai/ac	-
Dicamba fb dicamba	0.5 lb ae/ac fb[a] 0.5 lb ai/ac	7, 14, and 21 days
Glufosinate fb glufosinate	0.59 lb ai/ac fb 0.59 lb ai/ac	7, 14, and 21 days
Dicamba fb glufosinate	0.5 lb ae/ac fb 0.59 lb ai/ac	6 hours, 3, 7, 14, and 21 days
Glufosinate fb dicamba	0.59 lb ai/ac fb 0.5 lb ae/ac	6 hours, 3, 7, 14, and 21 days

[a]fb = followed by.

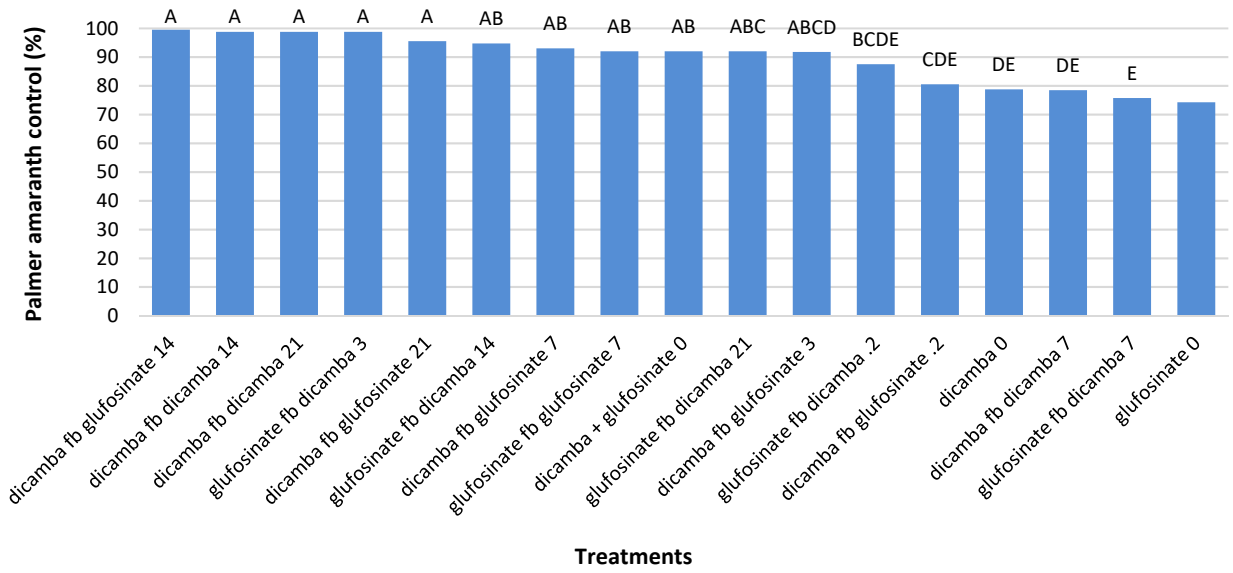

Fig. 1. Percent control of 3-in. tall Palmer amaranth provided by treatments at Crawfordsville, Arkansas, in 2019. The treatments are listed by herbicide A followed by herbicide B. The subsequent number represents the time interval in days between sequential applications.

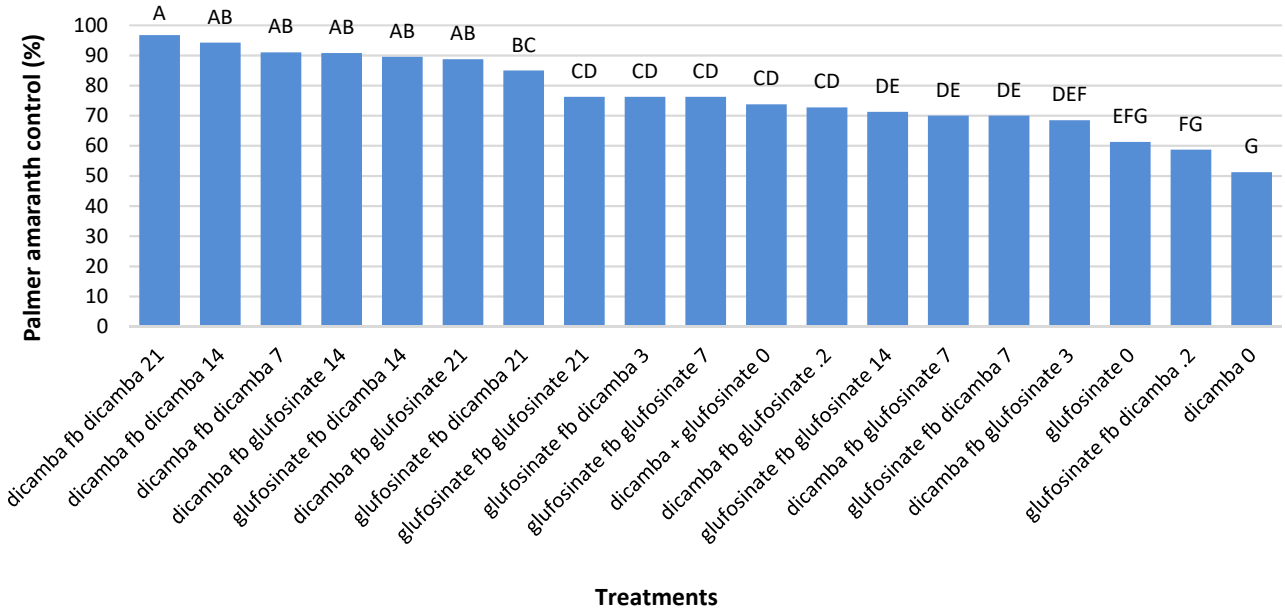

Fig. 2. Percent control of 7-in. tall Palmer amaranth provided by treatments at Keiser, Arkansas, in 2019. The treatments are listed by herbicide A followed by herbicide B. The subsequent number represents the time interval in days between sequential applications.

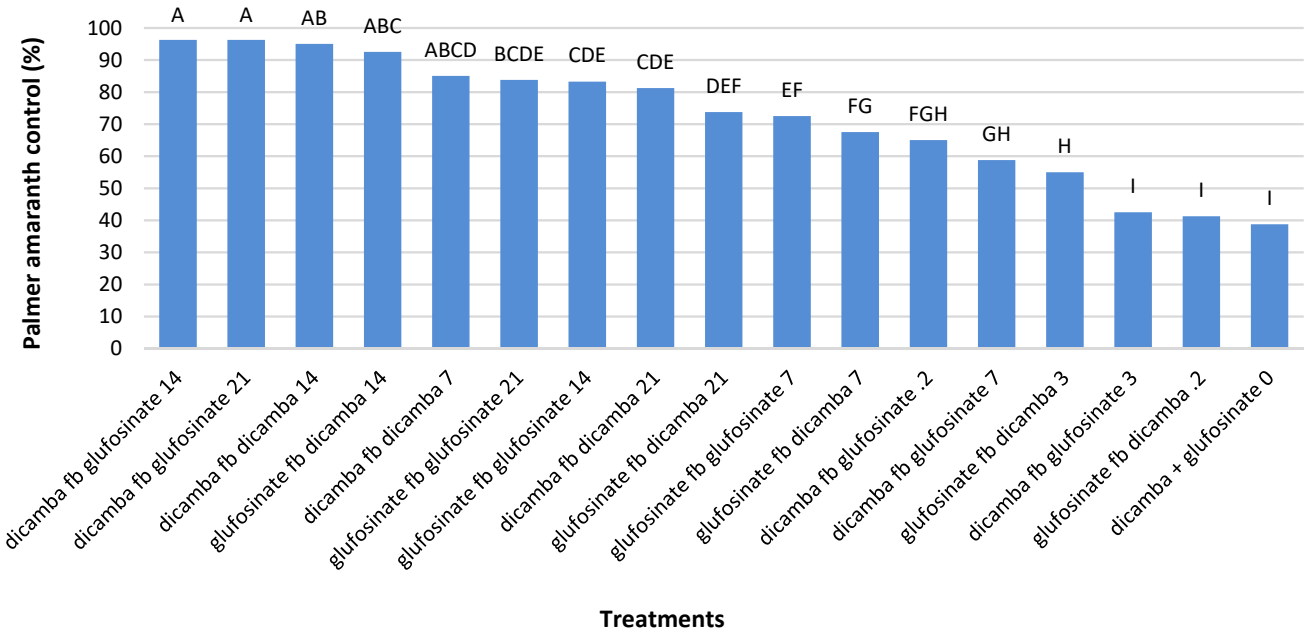

Fig. 3. Percent control of 8-in. tall Palmer amaranth provided by treatments, at Marianna, Arkansas, 2019. The treatments are listed by herbicide A followed by herbicide B. The subsequent number represents the time interval in days between sequential applications.

Managing Thrips in Mid-South Cotton

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Abstract

Thrips are a major pest of cotton in the mid-South, with the dominant species being tobacco thrips. Studies were conducted across the region to evaluate selected at-planting and foliar insecticide treatments against thrips infesting cotton seedlings. At most locations, thrips densities were low to moderate in the at-planting treatment trials. With few exceptions, the at-planting treatments reduced thrips densities and damage ratings from the first to the fourth true leaf stage compared to the control (fungicide only). Also, all of the insecticide treatments resulted in higher yields compared to the control (fungicide only). In the foliar insecticide trials, most insecticide treatments, except the pyrethroid Karate, reduced thrips densities and damage from 3 DAT to 14 DAT. At 6–7 DAT and at 10–11 DAT, Acephate performed similarly to Intrepid Edge and Radiant. No differences in yield were observed in the foliar insecticide trials. In general, the in-furrow insecticide treatments worked better than the insecticide seed treatments alone.

Introduction

There are several species of thrips that infest cotton seedlings including tobacco thrips, *Frankliniella fusca* (Hinds); western flower thrips, *F. occidentalis* (Pergande); flower thrips, *F. tritici* (Fitch); onion thrips, *Thrips tabaci* (Lindeman); and soybean thrips, *Neohydatothrips variabilis* (Beach). Tobacco thrips is the predominant species that infests cotton seedlings across much of the mid-South (Cook et al., 2003; Stewart et al., 2013). Aldicarb[10] (Temik 15G) was the standard at-planting management strategy prior to the introduction of the neonicotinoid seed treatments. Many growers transitioned to the neonicotinoid seed treatments following their introduction. Following the removal of aldicarb from the market, thrips have been managed almost exclusively with neonicotinoid seed treatments and supplemental foliar treatments. The two most widely used insecticide seed treatments for thrips management in cotton have been Gaucho (imidacloprid) and Cruiser (thiamethoxam), both are neonicotinoids. However, resistance to thiamethoxam has been observed in tobacco thrips populations from many areas of the mid-South (Huseth et al., 2016; Darnell-Crumpton et al., 2018). Consequently, performance of thiamethoxam has declined to the point that it is no longer offered as a commercial seed treatment for thrips control in the mid-South. Currently, almost all of the commercial (from seed companies) seed treatment packages include imidacloprid. Another aldicarb product (AgLogic 15G) was introduced into the market in recent years. Many growers are supplementing neonicotinoid seed treatments (imidacloprid) with Acephate either as an additional seed treatment or in-furrow spray, or have started using aldicarb again. One reason these are preferred over supplemental foliar applications for thrips management is that some of the newer transgenic herbicide (dicamba-tolerant crops) technologies do not allow co-application of an insecticide with dicamba. However, in some cases, supplemental foliar applications are needed. Acephate has been the standard foliar thrips treatment for decades, but less than satisfactory performance has been observed in some cases. In response, some growers are using spinetoram, either as Radiant or Intrepid Edge, for supplemental foliar thrips management. During 2019, studies were conducted in Arkansas, Louisiana, Mississippi, Tennessee, and Texas to evaluate the performance of selected seed treatments

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containing imidacloprid (Gaucho, Aeris), AgLogic 15G, and Acephate as a seed treatment and as an in-furrow spray treatment (alone and in combination with Gaucho) against thrips infesting cotton seedlings in the mid-South. Additionally, the performance of selected foliar treatments was evaluated in Tennessee, Mississippi, and Texas. These included the representative products from the organophosphate, spinosyn, pyrethroid, and carbamate insecticide classes.

Procedures

Studies were conducted during 2019 in Arkansas, Louisiana, Mississippi, Tennessee, and Texas to evaluate the performance of selected insecticide at-planting treatments against thrips in cotton. Treatments were arranged in a randomized complete block design with four replications. The variety PHY 333 WRF cotton seed was used in all trials. Cotton seed were treated at the University of Arkansas System Division of Agriculture's Lonoke Extension Center, Lonoke, Arkansas. All seed was treated with Trilex Advanced 300FS (1.6 oz/cwt) fungicide. Additionally, trials were conducted to evaluate the performance of selected foliar insecticides against thrips. These trials were conducted in Mississippi, Tennessee, and Texas. Cotton seed that did not have an insecticide seed treatment (DP 1646 B2XF in Mississippi, PHY 350 W3FE in Tennessee, and NG 3956 B3XF in Texas) was used in the foliar insecticide trials. Foliar treatments were applied at 10 gal/ac and trials were initiated at the first to second true leaf stage, depending on location. AgLogic was included as an at-planting comparison. Frequent rainfall occurred across the mid-South during April and May 2019 which delayed planting at several locations. Planting dates ranged from 30 April to 28 May for the insecticide seed treatment trials and from 7 May to 14 June for the foliar trials.

Thrips densities in the insecticide seed treatment trials were determined by sampling 5 plants per plot at the 1, 2, 3, and 4 leaf stage using a modified whole plant washing procedure. Thrips densities in the foliar trials were determined using the same method at 3, 6–7, 10–11, and 14 days after treatment (DAT) (foliar application). Also, plant damage was estimated at these timings using a 1–5 scale, with a rating of 1 = no damage to 5 = severe damage. Plots were machine harvested at crop maturity. Seedcotton yields were converted to lint yield based on 40% gin turnout. Data were subjected to analysis of variance procedures, with means separated according to Fisher's protected least significant difference.

Results and Discussion

At-Planting Treatment Trials

At the first true leaf stage, there were no differences among treatments for densities of thrips adults (Table 1). No significant treatment by location interaction was observed for any measurements. All of the insecticide treatments resulted in lower densities of thrips immatures and total thrips compared to the fungicide-only treatment, except for Acephate in-furrow for total thrips. Also plots treated with Acephate seed treatment, Acephate seed treatment plus Gaucho, Gaucho, Aeris, or Acephate in-furrow plus Gaucho had lower densities of immature and total thrips than plots treated with Acephate in-furrow. Only plots treated with Acephate seed treatment, Acephate seed treatment plus Gaucho, Gaucho, Aeris, or Acephate in-furrow plus Gaucho had lower thrips damage ratings compared to plots that did not receive an at-planting insecticide treatment (fungicide only). Thrips damage ratings for all insecticide treated plots, except Acephate in-furrow, were ≤1.6.

At the second true leaf stage, there were no differences among treatments for densities of thrips adults (Table 2). All of the insecticide treatments, except Acephate in-furrow, resulted in lower densities of thrips immatures compared to the fungicide-only treatment. Plots treated with Gaucho, Aeris, or Acephate in-furrow plus Gaucho had fewer thrips immatures compared to plots treated with Acephate seed treatment, or Acephate in-furrow. All of the insecticide treated plots had fewer total thrips compared to the plots that only received the fungicide seed treatment. Also, plots treated with Gaucho had fewer thrips immatures compared to plots treated with Acephate (either as a seed treatment or in-furrow). All of the insecticide treatments resulted in lower damage ratings compared to the fungicide-only treatment. Gaucho and Acephate in-furrow plus Gaucho resulted in lower damage ratings than Acephate applied as a seed treatment or in-furrow. Thrips damage ratings for all insecticide treated plots were ≤1.1.

At the third true leaf stage, there were no differences among treatments for densities of thrips adults (Table 3). All of the insecticide treatments resulted in lower densities of thrips immatures and total thrips compared to the fungicide-only treatment. Also, all of the insecticide treatments resulted in less thrips damage compared to the fungicide-only treatment. Plots treated with Acephate in-furrow or AgLogic had higher damage ratings compared all of the other insecticide treated plots, except those treated with Acephate as a seed treatment. Thrips damage ratings for all insecticide treated plots were ≤1.6.

At the fourth true leaf stage, there were no differences among treatments for densities of thrips adults (Table 4). All of the insecticide treatments resulted in lower densities of thrips immatures and total thrips compared to the fungicide-only treatment. Plots treated with AgLogic or Acephate in-furrow plus Gaucho had fewer immature thrips compared to plots treated with Aeris or Admire Pro. Also, plots treated with AgLogic had fewer total thrips compared to plots treated with Acephate as a seed treatment, Gaucho, Aeris, or Admire Pro. Also, all of the insecticide treatments, except Acephate seed treatment, resulted in less thrips damage compared to the fungicide-only treatment. Plots treated with Aeris or Acephate in-furrow plus Gaucho had lower damage ratings compared to plots treated with Acephate seed treatment, AgLogic, or Acephate in-furrow. Thrips damage ratings for all insecticide treated plots were ≤1.8.

All of the insecticide treatments resulted in higher lint yields compared to the fungicide-only treatment (Table 5). Yields for insecticide treated plots ranged from 1,237 lb to 1,279 lb lint per acre.

Foliar Treatment Trials

No significant treatment by location interaction was observed for foliar insecticide seed treatments. Only Radiant, Vydate, and AgLogic reduced thrips adults compared to the non-treated control at 3 DAT (Table 6). All of the insecticide treatments, except Karate, reduced densities of immature thrips and total thrips compared to the non-treated control. Plots treated with Radiant or AgLogic had fewer immature thrips and total thrips than plots treated with Acephate or Karate. All of the insecticide treatments resulted in lower damage ratings compared to the non-treated control.

All of the insecticide treatments, except Karate, resulted in lower densities of thrips adults compared to the non-treated at 6–7 DAT (Table 7). All of the insecticide treatments, except Karate, reduced densities of immature thrips and total thrips compared to the non-treated control. Plots treated with Radiant or Intrepid Edge had fewer immature thrips than plots treated with Dimethoate. All of the insecticide treatments, except Karate, resulted in lower damage ratings compared to the non-treated control. Plots treated with Radiant, Intrepid Edge, or AgLogic had lower damage ratings than plots treated with Acephate or Karate.

There were no differences among treatments for densities of thrips adults at 10–11 DAT (Table 8). All of the insecticide treatments, except Karate, reduced densities of immature and total thrips compared to the non-treated control. All of the insecticide treatments reduced thrips damage compared to the non-treated control. Also, plots treated with Intrepid Edge, Radiant, Acephate, or AgLogic had lower damage ratings than plots treated with Bidrin or Vydate.

At 14 DAT, only plots treated with Acephate, Karate, or AgLogic had fewer adult thrips than the non-treated plots (Table 9). Only plots treated with Intrepid Edge, Radiant, Acephate, or AgLogic had fewer immature thrips compared to the non-treated plots. All of the insecticide treatments, except Karate and Bidrin, reduced densities of total thrips compared to the non-treated control. Also, plots treated with AgLogic had fewer total thrips than plots treated with Bidrin, Dimethoate, Karate, or Vydate. All of the insecticide treatments reduced thrips damage compared to the non-treated control. Plots treated with Vydate or Karate had higher damage ratings compared to Radiant, Acephate, or AgLogic. AgLogic resulted in lower damage ratings compared to all of the other insecticides

There were no differences among treatments for yield (Table 10). Lint yields ranged from 1,060 lb to 1,207 lb per acre.

Practical Applications

Thrips management in cotton is essential for maintaining yield and earliness in cotton. With developing issues in herbicide management, insecticide resistance and profitability, determining best management practices for controlling this pest continue to evolve. Evaluating different ways to control thrips helps make better recommendations. In-furrow insecticides, such as acephate, are a good alternative to insecticide seed treatments.

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Literature Cited

Cook, D.R., C.T. Allen, E. Burris, B.L. Freeman, G.A. Herzog, G.L. Lentz, B.R. Leonard, and J.T. Reed. 2003. A survey of thrips (*Thysanoptera*) species infesting cotton seedlings in Alabama, Arkansas, Georgia, Louisiana, Mississippi, and Tennessee. J. Ento. Sci. 38:669-681.

Darnell-Crumpton, C., A.L. Catchot, D.R. Cook, J. Gore, D.M. Dodds, S.C. Morsello, and F. Musser. 2018. Neonicotinoid insecticide resistance in tobacco thrips (Thysanoptera: Thripidae) of Mississippi. J. Econ. Ento. https://dx.doi.org/10.1093/jee/toy298

Huseth, A.S, T.M. Chappell, K. Langdon, S.C. Morsello, S. Martin, J.K. Greene, A. Herbert, A.L. Jacobson, F.P. F. Reay-Jones, T. Reed, D.D. Reisig, P.M. Roberts, R. Smith, and G.G. Kennedy. 2016. *Frankliniella fusca* resistance to neonicotinoid insecticides: an emerging challenge for cotton pest management in the eastern United States. Pest Mang. Sci. 72:1934-1945.

Stewart, S.D., D.S. Akin, J. Reed, J. Bacheler, A. Catchot, D. Cook, J. Gore, J. Greene, A. Herbert, R.E. Jackson, D. L. Kerns, B.R. Leonard, G.M. Lorenz, S. Micinski, D. Reisig, P. Roberts, G. Studebaker, K. Tindall, and M. Toews. 2013. Survey of thrips species infesting cotton across the Southern U.S. cotton belt. J. Cotton Sci. 17: 263-269.

Table 1. Impact of selected at-planting treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 1-leaf growth stage in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	Application	Rate	Thrips/5 Plants			Damage Rating
			Adults	Immatures	Total	
Fungicide only	Seed Treatment	-	2.0	21.9 a	23.9 a	2.2 a
Acephate 97S	Seed Treatment	6.4†	1.9	3.2 c	5.1 c	1.4 bc
Acephate 97S + Gaucho 5FS	Seed Treatment	6.4† + 0.375‡	1.9	1.1 c	2.9 c	1.3 bc
Gaucho 5FS	Seed Treatment	0.375‡	1.8	0.8 c	2.4 c	1.4 bc
Aeris§	Seed Treatment	0.75‡	3.0	0.9 c	3.9 c	1.0 c
AgLogic 15G	In-Furrow Granule	0.6¶	3.3	8.0 bc	11.3 bc	1.6 ab
Acephate 97S +	In-Furrow Spray +	1.0# + 0.375‡	1.4	0.8 c	2.2 c	1.0 c
Acephate 97S	In-Furrow Spray	1.0#	3.3	11.9 b	15.1 ab	2.1 a
Admire Pro	In-Furrow Spray	0.33#	2.1	3.2 bc	5.9 bc	1.4 bc
P > F			0.18	<0.01	<0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†oz wt product/cwt.
‡mg ai/seed.
§mg ai/seed. Aeris applied at the listed rate contains 0.375 mg ai imidacloprid (Gaucho) and 0.375 mg ai thiodicarb.
¶lb ai/ac, in-furrow granule.
#lb ai/ac, in-furrow spray.

Table 2. Impact of selected at-planting treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 2-leaf growth stage in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	Application Method	Rate	Thrips/5 Plants			Damage Rating
			Adults	Immatures	Total	
Fungicide only	Seed Treatment	-	3.3	23.8 a	27.1 a	1.7 a
Acephate 97S	Seed Treatment	6.4†	3.0	11.4 bc	14.4 bc	1.0 bc
Acephate 97S + Gaucho 5FS	Seed Treatment	6.4† + 0.375‡	3.0	2.2 cd	5.2 cd	0.7 cd
Gaucho 5FS	Seed Treatment	0.375‡	2.6	1.7 d	4.2 d	0.7 cd
Aeris§	Seed Treatment	0.75‡	3.3	1.9 d	5.2 cd	0.6 d
AgLogic 15G	In-Furrow Granule	0.6¶	2.1	2.8 cd	4.9 cd	0.8 cd
Acephate 97S +	In-Furrow Spray +	1.0# + 0.375‡	3.5	2.0 d	5.5 cd	0.6 d
Acephate 97S	In-Furrow Spray	1.0#	2.1	15.1 ab	17.1 b	1.1 b
Admire Pro	In-Furrow Spray	0.33#	2.4	4.9 cd	7.3 bcd	0.8 cd
P > F			0.63	<0.01	<0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†oz wt product/cwt.
‡mg ai/seed.
§mg ai/seed. Aeris applied at the listed rate contains 0.375 mg ai imidacloprid (Gaucho) and 0.375 mg ai thiodicarb.
¶lb ai/ac, in-furrow granule.
#lb ai/ac, in-furrow spray.

Table 3. Impact of selected at-planting treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 3-leaf growth stage in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	Application Method	Rate	Thrips/5 Plants			Damage Rating
			Adults	Immatures	Total	
Fungicide only	Seed Treatment	-	4.6	33.3 a	38.0 a	2.6 a
Acephate 97S	Seed Treatment	6.4†	3.8	16.0 b	19.8 b	1.5b c
Acephate 97S + Gaucho 5FS	Seed Treatment	6.4† + 0.375‡	4.0	13.3 b	17.3 b	1.1c d
Gaucho 5FS	Seed Treatment	0.375‡	4.5	12.5 b	17.0 b	1.1 cd
Aeris§	Seed Treatment	0.75‡	4.2	11.0 b	15.2 b	1.0 d
AgLogic 15G	In-Furrow Granule	0.6¶	4.0	11.1 b	15.0 b	1.6 b
Acephate 97S +	In-Furrow Spray + Seed	1.0# +	3.8	8.9 b	12.7 b	1.1 cd
Acephate 97S	In-Furrow Spray	1.0#	3.1	16.5 b	19.6 b	1.6 b
Admire Pro 4.6SC	In-Furrow Spray	0.33#	3.5	10.5 b	14.0 b	1.1 cd
P > F			0.87	<0.01	<0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†oz wt product/cwt.
‡mg ai/seed.
§mg ai/seed. Aeris applied at the listed rate contains 0.375 mg ai imidacloprid (Gaucho) and 0.375 mg ai thiodicarb.
¶lb ai/ac, in-furrow granule.
#lb ai/ac, in-furrow spray.

Table 4. Impact of selected at-planting treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 4-leaf growth stage in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	Application Method	Rate	Thrips/5 Plants			Damage Rating
			Adults	Immatures	Total	
Fungicide only	Seed Treatment	-	5.0	31.5 a	36.5 a	2.0 a
Acephate 97S	Seed Treatment	6.4†	4.2	17.7 bc	21.9 b	1.8 ab
Acephate 97S + Gaucho 5FS	Seed Treatment	6.4† + 0.375‡	4.2	13.0 bc	16.8 bc	1.3 de
Gaucho 5FS	Seed Treatment	0.375‡	4.3	17.5 bc	21.8 b	1.5 cde
Aeris§	Seed Treatment	0.75‡	4.8	17.8 b	22.5 b	1.2 e
AgLogic 15G	In-Furrow Granule	0.6¶	2.3	9.4 c	11.7 c	1.6 bcd
Acephate 97S +	In-Furrow Spray +	1.0# + 0.375‡	4.2	11.6 c	15.9 bc	1.2 e
Acephate 97S	In-Furrow Spray	1.0#	3.5	15.5 bc	19.0 bc	1.7 bc
Admire Pro	In-Furrow Spray	0.33#	3.5	20.8 b	24.2 b	1.4 cde
P > F			0.28	<0.01	<0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†oz wt product/cwt.
‡mg ai/seed.
§mg ai/seed. Aeris applied at the listed rate contains 0.375 mg ai imidacloprid (Gaucho) and 0.375 mg ai thiodicarb.
¶lb ai/ac, in-furrow granule.
#lb ai/ac, in-furrow spray.

Table 5. Impact of selected at-planting treatments on cotton yield in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	Application Method	Rate	Lint Yield
			lb/ac
Fungicide only	Seed Treatment	-	1,132 b
Acephate 97S	Seed Treatment	6.4†	1,274 a
Acephate 97S + Gaucho	Seed Treatment	6.4† + 0.375‡	1,279 a
Gaucho 5FS	Seed Treatment	0.375‡	1,216 a
Aeris§	Seed Treatment	0.75‡	1,254 a
AgLogic 15G	In-Furrow Granule	0.6¶	1,276 a
Acephate 97S + Gaucho	In-Furrow Spray + Seed	1.0# + 0.375‡	1,242 a
Acephate 97S	In-Furrow Spray	1.0#	1,237 a
Admire Pro 4.6SC	In-Furrow Spray	0.33#	1,260 a
P > F			<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†oz wt product/cwt.
‡mg ai/seed.
§mg ai/seed. Aeris applied at the listed rate contains 0.375 mg ai imidacloprid (Gaucho) and 0.375 mg ai thiodicarb.
¶lb ai/ac, in-furrow granule.
#lb ai/ac, in-furrow spray.

Table 6. Impact of selected foliar treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 3 DAT in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

			Thrips/5 Plants			
Treatment	Insecticide Class	Rate	Adults	Immatures	Total	Damage
Non-Treated	-	-	3.3a	21.4 a	24.8 a	1.8 a
Intrepid Edge	Spinosyn + IGR	3.0§	2.1a-d	8.8 bc	10.8 bc	1.3 b
Radiant 1SC†	Spinosyn	1.5§	1.2cd	5.8 c	7.0 c	1.2 b
Acephate 97S	Organophosphate	0.21¶	2.0a-d	13.3 b	15.3 b	1.4 b
Bidrin 8E	Organophosphate	3.2§	2.4a-d	11.4 bc	13.8 bc	1.2 b
Dimethoate	Organophosphate	6.4§	2.9ab	12.5 bc	15.4 b	1.4 b
Karate 2.08CS	Pyrethroid	1.28§	2.5abc	21.4 a	23.8 a	1.8 a
Vydate CLV 3.77L	Carbamate	8.5§	1.8bcd	11.7 bc	13.5 bc	1.3 b
AgLogic 15G‡	Carbamate	3.5#	0.8d	5.1 c	6.0 c	1.2 b
P > F			0.05	<0.01	<0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†Dyne-Amic included at 0.5% v/v.
‡AgLogic applied as in-furrow granule at-planting.
§fl oz product/ac.
¶oz wt product/ac.
#lb product/ac.

Table 7. Impact of selected foliar treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 6-7 DAT in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	Insecticide Class	Rate	Thrips/5 Plants			Damage Rating
			Adults	Immatures	Total	
Non-Treated	-	-	5.1 a	26.4 a	31.6 a	2.8 a
Intrepid Edge	Spinosyn + IGR	3.0§	2.2 bc	6.3 c	8.4 b	1.6 c
Radiant 1SC†	Spinosyn	1.5§	2.9 bc	5.8 c	8.7 b	1.6 c
Acephate 97S	Organophosphate	0.21¶	2.9 bc	11.9 bc	14.9 b	1.9 b
Bidrin 8E	Organophosphate	3.2§	1.9 c	12.8 bc	14.7 b	1.7 bc
Dimethoate 4EC	Organophosphate	6.4§	2.8 bc	14.8 b	17.6 b	1.8 bc
Karate 2.08CS	Pyrethroid	1.28§	4.1 ab	29.6 a	33.6 a	2.6 a
Vydate CLV 3.77L	Carbamate	8.5§	2.8 bc	8.3 bc	11.1 b	1.8 bc
AgLogic 15G‡	Carbamate	3.5#	3.0 bc	10.0 bc	13.0 b	1.3 d
P > F			0.05	<0.01	<0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†Dyne-Amic included at 0.5% v/v.
‡AgLogic applied as in-furrow granule at-planting.
§fl oz product/ac.
¶oz wt product/ac.
#lb product/ac.

Table 8. Impact of selected foliar treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 10-11 DAT in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	Insecticide Class	Rate	Thrips/5 Plants			Damage Rating
			Adults	Immatures	Total	
Non-Treated	-	-	3.0	42.9 a	45.9 a	3.1 a
Intrepid Edge	Spinosyn + IGR	3.0§	2.0	15.0 b	17.0 b	1.4 ef
Radiant 1SC†	Spinosyn	1.5§	2.1	5.5 b	7.6 b	1.5 de
Acephate 97S	Organophosphate	0.21¶	2.1	18.0 b	20.1 b	1.5 de
Bidrin 8E	Organophosphate	3.2§	1.9	23.1 b	25.0 b	2.5 b
Dimethoate 4EC	Organophosphate	6.4§	2.1	18.3 b	20.4 b	1.9 cd
Karate 2.08CS	Pyrethroid	1.28§	3.6	46.3 a	49.9 a	1.8 de
Vydate CLV 3.77L	Carbamate	8.5§	2.8	15.5 b	18.3 b	2.3 bc
AgLogic 15G‡	Carbamate	3.5#	1.5	12.4 b	14.0 b	1.0 f
P > F			0.39	<0.01	<0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†Dyne-Amic included at 0.5% v/v.
‡AgLogic applied as in-furrow granule at-planting.
§fl oz product/ac.
¶oz wt product/ac.
#lb product/ac.

Table 9. Impact of selected foliar treatments on densities of thrips adults, immatures, and total thrips and thrips damage at the 14 DAT in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

			Thrips/5 Plants			
Treatment	**Insecticide Class**	**Rate**	**Adults**	**Immatures**	**Total**	**Damage Rating**
Non-Treated	-	-	19.6 a	16.5 ab	36.1 a	3.9 a
Intrepid Edge	Spinosyn + IGR	3.0§	14.8 ab	4.5 c	19.3 bc	2.3 cd
Radiant 1SC†	Spinosyn	1.5§	13.5 ab	5.3 c	18.8 bc	2.0 d
Acephate 97S	Organophosphate	0.21¶	13.1 b	5.9 c	19.0 bc	1.9 d
Bidrin 8E	Organophosphate	3.2§	17.5 ab	9.4 abc	26.9 ab	2.1 cd
Dimethoate 4EC	Organophosphate	6.4§	13.6 ab	8.1 bc	21.8 b	2.6 bc
Karate 2.08CS	Pyrethroid	1.28§	11.8 b	17.0 a	28.8 ab	3.0 b
Vydate CLV 3.77L	Carbamate	8.5§	14.1 ab	9.4 abc	23.5 b	2.7 bc
AgLogic 15G‡	Carbamate	3.5#	2.8 c	2.4 c	6.0 c	1.3 e
P > F			0.01	0.02	0.01	<0.01

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†Dyne-Amic included at 0.5% v/v.
‡AgLogic applied as in-furrow granule at-planting.
§fl oz product/ac.
¶oz wt product/ac.
#lb product/ac.

Table 10. Impact of selected foliar treatments on cotton yield in Arkansas (3), Mississippi (2), Tennessee, and Louisiana, 2019.

Treatment	**Insecticide Class**	**Rate**	**Lint Yield**
			lb/ac
Non-Treated	-	-	1,060
Intrepid Edge	Spinosyn + IGR	3.0§	1,166
Radiant 1SC†	Spinosyn	1.5§	1,199
Acephate 97S	Organophosphate	0.21¶	1,164
Bidrin 8E	Organophosphate	3.2§	1,194
Dimethoate 4EC	Organophosphate	6.4§	1,164
Karate 2.08CS	Pyrethroid	1.28§	1,159
Vydate CLV 3.77L	Carbamate	8.5§	1,105
AgLogic 15G‡	Carbamate	3.5#	1,207
P > F			0.14

Means within a column followed by a common letter are not significantly different (FPLSD *P* = 0.05).
†Dyne-Amic included at 0.5% v/v.
‡AgLogic applied as in-furrow granule at-planting.
§fl oz product/ac.
¶oz wt product/ac.

Efficacy of Select Insecticides for Control of Tarnished Plant Bug, *Lygus lineolaris*, in Arkansas Cotton

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Abstract

Plant bugs are the number one pest of flowering cotton in Arkansas. An experiment was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Lee County, Arkansas in 2019 to evaluate the efficacy of selected foliar insecticides and rates on tarnished plant bug (*Lygus lineolaris)* in cotton. Selected insecticides included Bidrin 0.25 lb ai/ac, Bidrin 0.375 lb ai/ac, Bidrin 0.5 lb ai/ac, Discipline 0.1lb ai/ac, Bidrin 0.25 lb ai/ac + Discipline 0.1 lb ai/ac, Bidrin 0.375 lb ai/ac + Discipline 0.1 lb ai/ac, Bidrin 0.5lb ai/ac + Discipline 0.1 lb ai/ac, Orthene 97 0.75 lb/ac + Discipline 0.1 lb ai/ac, and Transform 0.047 lb ai/ac. Results indicated that Discipline alone is not an adequate option to provide control of tarnished plant bugs. A trend was observed that adding Discipline to Bidrin can increase control and decrease fruit damage.

Introduction

Tarnished plant bug (TPB) is the number one insect pest for cotton producers in Arkansas. From 2016–2018 TPB cost growers up to $93.94/ac in cotton yield losses + control cost and was responsible for up to 56% of the total cotton yield lost from insects (Williams, 2017; Cook, 2018; Cook, 2019). Plant bug feeding causes square loss, deformed flowers, and damaged bolls ultimately resulting in reduced yield. Growers and consultants rely on foliar insecticide applications to control plant bugs. The purpose of this study was to compare several rates and combinations of Bidrin or acephate with bifenthrin for control of TPB. These data will aid growers and consultants with TPB insecticide selection.

Procedures

Cotton was planted on 7 May at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Lee County, Ark. Plot size was 12.5 ft (4 rows) by 40 ft, with a 2-row buffer between plots. Treatments were arranged in a randomized complete block design with 4 replications. Treatments consisted of: untreated control (UTC), Bidrin 0.25 lb ai/ac, Bidrin 0.375 lb ai/ac, Bidrin 0.5 lb ai/ac, Discipline 0.1 lb ai/ac, Bidrin 0.25 lb ai/ac + Discipline 0.1 lb ai/ac, Bidrin 0.375 lb ai/ac + Discipline 0.1 lb ai/ac, Bidrin 0.5 lb ai/ac + Discipline 0.1 lb ai/ac, Orthene 97 0.75 lb ai/ac + Discipline 0.1 lb ai/ac, and Transform 0.047 lb ai/ac. Insecticides were applied with a Mud Master fitted with TX6 cone jet nozzles with 19.5-inch spacing. Spray volume was 10 gal/ac at 40 psi. All treatments received insecticide applications on 19 July and 25 July. Plant bug numbers were determined by taking two samples with a 2.5-ft drop cloth per plot for a total of 10 row ft. Percent square retention was measured by recording the presence or absence of the first position square on the third node from the top of the plant from 25 randomly selected plants per plot. Boll damage was assessed by splitting 10 random thumb-sized bolls per plot and checking for discolored lint and/or warts on the inner boll wall. Samples for the first treatment were taken on 22 and 25 July. The second treatment was sampled on 29 July, and 1 and 8 August. Data were processed using Agriculture Research Manager 2019 (Gylling Data Management, Inc., Brookings, S.D.). Analysis of variance was conducted with Duncan's New Multiple Range Test ($P = 0.10$) to separate means.

Results and Discussion

At 3 days after first application, all treatments reduced TPB densities compared to UTC (Fig. 1). All other treatments reduced TPB numbers compared to Discipline (0.1 lb ai/ac), and Bidrin (0.25 lb ai/ac) + Discipline (0.1 lb ai/ac). Although there are no differences, trends showed the treatments with less plant bugs to have better square retention at 6 days after first application than the UTC (Fig. 2). Sim-

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ilarly, at 4 days after the second application, all treatments reduced plant bug numbers compared to the UTC and had fewer plant bugs than Discipline (0.1 lb ai/ac) (Fig. 3).

At 7 days after second application, boll damage was assessed. All treatments had less boll damage than the UTC (Fig. 4). Bidrin (0.375 lb ai/ac), Bidrin (0.25 lb ai/ac), Orthene 97 (0.75 lb ai/ac) + Discipline (0.1 lb ai/ac), Bidrin (0.5 lb ai/ac) + Discipline (0.1 lb ai/ac), Bidrin (0.375 lb ai/ac) + Discipline (0.1 lb ai/ac) and Transform (0.047 lb ai/ac) all had less boll damage than Discipline (0.1 lb ai/ac). At 12 days after second application, boll damage was similar to 7 days after application (Fig. 5). At 14 days after second application all treatments showed reduced TPB densities compared to the UTC (Fig. 6). Orthene 97 (0.75 lb ai/ac) + Discipline (0.1 lb ai/ac), Bidrin (0.5 lb ai/ac) + Discipline (0.1 lb ai/ac), Bidrin (0.5 lb ai/ac), Bidrin (0.375 lb ai/ac) + Discipline (0.1 lb ai/ac), Transform (0.047 lb ai/ac) and Bidrin (0.375 lb ai/ac) had fewer plant bugs than Discipline (0.1 lb ai/ac) alone. Orthene 97 (0.75 lb ai/ac) + Discipline (0.1 lb ai/ac) had fewer plant bugs than Discipline (0.1 lb ai/ac), Bidrin (0.5 lb ai/ac) + Discipline (0.1 lb ai/ac), Bidrin (0.25 lb ai/ac) and Bidrin (0.375 lb ai/ac).

Practical Application

Results indicated that Discipline alone is not an adequate option to provide control of tarnished plant bugs. A trend was observed that adding Discipline to Bidrin can increase control and decrease fruit damage.

Acknowledgments

Appreciation is expressed to the Lon Mann Cotton Branch Experiment Research Station and Amvac for their support.

Literature Cited

Cook, D.R. 2019. Cotton insect losses 2018. pp. 769-833 *In:* Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 8-10 Jan. National Cotton Council, Memphis, Tenn.

Cook, D.R. 2018. Cotton insect losses 2017. pp. 721-780. *In:* Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, Texas. 3-5 Jan. National Cotton Council, Memphis, Tenn.

Williams, M.R. 2017. Cotton Insect Losses 2016. pp. 710-754. *In:* Proc. Beltwide Cotton Conf., Dallas, Texas. 4-6 Jan. National Cotton Council, Memphis, Tenn.

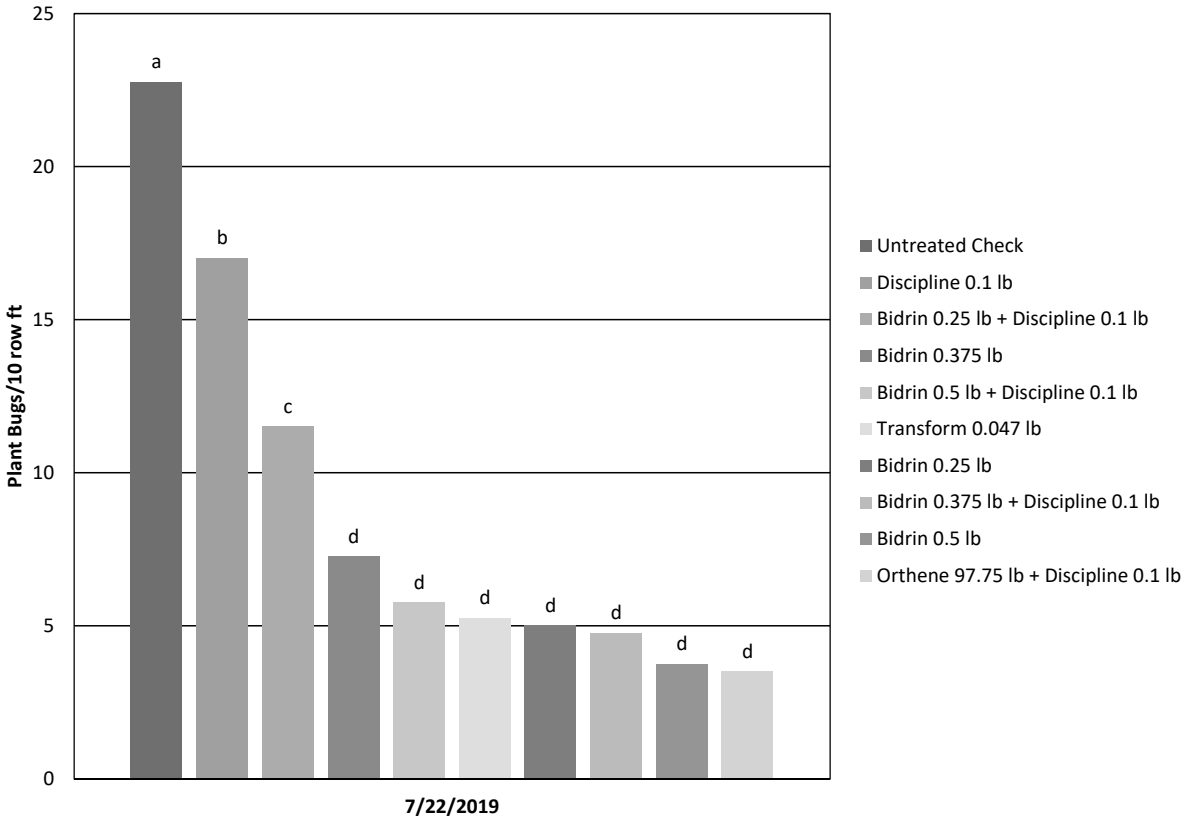

Fig. 1. Assessment of plant bug densities 3 days after application of foliar insecticide. Means followed by the same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test).

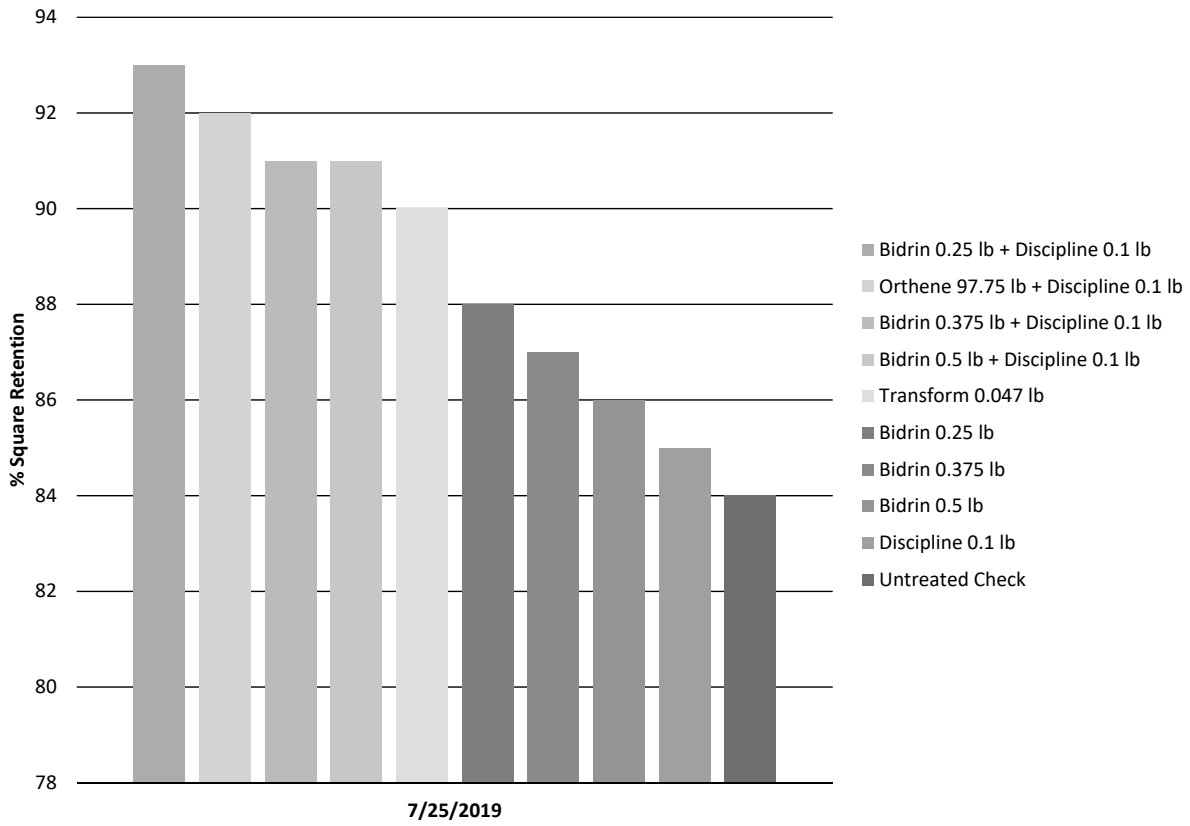

Fig. 2. Percent square retention of selected insecticides 6 days after application.

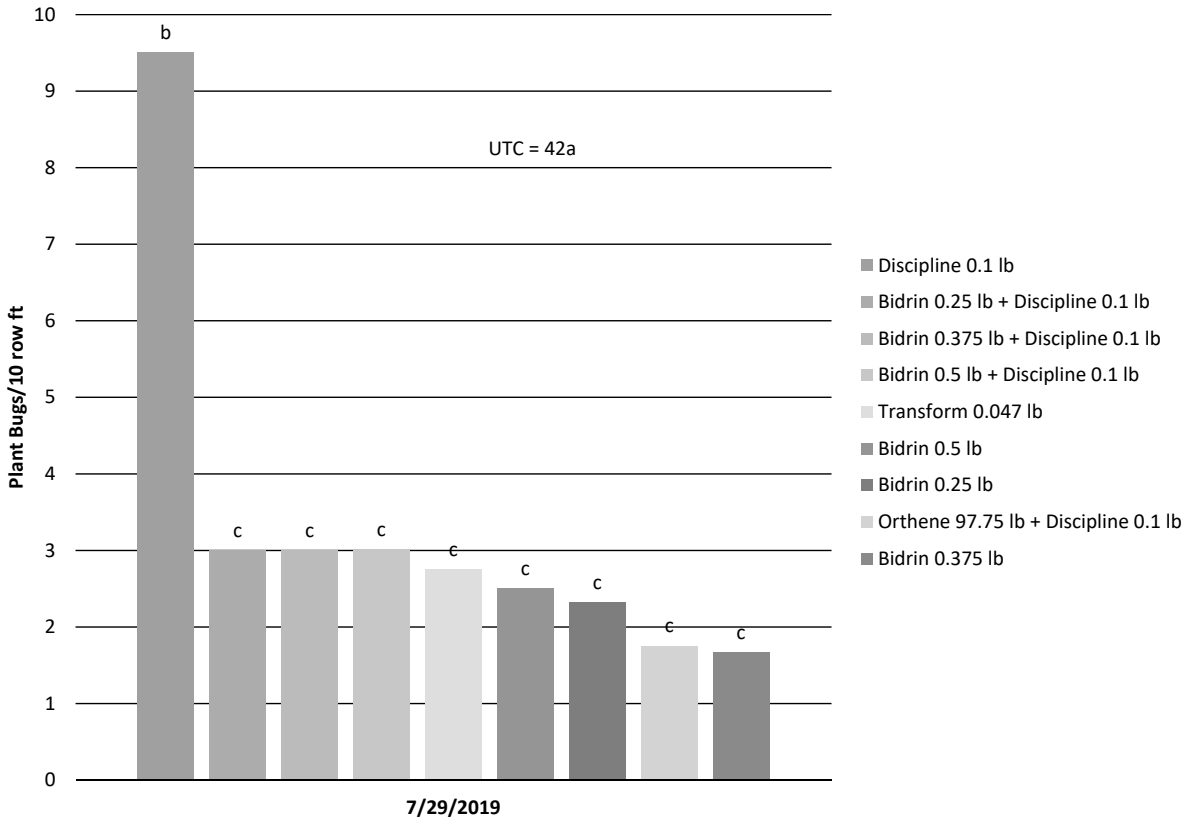

Fig. 3. Assessment of plant bug densities 4 days after 2nd application of foliar insecticide. Means followed by the same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test).

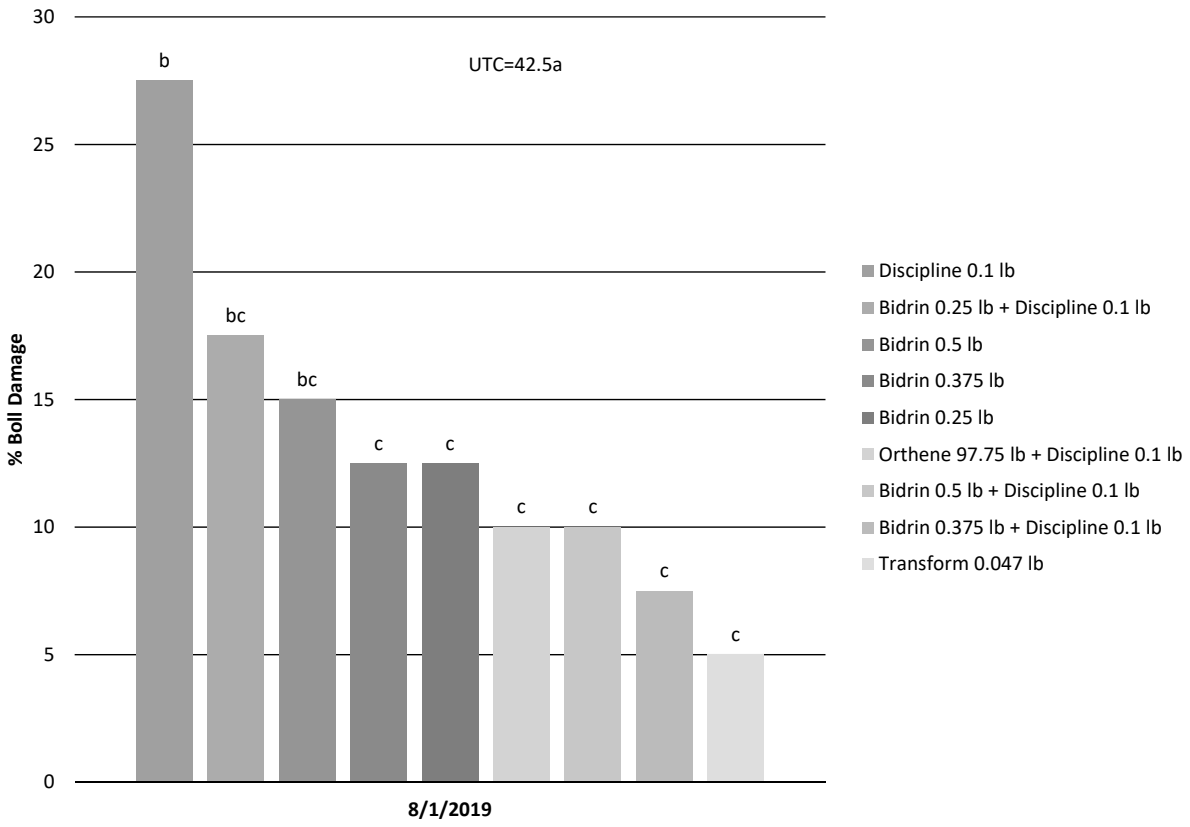

Fig. 4. Percent boll damage of selected insecticides 7 days after 2nd application. Means followed by the same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test).

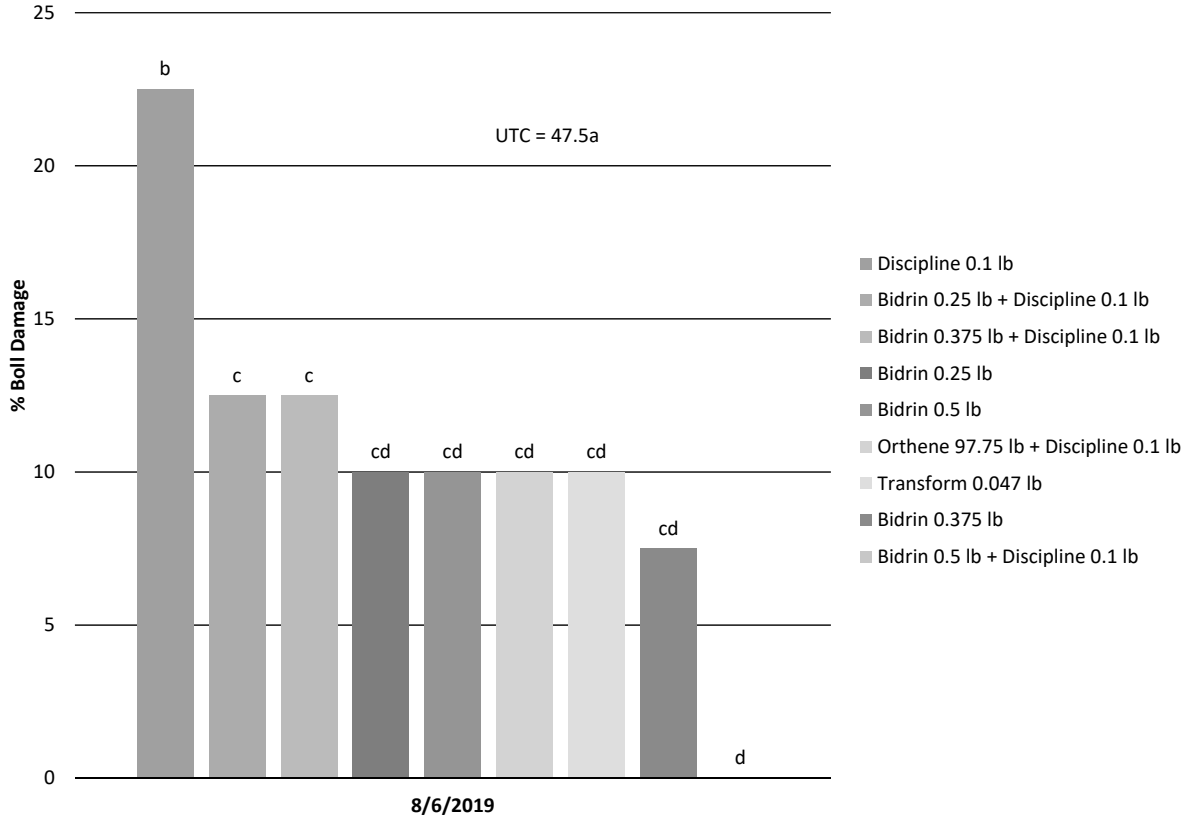

Fig. 5. Percent boll damage of selected insecticides 12 days after 2nd application. Means followed by the same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test).

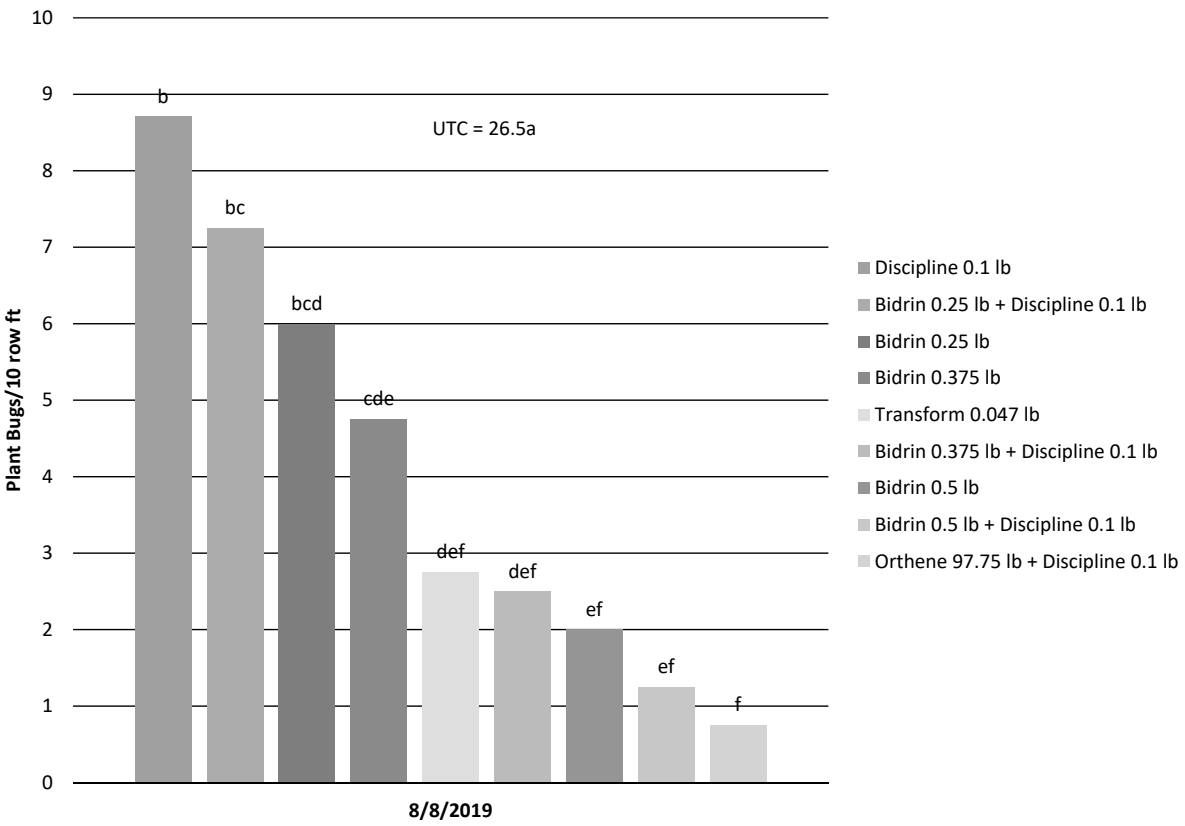

Fig. 6. Assessment of plant bug densities 14 days after 2nd application of foliar insecticide. Means followed by the same letter do not significantly differ (*P* = 0.10, Duncan's New Multiple Range Test).

Comparison of *Bacillus thuringiensis* Cultivars for Control of Cotton Bollworm With and Without a Foliar Application in Arkansas in 2019

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Abstract

The cotton bollworm (*Helicoverpa zea,* Boddie) is a major pest of cotton in Arkansas and can cause significant yield losses if not controlled. This experiment was conducted in Drew County, Arkansas in 2019 to evaluate 3 gene cotton cultivars for control of cotton bollworm. Each cultivar was evaluated as sprayed and unsprayed. Results indicated that dual gene cultivars may require supplemental foliar applications for control of high populations of bollworms while triple gene cultivars did not benefit from supplemental foliar applications.

Introduction

Cotton is a high input crop for growers, and insect control costs are a major portion of a grower's total budget. Each year, the cotton bollworm (*Helicoverpa zea,* Bodie*),* infests 100% of cotton planted in Arkansas. It remains a major pest of flowering cotton in the mid-South despite widespread use of transgenic *Bacillus thuringiensis (Bt)* cotton cultivars and foliar insecticides are often needed to supplement control. Kerns et al. (2018) conducted studies in 2017 that indicated widespread resistance to Cry1Ac, a major protein used in *Bt* cotton. Also, a meta-analysis of cotton data since 2007 throughout the mid-South indicated that there has been increasing amounts of square damage in dual gene technologies (Fleming et al., 2018). These findings led to research which established a new bollworm threshold based on damaged fruit rather than insect numbers with the new threshold being set at 6% fruit damage. In areas where bollworm populations get exceedingly high, such as Southeast Arkansas, an egg threshold of 25% is used.

Procedures

In 2019, two duplicate trials were conducted in a grower field in Drew County, Arkansas. The trial was planted on 30 April (Trial 1) and again on 16 May (Trial 2). Plot size was 12.5 ft. (4 rows) by 40 ft., in a randomized complete block design with 4 replications. Cultivars used were Non-*Bt* (DP 1822 XF); WideStrike 3 (PHY 330 W3FE); Twinlink Plus (ST 5471 GLTP); Bollgard 2 (DP 1518 B2XF); and Bollgard 3 (DP 1835 B3XF). Each cultivar was both unsprayed and sprayed with Prevathon 20 oz/ac. The Prevathon application was made on 24 July using a Mudmaster high clearance sprayer fitted with TXVS-6 flat fan nozzles at 19.5-in. spacing with a spray volume of 10 gal/ac, at 40 psi. Damage ratings were taken 6, 12, and 20 days after application (DAA) by sampling 25 squares, flowers, and bolls per plot when present. The data were processed using Agriculture Research Manager 2019 (Gylling Data Management, Inc., Brookings, S.D.) and Duncan's New Multiple Range Test (DNMRT; $P = 0.10$) to separate means. Means followed by same letter do not significantly differ ($P = 0.10$, DNMRT). Mean comparisons performed only when analysis of variance Treatment P (F) is significant at mean comparison observed significance level.

Results and Discussion

Trial 1

By 6 days after application, all treatments had less damage than the unsprayed non-*Bt* treatment; all other treatments, both sprayed and unsprayed, provided better control than the Bollgard 2 and Bollgard 3 unsprayed treatments (Fig. 1). When plots were sampled 12 days post application, all treatments reduced fruit damage compared to non *Bt*, sprayed and unsprayed, and Bollgard 2 unsprayed treatments (Fig. 2). Boll damage was assessed 20 days post application and all cultivars, sprayed and unsprayed, had less damage than the unsprayed non-*Bt* treatment with no differences in the non-*Bt* treatments (Fig. 3)

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Trial 2

By 6 days after application, all treatments had less damage than the unsprayed non-*Bt* plots and all sprayed 3-gene cultivars had less damage than WideStrike 3 unsprayed. Although there was an overall decrease in fruit damage, all cultivars, sprayed and unsprayed, reduced damage compared to the unsprayed non-*Bt* treatment (Figs. 4–5). When plots were sampled 20 days post application, damage continued to increase in the unsprayed non-*Bt* and unsprayed Bollgard 2 plots while all other treatments remained below the 6% damage threshold (Fig. 6).

Yield results from previous studies show that the impact of foliar applications on transgenic cultivars varies from year to year (Lorenz et al., 2012; Taillon et al., 2013; Orellana et al., 2014; Taillon et al., 2015, 2016, 2017). In 2012, foliar applications increased yield in Bollgard II and WideStrike; in 2015 foliar applications increased yield in WideStrike and WideStrike 3. In 2013, 2014 and 2016, yields did not increase with foliar applications. However, in 2017 WideStrike had higher yields with foliar applications, but WideStrike III and TwinLink Plus did not.

Practical Applications

This study indicates that dual gene cultivars may not provide the protection needed to prevent fruit damage from bollworms and may require foliar applications to keep damage at an acceptable level. In this study, the newer triple gene cotton cultivars are currently providing the control needed to maximize yield without requiring foliar applications. Studies should be continued to monitor these trends and keep growers informed.

Acknowledgments

Appreciation is expressed to A.J. Hood. We would also like to thank Dow and Bayer for their support.

Literature Cited

Fleming, D., F. Musser, D. Reisig, J. Greene, S. Taylor, M. Parajulee, G. Lorenz, A. Catchot, J. Gore, D. Kerns, S. Stewart, D. Boykin, M. Caprio, and N. Little. 2018. Effects of transgenic *Bacillus thuringiensis* cotton on insecticide use, heliothine counts, plant damage, and cotton yield: A meta-analysis, 1996-2015. PLoS ONE 13(7):e0200131. https://doi.org/10.1371/journal.pone.0200131

Kerns, D., F. Yang, G. Lorenz, J. Gore, A. Catchot, S.D. Stewart, S. Brown, D. Cook, and N. Seiter. 2018. Value of *Bt* Technology for Bollworm Management: Current Situation and Future Sustainability. *In:* Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, Texas. 3-5 Jan. National Cotton Council, Memphis, Tenn.

Lorenz, G., G. Studebaker, S. D. Stewart, D. Kerns, A. Catchot, J. Gore, D. Cook. 2012. Impact of Foliar Insecticide Application on Dual Gene Cotton. pp. 148-152. *In:* D.M. Oosterhuis (ed.) Summaries of Arkansas Cotton Research 2012. Arkansas Agricultural Experiment Station. Research Series 610. Fayetteville, Ark.

Orellana, L., G. Lorenz, N. Taillon, A. Plummer, M. Chaney, B. Thrash, D. Clarkson, M. Everett, and S. Flynn. 2014. Efficacy of Dual Gene *Bt* Cotton for Control of Bollworm, *Helicoverpa zea* (Boddie). *In:* Proc., Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 6-8 Jan. National Cotton Council, Memphis, Tenn.

Taillon, N.M., G. Lorenz, A. Plummer, M. Chaney, B.C. Thrash, D.L. Clarkson, L. Orellana Jiminez, and M. Everett. 2013. Efficacy of Dual Gene *Bacillus thuringiensis* (*Bt*) Cotton for Control of Bollworm, Helicoverpa zea (Boddie). pp. 144-149. *In:* D.M. Oosterhuis (ed.) Summaries of Arkansas Cotton Research 2013. Arkansas Agricultural Experiment Station. Research Series 618. Fayetteville, Ark.

Taillon, N., G. Lorenz, A. Plummer, M. Chaney, and J. Black. 2015. Impact of Foliar Applications for Control of Heliothines in Cotton. pp. 114-118. *In:* D.M. Oosterhuis (ed.) Summaries of Arkansas Cotton Research 2015. Arkansas Agricultural Experiment Station. Research Series 635. Fayetteville, Ark.

Taillon, N., G. Lorenz, A. Plummer, H.M. Chaney, J. Black, and A. Cato. 2016. Comparison of Control of Heliothines in Conventional and Dual Gene Cotton. pp. 74-79. *In:* F.M. Bourland (ed.) Summaries of Arkansas Cotton Research 2016. Arkansas Agricultural Experiment Station. Research Series 644. Fayetteville, Ark.

Taillon, N., G. Lorenz, A. Plummer, N. Bateman, B. Thrash, K. McPherson, A. Cato, J. Black, and J. Pace. 2017. Comparison of *Bt* Cultivars for Control of Cotton Bollworm with and Without a Foliar Application in Arkansas. pp. 54-59. *In:* F.M. Bourland (ed.) Summaries of Arkansas Cotton Research 2016. Arkansas Agricultural Experiment Station. Research Series 644. Fayetteville, Ark.

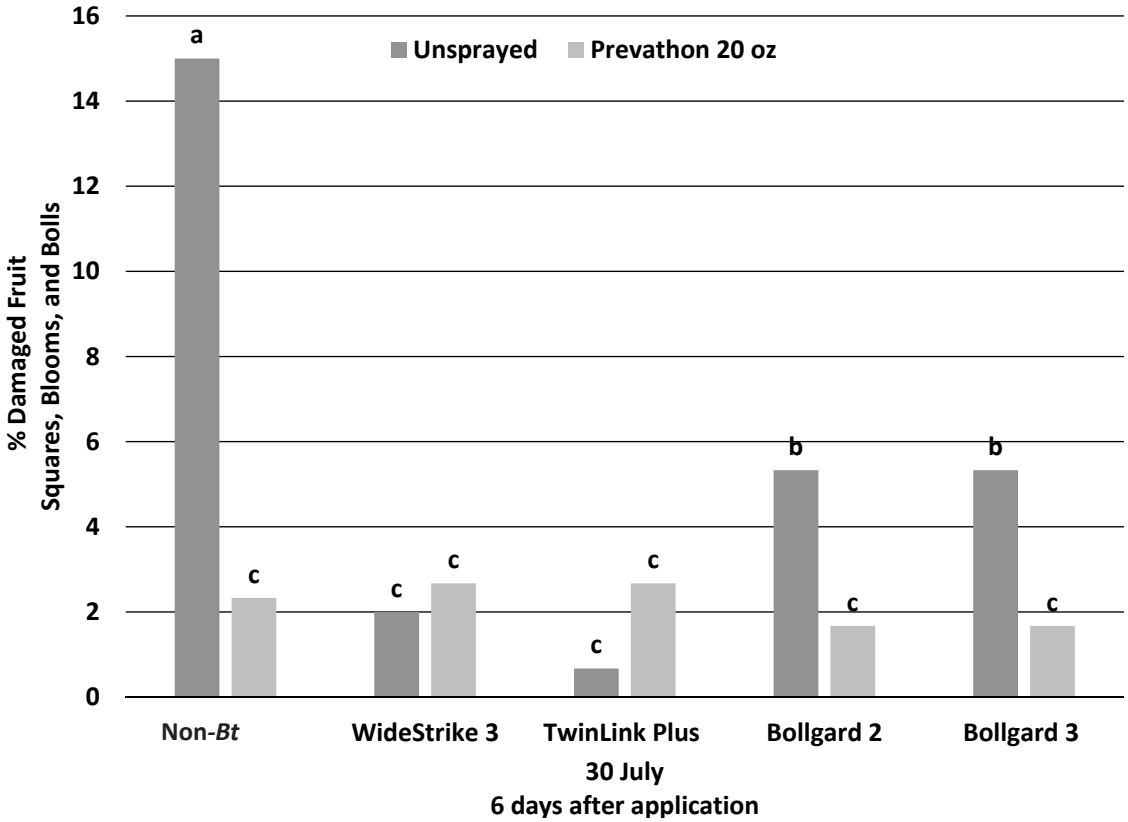

Fig. 1. Trial 1 (planted 30 April 2019)–Combined damage of 25 squares, blooms, and bolls 6 days after application of Prevathon 20 oz. in Drew County, Arkansas.

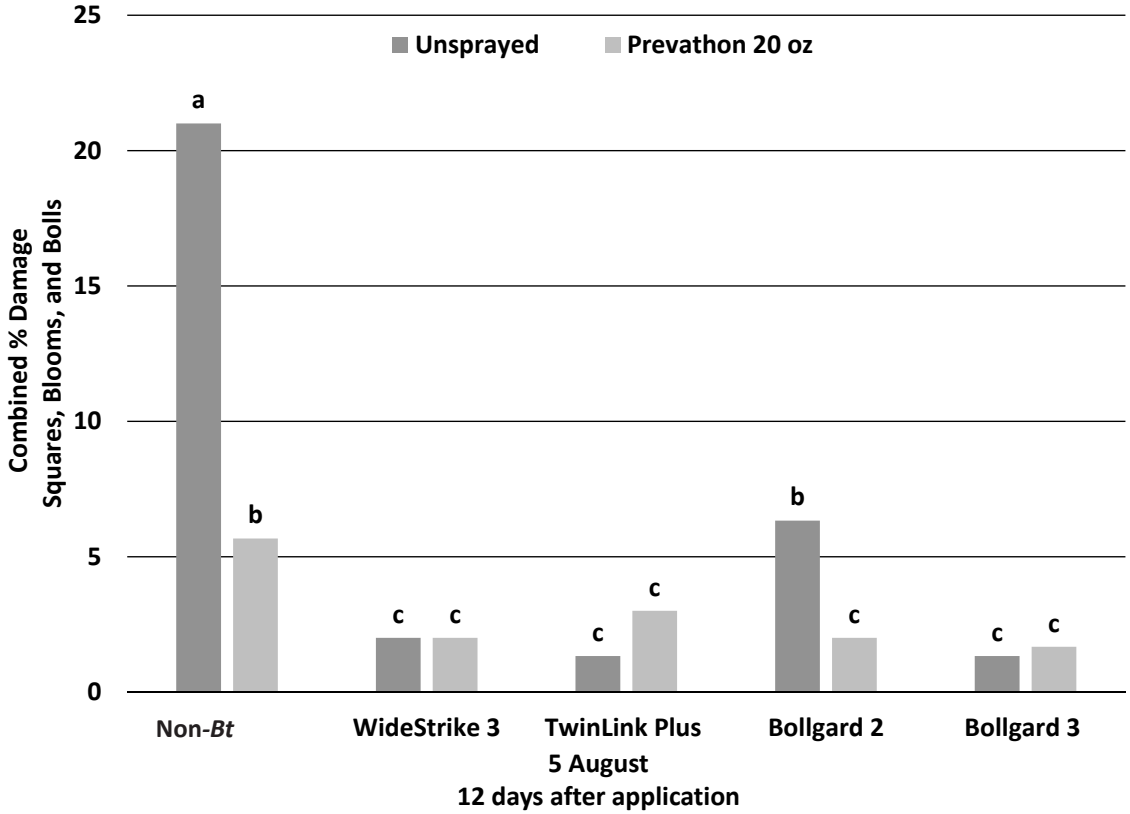

Fig. 2. Trial 1 (planted 30 April 2019)–Combined damage of 25 squares, blooms, and bolls 12 days after application of Prevathon 20 oz. in Drew County, Arkansas.

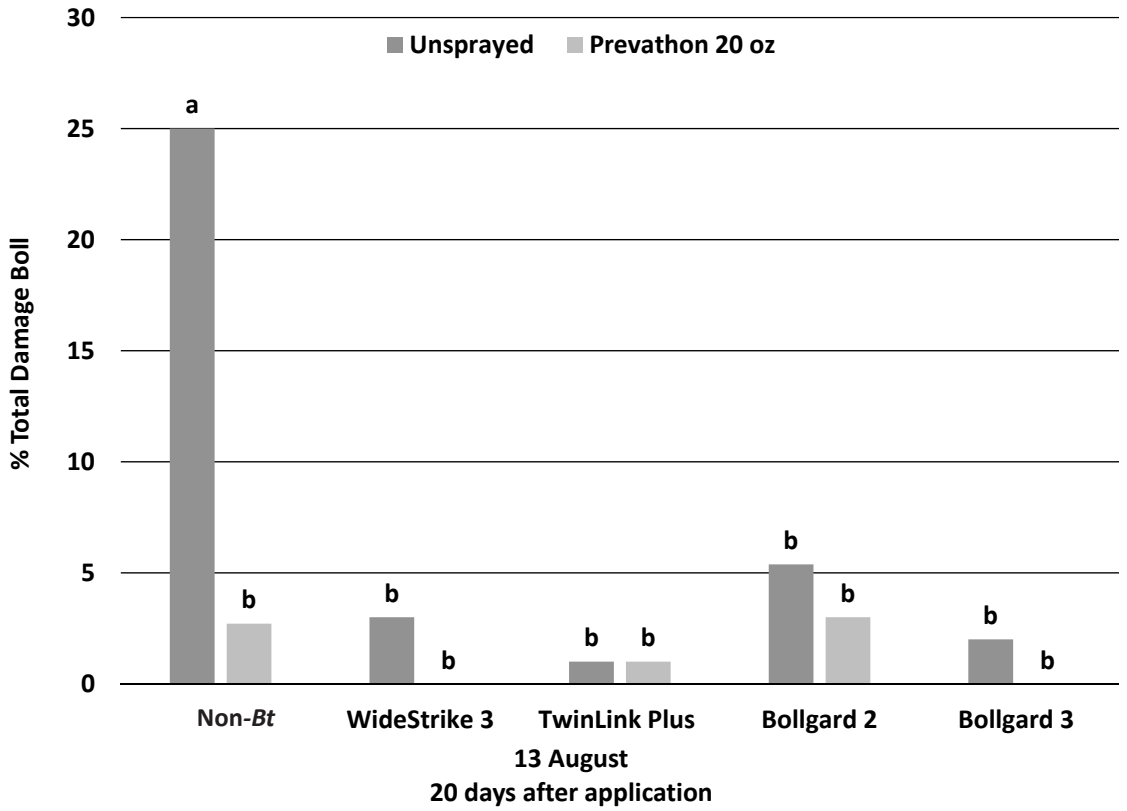

Fig. 3. Trial 1 (planted 30 April 2019)–Boll damage of 25 bolls 20 days after application of Prevathon 20 oz. in Drew County, Arkansas.

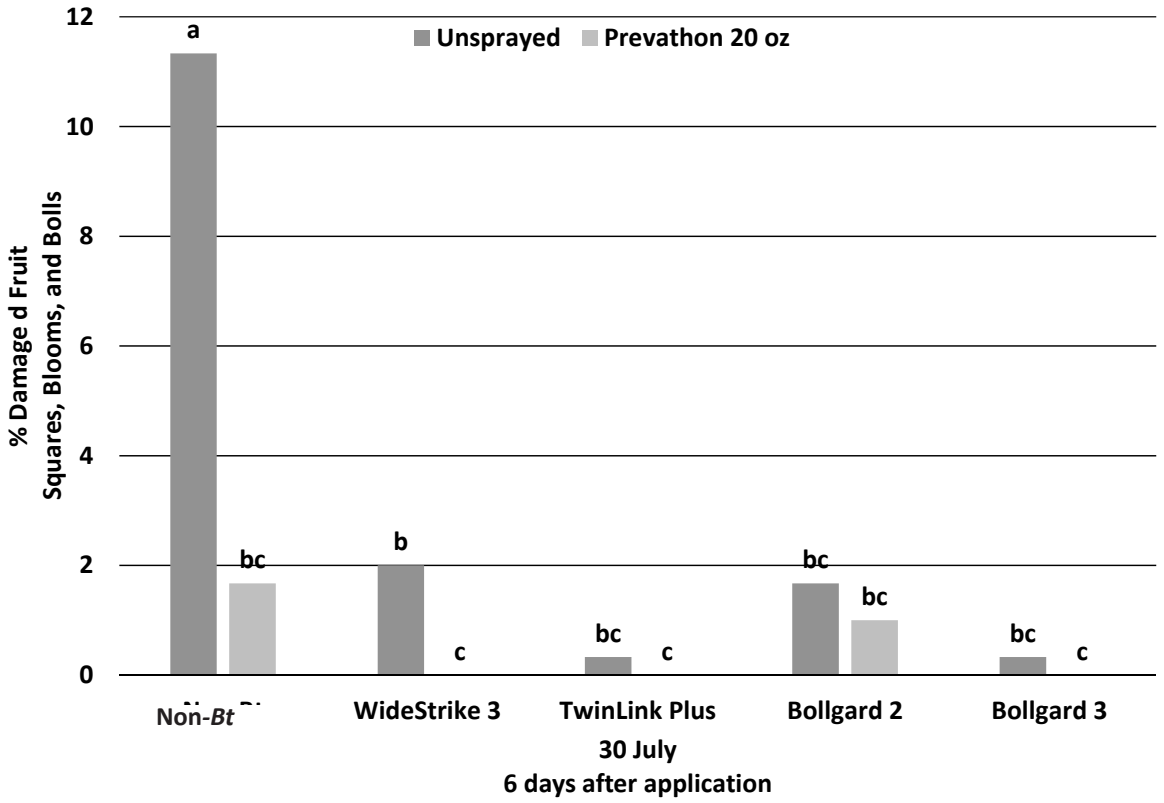

Fig. 4. Trial 2 (planted 16 May 2019)–Combined damage of 25 squares, blooms, and bolls 6 days after application of Prevathon 20 oz. in Drew County, Arkansas.

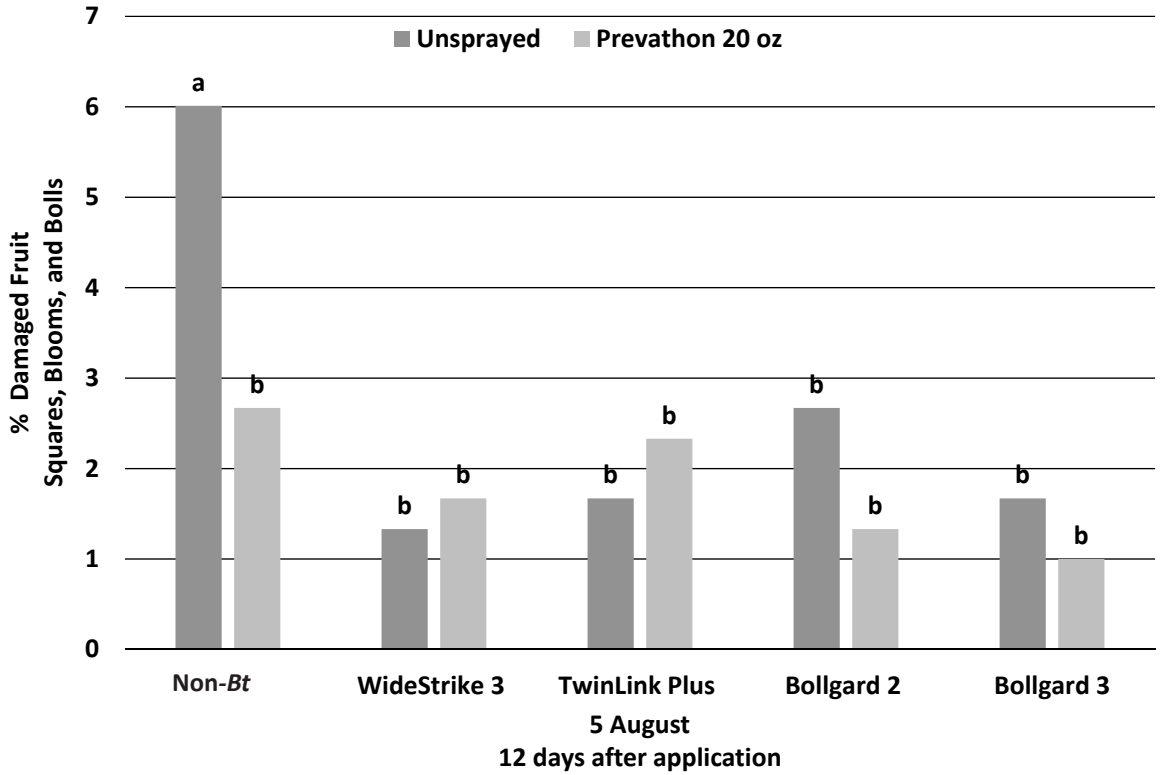

Fig. 5. Trial 2 (planted 16 May 2019)–Combined damage of 25 squares, blooms, and bolls 12 days after application of Prevathon 20 oz. in Drew County, Arkansas.

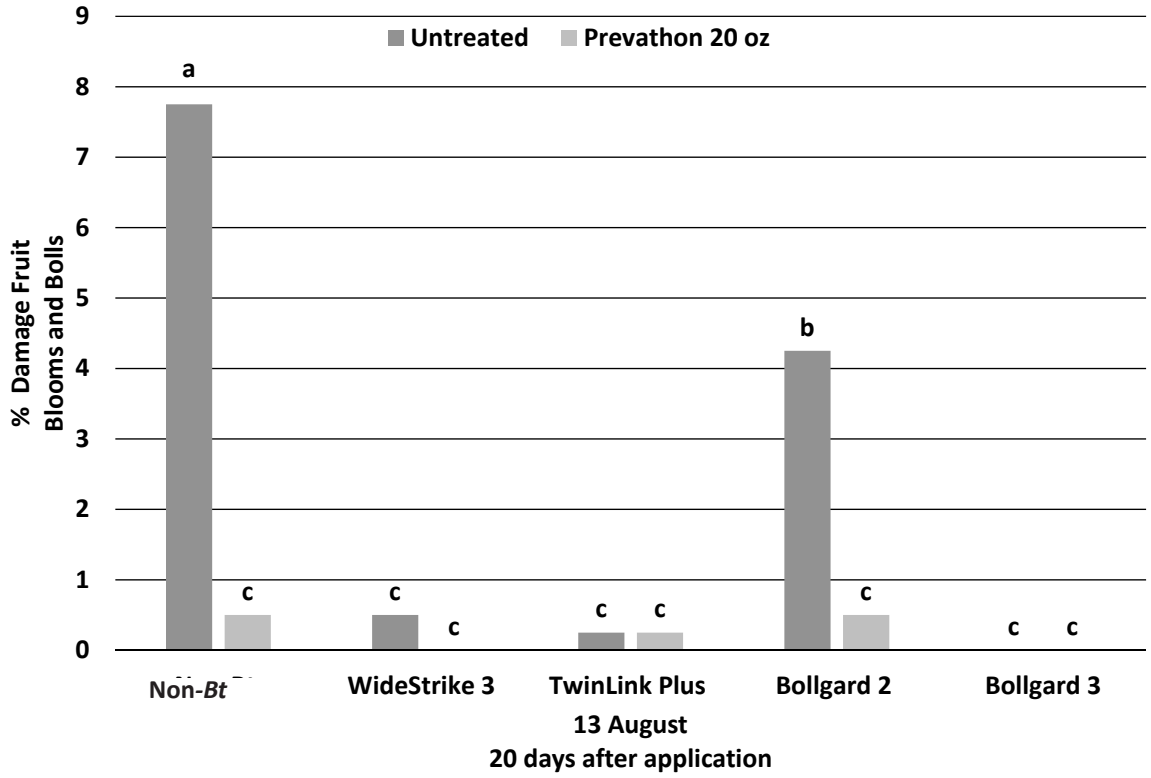

Fig. 6. Trial 2 (planted 16 May 2019)–Combined damage of 25 blooms, and bolls 20 days after application of Prevathon 20 oz. in Drew County, Arkansas.

Performance of Acephate Against Tobacco Thrips and Evidence of Possible Resistance

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Abstract

Historically, acephate has been considered the "go-to" insecticide for foliar applications due to its effectiveness and relatively low cost. However, the efficacy of acephate on thrips has seemingly declined in Tennessee during recent years. Therefore, research was done to assess the efficacy of acephate against multiple populations of tobacco thrips (*Frankliniella fusca*) collected from Tennessee and different locations in the mid-South and Southeast. Data from bioassays of field-collected thrips, as well as historical data of the field performance of acephate applications were presented. Results of the leaf-dip bioassays of tobacco thrips showed a considerable range of mortality for Orthene 97 (acephate) at 0.25 lb ai/ac. Radiant SC (spinetoram) at one-half the normal field use rate (0.012 lb ai/ac) provided consistent and higher mortality. Dose-response curves for three populations collected in Tennessee, including an F_1 population where the F_0 population was selected with acephate, indicated acephate at 1 lb ai/ac caused approximately 44–78% mortality. In contrast, acephate at 0.25 lb ai/ac caused an average mortality of about 96% for a laboratory colony of tobacco thrips maintained at Mississippi State University. Regression analysis of the field performance data for acephate showed a significant decline of thrips control with acephate in field trials done in Tennessee since 2005. Thrips control for Radiant or Intrepid Edge (spinetoram) at an equivalent rate of spinetoram has remained unchanged over time.

Introduction

Thrips are the most pervasive pest of seedling cotton in the mid-Southern and southeastern U.S. Due to the ubiquitous nature of this pest, virtually all cotton grown in the mid-South and Southeast receive at-planting treatments, typically a neonicotinoid seed treatment. Many acres are also treated postemergence with foliar-applied insecticides including, most commonly, acephate, dimethoate, and dicrotophos. Spinetoram (Radiant[10] SC or Intrepid Edge) is also recommended for thrips control but is seldom used because of the relatively higher cost.

Recently, tobacco thrips' (*Frankliniella fusca*) resistance to neonicotinoid insecticides has been documented in much of the Cotton Belt (e.g., Huseth et al., 2016; Darnell-Crumpton et al., 2018). This has led to an increased number of foliar applications targeting thrips. Historically, acephate has been considered the "go-to" insecticide for foliar applications due to its effectiveness and relatively low cost. However, the efficacy of acephate on thrips has seemingly declined in Tennessee during recent years. Therefore, research was done to assess the efficacy of acephate against multiple populations of tobacco thrips collected from Tennessee and different locations in the mid-South and Southeast.

Procedures

Bioassays

Thrips collections were done in 2019 at multiple locations in Tennessee, the mid-South, and Southeast to evaluate the efficacy of acephate on tobacco thrips using bioassays. Field-collected thrips populations were tested. Leaf discs were dipped into solution for one second and allowed to air dry for one hour. Twenty-four-hour leaf-dip bioassays were

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[8] Associate Professor/Extension Professor, Department of Entomology and Plant Pathology, North Carolina State University, Plymouth, North Carolina.
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[10] Mention of trade names or commercial products in this article is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture, an equal opportunity provider and employer.

done using fresh cotton leaf tissue. The lids of 1.5-ml microcentrifuge tubes were used to make the leaf discs for each tube. Eight adult, female tobacco thrips were aspirated into each tube; 10 reps (tubes) were used per treatment. Tubes with thrips and leaf tissue were placed into an incubator set at 27–29 °C. Mortality was assessed at 24 hours. Data were analyzed in SAS using Proc PROBIT ($\alpha = 0.05$) (SAS Institute, Cary, N.C.).

Field Performance

For individual efficacy trials done in Tennessee, mean treatment responses were converted in each trial to percent control. Data used were thrips numbers at 3–6 days after treatment. Linear regressions were done, weighted by the average number of thrips in the non-treated plots of each trial. Data were analyzed in SAS using Proc REG (SAS Institute, Cary, N.C.).

Results and Discussion

Results of the leaf-dip bioassays of tobacco thrips showed a considerable range of mortality for Orthene 97 (acephate) at 0.25 lb ai/ac. Radiant SC (spinetoram) at one-half the normal field use rate (0.012 lb ai/ac) provided consistently higher mortality (Fig. 1). Dose-response curves for three populations collected in Tennessee, including two field collected populations and one population generated from a field collection that had been sprayed with acephate, indicated acephate at 1 lb ai/ac caused approximately 44–78% mortality. In contrast, acephate at 0.25 lb ai/ac caused an average mortality of about 96% for a laboratory colony of tobacco thrips maintained at Mississippi State University (Fig. 2). Regression analysis of the field performance data for acephate showed a significant decline of thrips control with acephate in field trials done in Tennessee since 2005. Thrips control for Radiant or Intrepid Edge at an equivalent rate of spinetoram has remained unchanged over time (Figs. 3–5).

Acknowledgments

The authors thank Cotton Incorporated for their support of this project. Support also provided by the University of Arkansas System Division of Agriculture.

Literature Cited

Huseth, A.S., T.M. Chappell, K. Langdon, S.C. Morsello, S. Martin, J.K. Greene, A. Herbert, A.L. Jacobson, F. P.F. Reay-Jones, T. Reed, D.D. Reisig, P.M. Roberts, R. Smith, and G.G. Kennedy. 2016. *Frankliniella fusca* resistance to neonicotinoid insecticides: an emerging challenge for cotton pest management in the eastern United States. Pest Mgt.Sci. 72:1934-1945. https://doi.org/10.1002/ps.4232

Darnell-Crumpton C., A.L. Catchot, D.R. Cook, J. Gore, D. M. Dodds, S.C. Morsello, and F.R. Musser. 2018. Neonicotinoid insecticide resistance in tobacco thrips (Thysanoptera:Thripidae) of Mississippi. J Econ. Ento. 111(6): 2824-2830. https://doi.org/10.1093/jee/toy298

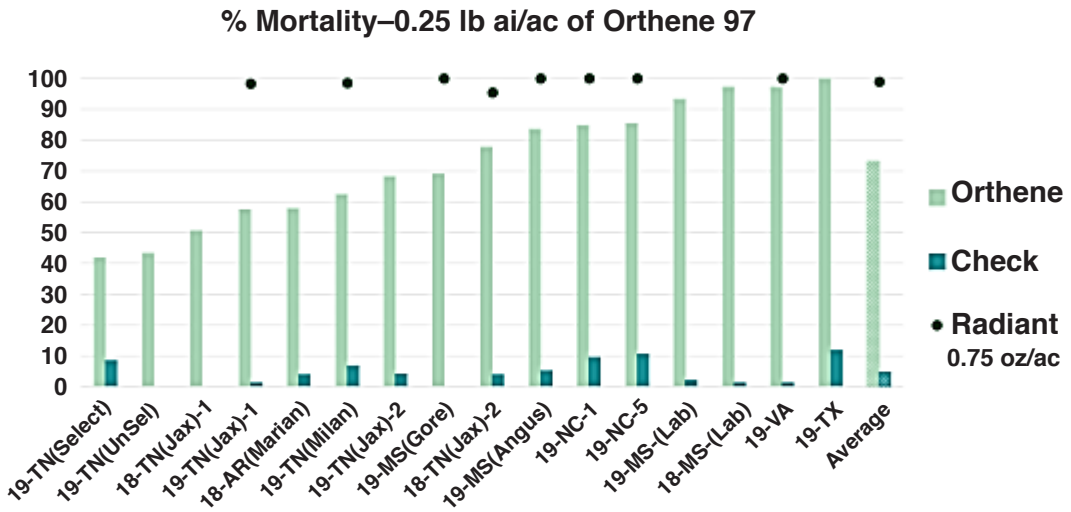

Fig. 1. Results of 24-hour leaf-dip bioassays to assess the efficacy of acephate (0.25 lb ai/ac of Orthene 97) against tobacco thrips populations from multiple locations in the mid-South and Southeast U.S. (2018, 2019).

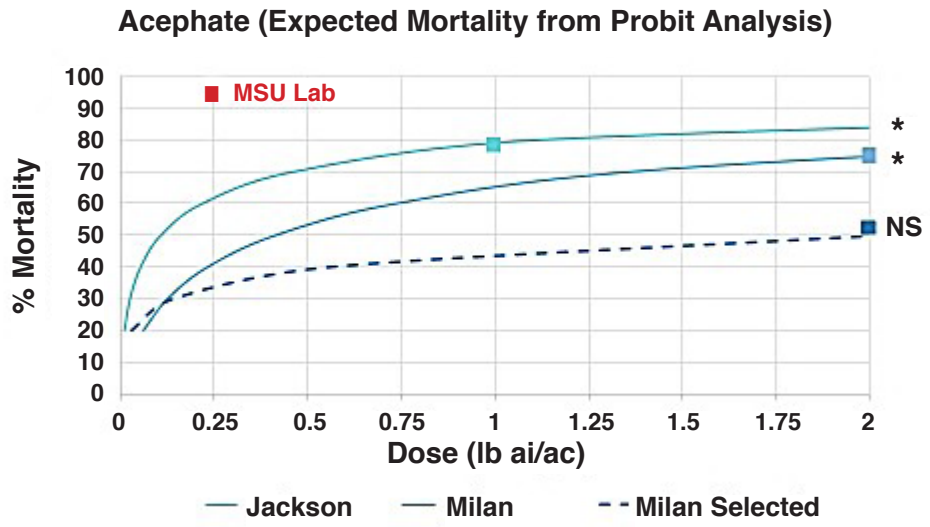

Fig. 2. Dose response to acephate using bioassays of three field collected populations of tobacco thrips from Tennessee compared with a lab colony from Mississippi State University (2019). An asterisk (*) indicates a significant probit fit ($P < 0.05$); squares show actual mortality at highest rate tested.

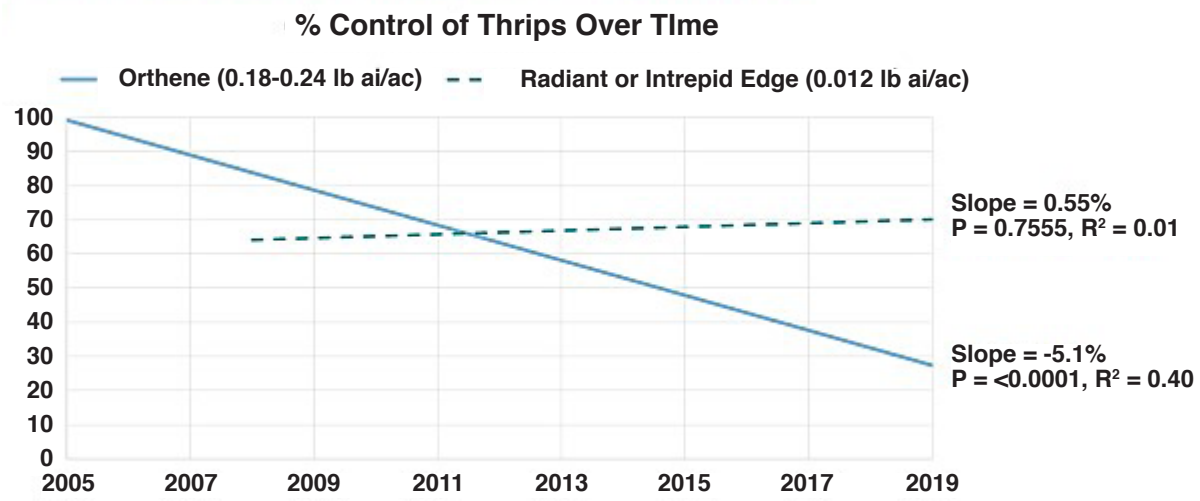

Fig. 3. Linear regression lines of thrips control over time for acephate (Orthene) and spinetoram (Radiant or Intrepid Edge) in replicated field trials in Tennessee since 2005.

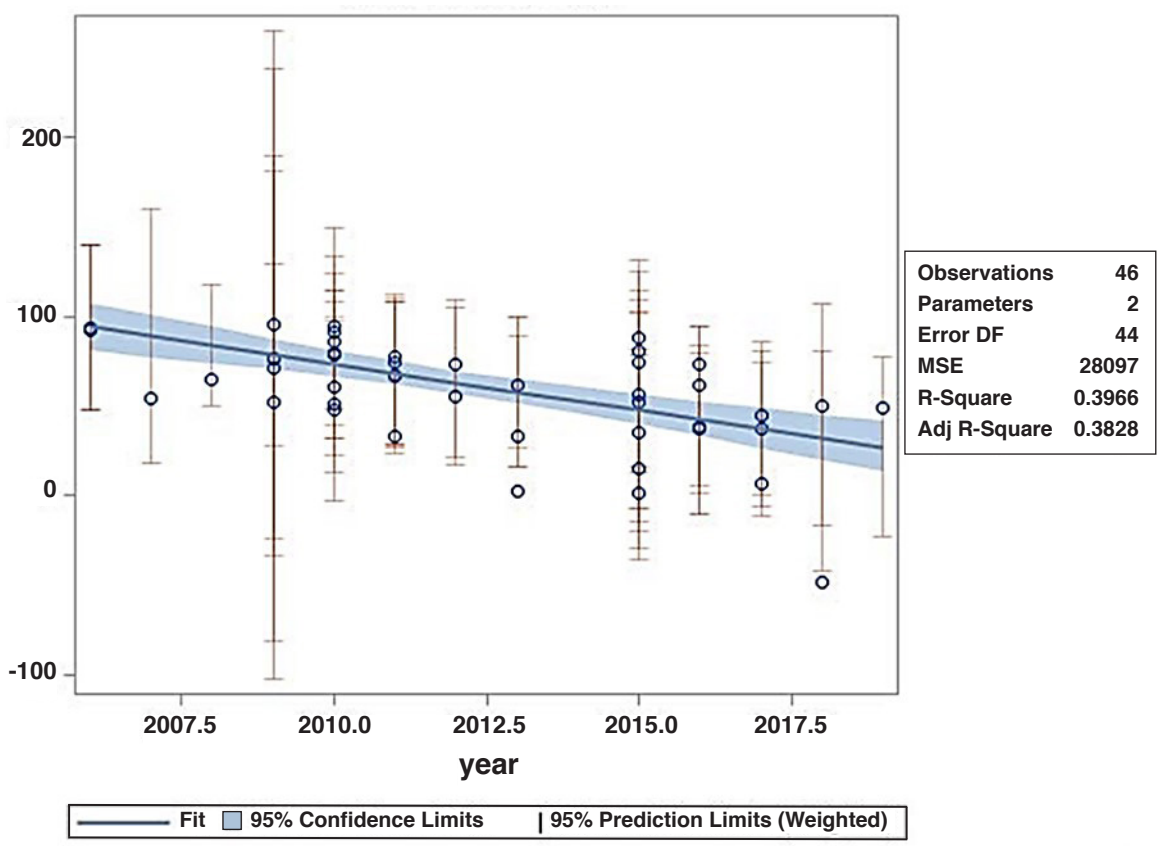

Fig. 4. Detailed regression analysis of thrips control over time for acephate (Orthene) in replicated field trials in Tennessee since 2005.

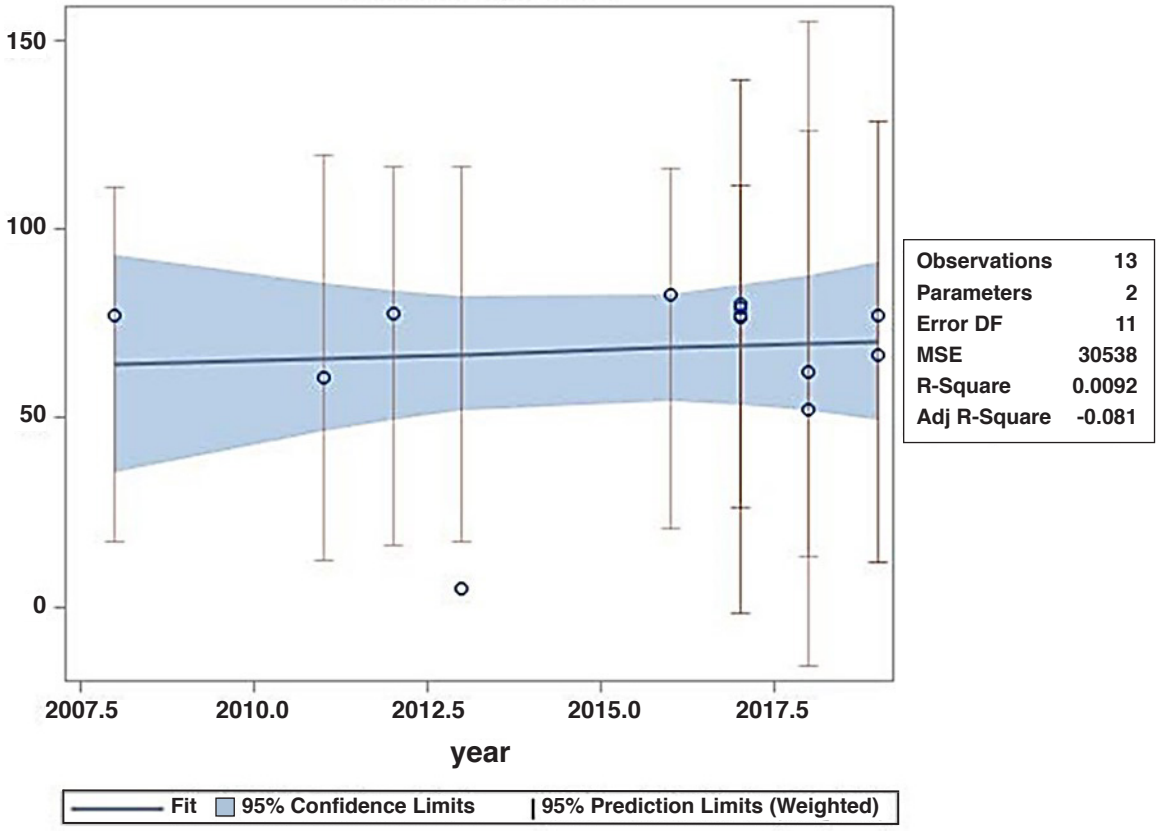

Fig. 5. Detailed regression analysis of thrips control over time for spinetoram (Radiant or Intrepid Edge) in replicated field trials in Tennessee since 2008.

Cereal Rye Cover Crop Termination Timing in Cotton

B. Robertson[1] and A. Free[1]

Abstract

Utilization of cover crops and reducing tillage are two practices that can have a significant impact toward improving soil health. The issues with cover crops that concern most growers relate to providing a "green bridge" for pests from the cover crop to the economic crop and obtaining a good stand through the residue. The objective of this study is to investigate the potential of timing cereal rye cover crop termination to provide the ample additional living roots in the soil profile to benefit soil microbes while avoiding excessive aboveground residue to ease planting concerns. A replicated field study was utilized to evaluate five termination timings of cereal rye. These timings were based on the growth stage of the cereal rye to include 1) early-boot, 2) late-boot, 3) heading, and 4) anthesis. Termination timing did influence aboveground biomass, root mass, and depth of rooting with greater quantities being produced as termination was delayed. Terminated cereal rye at planting did produce the greatest levels of aboveground biomass and root mass ratings. However, the treatment yielded less than the termination timing three weeks prior to planting; and 6 weeks prior to planting, however, no one treatment was statistically different. It is possible to terminate cereal rye three weeks prior to planting cotton to achieve benefits associated with a cover crop while avoiding pest issues from the existence of a "green bridge."

Introduction

Utilization of cover crops and reducing tillage are two practices that can have a significant impact on improving soil health. There are many measurements that can be used as an indicator of improved soil health. Water infiltration can be used as an indirect measure of soil health. As soil health improves, water infiltration rates often improve as well. Living roots in a field for as many months as possible help sustain soil microbes populations which are important in improving soil health. Issues with cover crops that concern most growers relate to providing a "green bridge" for pests from the cover crop to the economic crop and planting and obtaining a good stand through the residue. The objective of this study is to investigate the potential of timing cereal rye cover crop termination to provide the ample additional living roots in the soil profile to benefit soil microbes while avoiding excessive above–ground residue to ease planting concerns.

Procedures

A replicated field study was utilized to evaluate five termination timings of cereal rye. These timings were based on the growth stage of the cereal rye to include 1) early-boot, 2) late-boot, 3) heading, and 4) anthesis. Visual root ratings at a 6-in. interval down to 3 ft were recorded at planting to assess cover crop density and depth. Water-mark soil moisture sensors placed at a depth of 6, 12, and 18 in. were utilized to evaluate water infiltration in each termination timing. Lint yields were calculated from seedcotton weights from machine-picked plots. Turnout was calculated from a grab sample pulled from each plot and ginned on a tabletop gin.

Results and Discussion

2019 was a relatively wet year with the field only requiring two pivot irrigations. Visually, rates varied numerically by treatment. Root mass was denser and extended deeper into the soil the later the cereal rye cover crop was terminated. While no significant differences were observed, the two early termination timings were more similar to one another with less root mass and depth compared to the later termination timings. Water infiltration did not vary significantly between termination timings in 2019 (Fig. 1).

Lint yield differed numerically by termination timing in this study. The lowest yields were observed where cover crops were terminated at planting or later. Termination timing at heading yielded the highest in 2019 with 1730 lint lb/ac produced (Fig. 2).

As cereal rye matures, the C:N increases. As the C:N increases, soil microbes must mine additional N from the soil competing with the cash crop. Producers have observed similar yield decreases after cereal rye moves into seed set or seed fill.

Practical Applications

Termination timing did influence aboveground biomass, root mass, and depth of rooting with greater quantities being produced as termination was delayed. Termination timing of early-boot and heading resulted in the highest numerical yields. These timings ranged from 3 to 6 weeks prior to planting. Terminated cereal rye at planting did produce the greatest levels of above-ground biomass and root mass ratings. However, this treatment yielded less than the termi-

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nation timing at heading and early boot. It is possible to terminate cereal rye 2 weeks prior to planting cotton to achieve benefits associated with a cover crop while avoiding pest issues from the entrance of the "green bridge".

Acknowledgments

Support provided by the University of Arkansas System Division of Agriculture.

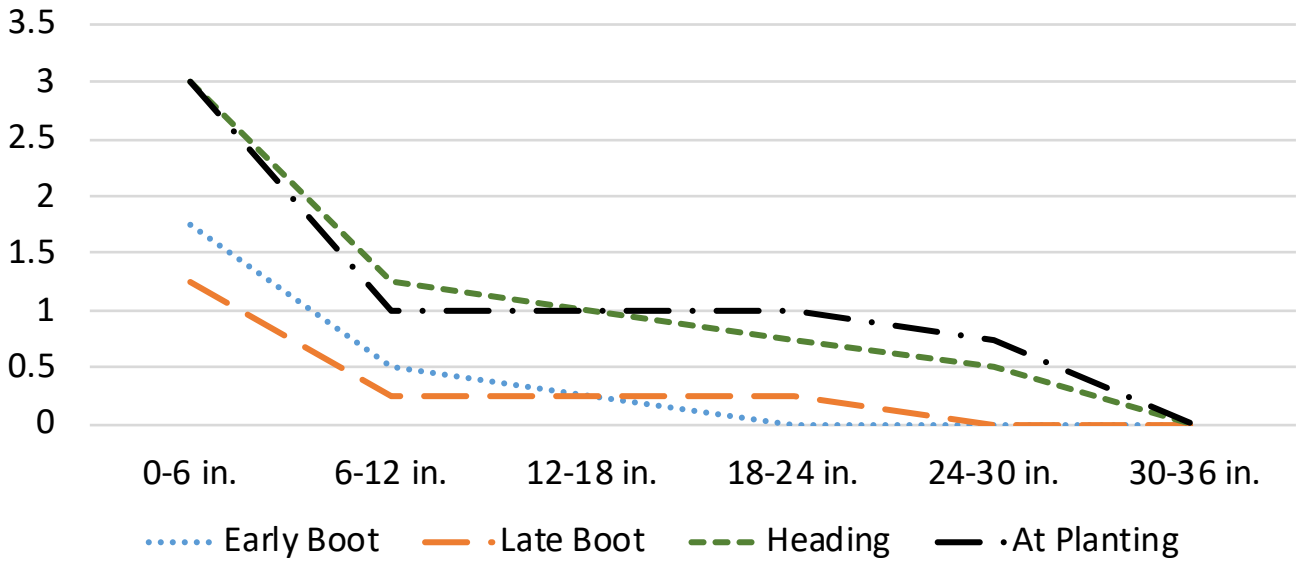

Fig. 1. Root mass evaluations, St. Francis termination study.

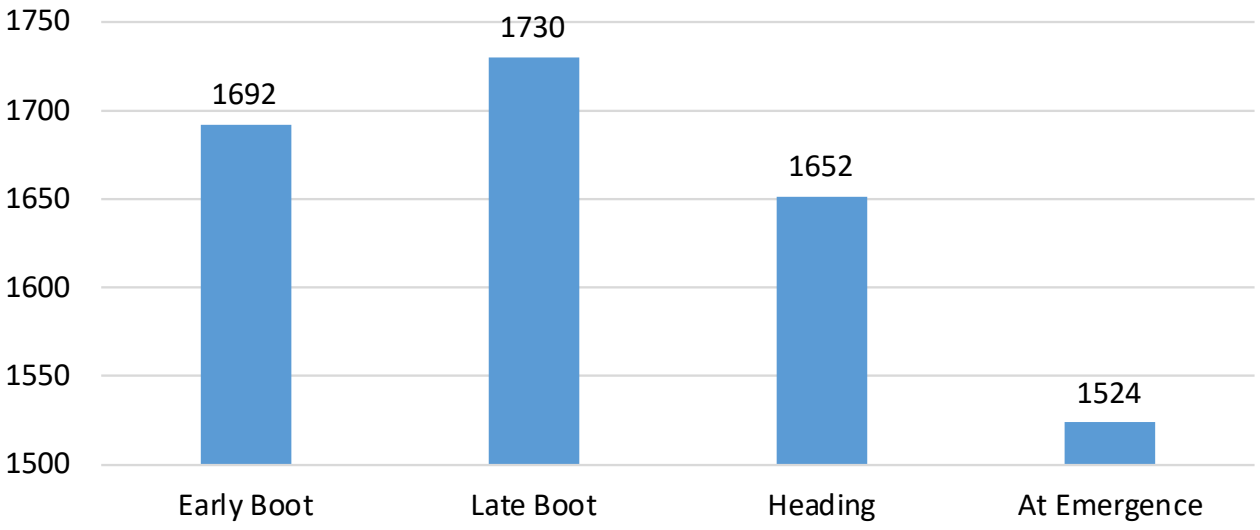

Fig. 2. Termination timing vs. lint yield.

Evaluation of Cotton Yield To In-Season Soil Applied Potassium

B. Robertson[1] and A. Free[1]

Abstract

The increased yield potential of new cultivars has pushed cotton yields in Arkansas to 3 - 4 bales/ac. Such high yields put a substantial demand on the cotton root systems' ability to take up sufficient potassium (K) and other nutrients especially in soils with shallow rooting. The objective of this study was to evaluate application timing and rates of K on cotton yield and quality. The on-farm study from 2016 to 2019 near Judd Hill was a conventional-tilled, furrow-irrigated field. The producer's standard K fertility program timings consisted of pre-plant, 4 to 6 leaf, and 1 week prior to first flower. Alternative strategies consisted of shifting the in-season K applications to either the 4 to 6 leaf or the one week prior to first flower timing. A treatment which consisted of no in-season applications represented the current University of Arkansas System Division of Agriculture's recommendations. While no statistical yield differences were observed within years, it appears that a trend for improved yields may be obtained when shallow rooting conditions exist especially during boll fill.

Introduction

New and improved cultivars and better management practices have pushed cotton yields in Arkansas to 3–4 bales/ac. Such high yields put a substantial demand on the cotton root systems' ability to take up sufficient potassium (K) and other nutrients. The frequency and severity of K deficiency symptoms also have increased on highly productive soils over the past decade especially in soils with shallow rooting. Insufficient K levels as a result of shallow rooting could decrease yields and fiber quality and lead to decreased grower profits. The objective of this study was to evaluate application timing and rates of K on cotton yield and quality. Based on these findings, soil K recommendations will be reevaluated and modified as appropriate to optimize yields.

Procedures

An on-farm study site was selected at Judd Hill based on cooperators' and consultants' desires to address their questions on K needs of cotton on their soil and yields. The site was a conventional-tilled, furrow-irrigated Mhoon Silt Loam field. The four-year study was conducted using a randomized complete block design with 4 replications. Plots were 6 rows (38 in.) wide and 1200 foot long. The producer's standard fertility program consisted of pre-plant, 4 to 6 leaf, and 1 week prior to first flower (Table 1). Alternative strategies consisted of shifting the in-season K applications to either the 4 to 6 leaf or the one week prior to first flower timing. A treatment which consisted of no in-season applications (all pre-plant) of K represented the current University of Arkansas System Division of Agriculture's Cooperative Extension Service recommendations (Table 2). Seedcotton was hand-picked from four plants (one hill) in each plot to calculate percent lint and provide samples for high volume instrument (HVI) fiber analysis. Plots were machine harvested.

Results and Discussion

A trend was observed for increased yield associated with in-season K applications in 2016, 2017 and 2019 in which dry conditions were observed during much of boll fill. When dry conditions during boll fill are experienced, the lack of water infiltration below six inches with furrow irrigation often results in the loss of deep roots shifting the plant into a shallow rooting/poor uptake situation. No advantage was observed in 2018 when significantly above average rainfall was received during boll fill allowing the plants to maintain a deeper, effective rooting zone.

Practical Applications

While no statistical yield differences within years were observed in this study, it appears that a trend for improved yields may be obtained when the effective rooting depth is restricted during boll fill. More research is needed to fully evaluate the impact of soil moisture in plant's response to soil-applied K.

Acknowledgments

The authors would like to acknowledge Cotton Incorporated for their support of this project. The authors would also like to thank producers Marty White and Jesse Flye at Judd Hill as well as their consultant Eddy Cates for their interest and support of this study. Support also provided by the University of Arkansas System Division of Agriculture.

[1] Professor/Cotton Extension Agronomist and Cotton Research Verification/Sustainability Program Coordinator, respectively, University of Arkansas System Division of Agriculture's Newport Extension Center, Newport.

Table 1. Producer standard fertilizer application timings and rates of nutrient applications season long at Judd Hill in 2016 to 2019.

	Application Timing			
Nutrient	Pre-plant	4 to 6 Leaf	1 week prior First Flower	Season Total
	----------lb/ac----------			
Nitrogen	18	46	46	110
Phosphorous	46	0	0	46
Potassium	60	30	30	120
Sulfur	0	12	12	24
Boron	0	0.5	0.5	1.0

Table 2. Alternative strategies evaluated for K-Study application timings and lint yield lb/ac at Judd Hill in 2016 to 2019 keeping all other nutrient rate and timings consistent with each strategy.

	Lint Yield				
K Timing	2016	2017	2018	2019	Average
	----------lb/ac----------				
In-season Early + Late	1627	1643	1640	1733	1661
In-season Early Only	1572	1588	1590	1671	1605
In-season Late Only	1459	1650	1745	1618	1618
Pre-plant Only	1413	1581	1740	1669	1601

Influence of Cultural Practices on Target Leaf Spot in Cotton

B. Robertson,[1] R. Benson,[2] A. Free,[1] and J. McAlee[1]

Abstract

In Arkansas, Target Leaf Spot (TLS) was observed on cotton statewide in 2016. Significant defoliation and boll drop were observed in northeast Arkansas. As many as three fungicide applications were recommended by some consultants. At harvest, the yield differences expected by these consultants between treated and untreated strips were not observed. The objectives of this study are to evaluate the efficacy and efficiency of applications of the fungicide, (fluxapyroxad + pyraclostrobin), on the disease damage, growth and yield of cotton infested with Target Spot caused by *Corynespora cassiicola* in various types of plant structures. An on-farm study site was selected based on historical occurrence of TLS. Georeferenced data including plant height, occurrence of TLS, and defoliation as a result of TLS were collected to overlay with other imagery and data collected during the season. Fungicide applications were made with the producer's sprayer to investigate the impact of effective coverage on disease control using two different application techniques. Differences in plant height and canopy coverage were observed and recorded with GPS coordinates. Plant height ranged from 18 in. to 42 in. and plant canopy coverage ranged from 50% to 95% in late September. The occurrence of TLS in this study was nonexistent in 2019. Differences in effective coverage were observed. However, it is very difficult to penetrate a dense canopy. While the risk of TLS impacting yield is likely very low in Arkansas because of the late timing involved with the occurrence of the disease, proper techniques are necessary to achieve effective coverage if treatment is deemed necessary.

Introduction

In Arkansas, Target Leaf Spot (TLS) was observed on cotton statewide in 2016. Although the disease developed during late boll fill when impact on yield was questionable, significant defoliation and boll drop were observed in northeast Arkansas. As many as three fungicide applications were recommended by some consultants. At harvest, yield differences expected by these consultants between treated and untreated strips were not observed. The severity of TLS appeared to be influenced by rankness. Where cotton canopies did not overlap, TLS was less. Managing plant structure to reduce the ability of the disease to develop in the interior canopy may be the best means to manage this disease. The objectives of this study are to evaluate the efficacy and efficiency of applications of the fungicide, (fluxapyroxad + pyraclostrobin), on the disease damage, growth and yield of cotton infested with Target Spot caused by *Corynespora cassiicola* in various types of plant structures.

Procedures

An on-farm study site was selected based on the occurrence of TLS and greater than 60% leaf defoliation of cotton in the 2016 cropping year. Native differences in soil types in this field result in great variations in plant canopy. Manipulation of cultural practices was not required to artificially induce canopy differences. Farmer standard cultural practices were employed season long with the exception of fungicide treatments. Georeferenced data including plant height, canopy coverage, occurrence of TLS, and defoliation as a result of TLS were collected to be overlaid with other imagery and data collected during the season. Fungicide applications were made with the producer's sprayer to investigate the impact of effective coverage on disease control using two different application techniques. One technique (BMP) was to apply fungicide treatments in 15 gal/ac spray solution at a speed of 10 mph with a 24-in. boom height. The other technique involved speeding the sprayer to deliver 10 gal/ac while using a boom height of 4 to 6 ft above the canopy (neighbor). Each sprayer treatment also included nozzles to deliver very coarse (VC) droplet. Plants were machine harvested.

Results and Discussion

Differences in plant height and canopy coverage were observed and recorded with GPS coordinates. Plant height ranged from 21 in. to 54 in. and plant canopy coverage ranged from 45% to 100% in late September. Fungicide treatments were made to and observed across the range of plant canopy types. The occurrence of TLS in this study was nonexistent in 2019. Differences in effective coverage were observed. Effective coverage for the 15 gal/ac treatments was double that of the 10 gal/ac treatment. It is very difficult to penetrate a dense canopy. This data highlights that challenge. The smallest droplets, traveling the slowest have the least penetration.

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[2] County Extension Agent, University of Arkansas System Division of Agriculture Cooperative Extension Service, Batesville.

Practical Applications

While the risk of TLS impacting yield is likely very low in Arkansas because of the late timing involved with the occurrence of the disease, proper techniques are necessary to achieve effective coverage if treatment is deemed necessary. Carrier volumes of 15 gal/ac with a sprayer speed of 10 to 12 mph are recommended with a spray boom height of 20 to 24 inches. Variations in this recommendation will significantly impact coverage. A coarser droplet is recommended as speed increases with ground application. As the cost of fungicide treatments per acre can be significant, any decrease in efficacy of the product as a result of poor application techniques must be avoided.

Acknowledgments

Support provided by the University of Arkansas System Division of Agriculture.

Interactions of Cotton Seeding Rate, Cover Crop Termination Timing, and Pest Insect Control

T.G. Teague,[1] J. Krob,[1] A.J. Baker,[1] J. Nowlin,[1] and N.R. Benson[2]

Abstract

Mid-South cotton producers increasingly are integrating winter cover crops into their production systems. With new practices, new questions emerge, including the costly decision of whether to increase cotton seeding rates. There also are uncertainties regarding cover crop termination timing and potential arthropod pest risks. We conducted a field trial in 2019 to evaluate these factors. The experiment was located at the Manila Airport Complex in Mississippi County, Arkansas. Cultivar DG3385B2XF was planted 29 May using a 12-row precision planter at 3 seeding rates—high, recommended, low (4.5, 3, 1.5 seeds per ft of row (38-in. row spacing), respectively—in a field with banded black oats (*Avena strigosa*) cover crop terminated at 4 timings. The study also included evaluation of insect pest responses (*Lygus lineolaris* and thrips spp. (*Thrips tabaci*, *Frankliniella occidentalis*)). For yield evaluations, we used georeferenced yield monitor data and corresponding soil apparent electrical conductivity (EC_a) measurements. Results from this late-planted trial showed that with a time-limited growing season, there were lower yields with the lowest seeding rate; however, net revenue from the low seeding rate treatments was highest for the experiment. Increased square shed following *Lygus* feeding was associated with higher stand density and proximity to a field edge with a plant bug-favorable habitat. *Lygus*-induced square shed affected yield of plants in coarse sand but not loamy sand. Termination timing of the banded black oats did not affect yield in 2019. From these and previous findings, we advise producers to choose the least expensive seeding rate to achieve a stand of at least 1 plant per ft of row. Broadleaf plants should be selectively killed at least one month before sowing cotton to avoid providing a "green bridge" that allows pests to survive. *Lygus* scouting protocols should include plant monitoring to determine square retention. Scouting site selection should allow detection of pest dispersion patterns associated with field borders.

Introduction

One of the most expensive cotton production inputs is treated, transgenic seed. We initiated field studies in 2014 at the Manila Airport Cooperative Research Farm to evaluate profitability and productivity of reduced seeding rates. Working with cooperating producers and using their equipment, our aim is to provide research-based guides that inform cotton producers on practical ways to reduce their input costs without sacrificing economic yield. Results from the first 3 years of the study showed that reducing cotton seeding rate from 4.5 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). Expanded 2017 and 2018 field trials included cotton seeding rate evaluations in cover crop systems with different species and termination timing (Teague et al., 2018, 2019). Results from those studies showed early termination of winter cover crops was advantageous. There were significant maturity and yield penalties for "planting green" (i.e., planting the cash crop into a non-terminated cover crop); those effects largely resulted from delayed cotton seedling emergence and delayed stand establishment. In 2019, there was a dry period leading up to cotton planting, and delayed cotton stand establishment observed with the non-terminated cover crop was related to soil moisture depletion by the growing cover crop. In addition to cover crop treatment effects, we also have included soil texture as a co-variant in analysis of yield monitor data. The field site is characterized by spatially variable soils, and we examined potential for reducing input costs by using variable rate planting and site-specific, zone management. In field areas dominated by coarse sand soil texture, low cotton seeding rates (1.5 seeds per ft of row on 38-in. rows) have typically 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 the higher rate (4.5 seeds per ft of row) (Teague et al., 2019).

In this paper, we report results from a 2019 study at the same site. We evaluated cotton seeding rates and interactions with termination timing of banded, black oats (*Avena*

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strigosa) cover crop. Weather delayed our date of planting until the very end of the planting window for northeast Arkansas, therefore increasing the importance of treatment effects on late season plant maturity and harvest timing. We also included insect control evaluations in the multi-factor study with particular attention to pest dispersion patterns associated with field borders. Results will allow us to develop and refine current crop and pest management recommendations for cover crop management and seeding rates with consideration of within-field soil variability and insect pest induced injury. Results also will provide baseline data to identify opportunities for site-specific management with an overall goal to improve production efficiency and reduce production costs.

Procedures

The 4*3*2 factorial experiment was arranged in a split-plot design with cover crop treatments considered main plots; seeding rate and *Lygus* insect pest control were considered sub-plots. There were 3 replications. The 4 cover crop treatments were: 1) banded oats, early termination (16 days prior to seeding cotton); 2) banded oats, at-planting termination; 3) banded oats, at-planting termination and no foliar insecticide for thrips control (Thysanoptera: Thripidae); and 4) winter/spring fallow. The 3 cotton seeding rate treatments were 1.5, 3, or 4.5 seeds of DG 3385 B2XF per ft of row (on 38-in. rows this was 20,634, 41,267, and 61,901 seeds per acre, respectively) planted on 29 May. For the *Lygus lineolaris* (tarnished plant bug (Hemiptera: Miridae)) control treatment, plant protection was either 1) full season or 2) post-flower only (one protective spray for *Lygus* was withheld during pre-flower period, but after first flower, multiple field-wide foliar insecticide sprays were made by the cooperating farmer). Plots were 12 rows wide and 100 ft long. All production activities including land preparation, fertilizer application, irrigation, and pest control were performed by the cooperating producers with their equipment and following their standard management practices (Fig.1). The only exceptions were selective foliar pesticide applications: 1) herbicide (glyphosate) on 13 May for early cover crop termination, 2) insecticide (dicrotophos) for thrips spp. control at 17 days after planting (DAP), and 3) insecticide (sulfoxaflor) for *Lygus* control at 44 DAP (Table 1).

Stand counts were made at 6, 14, and 22 DAP using line-transect sampling. Samplers counted plants per 3 ft in two transects across each 12-row sub-plot using T-stick samplers. Stand density was gauged by comparing seedling counts to the seeding rate target. COTMAN® plant monitoring activities were initiated at first square and included evaluations of plant main-stem nodal development and first position square and boll retention using standard SquareMap and BOLLMAN sampling protocols (Oosterhuis and Bourland, 2008). Arthropod pests were monitored weekly from seedling emergence through physiological cutout (NAWF = 5). 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 assessments were made 16, 19, 23 and 27 DAP using whole plant alcohol washes with 10 plants collected per sub-plot. *Lygus* were monitored weekly starting in the first week of squaring (~35 DAP) through physiological cutout. Sampling included use of sweep nets (pre-flower) and drop cloths (full season). Yield assessments were based on data collected from the cooperating producer's 6-row cotton picker equipped with calibrated yield monitor with GPS receiver to attain site-specific lint yield. Yield monitor data were "cleaned" using Yield Editor (ver. 2.0.7 https://data.nal.usda.gov/dataset/yield-editor-207). Georeferenced data layers from the yield monitor and from a Veris Soil Surveyor (5-m shallow measurements) (Veris Technologies, Salina, Kan.) were joined using ArcGIS (ESRI; ver10.7) to enable inclusion of soil texture as a covariate in yield analysis. Soil apparent electrical conductivity (EC_a) measurements had been made previously with a Veris Soil Surveyor (5-m shallow). For yield evaluations, we stratified the field into two soil textural classes—coarse sand (<9 mS m^{-1}) and loamy sand (≥ 9 mS m^{-1}), using soil EC_a as a proxy for soil texture. Approximately 35% of the field was classified in the coarse sand category (Fig. 2). Class categories were based on previous experience at the field site (Teague et al., 2018, 2019). A factorial structure was used for analysis of the yield monitor measured yield data with seeding rate, cover crop termination timing, insect control and block effect; soil EC_a classifications were used as a co-variate. Statistical analyses were performed using SAS 9.4 (SAS Institute, Inc., Cary N.C.). Analysis of variance was conducted using mixed model procedures (PROC MIXED and PROC GLIMMIX). Mean comparisons were made using LSMEANS procedure with the Tukey adjustment ($P \leq 0.05$). A partial budget analysis was performed to calculate returns to operating expenses (variable costs) using the University of Arkansas System Division of Agriculture's Cotton Enterprise budgets (https://www.uaex.edu/farm-ranch/economics-marketing/farm-planning/budgets/docs/budgets2016/Budget_Manuscript_2019.pdf).

Results and Discussion

Results from transect sampling indicated that seeding rate treatments reached at least 85% of target stand by 14 DAP, and final stand densities were within 85% of target seeding rate (Fig. 3). Plant stand density was not affected by cover crop termination timing.

Thrips numbers were low in 2019, and infestations had no measurable effects on plant development, maturity, or yield (data not shown). Results from intensive sweep net and drop cloth sampling for *Lygus* showed sub-threshold numbers in pre-flower counts. The Arkansas action threshold using sweep net sampling is 8 to 12 bugs per 100 sweeps. In our sampling, with 1440 sweep net samples at optimal sampling times in mid-morning and over two sample dates, 36 and 42 DAP, only 8 total *Lygus* bugs were observed. Drop cloth

sample results also indicated low infestation levels (Table 2). Adult feeding activity was detected with plant monitoring using COTMAN SquareMap sampling with measures of 1st position square sheds (Fig. 4). Differences in adult *Lygus* induced square shed among treatments were detected on 10 July (42 DAP) with higher shed levels among plants with seeding rates 3 and 4.5 compared to 1.5 seeds per ft of row ($P = 0.01$) (Table 3) Transform insecticide (sulfoxaflor (0.05 lb ai/ac) was applied in appropriate treatment plots on 12 July (44 DAP).

Results from SquareMap sampling also indicated spatial variability in adult *Lygus* feeding activity with higher square sheds associated with plants positioned nearest the field border in treatment plots with highest plant stand densities. A simple presentation from 50 DAP of square shed data sorted into different replications effectively depicts the spatial variation observed during the experiment (Fig. 4.)

COTMAN growth curves for the seeding rate main effects showed effects of good early season growing conditions (Fig. 5). Pace of nodal development was slightly advanced in the low seeding rate treatments. The late planting date (and accompanying warm growing conditions) resulted in growth curves above the standard curve prior to first flower and fewer days to first flower. Days to cutout ranged from 81 to 85 DAP across treatments; however, because scouts did not consider soil texture in their sample site selection for plant monitoring activities, variation in plant maturity associated with soil texture was not measured. Cover crop termination timing had no significant effect on maturity. There was seeding rate*insect control interaction with earlier maturity (3 days) for insecticide protected plants growing in higher stand density compared to unprotected plants with higher square shed levels.

Lint yield varied across heterogeneous soils (Table 4), *Lygus* control treatments (Tables 4 and 5), and seeding rates (Table 5), but there were no significant differences associated with cover crop termination timing (including differential insecticide sprays for thrips) (data not shown). Yield response to seeding rate varied with soil texture and *Lygus* control treatment combinations ($P < 0.001$) (Tables 4 and 5).

Lowest overall yields were associated with coarse sand (EC_a <9 mS/M) compared to loamy sand field areas (Fig. 6). There was a significant ($P < 0.001$) seeding rate*soil texture interaction (Table 4). Reduced yield in the 1.5 seed/ft of row likely was related to the limited growing season due to late date of planting. In previous years, contribution of monopodial bolls to overall yield was higher in the low-density planting compared to recommended and high seeding rate treatments (Benson et al., 2014, 2015). Dates of planting in those previous studies were 2 to 4 weeks earlier than the 2019 trial, and with the longer growing season there was additional time to mature monopodial bolls.

Yield following *Lygus* feeding injury varied across soil texture classes (Table 4). In coarse sand areas, unprotected plants produced lower lint yield compared to protected plants; however, there were no differences in mean yields between protected and unprotected plants in areas with loamy sand. We interpret the *Lygus* control*soil texture interaction in yield response as an indication of differential tolerance and compensation capacity of plants growing in different soil textures. Similar plant response to pre-flower square loss has previously been reported (Teague, 2016).

Yields with higher seeding rates may have been good, but profits were not (Table 5). Seed costs to the producer were ~$100 per acre more for highest compared to lowest seeding rate. Net revenue estimates do not include consideration of fixed costs; had those costs been considered, there were no profitable treatment combinations in the 2019 study. We also did not calculate management or equipment costs for variable rate seeding prescriptions; those additional costs would have further increased losses.

Practical Applications

We suggest several practical applications based on these 2019 findings and our previous seeding rate and cover crop work. For cotton seeding rate, producers should choose the least expensive option that results in an acceptable stand of at least 1 plant per ft of row. Our overall results do not support the additional management and capital equipment costs required to implement variable rate planting. Cereal cover crop termination is recommended at least 2 weeks prior to planting to reduce risks of allelopathic effects on cotton seedlings and to conserve soil moisture for planting. Cover crop management did not affect arthropod pest risks in this 2019 study where broadleaf weeds were selectively killed one month before sowing cotton to avoid providing a "green bridge" that could allow pests to survive. Using COTMAN plant monitoring provided a better assessment of early season adult *Lygus* activity (% square shed) than direct insect counts with sweep nets and drop cloths. We observed higher levels of *Lygus* feeding injury with increased stand density from high cotton seeding rates. Field border landscape also impacted risk from adult *Lygus* feeding injury. Plants tolerated moderate levels of pre-flower square shed unless they were growing in coarse sand areas of the field. Crop advisors should adjust their scouting protocols to include additional inspections near high-risk, insect pest favorable, field borders. Supplementary scouting should allow early detection and will inform crop managers about pest dispersion patterns associated with field borders. Site-specific border sprays rather than broadcast sprays may be economically appropriate at field edges adjoining insect pest favorable habitat.

Acknowledgments

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ARK02569. The University of Arkansas System Division of Agriculture and Arkansas State University College of Agriculture also are acknowledged.

Literature Cited

Benson, N.R., D.K. Morris, and T.G. Teague. 2015. Effects of irrigation timing and seeding rate on the maturity and yield of cotton grown in a northeast Arkansas field. pp. 91-97. *In*: D.M. Oosterhuis (ed.) Summaries of Arkansas Cotton Research 2014. Arkansas Agricultural Experiment Station. Research Series 625. Fayetteville, Ark.

Benson, N.R., A.M. Mann, D.K. Morris, and T.G. Teague. 2016. Seeding rate decisions and impacts on spatial yield variability in Northeast Arkansas cotton pp. 25-30. *In:* D.M. Oosterhuis (ed.) Summaries of Arkansas Cotton Research 2015. Arkansas Agricultural Experiment Station. Research Series 635. Fayetteville, Ark.

Benson, N.R., A.M. Mann, and T.G. Teague. 2017. Cultivar selection, seeding rate, and irrigation timing effects on yield of NE Arkansas cotton. pp. 89-96. *In:* F.M. Bourland (ed.) Summaries of Arkansas Cotton Research 2016. Arkansas Agricultural Experiment Station. Research Series 644. Fayetteville, Ark.

Oosterhuis D.M. and F.M. Bourland. (eds.), 2008. COTMAN Crop Management System, University of Arkansas Agricultural Experiment Station, Fayetteville, Ark. pp. 107. http://www.cotman.org

Teague, T.G. 2016. Plant-insect interactions and cotton development. pp. 27-65. *In:* J. Snider and D.M. Oosterhuis (eds.), Linking Physiology to Management. Cotton Foundation Reference Book Series Number Nine. The Cotton Foundation. Cordova, Tenn., USA.

Teague, T.G., N.R. Benson, K.D. Wilson, and A.M.H. Mann 2018. Seeding rate, cultivar selection and winter cover crop effects on maturity and yield of cotton pp. 98-107. *In:* F.M. Bourland (ed.) Summaries of Arkansas Cotton Research 2017. Arkansas Agricultural Experiment Station. Research Series 652. Fayetteville, Ark.

Teague, T.G., K.D. Wilson, N.R. Benson, J. Nowlin, and B. Robertson. 2019. Seeding rate and winter cover crop effects on maturity and yield of mid-South cotton. pp 632-645. *In:* Proc., Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 8-10 Jan. National Cotton Council, Memphis, Tenn.

Fig. 1. Cover crop treatments in 2019 consisted of winter fallow, or spring planted black oats (*Avena strigosa*) with different termination timing. Banded cover crops commonly are used by Northeast Arkansas and Southeast Missouri cotton producers to protect seedlings from winds and blowing sand. Fall-seeded, winter cover crops typically include wheat (*Triticum aestivum*) or cereal rye (*Secale cereale*), but if conditions preclude fall fieldwork, black oats will be seeded in spring. Planting green refers to planting the cash crop (cotton) into a non-terminated cover crop.

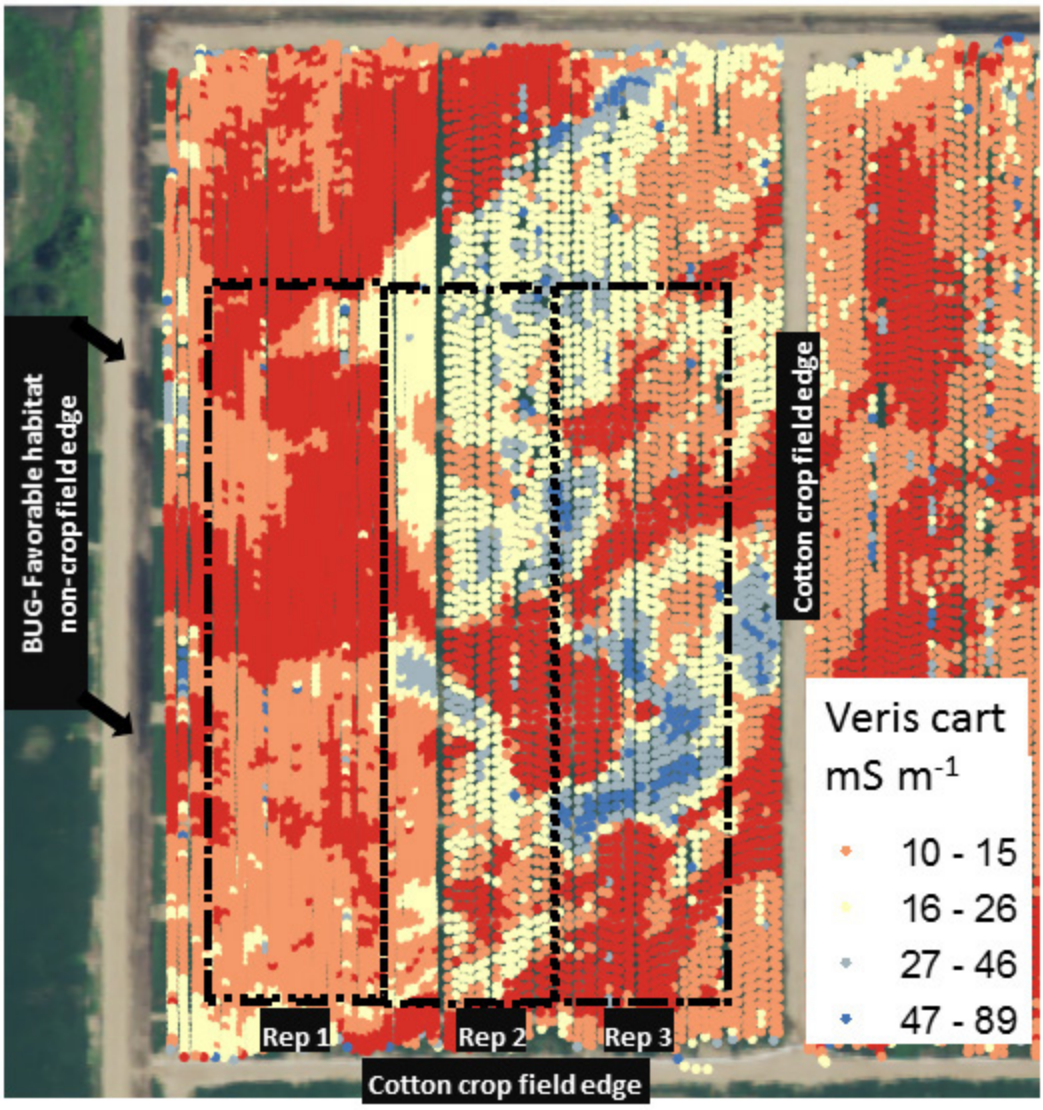

Fig. 2. The soil spatial variability of the research area is apparent in this soil apparent electrical conductivity map generated using Veris Soil Surveyor. The red color denotes the coarse sand portions of the field. The 8-acre plot area and boundaries for replications are indicated with dotted lines. Field edge descriptions are included, 2019, Manila, Arkansas.

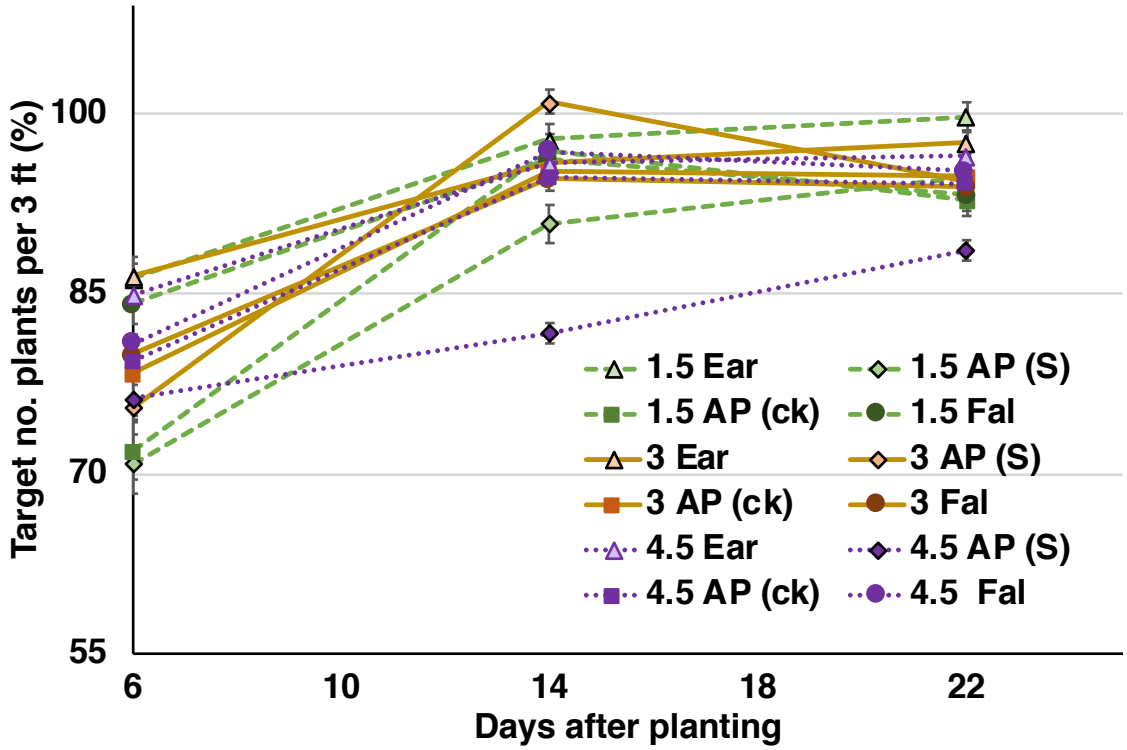

Fig. 3. Plant stand density determined on 6, 14, and 22 days after planting for treatment combinations of seeding rates (1.5, 3, and 4.5 seeds per ft of row), cover crop burndown timing and protective sprays for thrips (early termination (Ear); at-planting termination plus thrips insecticide (AP (S)); at-planting termination with no insecticide (AP (ck)) and winter fallow (Fal) in 2019 at Manila, Arkansas.

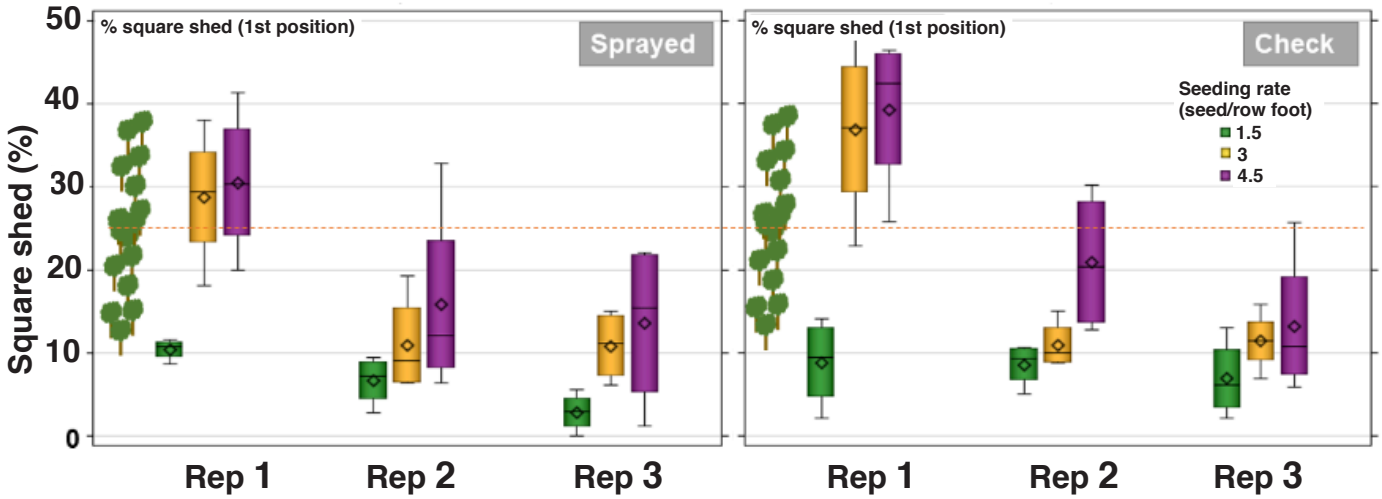

Fig. 4. First position square shed (%) in different seeding rate treatments (1.5, 3, or 4.5 seeds/ft of row), from SquareMap sampling conducted at 50 DAP, 6 days after application of sulfoxaflor insecticide on 12 July (44 DAP). Square shed resulting from Lygus feeding injury was greater proximal to the field border (rep 1) and in plots with higher plant population density (P = 0.0001). The University of Arkansas System Division of Agriculture's Cooperative Extension Service recommended minimum threshold for square retention, 75% retention at first flowers, is indicated by the orange dotted line in 2019 at Manila, Arkansas.

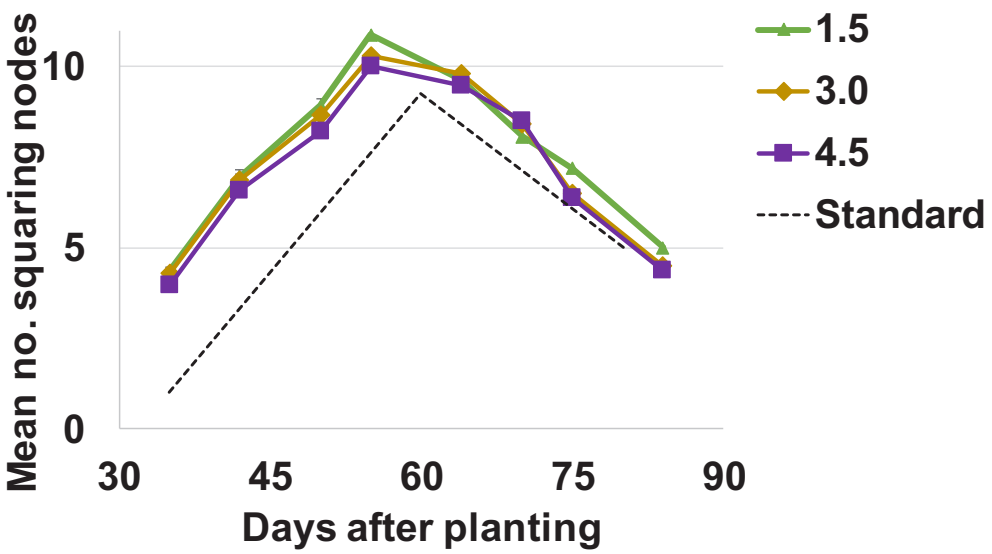

Fig. 5. COTMAN growth curves for 29 May planted cotton for seeding rate main effects for 2019 seeding rate*cover crop*insect control study in 2019 at Manila, Arkansas.

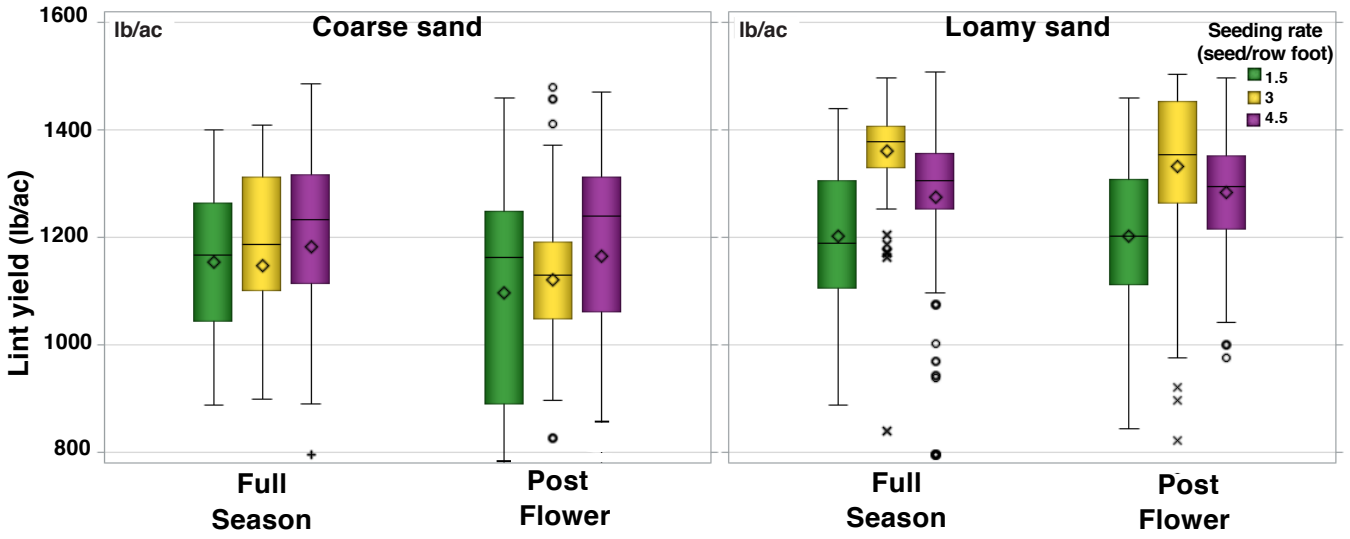

Fig. 6. Lint yields for seeding rate*insect control interactions ($P < 0.05$) in the coarse sand and loamy sand soil textures. Box plots show mean (triangles), median (line), quartiles (box), and minimum and maximum observations along with outliers for each treatment group in 2019 at Manila, Arkansas.

Table 1. Dates of planting, and timing for irrigation, sampling, foliar insecticide application, and harvest for the 2019 airport study, Manila, Arkansas.

Operation	Date	Days after planting
Field re-bedded and black oats cover crop seeded (banded in furrows)	22 March	-68
Selective burndown–broadleaf weeds	pre 16 April	-43
Cover crop termination	Early termination 16 May, At planting 30 May	-13, 1
Cotton planted (Dynagro 3385B2XF)	29-May	0
Stand counts	6, 12 June 20 July	6, 14, 22
Foliar insecticides	17-June (thrips- all plots excluding cc trt 3) 12-July (all plots excluding *Lygus* 1)/ and 1, 13, 28 August (whole field)	19, 44, 64, 76, 91
Furrow irrigation	1, 24 July, 5, 20 August, 3 September	33, 56, 68, 83, 97
Defoliation initiated	14 October	138
Machine harvest	19 November	174

Table 2. *Lygus lineolaris* (tarnished plant bug) counts from drop cloth samples–insecticide sub-plot effects. Sulfoxaflor was selectively applied at 44 days after planting (DAP). After first flowers, insecticides were broadcast applied starting at 64 DAP. Action thresholds for Arkansas are 3 plant bugs per 5 row feet (drop cloth sample) or if square set is less than 85%, 2 plant bugs per sample.

Days after Planting	Full season protection	Post Flower protection only
50	0.20	1.2†
55	0.14	0.5
64	0.50	0.6

†Significant at $P = 001$.

Table 3. Mean first position square shed (%) in different seeding rate treatments determined using COTMAN SquareMap monitoring conducted at 42, 50, 55, 64 and 70 days after planting (DAP).

Lygus control§	Seeding rate	Square shed†‡ at each sample date				
		42	50	55	64	70
	(no. seeds per ft. of row)	(%)				
Preflower Spray	1.5	7.3 b	6.6 b	11.0 c	8.6 c	3.8 d
	3	15.1 a	16.8 ab	25.4 b	21.2 ab	15.4 bc
	4.5	15.8 a	20.0 a	27.7 b	24.4 a	15.7 bc
Check	1.5	6.2 b	8.1 b	12.3 c	13.6 bc	8.3 cd
	3	14.2 a	19.7 a	31.6 b	27.6 a	21.2 ab
	4.5	12.9 a	24.5 a	42.2 a	30.7 a	24.7 a

†Tukey-Kramer Grouping for seeding rate*insect control; least squares means ($\alpha = 0.05$) within each sample date with the same letter are not significantly different.
‡Percent shed of first position squares on main stem sympodia determined using COTMAN sampling protocols.
§Transform (sulfoxaflor) insecticide was applied 44 DAP to selected plots and then broadcast at 64 DAP.

Table 4. Mean lint yields for soil texture and plant bug control effects for 2019 seeding rate*cover crop*insect control study, Manila, Arkansas.

Soil Texture Classification	Protection	Mean lint yield†
		(lb/ac)
Loamy Sand	Full Season	1276 a
Loamy Sand	Post Flower	1271 a
Coarse Sand	Full Season	1138 a
Coarse Sand	Post Flower	1095 b

†Tukey-Kramer Grouping for seeding rate*soil texture; least squares means (α = 0.05) for yield with the same letter are not significantly different.

Table 5. Mean lint yields and estimated net revenue for insect control*seeding rate effects for 2019 seeding rate*cover crop*insect control study, Manila, Arkansas.

Protection	Seeding rate	Mean lint yield†	Net Revenue‡
	(no. seeds per ft of row)	(lb/ac)	($/ac)
Full Season	1.5	1171 bc	$153
Post Flower	1.5	1149 c	$150
Full Season	3	1230 a	$134
Post Flower	3	1198 ab	$117
Full Season	4.5	1221 a	$79
Post Flower	4.5	1203 ab	$78

†Tukey-Kramer Grouping for seeding rate*insect control; least squares means (α = 0.05) for yield with the same letter are not significantly different.

‡Net returns for mean yields were based on $0.70 per lb price with land rent included as 25% share rent. Seed costs were those paid by the cooperating producers and were $48.60, $97.21, and $145.81 for the 1.5, 3, and 4.5 seeds per ft of row rates, respectively. Product cost for Transform insecticide was $7.44 (application cost was not included because it was considered a tank mix with plant growth regulators). Capital recovery and fixed costs estimated by the Enterprise Budget generator were $162 per acre but were not included above.

Field Performance of Twelve Peanut Cultivars in Mississippi County, Arkansas

T.R. Faske,[1] A. Vangilder,[2] and M. Emerson[1]

Abstract

Twelve peanut (*Arachis hypogea* L.) cultivars were planted in an on-farm trial in 2019 in a loamy sand soil previously cropped (2017 and 2018) in cotton (*Gossypium hirsutum* L.). Of the runner-type peanut cultivars, TUFRunner 297, Lariat, and Georgia 12Y had greater pod yield compared to Georgia 18RU. The average yield was 6,319 lb/ac across all runner-type cultivars. Disease pressure was low with the most common disease being late leaf spot caused by *Cercosporidium personatum* (Berk. and M. A. Curtis) Deighton. Of these cultivars, AU-NPL 17 had the greatest severity of late leaf spot compared to Georgia 09B, Georgia 12Y, Lariat, and Georgia 18RU. The southern root-knot nematode [*Meloidogyne incognita* (Kofoid and White) Chitwood] population density dropped from 120 J2/100 cm^3 soil at planting to 0 J2/100 cm^3 at harvest. These runner-type cultivars are adapted to the area and have excellent yield potential in northeast Arkansas and an excellent rotational crop to manage the southern root-knot nematode.

Introduction

The southern root-knot nematode, *Meloidogyne incognita* (Kofoid and White) Chitwood, is one of the most yield-liming plant-parasitic nematodes that affect U.S. cotton (*Gossypium hirsutum* L.) production (Thomas and Kirkpatrick, 2001). During the past two cropping seasons (2017–2018) estimated yield losses by *M. incognita* averaged 4.1% across the U. S. Cotton Belt and 2.0% in Arkansas (Lawrence et al., 2018; Lawrence et al., 2019).

Management strategies consist of nematicides, resistant cultivars, and crop rotation with non-host crops. A few seed- and soil-applied nematicides are available, but are variable in suppression of the southern root-knot nematode and yield protection (Faske et al., 2018; Faske et al., 2019). Though there are a few cotton cultivars with resistance to the southern root-knot nematode, few are early- or mid-season in maturity, which is the most common maturity in the state. Peanut (*Arachis hypogea* L.), which includes all types (runner, spanish, valencia and virginia) is a non-host to the southern root-knot nematode. Currently, the most common peanut type grown in the state is the runner-type peanut (*Arachis hypogea* L. subsp. *hypogaea* var. *hypogeae*) because of its high yield potential.

Peanut production in Arkansas was first reported in 1909 with 10,000 acres for seed, feed (pasture for swine), and forage (hay for cattle) (McClelland, 1944). During the 1940s, peanut production peaked with 110,000 acres in 1943 with most of this production in the Arkansas River Valley (USDA-NASS, 2020; Wilson and Slusher, 1943). At that time, a land race peanut 'white spanish' was the most common peanut grown in the state. The last report of a peanut variety trial by the University of Arkansas was in 1944 at the Fruit and Truck Branch Station (Southwest Research and Extension Station) in Hope, Arkansas (McClelland, 1944). Pod yield average across several land race entries ranged from 1,302 to 1,883 lb/ac. After the 1950s, there was no record of peanut production in the state by the USDA, until the after the turn of the century.

Since 2010, there has been a renewed interest in peanut production in Arkansas. According to the USDA-FSA, some 560 acres were produced in 2010 in Arkansas and by 2012, there were 18,610 acres, with most of the acreage in Lawrence, Randolph, White and Clay counties. There were less than 500 acres of peanut in 2014 in Mississippi and Craighead counties and now (2019), according to the USDA-FSA, these two counties accounted for 20,568 acres or 62% of Arkansas peanut crop. Though peanut acreage has increased, no peanut variety trial has been conducted by the University of Arkansas. Thus, the objective of this study was to evaluate twelve peanut cultivars for disease resistance, yield production, agronomic characteristics, and profitability potential in Mississippi County.

Procedures

Twelve peanut cultivars were planted in a field trial, near Manila, Arkansas. The cultivars (Table 1) were planted at 1-in. deep on 15 May at a seeding rate of 6 seed/ft of row in a Bruno-Crevasse complex, loamy sand soil previously cropped in cotton (2017 and 2018). Weeds were controlled based on recommendations by the University of Arkansas System Division of Agriculture's Cooperative Extension Service. This study was furrow irrigated. Plots consisted of two, 30-ft-long rows spaced 38-in. apart separated by a 10-ft fallow alley. Imidacloprid (Admire Pro®, Bayer Crop-

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[2] Instructor, Associate Director Agriculture and Natural Resources, Paragould.

Science, Research Triangle Park, N.C., at 9.0 fl oz/ac) and peanut inoculant (Primo Power CL™, Verdesian Life Sciences, Cary, N.C., at 7.0 fl oz/ac) was applied in-furrow at planting through a 0.07-in.-diameter (1.8-mm-ID and 4.0-mm-OD) poly tubing using a pressurized sprayer to deliver 7.9 gal/ac. The experimental design was a randomized complete block design with four replications per cultivar.

Late leaf spot was assessed in October using the 10-point Florida leaf spot scale where 1 = no disease and 10 = 100% defoliation. Peanut maturity of the runner-type peanut cultivars was evaluated on 30 September (139 days after planting (DAP)) based on hull-scrape method (Williams and Drexler, 1981). Pod loss was estimated after digging based on number of pods in a 1-sq ft transect systemically placed at the beginning and middle of each plot. Air-dry pod (n = 100) weights of each cultivar were used to estimate yield loss. Plots were dug on 18 October (156 DAP) and thrashed on 5 November with a mobile plot thrasher (Kincaid Equipment Manufacturing, Haven, Kansas). Pod yields are reported as air-dry weights at 6% moisture. A subsample (2-lb) of each cultivar was graded by USDA at Birdsong Peanut near Portia, Arkansas. Data were subjected to analysis of variance using ARM Software (Version 9.0) and mean separation by Tukey's honestly significant difference at $P = 0.05$.

To assess the change in *M. incognita* population density with peanut as a rotation crop, soil samples were collected within two blocks at planting and at harvest. Additionally, soil samples were collected in two fields with a two-year history of peanut-cotton rotation at harvest near Leachville, Arkansas. These fields were planted in Georgia 06G. Soil samples were a composite of a minimum of 10 soil cores taken 8- to 10- in. deep with a 0.75-in.-diameter soil probe. Second-stage juveniles were collected with a Baermann ring system and enumerated using a stereoscope.

Results and Discussion

All peanut cultivars had good emergence at 7 DAP, and most had a uniform stand of 5–6 plants/ft of row, except Contender. Contender is a virginia-type peanut with a very large seed size at 385 seed/lb (Table 1). These seed bridged in the planter tubes and impacted plant stand. Thus, on average, the Contender plots had 30-40% fewer plants than that of the runner- and spanish-type peanut plots. Most runner-type peanuts had a semi-bunch or prostrate growth with intermediate canopy height, while Lariat had a bunch-like growth and tall canopy height.

Most of the runner-type peanuts are marketed as medium maturity (135–145 days), while Algrano IPG 914 and IPG QR-14, as early and early-mid maturity, respectively, and Georgia 12Y, as medium-late maturity. However, based on the hull-scape method, Algrano IPG 814 and Georgia 18RU had the most mature pods (Table 2). Of the runner-type peanut cultivars, TufRunner 297, Georgia 12Y, and Lariat had the greatest ($P = 0.05$) pod yield compared to Algrano IPG 914, Algrano IPG QR-14 and AU-NPL 17. These yield data do not include estimated pod loss at digging, which likely lowered yield for Algrano IPG QR-14, Georgia 16HO, and Lariat as these cultivars had significant pod losses.

The runner-type peanut cultivars with the best grade were Georgia 16HO and Georgia 18RU, which calculated to greater value per ton (Table 3). There was a high percentage of sound splits with Georgia 09B, Lariat, Georgia 18RU, which may have been due to very low percent moisture (6%) at the time of grading. Those cultivars with the greatest value per acre were TUFRunner 297 and Lariat, which were considered the most profitable. Currently, the average cost of peanut production is $430 to $450/ac. The yield average was 6,319 lb/ac across all runner-type cultivars, which was slightly over the statewide average of 5,147 lb/ac estimated by the USDA-FSA.

The most common diseases of peanut in Arkansas are southern blight caused by *Sclerotium rolfsii* Sacc., a soil-borne disease, and late leaf spot caused by *Cercosporidium personatum* (Berk. and M.A. Curtis) Deighton, a foliar disease. Late leaf spot was observed in October, but too late to have a significant impact on yield. The cultivar with the greatest numeric severity of late leaf spot was AU-NPL 17 (Table 2). All of the cultivars are marketed as susceptible or moderately susceptible to late leaf spot. No other yield-limiting disease was observed in the field.

The field was previously grown for two years in cotton and the initial southern root-knot nematode population density at planting was 120 J2/100 cm^3 of soil, which is a moderate threshold for cotton in Arkansas (Mueller et al., 2012). The southern root-knot nematode population density at harvest was zero with a slight increase in lesion nematode (*Pratylenchus* sp., 13 individuals/100 cm^3 soil) and spiral (*Helicotylenchus* sp., 166 individuals/100 cm^3 soil), but not at an action threshold for peanut or cotton. In the two fields near Leachville, southern root-knot and stubby-root nematode (*Paratrichodorus* sp.) were observed in soil samples from cotton, while lesion nematode was observed in soil samples from cotton and soybean fields. These data support the rotation of peanut with cotton to manage southern root-knot and possibly stubby-root nematode.

Practical Applications

Peanut is an excellent non-host crop to the southern root-knot nematode and a profitable rotation crop that fits well in the Arkansas cotton production system. Currently, the most common peanut cultivars grown are Georgia 09B and Georgia 06G with less than 10% of acreage planted in TUFRunner 297 and FloRun 331. These results provide information on a few runner-type peanut cultivars that farmers may consider as future rotation in their cotton production system.

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Literature Cited

Faske, T.R., T.W. Allen, Z. Grabau, R.C. Kemerait, K.S. Lawrence, H.L. Mehl, C. Overstreet, L.D. Thiessen, and T.A. Wheeler. 2019. Beltwide nematode research and education committee report on field performance of seed-applied and soil-applied nematicides, 2018. pp. 75-78. *In:* Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 8-10 Jan. National Cotton Council, Memphis, Tenn.

Faske, T.R., T.W. Allen, G.W. Lawrence, K.S. Lawrence, H. L. Mehl, C. Overstreet, and T.A. Wheeler. 2018. Beltwide nematode research and education committee report on cotton cultivars and nematicides responses in nematode soils, 2017. pp. 811-814. *In:* Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, Texas. 3-5 Jan. National Cotton Council, Memphis, Tenn.

Lawrence, K., A. Hagan, R. Norton, J. Hu, T. Faske, R. Hutmacher, J. Mueller, I. Small, Z. Grabau, R. Kemerait, P. Price, T. Allen, S. Atwell, J. Idowu, L. Thiessen, S. Byrd, J. Goodson, H. Kelly, T. A. Wheeler, T. Isakeit, and H. Mehl. 2019. Cotton disease loss estimates committee report, 2018. pp. 54-56. *In:* Proc. Beltwide Cotton Prod. Res. Conf., New Orleans, LA. 8-10 Jan. National Cotton Council, Memphis, Tenn.

Lawrence, K., A. Hagan, R. Norton, J. Hu, T. Faske, R. Hutmacher, J. Muller, I. Small, Z. Grabau, R. Kemerait, C. Overstreet, P. Price, G. Lawrence, T. Allen, S. Atwell, J. Idowu, R. Boman, J. Goodson, H. Kelly, J. Woodward, T.A. Wheeler, and H. Mehl. 2018. Cotton disease loss estimates committee report, 2017. pp. 161-163. *In:* Proc. Beltwide Cotton Prod. Res. Conf., San Antonio, Texas. 3-5 Jan. National Cotton Council, Memphis, Tenn.

McClelland, C.K. 1944. Peanut production experiments, 1931-41. pp. 1-27. Bulletin no. 448, University of Arkansas, College of Agriculture, Agricultural Experiment Station, Fayetteville.

Mueller, J., S. Koenning, T. Kirkpatrick, B. Kemerait, C. Overstreet, and R. Nichols. 2012. pp. 1-4. Managing nematodes in cotton-based cropping systems. Cotton Inc.

Thomas, S.H., and T.L. Kirkpatrick. 2001. Root-knot nematodes. pp. 40-42. *In:* T.L. Kirkpatrick and C.S. Rothrock, eds. Compendium of cotton diseases. St. Paul, Minn. APS Press.

USDA-NASS. *Quick Stats* USDA NASS, Accessed on 20 March 2020. Available at: https://quickstats.nass.usda.gov/data/printable/97823BBB-86F9-31A2-B94F-409A09A78D26

Williams, E.J. and J.S. Drexler. 1981. A non-destructive method for determining peanut pod maturity. Peanut Sci. 8:134-141.

Wilson, W. R. and M.W. Slusher. 1943. Peanuts: a war crop for Arkansas. pp. 1-17. University of Arkansas, Department of Rural Economics and Sociology in cooperation with the Bureau of Agricultural Economics, USDA. Fayetteville.

Table 1. Peanut cultivars, type, seed size and source used in 2019 in an on-farm cultivar trial in Mississippi County.

Cultivars†	Peanut Type	Number of seeds/lb	Seed Source
Algrano IPG 914	High O/L, runner	675	Algrano Peanuts/International Peanut Group, Brownfield, Texas
Algrano IPG QR-14	High O/L, runner	749	Algrano Peanuts/International Peanut Group
AU-NPL 17	High O/L, runner	555	Alabama Crop Improvement Association, Inc., Headland, Alabama
Georgia 09B	High O/L, runner	672	Alabama Crop Improvement Association
Georgia 16HO	High O/L, runner	598	Alabama Crop Improvement Association
Georgia 12Y	High O/L, runner	758	Alabama Crop Improvement Association
TUFRunner 297	High O/L, runner	588	Florida Foundation Seed Producers, Inc., Greenwood, Florida
FloRun 331	High O/L, runner	725	Florida Foundation Seed Producers
Lariat	High O/L, runner	579	Oklahoma Foundation Seed Stocks, Stillwater, Oklahoma
Georgia 18RU	Low O/L, runner	627	Georgia Seed Development, Plains, Georgia
Olé	High O/L, Spanish	825	Oklahoma Foundation Seed Stocks
Contender	High O/L, Virginia	385	Oklahoma Foundation Seed Stocks

†All cultivars are runner-type peanut except Ole and Contender which are Spanish- and Virginia-type, respectively. All are high oleic except Georgia 18 RU.

Table 2. Peanut maturity, leaf spot severity, pod loss, and yield of twelve peanut cultivars in a 2019 on-farm trial in Mississippi County.

Cultivars†	% Mature‡ (September 30)	Late Leaf Spot§ (October 16)	Pod Loss¶	Yield
			(lb/ac)	(lb/ac)
Algrano IPG 914	93	3.8 ab#	243.5 def	5,631.1 cd
Algrano IPG QR-14	85	3.0 abc	701.1 ab	5,723.7 cd
AU-NPL 17	80	4.0 a	131.8 f	5,302.2 d
Georgia 09B	85	2.5 bc	447.7 a-d	6,212.5 bcd
Georgia 16HO	77	3.3 abc	533.0 abc	6,354.5 bcd
Georgia 12Y	83	2.5 bc	172.4 ef	6,641.7 abc
TUFRunner 297	83	3.5 abc	332.0 cde	7,559.7 a
FloRun 331	85	3.0 abc	291.7 cde	6,446.9 a-d
Lariat	80	2.3 c	787.8 a	7,111.4 ab
Georgia 18RU	90	2.5 bc	330.3 cde	5,274.8 d
Olé	--	3.8 ab	402.5 bcd	7,255.6 ab
Contender	--	2.8 abc	723.0 ab	6,638.9 abc
P > F		0.0003	0.0001	0.0001

†All cultivars are runner-type peanut, except Ole and Contender which are Spanish- and Virginia-type, respectively. All are high oleic except Georgia 18RU.
‡Percent of pods from a sample that are dark brown to black (harvestable peanuts) based on hull scrap method. This method does not apply to Spanish- or Virginia-type peanuts
§The 10-pt Florida leaf spot scale was used where 1 = no disease and 10 = 100% defoliation.
¶Estimated number of pods detached from plants after digging.
#Means in each column followed by the same letter are not significantly different at α = 0.05 according to Tukey's honest significant difference test.

Table 3. Yield, grade, and value of twelve peanut cultivars in a 2019 on-farm trial in Mississippi County.

Cultivars†	Yield	Grade‡	% Sound Splits	Value/T§	Value/ac
	lb/ac				
Algrano IPG 914	5,631.1 cd¶	77	6	$370.17	$1,042.23
Algrano IPG QR-14	5,723.7 cd	77	8	$368.57	$1,054.79
AU-NPL 17	5,302.2 d	78	5	$375.78	$996.23
Georgia 09B	6,212.5 bcd	78	10	$371.78	$1,154.84
Georgia 16HO	6,354.5 bcd	81	6	$389.41	$1,235.50
Georgia 12Y	6,641.7 abc	77	6	$370.17	$1,229.27
TUFRunner 297	7,559.7 a	78	6	$374.98	$1,417.36
FloRun 331	6,446.9 a-d	77	9	$367.77	$1,185.48
Lariat	7,111.4 ab	78	10	$371.78	$1,321.90
Georgia 18RU	5,274.8 d	81	13	$383.81	$1,012.26
Olé	7,255.6 ab	71	4	$342.91	$1,244.00
Contender#	6,638.9 abc	78	1	$376.58	$1,250.03
P > F	0.0001	--	--	--	--

†All cultivars are runner-type peanut except Ole and Contender which are Spanish- and Virginia-type, respectively. All are high oleic except Georgia 18RU.

‡Grade was based on USDA standard for peanut and conducted at Birdsong Peanut in Portia, Arkansas.

§USDA Price Table for 2016 (each SS% >4% docked $0.80/%).

¶Means in each column followed by the same letter are not significantly different at α = 0.05 according to Tukey's honest significant difference test.

#Hand shelled for grading.

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