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Summaries of Arkansas Cotton Research 2018

Pigweed in cotton dictates Arkansas cotton productions systems

Edited by Fred Bourland

UofA
DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

ARKANSAS AGRICULTURAL EXPERIMENT STATION

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Cover Photo: Palmer amaranth (pigweed) in cotton plot at the Arkansas Agricultural Experiment Station, Fayetteville, Arkansas. Jason Norsworthy, University of Arkansas System Division of Agriculture.

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3

Summaries of Arkansas Cotton Research 2018

Fred Bourland, Editor

University of Arkansas System
Division of Agriculture
Arkansas Agricultural Experiment Station
Fayetteville, Arkansas 72704

Table of Contents

Cotton Incorporated and the Arkansas State Support Committee

The *Summaries of Arkansas Cotton Research 2018* was 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 are allocated to the State Support Committees of cotton-producing states. The sum allocated 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 in part by Cotton Incorporated directly from its national research budget and also 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 2018.

		2017	2018
New Funds		$180,000	$161,000
Previous Undesignated		$68,652	$42,929
Total		$248,652	$203,929
Researcher	**Short Title**	**2017**	**2018**
Robertson	Cotton Research Verification/Applied Research	$50,000	$50,000
Bourland	Breeding	$26,000	$26,000
Lorenz	Alternative Thrips Control	$21,724	$0
Roberston	Potash	$11,000	$0
Roberston	Soil health - no till	$12,074	$12,074
Barber	New Herbicide Tech	$25,000	$25,000
Adviento-Borbe	Tillage Practices and Water Quality	$15,000	$5,000
Robertson	Target Leaf Spot IPM	$15,000	$15,000
Robertson	Cereal Rye Termination Timing	$15,000	$27,000
Reba	Improving Research Capacity	$17,000	$0
Lorenz	OVT Thrips tolerance	$0	$5,000
Uncommitted		$40,854	$65,855
Total		**$207,798**	**$165,074**

Acknowledgements

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

Summaries of
Arkansas Cotton Research
— 2018 —

Review of the 2018 Arkansas Cotton Crop

Overview

Both heat units and rainfall in 2018 exceeded historical averages. The warm temperatures in May provided excellent conditions for emergence and early growth of seedlings. Despite the high heat unit accumulations for the season, temperatures exceeding 95 °F were relatively rare. The absence of extremely high temperature and the occurrence of relatively high rainfall provided excellent growing conditions through the season.

Even with one of the wettest falls on record that resulted in significant delays in harvest and ginning, Arkansas cotton producers harvested their second best crop ever at 1150 lb lint/acre from 480,000 harvested acres in 2018. Lint averages were 27 lb/acre below last year's record yield. The five-year lint yield average is 1129 lb lint/acre. Each of the last five years have yields that rank historically in the top 7 of all time.

Planting

Essentially all of the 2018 Arkansas cotton crop was planted with varieties that contained traits for enhanced insect and weed control. Reports released by Agricultural Marketing Service estimated 82% of the cotton varieties planted in 2018 contained XtendFlex® herbicide-tolerant traits (XF), up from 70% in 2017 and 58% in 2016. Plantings of varieties containing the Enlist™ weed control system traits (FE) was estimated at 8% of the total acres statewide. The remaining 10% of the cotton acres were planted to cotton with traits for herbicide tolerance to only glyphosate and glufosinate (RF or GL). The two most widely planted varieties DP 1518 B2XF and DP 1646 B2XF accounted for 31.7% and 29.4% of planted acres, respectively.

The Agricultural Marketing Service estimated 90% of the cotton varieties planted in 2018 contained two-gene *Bt* traits (B2, T and W) with the remaining 10% planted to three-gene *Bt* traits (B3, TP and W3). The need for improved efficacy of the three-gene varieties for boll worm management exists especially in south Arkansas. The lower than desired yield potential of the three-gene varieties is the major limiting factor in the switch away from the two-gene varieties.

The early planting window, which we generally have in April, never materialized. Conditions did not become favorable for cotton planting until the last few days of April. While planting progress was behind the five-year average the first half of May, it surpassed the five-year average by mid-May and crop progress the remainder of the season surpassed that of the previous year and the five-year average. Much of the progress can be attributed to the above average temperatures experienced the entire month of May.

Fruiting and Harvest

The condition of the crop was very good all season long. Reports by the United States Department of Agriculture National Agricultural Statistics Service (USDA-NASS; available at: https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Progress_&_Condition/2018/) indicated the percentage of the acres statewide receiving a rating of excellent never dropped to less than 37% once the crop started flowering. The percent of the crop rated good and excellent was greater than 80% the entire season.

We had a full soil moisture profile at planting. But as May was relatively dry, we began to lose moisture at the surface. The early planted cotton was able to develop a deep root system and was able to extract moisture at the deeper depths to maintain plant development at an acceptable pace. The less developed root systems of younger plants were not able to tap into the moisture at the deeper depths.

By mid-June the top 6 inches was dry and soil moisture at 6 to 12 inches was marginal. Soil moisture was still very good below 12 inches. The later planted fields struggled with plant development rates as a result of moisture stress. Values for nodes above white flower (NAWF) on the early planted cotton were 6 to 7 at first flower while later planted fields were at or just above cutout at first flower. The goal is 9 to 10 NAWF at first flower.

Once producers completed herbicide applications and were able to irrigate, they luckily were able to maintain NAWF values just above cutout in the early planted fields to extend the effective flowering period the full three weeks needed to achieve yield goals. The later planted fields lost yield potential as a result of the lower NAWF values at first flower and their inability to prevent premature cutout.

Harvest progress started off well ahead of last year and the five-year average. Rainfall during harvest greatly impacted this trend. Arkansas experienced drier than average conditions in May through July. The tables turned as rainfall during the period from 1 August to 31 October exceeded average rainfall totals by 204% in Little Rock and 222% in Jonesboro. Harvest progress slowed and many fields were rutted by harvest equipment in 2018.

Inputs

In the 2018 Cotton Research Verification Sustainability Program (CRVSP), operating expenses per acre averaged $612.85 across all fields, up from $593.36 last year. The greatest operating expenses were seed, herbicides, insecticides, and fertilizers. Seed and related fees averaged $109.59 and fertilizer products, $157.22 per acre. These accounted for 44% of the total operating expenses per acre.

Plant bugs and Palmer pigweed continue to be key pests. Fields in the CRVSP fields were treated an average of 3.33 times for plant bugs in 2018. Each field had an average of 1.83 burndown and 4.33 in-season herbicide applications. All fields averaged 1.92 treatments for moths/worms. Average costs for herbicides and insecticides were $78.14/acre and $61.72/acre, respectively. Pest control expenses accounted for an additional 23% of operating expenses per acre.

The average yield in the 2018 CRVSP was 1691 lb/acre. Average fixed costs were $154.63 which led to average total costs of $767.48/acre. Total specified costs averaged $0.46/lb lint. With a crop share rental agreement of 20% crop and no cost share, the producer specified cost average would increase to approximately $0.58/lb. The Arkansas annual average price for the 2018 production year was $0.65/lb lint. This leaves only $0.07/lb to contribute to management and overhead with this rental scenario.

Yield and Quality

The NASS September Crop Production report projected that Arkansas producers would harvest 1112 lb lint/acre. Their estimates increased to 1150 lb lint/acre in September and up again to 1160 lb lint/acre in December. The annual summary released in February of 2019 (available at: https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Progress_&_Condition/2018/) dropped lint yield back to 1150 lb/acre down 27 lb/acre from 2017. Production was estimated at 1.15 million bales up 27% from 2017.

Fiber quality was only fair in 2018 as 70.4% of bales classed for Arkansas were tenderable compared to 90.1% in 2017, 81.4% in 2016 and 60.6% in 2015. Rainfall extended the harvest season and impacted quality. Consequently, color grades were disappointing with only 8.1% of bales receiving color grades of 31 or better and 66.2% of bales classed received a color grade of 41 or better. Micronaire averaged 4.61, with almost 87% of Arkansas cotton classed having micronaire in the target value range of 3.5 to 4.9. Staple averaged 37.54 with 20.2% of the bales classed having a staple 38 or greater. Leaf was less of an issue in 2018 with 77.7% of the bales classed receiving a leaf of 4 or less compared to 38.8 in 2017. Leaf values for the 2018 crop averaged 3.95 for the season.

Summary

Arkansas ended the 2018 season ranked 5th nationally in harvested acres (480,000 acres), 4th in lint yield (1150 lb/acre), and 4th in total production (1,150,000 bales). The string of consecutive years with good yields is helping to drive the increase in cotton acres. Harvest and ginning capacity is a major limiting factor for acre expansion. Cotton planting intentions for 2019 released in late March are at 580,000 acres, up 20% from the 485,000 acres planted in 2018. This continues to push the ginning capacity of 28 gins in 2018 and on-farm picker capacity to the limit. Optimism for cotton is greater than for most other commodities, but may not be great enough to invest in more gins or pickers

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

2018 Northeast Research and Extension Center: Overview of Cotton Research

A. Beach[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 the city of 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, but it provides an environment with a soil type that contrasts with other cotton stations, and one that has very low incidence of Verticillium wilt. Since cotton normally does not require application of mepiquat chloride on this soil type, plants develop unaltered heights at this station.

Table 1. List of 2018 cotton research at Northeast Research and Extension Center, Keiser.

Project leader	Discipline	Title
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (transgenic tests, 65 entries and conventional test, 15 entries)
Fred Bourland	Cotton Breeding	National Cotton Variety Test (10 entries), Regional High Quality Strain Test (22 entries) and Regional Breeders' Network Test (24 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests, six tests evaluating a total of 120 entries
Fred Bourland	Cotton Breeding	Cotton industry strain tests, four tests evaluating a total of 74 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
Morteza Mozaffari	Soil Fertility	Evaluation of nitrogen fertilizer source, rate, and timing on seedcotton yields
Morteza Mozaffari	Soil Fertility	Soil fertility and soil testing research for improving cotton phosphorus and potassium fertilization practices
Jason Norsworthy	Weed Science	Evaluation of Factors Contributing to the Of-Target Movement of Dicamba
Glenn Studebaker	Entomology	TPB 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 and Professor, respectively, University of Arkansas System Division of Agriculture, Northeast Research and Extension Center, Keiser.

2018 Conditions and Observations

Rainfall in April delayed land preparation at Keiser (Fig. 1). Planting of cotton plots was completed in a narrow window (8 May to 15 May). Adequate moisture and good soil temperatures resulted in good stands in most plots. Most of the small plot replicated tests were moved from a field (N6) on the north end of the station to a field (S15) on the south end. Less pigweed pressure was anticipated in this field, though the lower end of the field drained poorly. Some plots were adversely affected by directed application of gramoxone on June 11, but good yields were obtained. Gramoxone injury was more severe in the breeding nursery field, which was sprayed on the same day as field S15, but has opposite row direction. Total Degree-Day 60 (DD60) accumulations from May through October 2018 were 27% higher than the historical average (Table 2). The DD60 accumulations were greater than average for each month from May through October. Seasonal rainfall (May through October) was 19% higher than normal, while July rainfall was less than half as normal. Both insect and disease incidences were low at Keiser in 2018. Defoliants were applied on time using ground application. Rainfall in early October delayed harvest. The harvest of the S15 field began on 29 October, but was stopped by a hydraulic problem on the plot picker. Persistent rainy weather commenced by the time the picker was repaired. These wet conditions delayed harvest until 31 January 2019. This field included evaluation of six strain tests from the Division's Cotton Breeding Program (similar materials in each test)—two were harvested in October, two harvested in January and two were partly harvested on the two dates. The 29 October harvested area (224 plots) yielded 557 lb/ac more seedcotton than the 31 January harvested area (256 plots).

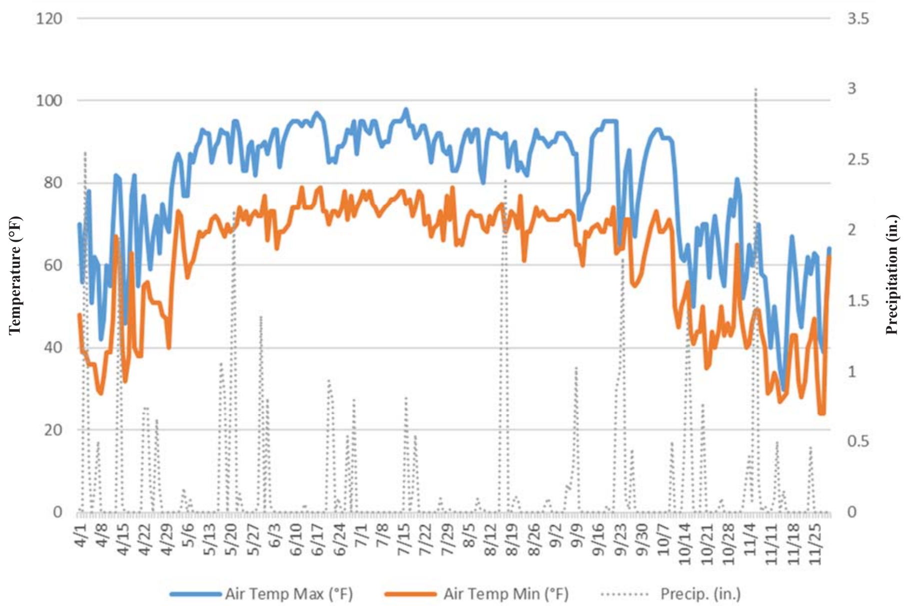

Fig. 1. 2018 Northeast Research and Extension Center, Keiser, temperature and precipitation.

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

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2018	47	563	669	718	607	488	216	3306
Historical avg. DD60s[a]	49	293	522	634	552	348	57	2612
Rainfall (in.) 2018	8.1	6.6	4.1	1.6	4.5	6.1	4.0	35.1
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; dd60.uaex.edu

[b] 30-year average of data collected at the Keiser Station 1981-2010; www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgements

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.

2018 Judd Hill Cooperative Research Station: Overview of Cotton Research

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 (Table 1). 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 2018 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 Tests: transgenic tests with 65 entries and conventional test with 15 entries
Fred Bourland	Cotton Breeding	Cotton Strain Tests, six tests evaluating a total of 120 entries
Fred Bourland	Cotton Breeding	Cotton industry strain tests, nine tests with a total of 512 plots
Morteza Mozaffari	Soil Fertility	Effect of phosphorus and potassium rates on seedcotton yield
Tina Teague	Multi-disciplinary	On-farm water, soil, and plant monitoring—irrigation, nitrogen fertilizer, and cultivar effects in no-till, cover crop, and conventional tillage systems

2018 Conditions and Observations

With adequate moisture and good soil temperatures in 2018, most plots at Judd Hill achieved excellent stands. The plants grew well and established excellent boll loads. Insect pressure was light throughout the season. High incidence of Verticillium in 2017 provided ample levels of inoculum of this soilborne fungus, but visual symptoms of the disease were relatively low in 2018. Daily high temperatures never exceeded 100 °F during the season (Fig. 1), but accumulative Degree-Day 60s (DD60s) were about 30% higher than normal. Total rainfall in August through October was 24.8 in., far exceeding the historical average of about 10 in. (Table 2). The excess rainfall hampered harvest, and likely reduced yields.

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

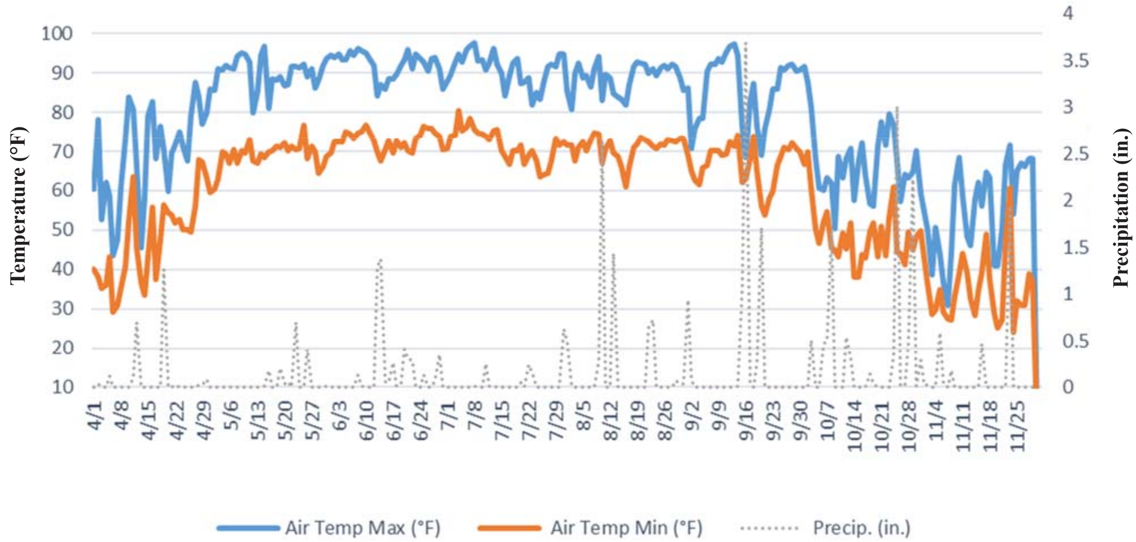

Fig. 1. 2018 Judd Hill temperature and precipitation.

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

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2018	99	600	674	661	616	488	70	3210
Historical avg. DD60s[a]	49	293	522	634	552	348	57	2455
Rainfall (in.) 2018	2.4	1.6	4.8	1.4	6.4	7.8	10.6	34.8
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; dd60.uaex.edu
[b] 30-year average of data collected at the Jonesboro Municipal Airport 1981-2010; www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgements

We are indebted to Mike Gibson and the Judd Hill Foundation for their generous support and assistance. Cooperation of Marty White, Jessie Flye, Billy Baker, and Jim Baker is greatly appreciated. Additionally, we thank Mike Duren, Resident Director and Charles Wilson, Center Director of the Northeast Research and Extension Center; and Timothy Burcham, Dean of Agriculture and Technology, Arkansas State University. Support also provided by the University of Arkansas System Division of Agriculture.

2018 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 regard 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).

Table 1. List of 2018 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 (65 entries)
Morteza Mozaffari	Soil Fertility	Cotton response to nitrogen source, rate and timing
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

Conditions and Observations

Wet conditions delayed planting of plots at Manila until 19 May. Adequate moisture and good soil temperatures resulted in good stands in most plots. Weather conditions in the area were wetter than normal throughout the season until fall. Evapotranspiration (ET) gauge readings were collected weekly, and used to estimate and track field moisture status during the season. Irrigation events were initiated based on the cooperating producer's standard production practices. Seven furrow irrigations were triggered during the production season. Insect pressure was generally light in 2018. Incidence of bacterial blight and target spot diseases was very light. Harvest was completed by late-October. Average lint yield achieved in the 2018 Arkansas Cotton Variety Test at the Manila Airport was the second highest that we have achieved since we began conducting the test at Manila Airport in 2014.

Yield monitor data (Fig. 1) from the field just south of our research area indicated incremental yield gains from irrigation in this area during the 2018 production season. In this adjacent field, the irrigated cotton under a center pivot averaged

[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.

1,485 lb/ac and the non-irrigated corners yielded 1,461 lb/ac. Arkansas Cooperative Extension Service budgets designate a cost of $5.32/acre-inch for supplemental irrigation. Five irrigations at 1.25 acre-inches would cost $33.25/ac. Thus, the 24 lb/ac of additional lint for irrigation, assuming $0.80/lb and adjusted for crop rent (25%) and irrigation costs produced a reduction in net revenue of $18.85/ac. These observations suggest the need to develop strategies to improve irrigation water use efficiency.

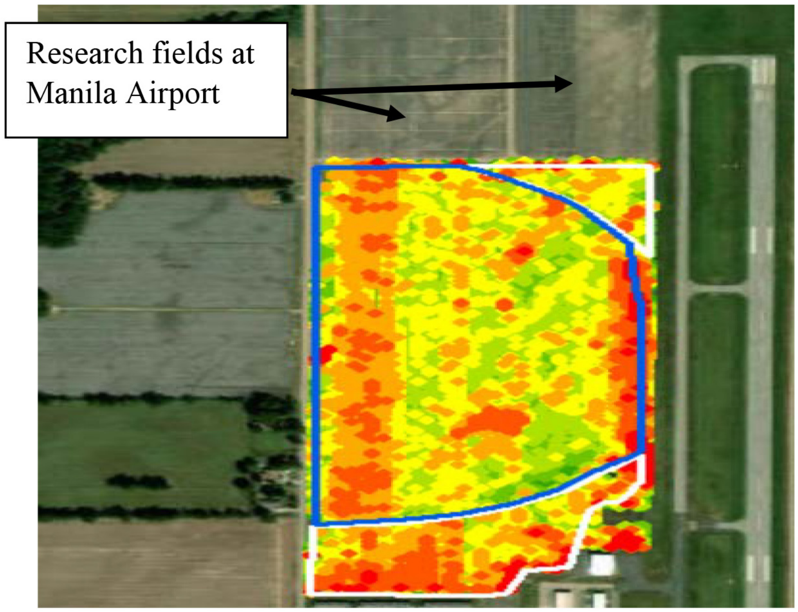

Fig. 1. Yield monitor data from field just south of research field at Manila Airport in 2018. Yield levels vary from high (green) to red (low).

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.

Acknowledgements

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

2018 Lon Mann Cotton Research Station: Overview of Cotton Research

C. Kennedy[1]

Background

The Lon Mann Cotton Research Station (LMCRS) had its beginning 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 a primary focus of the station (Table 1). The station includes 655 acres (about 640 in 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 work on breeding, variety testing, pest control (insects, diseases, and weeds), soil fertility, plant physiology, and irrigation.

Table 1. List of 2018 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 new herbicides and new potential uses for old herbicides in cotton weed control systems
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (transgenic test, 65 entries and conventional test, 15 entries)
Fred Bourland	Cotton Breeding	Cotton strain tests, six tests evaluating a total of 120 entries
Fred Bourland	Cotton Breeding	Cotton industry strain tests, two tests with a 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
Leo Espinoza	Soils	Varietal response to potassium rates under sub-optimal soil potassium levels
Gus Lorenz	Entomology	Thrips efficacy trials (6 trials, 48 total treatments)
Gus Lorenz	Entomology	Thrips variety trials (2 trials; Bt, 34 Entries; conventional, 20 entries
Gus Lorenz	Entomology	Plant bug efficacy trials (9 trials, 94 treatments, 846 plots)
Gus Lorenz	Entomology	Plant bug transgenic trials (2 trials, 16 treatments, 64 plots)
Morteza Mozaffari	Soil Fertility	Fertilizer rate trails to evaluate cotton response to NPK
Jason Norsworthy	Weed Science	Evaluation of weed control programs using Brake FX
Jason Norsworthy	Weed Science	Evaluation of weed control programs in Enlist cotton
Jason Norsworthy	Weed Science	Evaluation of Xtend, Enlist, and Glytol/LL cotton varietal tolerance to Intermoc
Chuck Wilson	Soil Fertility	Cotton response to P and K fertilizer rates

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

2018 Conditions and Observations

Frequent rains and relatively mild temperatures characterized the 2018 growing season at LMCRS (Fig. 1). Abnormally cool temperatures in April (Table 2) delayed 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 (DD60s) accumulated in May and October were 24% higher than normal. Rainfall during the same period was 57% higher than normal. Wet conditions in October caused some problems with 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 mid-October.

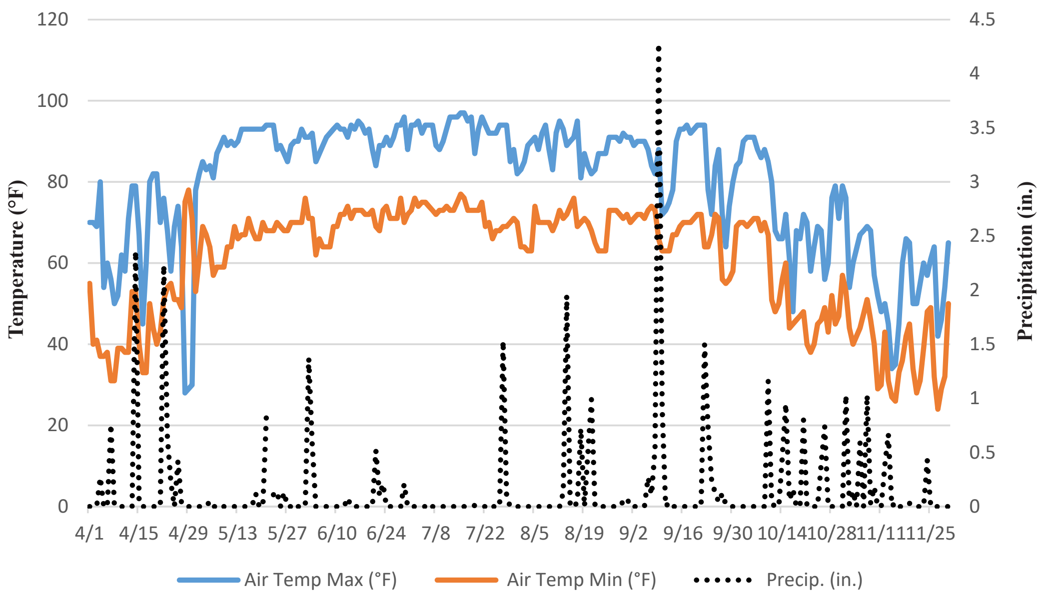

Fig. 1. 2018 Marianna temperature and precipitation.

Table 2. Weather conditions at Marianna.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2018	32	544	626	698	590	581	214	3284
Historical avg. DD60s[a]	87	339	548	650	594	398	98	2714
Rainfall (in.) 2018	7.0	6.8	6.8	6.0	7.1	6.1	4.8	44.5
Hist. avg. rainfall (in.)[b]	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; dd60.uaex.edu
[b] 30-year average of data collected at the Marianna Station 1981-2010; www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgements

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2018 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 in research plots) 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 (Table 1).

Table 1. List of 2018 cotton research at Rohwer Research Station.

Project Leader	Discipline	Title
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (Transgenic, 65 entries and Conventional, 15 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests, six 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
Terry Spurock	Plant Pathology	Corteva Cotton Trial
Terry Spurlock	Plant Pathology	NST Cotton Trial
Terry Spurlock	Plant Pathology	Syngenta Cotton Trial
Terry Spurlock	Plant Pathology	Cotton Seed Treatment – Q2, 1 Trial

2018 Conditions and Observations

Research trials at Rohwer were planted during May. Sufficient moisture and good soil temperatures resulted in excellent emergence/plant stands for trials (Fig. 1 and Table 2). Seedling diseases and insect pest were minor resulting in effective seed treatments. Weed control programs were successful at controlling early season grass and broadleaf species. Post-emergence applications were effective in controlling grass and broadleaf species, including Palmer amaranth. Slight hand weeding was essential to control escaped Palmer amaranth in particular trials. Four irrigations were required to maintain adequate moisture (2 inch allowable deficient) with the last irrigation applied during last week of July. Insect pests met threshold level once during the season that required an application of insecticides. Termination timings for plant bugs, worms, and irrigations were late-July to mid-August. Harvest began dry but quickly turned wet before the harvest was completed. Some hard-locked cotton was evident and quality reduced.

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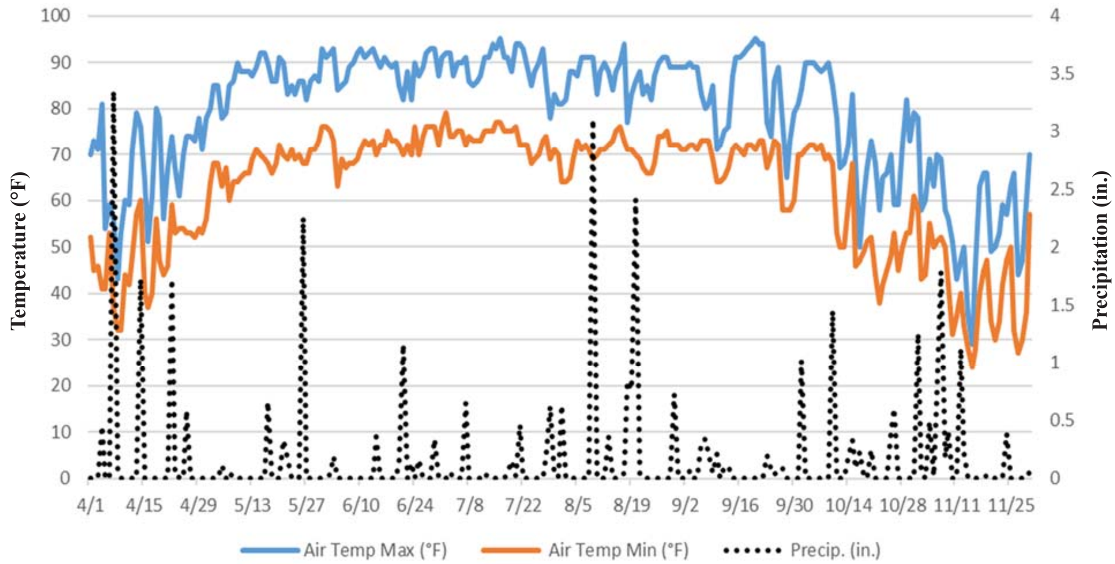

Fig. 1. 2018 Rohwer temperature and precipitation.

Table 2. Weather conditions at Rohwer.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2018	54	525	618	662	586	493	241	3178
Historical avg. DD60s[a]	100	354	551	661	618	415	167	2866
Rainfall (in.) 2018	8.0	3.6	2.5	2.3	8.9	1.9	4.6	31.8
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; dd60.uaex.edu

[b] 30-year average of data collected at the Rohwer Station 1981-2010; www.ncdc.noaa.gov/cdo-web/datatools/normals

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The author would like to thank Larry Earnest, Director and Kelly Bryant, Center Director of the Southeast Research and Extension Center. Support also provided by the University of Arkansas System Division of Agriculture.

Cotton Research Verification Sustainability Program: Sustainability Report

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

Abstract

Practices that lead to improved soil health often improve profitability and sustainability as well as having a positive impact on a field's environmental footprint. The objectives of this project were to improve efficiency specifically regarding irrigation water use, increase soil health, and document differences between farmer standard tillage fields and a modified production system no-till cover through utilization of the Fieldprint Calculator. The University of Arkansas System Division of Agriculture's Cotton Research Verification Sustainability program conducted research along with Discovery Farms in two fields in Southeast Arkansas in 2015-2018. Each field was composed of two irrigation sets allowing for evaluation of farmer standard practices, till no-cover to that of a modified production system no-till cover. In 2016, three new fields were added with cover crop systems initiated. All fields were monitored for inputs and entered into the Fieldprint Calculator and used to calculate expenses. Yield on no-till cover increased an average of 7.31% and was $0.03 per pound of lint cheaper to produce than farmer standard tillage no-cover in 2015-2018. The metrics from the Fieldprint Calculator all favored no-till cover with regard to improving sustainability. Soil conservation or erosion was reduced by 75.41% and greenhouse gas emissions decreased by 10.57%. Through the use of no-till and cover crops in this study several improvements were observed, resulting in increased yield, decreased footprint size, and increased profitability.

Introduction

As cost of production continues to increase, producers are striving to increase profitability. The key to remaining profitable is to continuously introduce technologies that will improve efficiency. Since not any one practice will benefit all producers, cotton producers utilize many different production practices to improve efficiency and profitability. Producers are often hesitant to convert from conventional tillage to no-till with cover not only due to the associated costs, but also to concern for irrigation efficiency. 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 their production recommendations. In 2014, the CRVP became known as the CRVSP. The CRVSP conducted research in three Arkansas counties in 2018: Desha, Mississippi, and St. Francis. In Desha County, the CRVSP conducted research along with Discovery Farms in Southeast Arkansas for two fields, Shopcot and Weaver fields. Discovery Farms' main focus is on edge-of-field water quality, where they monitor irrigation efficiency and nutrient and sediment losses. All fields in Desha County were composed of two irrigation sets allowing for comparisons of farmer standard tillage practice to a modified production system. Watering fields into two irrigation sets, allowed for comparisons of how each impacted edge-of-field water quality and ultimately profitability and sustainability of each fields' system. Fields located in Mississippi and St. Francis Counties were not composed of two irrigation sets, but fields were split in half for observation of farmer standard tillage to that of a modified production system no-till cover.

All fields were monitored for inputs and entered into the Fieldprint Calculator (www.fieldtomarket.org). The Fieldprint Calculator is a relatively new tool developed by Field to Market: The Alliance for Sustainable Agriculture. The Fieldprint Calculator was designed to help educate producers on how adjustments in management could affect environmental factors. Utilization of the calculator assists producers by making estimates over seven sustainability factors: land use, soil conservation, soil carbon, irrigation water use, greenhouse gas emissions, energy use, and water quality. Fieldprint Calculator estimates fields' performance and compares results to national and state averages. Calculated summaries give producers insight to the ability areas for improved management on their farm. The objectives of this project were to improve efficiency, specifically regarding irrigation water use; increase soil health; and document differences between

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farmer standard tillage fields and that of a modified production system no-till cover through utilization of the Fieldprint Calculator.

Procedures

The 2018 CRVSP was composed of 5 fields, which provided comparison of farmer standard tillage system to a modified production system no-till cover system in an effort to improve efficiency, profitability, sustainability and soil health. 'Elbon' cereal rye was the cover crop used in all no-till cover fields, and it was broadcast at a rate of 56 lb/ac. The fields in this project averaged approximately 40 acres in size with each practice comprising half of the field. Throughout the study, all producers' inputs were recorded providing the information needed to calculate both fixed and variable costs. Field data were collected through utilization of soil moisture sensors, rain gauges, evapotranspiration (ET) gauges, flow meters and trapezoidal flumes. A set of three Watermark soil moisture sensors were also placed in both no-till with cover and farmer standard tillage at 6, 12, and 18 inches. Evapotranspiration gauges were adjusted after each rainfall or irrigation event at fields and were used to trigger irrigations. The use of trapezoidal flumes at the Discovery farm fields provided the opportunity to determine the efficiency of each rainfall or irrigation event. Being able to calculate both rainfall and irrigation efficiency of two fields allowed us to set the ET gauges accurately. In the other three fields, an estimate was made on how efficient each irrigation or rainfall event was believed to have been and adjusted accordingly. Flow meter readings allowed for documentation for how much water was applied across furrow-irrigated fields. Plots were machine harvested.

Results and Discussion

Compared to the farmer standard tillage, the no-till cover crop system consistently had lower soil compaction, higher soil moisture, and slower irrigation water flow rates down the row. There was concern initially that water flow rates down the row would be a problem in no-till with cover fields. After the first irrigation, this was no longer a concern and actually resulted in a benefit. After large rain events, we observed that the no-till with cover system infiltrated water quicker, which allowed for decreased runoff when compared to that of a stale seedbed re-hipped with a cover crop. Across all fields, no-till with cover had one tillage operation FurrowRunner versus multiple tillage operations in farmer standard tillage. The only exception was at the Manila fields where a do-all had to be run prior to planting on all fields so that seed could be planted in moisture as field conditions were very dry. The FurrowRunner allowed for a narrow trench in the furrow to help with water movement while leaving all cover crop residue on the sides of the furrow and top of the row, only having minimal disturbance. Water movement slowed as water worked its way through stubble allowing for better water infiltration and less runoff. The no-till cover system produced 1368 lb lint/ac compared to farmer standard tillage of 1268 lb lint/ac. Improvements were also observed with regard to sustainability measures with an established no-till cover crop production system when compared to farmer standard tillage practice (Table 1). Periodically throughout the growing season, holes were dug, and several earthworms were spotted in the no-till cover crop fields. Soil structure of these fields seemed to be visually improved as evidenced by several noticeable earthworm channels. The environmental footprint calculated by Fieldprint Calculator, showed a smaller or more sustainable footprint in no-till with cover.

Practical Applications

In this study, no-till with cover crop increased water use efficiency requiring 22% less water to produce a pound of cotton. Although water movement through the field was slower than farmer standard tillage with no-cover, better water infiltration and less runoff was observed. No significant differences were observed for lint yield with 1368 lb lint/ac for no-till with cover and 1268 lb lint/ac for the farmer standard tillage practice. Additional research is needed to further evaluate how profitability, irrigation water use efficiency, size of environmental footprint, soil health, and continuous improvement are related.

Table 1. Harvested lint yield, lint yield equivalent[a], operating expenses and metrics used to evaluate sustainability as affected by tillage and cover crops.

Parameters	No-till Cover (2015-2018)	Till No-Cover (2015-2018)	% Change No-till vs. Till
Yield (lb lint har./ac)	1368.00	1268.00	7.31%
Operating Expenses ($/ac)	571.71	552.97	3.28%
Operating Expenses ($/lb lint harvested)	0.428	0.464	-8.48%
Land Use (ac/lb lint eq.)	0.00065	0.00071	-9.21%
Soil Conservation (Tons/lb lint eq/yr.)	0.00078	0.00319	-75.41%
Irrigation Water Use (ac-in./lb lint eq. above dryland lint eq.)	0.018	0.022	-22.22%
Energy Use (BTU/lb lint eq.)	5017.00	5641.00	-12.44%
Greenhouse Gas Emissions (lb CO_2eq/lb. lint eq.)	1.23	1.36	-10.57%

[a] To account for the economic contribution of cotton seed to the value of lint with regard to sustainability, harvested lint yield/0.83 = lint yield equivalent.

Cotton Research Verification Sustainability Program: 2018 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 produce cotton more efficiently with the objective of improving profitability. As cost of production continues to increase, producers are searching for ways in which a modifications can be made 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. This 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 307 irrigated fields entered into the program. The success of the cotton program spawned verification programs in rice, soybean, wheat and corn in Arkansas and 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 program by measuring the producers' environmental footprint for each field and evaluating the connection between profitability and sustainability.

Procedures

The 2018 CRVSP was composed of 12 fields at 3 locations/counties, with 8 fields being in Desha County, 2 fields in Mississippi County, and 2 fields in St. Francis County. Each field was entered into the Field to Market Fieldprint Calculator. Two fields entered the fourth year of research regarding farmer standard tillage with a stale seedbed compared to a modified no-till with cover production system. Increasing both efficiency and profitability will continue to be a main part of the program.

The CRVSP has worked along with the University of Arkansas System Division of Agriculture's Discovery Farms Program in Southeast Arkansas for 6 of the 12 fields in the program. Discovery Farms' main focus is to monitor edge-of-field water quality. Fields are watered in two sets. The split-field arrangement provides the opportunity to compare two production strategies. The farmer standard tillage and cover crop usage was compared to a no-till system with a cereal rye cover crop. The fields at Mississippi and St. Francis counties did not have the opportunity to be watered in two sets. In fall 2017, all no-till cover fields with exception of St. Francis County had either Elbon, or Wrenz Albrunzi cereal rye broadcasted, with a target seeding rate of 56 lb/ac. In St. Francis County a mix of 22 lb/ac of each Elbon cereal rye, and Cosaque black seeded oats was broadcasted. 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 analyses were conducted at seasons end to determine net return/acre for each field in the program.

Results and Discussion

The majority of cotton in Arkansas was planted from late April to late May. Tarnished plant bug (TPB) numbers decreased this year compared to 2017; fields in the CRVSP were treated an average of 3.33 times for TPB. Tarnished plant bug pressure was similar across all locations as all fields were sprayed 2–4 times during the growing season. Each field had an average of 1.83 burndowns and 4.33 herbicide applications for the 2018 season. The average number of treatments for moths/worms was 1.92. The average costs for herbicides and insecticides were $78.14 and $61.72 respectively. Pest control represents a big expense and can impact yields greatly.

Records of field operations on each field provided the basis for estimating expenses. Production data from the 12 fields were applied to determine costs and returns above op-

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erating 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 $0.65/lb is the estimated Arkansas annual average for the 2018 production year. Average cotton yield for these verification fields was 1691 lb/ac.

The average operating cost for cotton in Table 1 was $612.85/ac. Table 1 indicates that chemicals averaged $163.25/ac and were 27% of operating expenses. Seed and associated technology fees averaged $109.59/ac, or 18% of operating expenses and included 6 fields with a cover crop. Fertilizer and nutrient costs averaged 26% of operating expenses and were $157.22/ac.

With average yield of 1691 lb/ac, average operating costs were $0.37/lb in Table 1. Operating costs ranged from a low of $552.37 in the Weaver FS/NC field to a high of $834.36 in the Manila NT/C field. Returns to operating costs averaged $486.36/ac. The range was from a low of $134.63 in the Wellcot FS/NC field to a high of $748.34 in the Conder FS/NC field. Average fixed costs were $154.63 which led to an average total cost of $767.48/ac. The average return to total specified costs are $331.73/ac. The low was -$21.60 in the Wellcot FS/NC field and the high was $592.54 in the Conder FS/NC field. Total specified costs averaged $0.46/lb.

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.

Acknowledgements

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

Table 1. Summary of revenue and expenses per acre for 2018 Cotton Research Verification Sustainability Program fields comparing farmer standard tillage (FS) with or without a cover crop to no-till (NT) with cover crop.

	Field												
Revenue	**Shop NT/C**	**Shop FS/NC**	**Weaver NT/C**	**Weaver FS/NC**	**Grain Bin NT/C**	**Grain Bin FS/NC**	**Home-Place FS/NC**	**Wellcot FS/NC**	**Manila NT/C**	**Manila FS/C**	**Conder NT/C**	**Conder FS/NC**	**Average**
Yield (lb)	1636.00	1877.00	1890.00	1544.00	1654.00	1570.00	1522.00	1134.00	2115.00	1919.00	1414.00	2018.00	1691.00
Price ($/lb)	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Total Crop Revenue	**1063.40**	**1220.05**	**1228.50**	**1003.60**	**1075.10**	**1020.50**	**989.30**	**737.10**	**1374.75**	**1247.35**	**919.10**	**1311.70**	**1099.20**
Cottonseed Value	**244.83**	**280.89**	**282.84**	**231.06**	**247.52**	**234.95**	**227.77**	**169.70**	**316.51**	**287.18**	**211.61**	**301.99**	**253.07**
Expenses													
Seed	116.11	102.11	116.11	103.40	114.30	100.30	96.35	96.35	116.11	120.53	122.99	110.45	109.59
Fertilizer& Nutrients	129.56	124.63	129.56	124.63	129.56	124.63	151.02	129.56	353.97	160.52	162.72	166.23	157.22
Herbicides	73.22	64.02	57.29	67.71	67.99	73.18	112.39	89.85	96.35	124.06	36.39	75.26	78.14
Insecticides	71.00	73.12	71.02	51.57	71.02	70.51	70.51	70.50	62.33	62.32	33.34	33.34	61.72
Other Chemicals	22.02	23.02	22.79	22.23	22.02	22.02	22.79	23.05	27.96	26.06	22.12	24.57	23.39
Custom Applications	56.00	56.00	49.00	49.00	56.00	56.00	49.00	49.00	0.00	3.92	42.00	14.00	39.99
Other Inputs	3.88	3.88	3.88	3.88	3.88	3.88	3.88	3.88	39.12	35.85	27.44	37.50	14.25
Diesel Fuel	21.68	22.57	21.68	22.89	21.38	23.10	24.15	23.59	19.26	16.76	16.62	16.76	20.87
Irrigation Energy Costs	33.88	32.04	24.37	22.35	17.59	19.12	23.05	30.22	36.38	36.38	20.33	13.38	25.76
Input Costs	**527.35**	**501.39**	**495.70**	**467.66**	**503.73**	**492.74**	**553.13**	**516.00**	**751.47**	**586.40**	**483.94**	**491.49**	**530.92**
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
Repairs & Maintenance[1]	28.50	31.11	27.62	29.96	26.61	29.40	29.43	30.01	31.88	30.85	29.76	29.46	29.55
Labor, Field Activities	21.20	21.67	21.04	21.72	20.72	21.70	22.72	22.36	12.05	11.65	10.90	9.14	18.07
Production Exp.	**598.46**	**575.57**	**565.76**	**540.74**	**572.47**	**565.24**	**626.69**	**589.79**	**816.80**	**650.31**	**546.01**	**551.50**	**599.95**
Interest	12.87	12.37	12.16	11.63	12.31	12.15	13.47	12.68	17.56	13.98	11.74	11.86	12.90
Post Harvest Exp.	244.83	280.89	282.84	231.06	247.52	234.95	227.77	169.70	316.51	287.18	211.61	301.99	253.07
Operating Exp.	**611.33**	**587.95**	**577.93**	**552.37**	**584.78**	**577.39**	**640.16**	**602.47**	**834.36**	**664.29**	**557.75**	**563.36**	**612.85**
Returns to Operating Exp.	**452.07**	**632.10**	**650.57**	**451.23**	**490.32**	**443.11**	**349.14**	**134.63**	**540.39**	**583.06**	**361.35**	**748.34**	**486.36**
Cap. Recovery and Fixed Costs	145.27	155.71	141.04	153.76	134.23	149.80	151.51	156.23	177.01	171.59	163.64	155.80	154.63
Total Specified Exp.[2]	**756.60**	**743.65**	**718.97**	**706.13**	**719.02**	**727.20**	**791.68**	**758.70**	**1011.37**	**835.89**	**721.38**	**719.16**	**767.48**
Returns to Spec. Exp.	**306.80**	**476.40**	**509.53**	**297.47**	**356.08**	**293.30**	**197.62**	**-21.60**	**363.38**	**411.46**	**197.72**	**592.54**	**331.73**
Operating Exp./lb	0.37	0.31	0.31	0.36	0.35	0.37	0.42	0.53	0.39	0.35	0.39	0.28	0.37
Total Expenses/lb	0.46	0.40	0.38	0.46	0.43	0.46	0.52	0.67	0.48	0.44	0.51	0.36	0.46

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

[2] Does not include land costs, management, or other expenses and fees not associated with production.

[3] Abbreviations: C = Cover, NC = No Cover.

University of Arkansas Cotton Breeding Program: 2018 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 cultivars. A strong breeding program relies upon continued research to develop techniques, which will 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, which are highly adapted to Arkansas environments and possess good host-plant resistance traits. Bourland has led the program since 1988, and has been responsible for almost 100 germplasm and cultivar releases. He has established methods for evaluating and selecting several cotton traits. The current program primarily focuses on the development of improved 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. Backcrossing transgenes into advanced conventional genotypes results in the development of most transgenic cultivars.

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. Breeding line tests include initial crossing of parents, generation advance in early generations, individual plant selections from segregating populations, and evaluation of the 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 capabilities. Selected progeny are promoted to strains, which are evaluated in replicated strain tests at multiple Arkansas locations to determine traits associated with yield, yield component, 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 cultivars.

Results and Discussion

Breeding Lines

The primary objectives of crosses made in 2013 through 2018 (F_1 through F_6 generations evaluated in 2018) 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 combine the fiber quality of UA48 cotton (Bourland and Jones, 2012a) into higher yielding lines. Breeding line development exclusively focuses on conventional cotton lines.

The 24 cross combinations made in 2018 included 10 crosses made with Ark 0812-87ne (released as UA212ne in 2018) and 5 crosses with another UA advanced nectariless line (Ark 0921-31ne). Twelve of the 24 crosses used lines from Gerald Myers (Cotton Breeder, LSU Ag Center) as a parent. Other crosses were between superior UA lines. The F_1 seed of the crosses were increased in the Costa Rica winter nursery for generation advance, and F_2 populations will be grown at Keiser in 2019. The 2018 breeding effort also included field evaluation of 23 F_2 populations, 12 F_3 populations, 17 F_4 populations, 888 first-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 (850) were selected from the F_4 populations. An additional 350 second-cycle selections were made from advanced lines. After discarding individual plants for fiber traits, 888 progenies from the individual plant selections will be evaluated in 2019. From the first-year progenies in

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2018, 216 were advanced to 2019 testing. Out of the 2018 Advanced Progeny, 72 F_6 advanced progenies were 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 2018, a total of 112 strains (72 Preliminary Strains, 18 New Strains, 18 Advanced Strains, and 5 in the 2018 Arkansas Conventional Variety Test) were evaluated in replicated tests at 4 experiment stations in Arkansas. Cotton lines UA48 and UA222 were included as checks in each test. Most (65) of the 72 Preliminary Strains, 15 of 18 New Strains, and 16 of 18 Advanced Strains produced higher yields than either check over all locations. Based on Q-score values, 64 and 15 of the 108 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, seedling disease, bacterial blight, Verticillium wilt, and tarnished plant bug. Work continues in order to improve yield stability by focusing on yield components and to improve fiber quality by reducing bract trichomes.

Germplasm Releases

Genetic releases are a major function of public breeding programs. A total of 91 germplasm lines and 7 cultivars have been released from this program, including three lines (Arkot 0611, Arkot 0617, and Arkot 0712, Bourland et al., 2018) and one cultivar (UA212ne, Bourland and Jones, 2019) in 2018. These lines represent unique genetic materials that have demonstrated improved yield, yield components, host-plant resistance and/or fiber quality. Since 2010, 6 conventional cultivars have recently been released by the Arkansas Agricultural Experiment Station: UA48, UA103 (Bourland and Jones, 2013); UA222, UA107 (Bourland and Jones, 2018a); UA114 (Bourland and Jones, 2018b); and UA212ne. All of these cultivars 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 adaption, 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 line that has performed well in certain areas. Cultivar UA107, another okra leaf line, has wider adaptation than UA103. Cultivar UA212ne is nectariless with wide adaptability and harbors lower populations of tarnished plant bugs. Since nectariless cultivars do not produce nectar that attract bees, they should be exempt from any restrictions that might be imposed on neonicotinoid insecticides. 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 cultivars. In either case, Arkansas cotton producers should benefit from having cultivars that are specifically adapted to their growing conditions.

Acknowledgements

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

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Arkansas Cotton Variety Test 2018

F.M. Bourland[1], A. Beach[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, growers' 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. Previously, new lines were tested in our tests for at least three years before they were widely grown in the state. Our current testing system attempts to offset this rapid turnover by supplementing small plot variety testing (coordinated by Bourland) with subsequent evaluation in large plot extension plots (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

Entries in the 2018 Arkansas Cotton Variety Test were evaluated into three groups—main transgenic (entries returning from 2017 test), first-year transgenic, and conventional varieties (Bourland et al., 2019). The 21 entries in the main transgenic test included 6 B2XF, 3 B3XF, 2 WRF, 8 W3FE and 2 GLT; the 44 entries in the first-year transgenic test included (8 B2XF, 19 B3XF, 3 GLT, 6 GLTP, and 8 W3FE). The transgenic tests were evaluated at all 5 locations. The conventional test included 15 entries and was evaluated at all locations except Manila. All entries in the experiments were evaluated for response to tarnished plant bug and bacterial blight in separate tests at Keiser.

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-inch centers and ranged from 40 to 50 feet in length. Experiments were arranged in a randomized complete block. Replications of the main and first-year transgenic tests were alternated in each field. 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™ Cotton Management System protocols for insecticide termination (Oosterhuis and Bourland, 2008). Cereal rye was planted in the test plot areas 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.

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[2] Resident Director, University of Arkansas System Division of Agriculture, Lon Mann Cotton Research Station, Marianna.
[3] Program Technician, University of Arkansas System Division of Agriculture, Rohwer Research Station, Rohwer.
[4] Professor/Cotton Extension Agronomist, University of Arkansas System Division of Agriculture Newport Extension Center, Newport.

Large Plot Tests

From 7 to 12 transgenic varieties were evaluated at 11 locations from Ashley County to Clay County. Two varieties from 5 seed companies were entered for this study: Bayer, Americot, Monsanto, Dow, and Crop Production Services. 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 marked separately for each variety in Clay County. The test plots 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 2018 exceeded historical averages at each Arkansas location. The warm temperatures in May provided excellent conditions for emergence and early growth of seedlings. Despite the high heat unit accumulations for the season, temperatures exceeding 95 °F were relatively rare—5 days at Keiser, 8 days at Marianna and zero days at Rohwer. Of the 13 days about 95 °F, 9 were recorded at 96 °F, 3 at 97 °F and 1 at 98 °F. Most of the days with the highest temperatures occurred from 12 July through 18 July. Rainfall in 2018 exceeded historical average rainfall at each location. The rainfall in October had detrimental effects on cotton harvest throughout much of the region. Wet conditions continuing through November and December often delayed harvest with ruts in fields, and negated fall tillage operations. The absence of extremely high temperatures and the occurrence of relatively high rainfall provided excellent growing conditions through the season.

Parameters reported for each location included lint yield, lint percentage, plant height, percentage open bolls, seed index, lint index, seed per acre, fibers per seed, fiber density, and fiber properties (quality score, micronaire, length, uniformity index, strength and elongation). Variety by location interactions were significant in all three tests for lint yield, percentage of open bolls, and seed per acre. Despite the interaction, 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 the parameters were found in each test.

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 (Oosterhuis and Bourland, 2008). Nodes above white flower data were recorded for all varieties to calculate days to cutout. Plant height, canopy closure and visual ratings were recorded at or just prior to defoliation. Lint yield was summarized across locations. Discounts associated with excessive leaf grades are a major concern. Leaf grades from commercially ginned plots in Clay County were evaluated and summarized by the percent of bales in the module receiving specific leaf grades. Harvest preparation in this study did an excellent job of defoliation and boll opening with no desiccated leaves present for any variety. All bales from the module harvested for each variety and ginned in a commercial gin of some varieties received a leaf grade of 1 or 2, while other varieties had no bales that received a leaf grade of 1 or 2. The potential to receive leaf discounts especially when less than ideal defoliation has occurred appears to be much greater for some varieties.

Practical Applications

Varieties that perform well over all locations of the Arkansas Cotton Variety Test possess wide adaptation. Specific adaptation may be found for varieties that do particularly well at Keiser (clay soil adapted), Judd Hill (Verticillium wilt tolerant), Manila (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 fiber quality. 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 and morphological features from small plot tests. Finally, results from the small plot tests can identify new lines that may be considered.

Acknowledgements

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 our Arkansas Cotton Variety Testing.

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Evaluation of Cotton in County Large-Plot On-Farm Variety Testing in Arkansas

B. Robertson[1], A. Free[1], C. Manuel[1], and A. Howell[2]

Abstract

Yield is often the primary selection criteria used for variety selection. The objective of this study is to evaluate growth characteristics and lint yield, of select varieties in large-plot on-farm testing. Replicated strips were planted the length of the field and managed according to the remainder of the field in which the study was located. The study was harvested with the producer's equipment. Grab samples were collected for lint fractions and fiber quality. On-farm plots were established at 10 locations with a wide range of planting and harvest dates. Lint yield was summarized across locations containing all technologies. While the lint yield differences were observed, it is important to remember that the varieties tested are a subset of the top-performing commercially available varieties.

Introduction

Yield is often the primary selection criteria used for variety selection. When selecting the varieties for planting, a producer should not simply choose the top yielding variety at any single testing location or year, but look at the averages of several years and locations. Each variety has its strengths and weaknesses. The challenge is to identify these characteristics and adjust management strategies to enhance strengths while minimizing the weaknesses. The best experience is based on first-hand, on-farm knowledge. Yield and quality parameters of unbiased testing programs should be evaluated to learn more about new varieties. Plantings of new varieties should be limited to no more than 10% of the farm. Acreage of a variety may be expanded slightly if it performs well the first year. Consider planting the bulk of the farm to three or four proven varieties of different maturity to reduce the risk of weather interactions and to spread harvest timings. The objective of this study is to evaluate growth characteristics and lint yield, of select varieties in large-plot on-farm testing.

Procedures

Replicated strips were planted the length of the field and managed according to the remainder of the field in which the study was located. Two varieties chosen from 5 seed companies were entered for this study: Bayer, Americot, Monsanto, Dow, and Crop Production Services. The study was harvested with the producer's equipment. Grab samples were collected for lint fraction and fiber quality with the exception of Clay County. The Clay County location was a large block variety trial where a full sized module of each variety was harvested, ginned in a commercial gin, and marked separately for each variety.

Results and Discussion

On-farm plots were established at 10 locations (Table 1) with a wide range of planting and harvest dates. Full season data, obtained using COTMAN™ Cotton Management Expert System Software (SQUAREMAN and BOLLMAN), indicated no unexpected stress at any of the 8 locations (Oosterhuis and Bourland, 2008; Table 2). Nodes-above-white-flower data were recorded for all varieties at the selected locations to calculate days to cutout. Lint yield was summarized across all locations containing all technologies (Table 3) and across all locations.

Practical Applications

Relative differences were apparent between varieties in maturity as measured by days to cutout. While the lint yield differences were observed, it is important to remember that the varieties tested are a subset of the top-performing commercially available varieties.

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Table 1. Planting and harvest dates at the 10 locations for the Large-plot On-farm Variety Testing Program.

	Ashley County	Clay County	Craighead County	Jefferson County	Lee County	Lonoke County	Mississippi Basset	Mississippi County	Poinsett County	St. Francis County
Planted	5/10/2018	5/3/2018	5/7/2018	5/8/2018	5/7/2018	5/11/2018	5/10/2018	5/16/2018	5/2/2018	5/6/2018
Harvested	11/2/2018	10/9/2018	10/30/2018	11/21/2018	10/29/2018	11/3/2018	10/29/2018	10/30/2018	10/3/2018	10/29/2018

Table 2. Days from planting to cutout (nodes above white flower = 5) at the 8 of the 10 locations for the Large-plot On-farm Variety Testing Program.

	Ashley County	Craighead County	Jefferson County	Lee County	Lonoke County	Mississippi County	Poinsett County	St. Francis County
Variety	Days	Days	Days	Days	Days	Days	Days	Days
DG 3214 B2XF	81	82	69	78	85	72	81	70
DG 3385 B2XF	65	74	69	74	88	70	80	69
DP 1518 B2XF	81	79	69	78	86	70	82	73
DP 1646 B2XF	70	79	75	79	99	67	80	71
DP 1820 B3XF	75	82	69	79	84	69	81	74
NG 3729 B2XF	63	75	67	71	83	73	81	65
NG 5007 B2XF	64	81	66	73	83	73	81	70
PHY 330 W3FE		79				69	74	66
PHY 350 W3FE	78		66	78	84			
PHY 430 W3FE	75	77	76	75	83	68	85	72
ST 5122 GLT	74	83	61	67	83	71	66	70
ST 5471 GLTP	72	69	61	69	85	72	77	69

Table 3. Lint yield summarized for 10 locations of the county Large-plot On-farm Variety Testing Program.

	Ashley County		Clay County		Craighead County		Jefferson County		Lee County		Lonoke County		Mississippi Basset		Mississippi County		Poinsett County		St. Francis County		Average Rank	
Variety	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R	Lint lb/ac	R
DP 1646 B2XF	1378	1	1473	5	1885	1	2038	1	1385	1	1206	1	1701	5	1739	6	1781	1	2002	1	1659	2.3
ST 5471 GLTP	1188	6	1606	1	1825	3	1784	2	1377	2	1087	2	1975	1	1837	2	1652	2	1872	3	1620	2.4
ST 5122 GLT	1102	9	1362	6	1786	5	1730	3	1385	1	1058	3	1858	2	1791	5	1558	4	1976	2	1561	4.0
NG 3729 B2XF	1221	3	1567	2	1751	7	1658	6	1299	5	969	9	1569	7	1855	1	1463	7	1754	4	1511	5.1
DG 3385 B2XF	1271	2	1565	3	1843	2	1662	5	1325	3	1043	4	1426	10	1644	10	1507	5	1619	10	1491	5.4
DP 1820 B3XF	1126	8			1710	9	1652	7	1104	10	1004	5	1747	3	1832	3	1447	8	1742	5	1485	6.4
DG 3214 B2XF	1205	4	1497	4	1681	10	1572	11	1195	8	970	8	1373	11	1817	4	1575	3	1680	8	1457	7.1
NG 5007 B2XF	1193	5	1357	7	1713	8	1684	4	1255	6	1000	6	1472	9	1701	7	1339	11	1167	11	1384	7.4
PHY 430 W3FE	1092	11			1800	4	1639	9	1192	9	978	7	1716	4	1670	8	1349	10	1701	6	1460	7.6
DP 1518 B2XF	1096	10			1758	6	1584	10	1316	4	861	11	1436	8	1651	9	1488	6	1684	7	1430	7.9
PHY 350 W3FE	1142	7					1649	8	1201	7	914	10									1227	8.0
PHY 330 W3FE					1533	11							1682	6	1496	11	1365	9	1674	9	1550	9.2

Monitoring Tarnished Plant Bug Resistance in Cotton Cultivars

G. Studebaker[1], C. Spinks[1], and F.M. Bourland[1]

Abstract

Tarnished plant bug (TPB), *Lygus lineolaris* is one of the most prominent pests of cotton in Arkansas. It has been ranked as the number one pest of cotton, causing the highest crop losses in recent years. The objective of this research study was to evaluate TPB populations on a range of cotton (*Gossypium hirsutum* L.) cultivars that vary in their resistance to TPB in larger plots (16 rows by 100 feet). Four cultivars (DP 1518B2XF, DP 1820B2XF, PHY 350W3FE and ST 4949GLT) exhibited minimal yield loss under high TPB populations. Use of these data could potentially reduce the number of grower insecticide applications as well as delay resistance to commonly used insecticides and provide growers with additional knowledge of what cotton cultivars work best for their pest management programs.

Introduction

Tarnished plant bug (TPB) has risen as the most prominent pest in cotton in Arkansas causing the highest crop losses each year since 2004 (Cook, 2018). Insecticides are the most commonly used tool for managing TPB in cotton (Studebaker, 2018). Due to the growing development of resistance in the TPB to some of the most commonly used insecticides, it is important to evaluate other management options such as host-plant resistance. Host-plant resistance is one of the main tenets of integrated pest management and can be a useful tool in managing insect pests (Studebaker et al., 2009). Previous small plot research has indicated certain cotton cultivars to be less attractive to TPB. Therefore, large plot studies such as this one, are needed to validate conclusions made from small plot studies.

Procedures

A large plot field trial was planted at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center at Keiser in 2018 to validate TPB resistance found in small field plots. Plots were 16 rows by 100 feet long arranged in a randomized complete block design with four replications. Six cultivars showing resistance from the 2017 small plot data (ST 4949GLT, PHY 312WRF, PHY 350W3FE, PHY 430W3FE, DP 1518B2XF and DP 1820B2XF) were evaluated. CROPLAN 9608B3XF and DG 3214B2XF were planted as susceptible checks to validate TPB populations within the test. Treated plots were sprayed with acephate at 0.75 lb/ac when TPB reached the recommended treatment threshold of three plant bugs per five row feet. The TPB numbers were determined by taking two shake sheet samples from the center of each plot on a weekly basis throughout the growing season until cotton reached cutout (nodes above white flower, NAWF = 5) plus 250 accumulated heat units. Heat units were determined on a Degree-Day 60 (DD60) heat unit scale. Yield in the plots was determined by harvesting the center rows in each plot with a plot cotton picker.

Results and Discussion

The TPB populations were high, reaching a peak of over 75 per 10 row feet in some cultivars near the end of the season (Fig. 1). The TPB numbers are reported in levels per 10 row-ft, therefore the economic threshold in the figure would be 6 per 10 row-ft. All cultivars reached economic threshold. Cultivars CROPLAN 9608B3XF, DP 1518B2XF, PHY 350W3FE and PHY 430W3FE reached threshold three times, while ST 4949GLT, PHY 312WRF, DP 1820B2XF and DG 3214B2XF reached threshold four times. Yield loss was determined by subtracting yields from the untreated plots from those that were treated at threshold (Fig. 2). Cultivars PHY 350W3FE, DP 1820B2XF, DP 1518B2XF and ST 4949GLT had the lowest yield loss, while PHY 312WRF, PHY 430W3FE, CROPLAN 9608B3XF and DG 3214B2XF had the highest yield losses. Lower yield losses would indicate there is some level of resistance or tolerance in ST 4949GLT, PHY 350W3FE, and DP 1820B2XF. Results have been variable with some cultivars over time. The cultivar DP 1518B2XF has exhibited some resistance in small plots, yet it has shown the highest yield loss in large plots the previous two years (Studebaker et al., 2017; Jackson et al., 2018). However, this year DP 1518B2XF had little yield loss from

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TPB, indicating large plot data correlate well with small plot data. Similar results were exhibited by PHY 312WRF with high yield loss three years. This may indicate that environment factors or other growing conditions may affect resistance in these cultivars. Results from this test indicate the need to continue to verify resistance found in small plots.

Practical Applications

While resistance/tolerance is evident in some cultivars, they still may require multiple applications to control TPB under heavy pressure. However, it appears that with some cultivars, yield loss is reduced, even under high TPB populations. These data will help growers in selecting cotton cultivars for resistance to TPB, as well as help breeders select for desirable resistant traits in certain cultivars.

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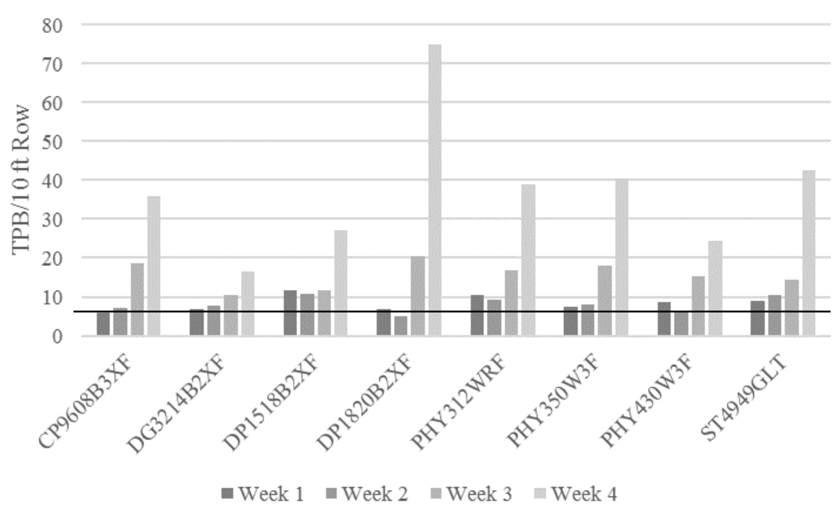

Fig. 1. Tarnished plant bug (TPB) densities in untreated plots across four weeks of data collection at Keiser, Ark. in 2018. Horizontal line indicates treatment threshold of 6 TPB per 10 row-ft).

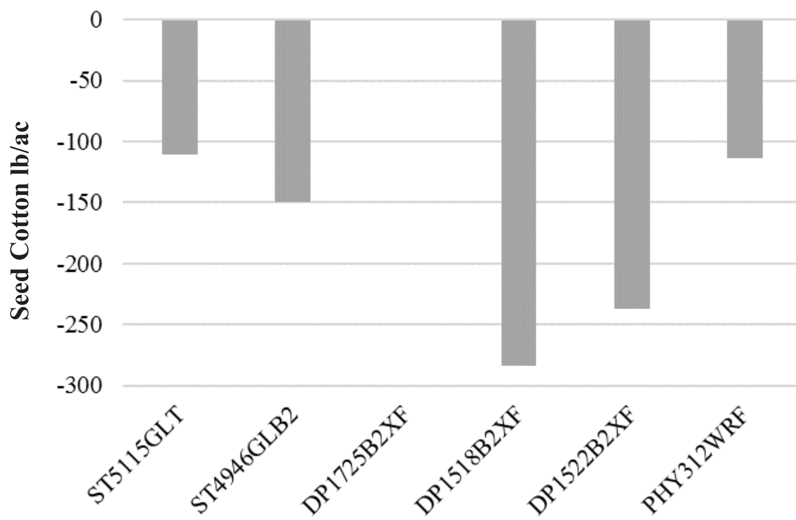

Fig. 2. Seed cotton yield loss associated with tarnished plant bug damage to six cotton cultivars at Keiser, Ark. in 2018.

Alternatives to Neonicotinoids for Control of Thrips in Cotton

N.M. Taillon[1], G. Lorenz[1], B. Thrash[1], W.A. Plummer[1], K. McPherson[1], A.J. Cato[2], and N. Bateman[3]

Abstract

Thrips are an early season pest in cotton that can delay maturity and cause yield loss. With the uncertain future of neonicotinoids and thrips resistance to thiamethoxam (Cruiser) being found in Arkansas, there is a need to evaluate alternative products for thrips control. The objective of this study, conducted at both the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, and Tillar, Arkansas, was to evaluate other insecticide classes as a seed treatment or in-furrow treatment for control of thrips. Results indicated that Orthene alone and in combinations, and aldicarb consistently provided the best level of control for thrips.

Introduction

Thrips are an early season pest in cotton that can delay maturity and cause yield loss. Symptoms of thrips damage on seedling cotton are crinkled leaves, burnt edges, and a silvery appearance. The level of damage varies from year to year based on severity of the thrips infestation (Hopkins et al., 2001). In 2012 and 2013, observations were made that indicated tobacco thrips (*Frankliniella fusca*), the predominant species found in cotton, had developed tolerance/resistance to Cruiser (thiamethoxam) (Lorenz et al., 2017). In 2015, Herbert and Kennedy conducted studies in the mid-South and Southeastern U.S. that confirmed resistance to the neonicotinoid insecticides thiamethoxam and imidacloprid. Studies conducted in Arkansas verified these findings (Plummer et al., 2015). Insecticide seed treatments and additional foliar insecticide application(s) are often necessary to effectively control thrips creating high input costs for growers. In recent years, neonicotinoids have come under scrutiny for their impact on pollinators (Krupke et al., 2012). Although studies conducted by Stewart et al. (2014) showed no deleterious effects on honeybees, popular opinion and social trends to do away with this class of chemistry further present the need to find alternative modes of action to control thrips.

Procedures

Trials were conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna and at Tillar Farms in Tillar. Plot size was 12.5 ft by 40 ft in a randomized complete block design with 4 replications. Insecticide seed treatments included: Cruiser (thiamethoxam) 12.3 oz/cwt, Avicta Elite (abamectin + thiamethoxam + imidacloprid) 33.6 oz/cwt, Gaucho (imidacloprid) 12.32 oz/cwt, Orthene (acephate) 6.4 oz/cwt, Orthene 6.4 oz/cwt + Gaucho 12.32 oz/cwt; and Aeris Seed Applied System (imidacloprid + thiodicarb) 24.64 oz/cwt as the commercial neonicotinoid standard. In-furrow (IF) treatments included: Admire Pro (imidacloprid) 9.2 oz/ac, Orthene 1 lb/ac, Orthene 1 lb/ac + Admire Pro 9.2 oz/ac, and AgLogic (aldicarb) 3.5 lb/ac. All treatments, including the untreated check (UTC), were treated with a base fungicide package of Trilex Advanced 1.6 oz/cwt. Insecticide seed treatments were applied using a small batch treater, and IF applications were applied with an IF mounted sprayer system at 10 gal/ac set at 40 psi using Tee Jet 9001 VS flat fan nozzles for Admire Pro and Orthene; while a planter-mounted granular applicator was used for AgLogic treatments. Plots at Marianna and Tillar were planted on 1 May using PHY333. Thrips samples were taken 22 and 30 days after planting (DAP), and 37 and 43 DAP respectively, by collecting 5 plants per plot and placing in jars with 70% alcohol solution. Samples were washed and filtered in the lab at the Lonoke Extension Center, Lonoke, Ark. and thrips were counted using a dissection scope. Data were processed using Agriculture Research Manager, Version 2018.5 (Gylling Data Management, Inc., Brookings, S.D.). Analysis of variance was conducted and Duncan's New Multiple Range Test ($P = 0.10$) to separate means.

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Results and Discussion

Results at Marianna indicate that at 22 DAP, only Orthene (IF) 1 lb/ac, alone and in combination with Admire Pro (IF) 9.2 oz/ac; Orthene (IST) 6.4 oz/ac, alone and in combination with Gaucho (IST) 12.32 oz/cwt; and Ag Logic (IF) 3.5 lb/ac reduced thrips densities when compared to the untreated check. At 30 DAP, Cruiser (IST) and Avicta Elite (IST), had more thrips than the UTC (Figs. 1 and 2).

Results at Tillar indicate that at 37 DAP all treatments had fewer thrips when compared to the UTC, Orthene (IST) 6.4 oz/cwt, and Cruiser (IST) 12.3 oz/cwt with similar results at 43 DAP (Figs. 3 and 4).

Practical Applications

Resistance of tobacco thrips to the neonicotinoid class of chemistry is a major concern to growers. Cruiser (thiamethoxam) is no longer recommended for control of thrips in Arkansas and Gaucho (imidacloprid) appears to be losing efficacy as well. With neonicotinoids, only Admire Pro (IF) is consistently providing thrips control. Orthene alone and in combination with other insecticides, and Ag-Logic (aldicarb) provided excellent control of thrips in these trials.

Use of these products will be driven by price of application, planting system, and market prices. With so few insecticides left to control thrips, cultural control methods need to be implemented to help reduce their impact on cotton yields. Research and labeling of novel insecticide seed treatments would also provide a great benefit to Arkansas cotton producers.

Acknowledgements

Appreciation is expressed to the Lon Mann Cotton Branch Experiment Station, and Tillar and Co. Support also provided by the University of Arkansas System Division of Agriculture.

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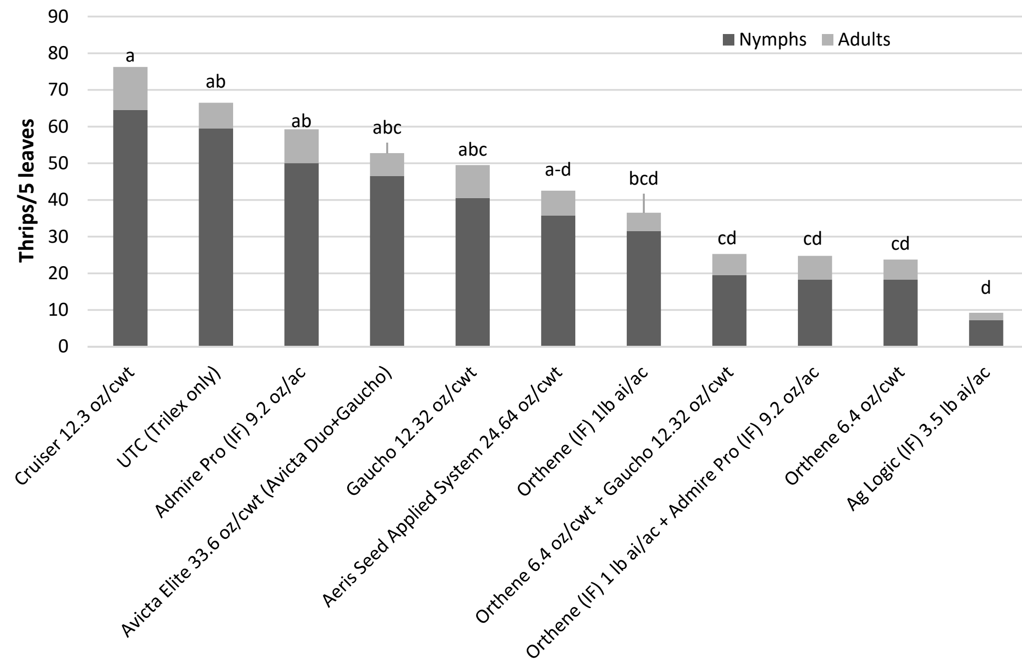

Fig. 1. Thrips counts on cotton 22 days after planting (planted 1 May) at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Arkansas in 2018.

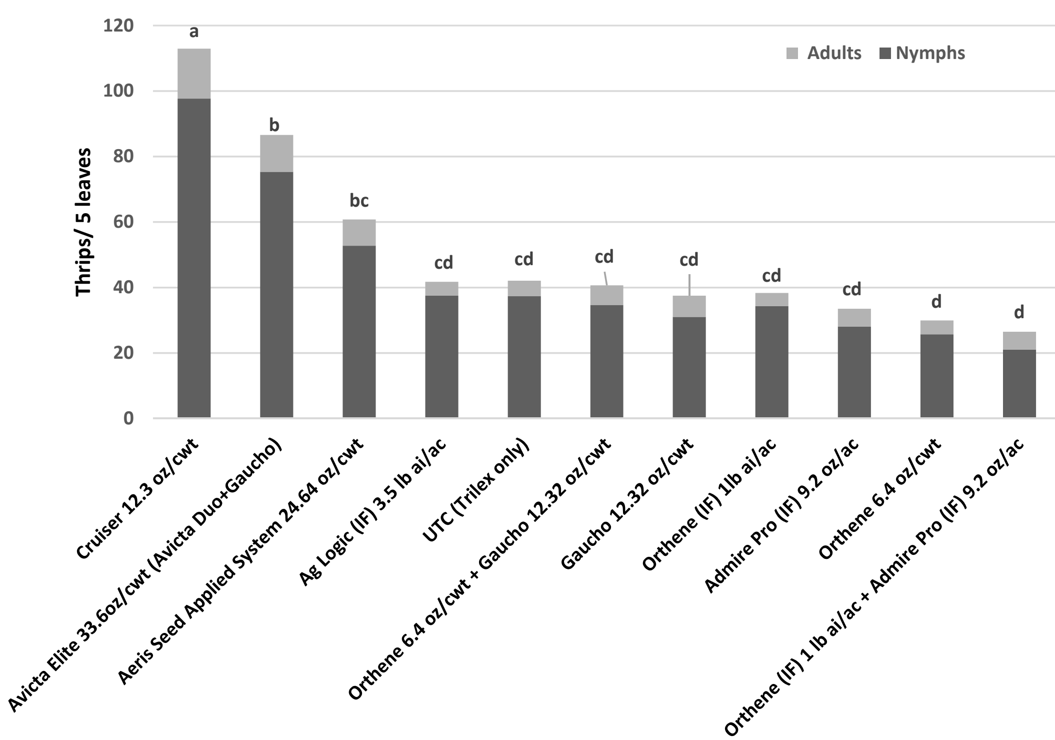

Fig. 2. Thrips counts on cotton 30 days after planting (planted 1 May) at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Arkansas in 2018.

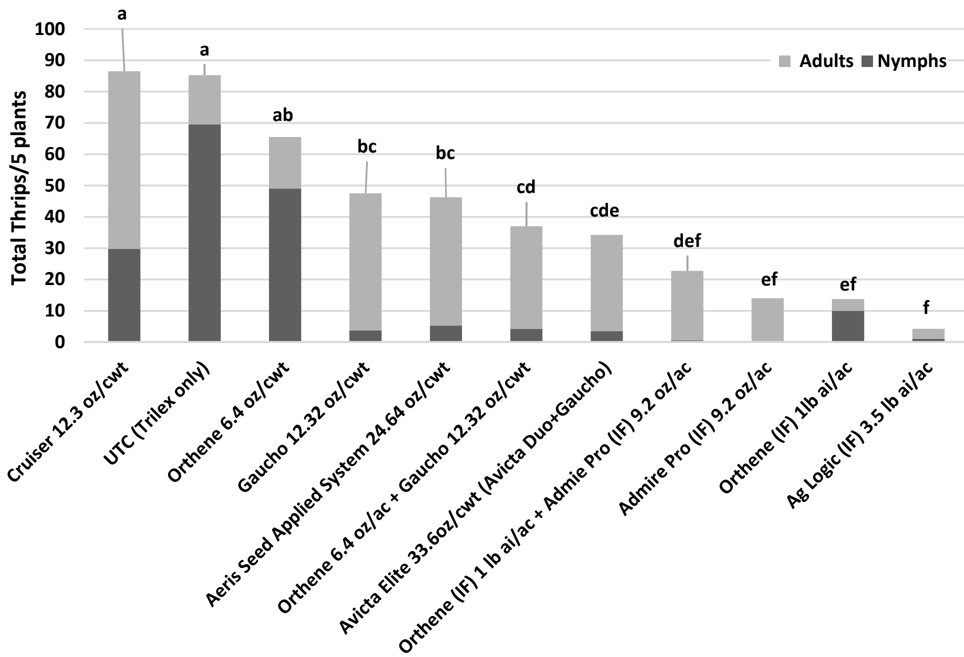

Fig 3. Thrips counts on cotton 37 days after planting (planted 1 May) at Tillar, Arkansas in 2018.

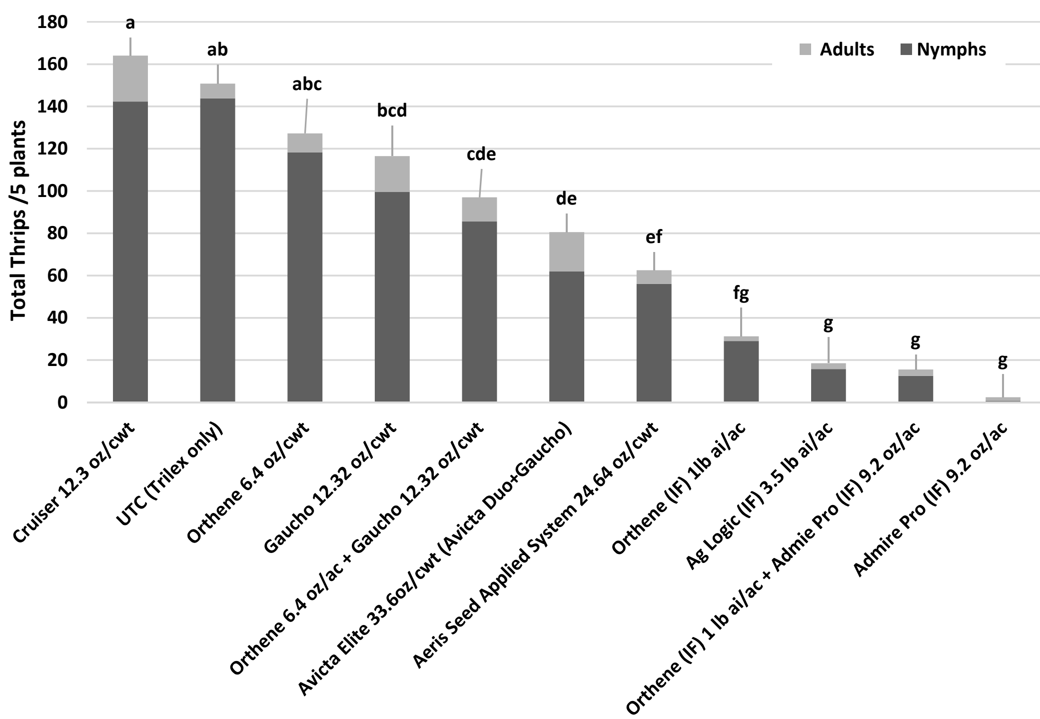

Fig. 4. Thrips counts on cotton 43 days after planting (planted 1 May) at Tillar, Arkansas in 2018.

Changes in Plant Bug Efficacy Over 14 Years in Arkansas

B. Thrash[1], G. Lorenz[1], N.M. Taillon[1], W.A. Plummer[1], K. McPherson[1], A.J. Cato[2], and N. Bateman[3]

Abstract

Data from a total of 121 tarnished plant bug efficacy trials conducted in Arkansas from 2005 to 2018 were combined to evaluate the performance of insecticides classes over time. Based on this analysis, there were no changes in organophosphate, neonicotinoid, sulfoxamine, or benzoylurea efficacy. However, pyrethroid efficacy declined substantially over the same time period. Even with the decline in pyrethroid efficacy, the addition of bifenthrin to acephate continued to increase control of plant bugs over acephate alone. Data from the past five years indicate acephate, dicrotophos, novaluron, and sulfoxaflor provide the greatest control of tarnished plant bug in cotton at 2–4 and 5–8 days after treatment.

Introduction

Tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), is the most damaging insect pest of cotton in Arkansas totaling near $74 million in losses plus cost in 2018 (Cook, 2019). Plant bugs are a difficult pest to manage in cotton with growers averaging 4.7 insecticide applications per acre treated. Few currently labeled insecticides provide effective control of plant bugs meaning growers must tank mix products with multiple modes of action to obtain an acceptable level of control. With few effective modes of action, insecticide resistance is an issue growers continue to face. Comparing insecticide performance in past trials to current ones can provide insight on how efficacy has changed over time.

Procedures

Efficacy trials were conducted from 2005 to 2018 in Arkansas. Of the total 121 trials used in the analysis, 116 were conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Lee County, Ark., while the remaining were conducted on grower fields across the state. Plots were sprayed using a Mud-Master sprayer fitted with either 80-02 dual flat fan nozzles or TXVS-6 hollow cone nozzles with 19.5 inch spacing. Spray volume was 10 gal/ac at 40 psi. Plot sizes were 12.5 ft (4 rows) by 40 ft. Insecticide classes, active ingredients, and the rates included in this study can be found in Table 1. All products, formulations, and rates were standardized to lb ai/ac. Insecticide rates within 10% of the most commonly used rate were combined with the more common rate. Plant bug densities were determined by using a 2.5 ft drop cloth and taking 2 samples per plot (10 row ft). Plant bug densities were standardized within each sample date as percent control relative to the untreated check. Only samples collected 2–4 days after treatment (DAT) are reported unless otherwise indicated. Analysis was conducted in JMP 14 using analysis of variance and regression analysis. Means were separated using Tukey's honestly significant difference (HSD) ($P < 0.05$). Sample dates where plant bug densities were lower than threshold (6 per 10 row ft) in the untreated check were eliminated from analysis.

Results and Discussion

Analysis of selected insecticides from 2014–2018 at 2–4 days after treatment indicated that sulfoxaflor provided the greatest overall control of plant bugs but was not different than acephate, dicrotophos, flonicamid, or novaluron (Fig. 1). Control at 5–8 DAT was similar to that at 2–4 DAT, with the exception of flonicamid, which dropped substantially in the amount of control provided (Fig. 2). Regression analysis found there were no changes in organophosphate, neonicotinoid, sulfoxamine, or benzoylurea efficacy over the evaluated time period (organophosphate, $P = 0.11$; neonicotinoid, $P = 0.15$; sulfoxamine, $P = 0.21$; benzoylurea, $P = 0.72$) (Figs. 3–6). However, pyrethroid efficacy declined substantially over the same period of time ($P = 0.02$) (Fig. 7). Although pyrethroid efficacy has declined in recent years, mixtures of bifenthrin + dicrotophos continued to provide an increase level of control over dicrotophos alone (Fig. 8).

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Practical Applications

Over the past five years, acephate, dicrotophos, novaluron, and sulfoxaflor provided the greatest mean control of tarnished plant bug in cotton at 2–4 DAT and 5–8 DAT. Analysis indicated that pyrethroids were the only insecticide class of those tested to have reduced efficacy across the analyzed time period. Even though there was a reduction in pyrethroid efficacy over that time, a mixture of bifenthrin (a pyrethroid) + acephate continued to provide increased control over acephate alone. Several studies including Snodgrass et al., 2009 and Parys et al., 2018 found great variation in the susceptibility of tarnished plant bugs to multiple insecticide classes across locations. Because the majority of the data included in this analysis was from one location, including data from other locations across the mid-South would help provide a better idea of how insecticides have performed over time.

Acknowledgements

We would like to acknowledge the personnel at the Lon Mann Cotton Research Station for their assistance in plot maintenance. Support also provided by the University of Arkansas System Division of Agriculture.

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Table 1. Insecticide classes, active ingredients, and rates included in analysis.

Insecticide class	Active Ingredient	Rate (lb ai/ac)
Organophosphate	Acephate	0.75
	Dicrotophos	0.5
Pyrethroid	Bifenthrin	0.1
	Gamma-cyhalothrin	0.015
	Lambda-cyhalothrin	0.03
	Zeta-cypermethrin	0.025
Sulfoxamine	Sulfoxaflor	0.047
Neonicotinoid	Acetamiprid	0.013
	Imidacloprid	0.0625
	Thiamethoxam	0.05

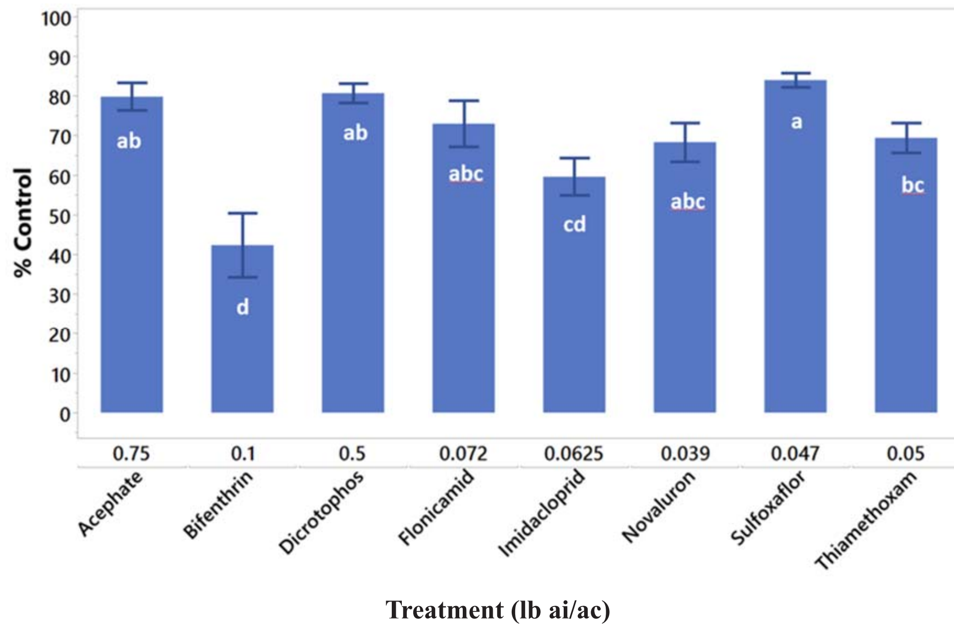

Fig. 1. Mean efficacy of selected insecticides for control of tarnished plant bug 2–4 days after treatment in Arkansas test from 2014 to 2018.

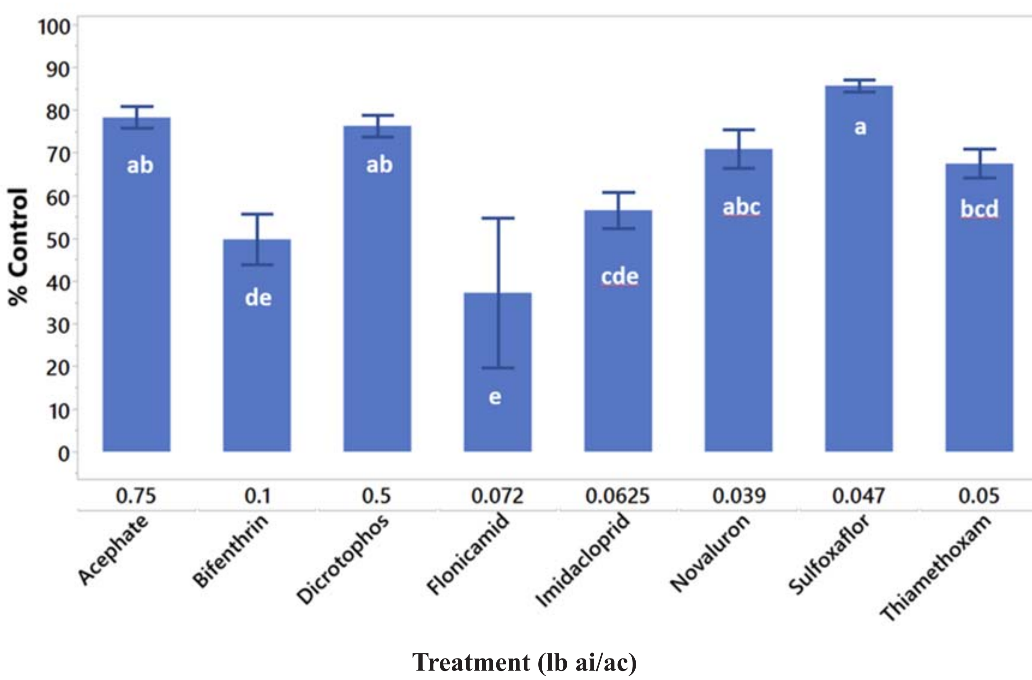

Fig 2. Mean efficacy of selected insecticides for control of tarnished plant bug 5–8 days after treatment from 2014 to 2018.

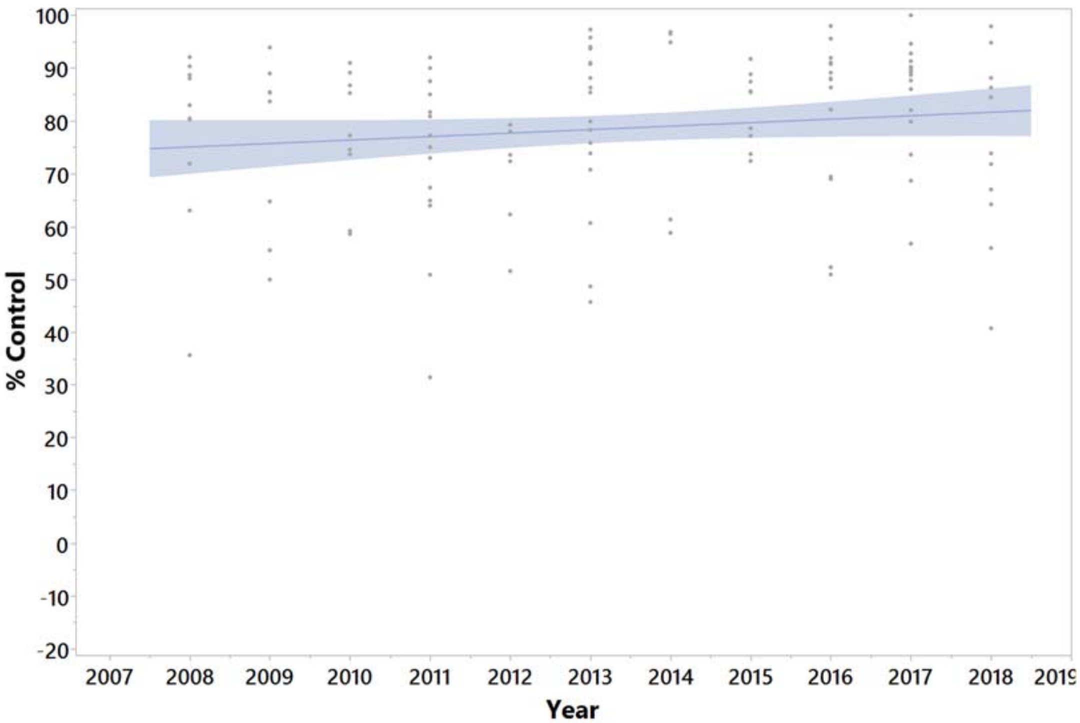

Fig 3. Organophosphate (acephate 0.75 lb ai/ac, dicrotophos 0.5 lb ai/ac) efficacy for control of tarnished plant bug over time (*P* = 0.11) in Arkansas.

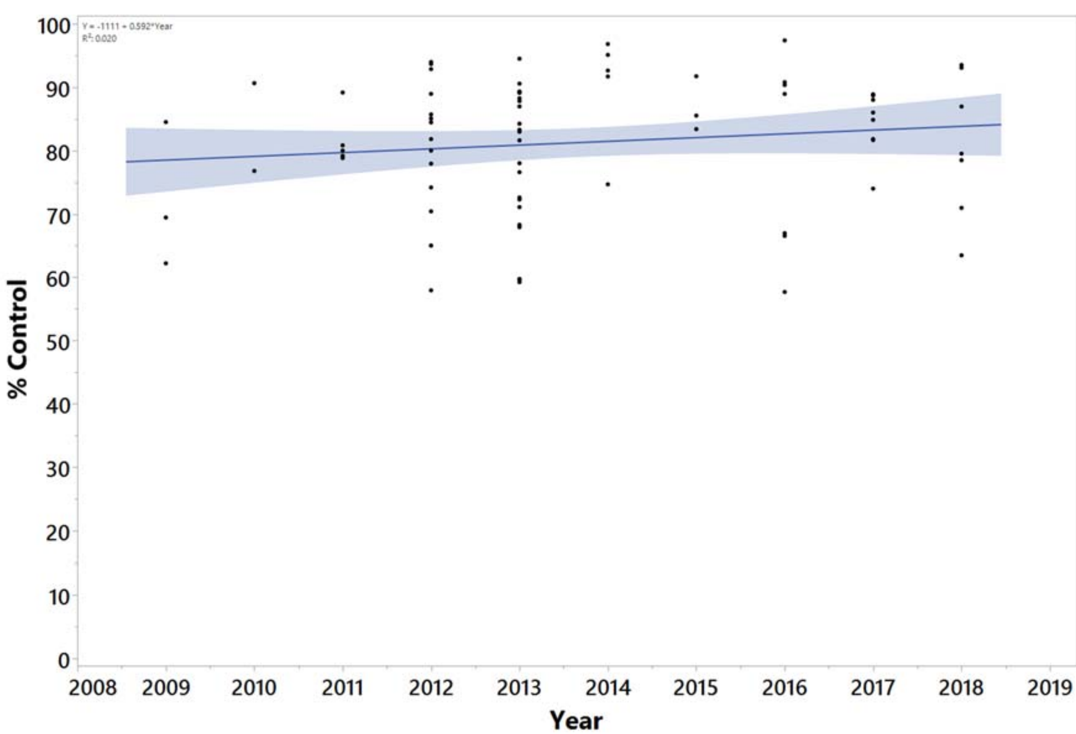

Fig. 4. Sulfoxamine (sulfoxaflor 0.047 lb ai/ac) efficacy for control of tarnished plant bug over time (*P* = 0.21) in Arkansas.

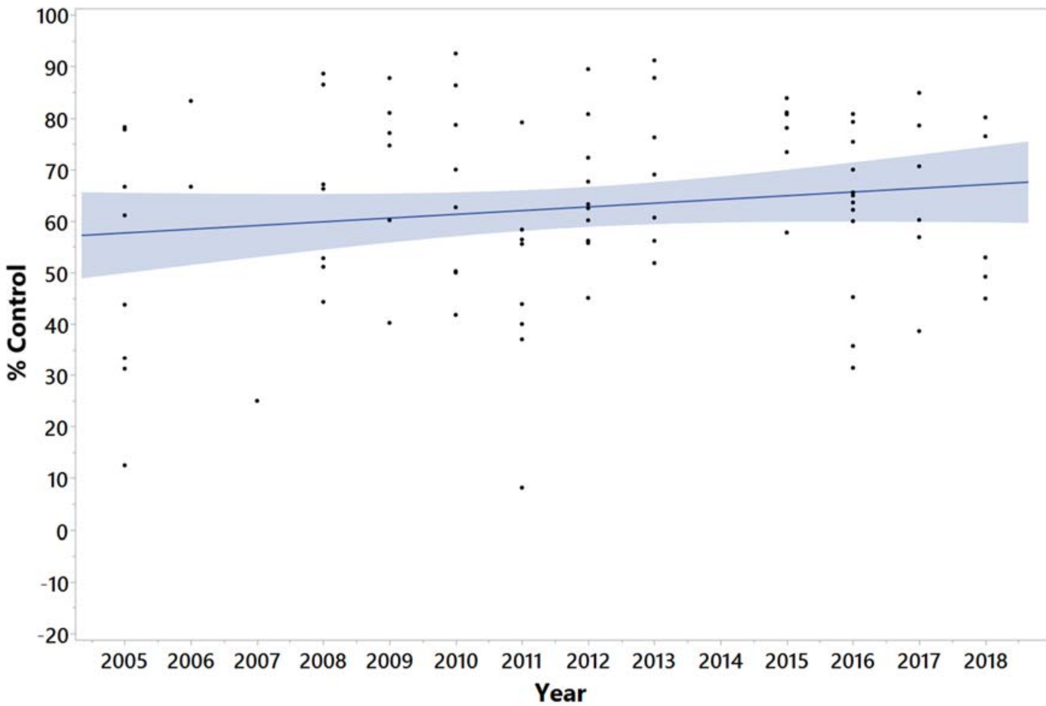

Fig. 5. Neonicotinoid (acetamiprid 0.013 lb ai/ac, imidacloprid 0.0625 lb ai/ac, thiamethoxam 0.05 lb ai/ac) efficacy for control of tarnished plant bug over time (*P* = 0.15) in Arkansas.

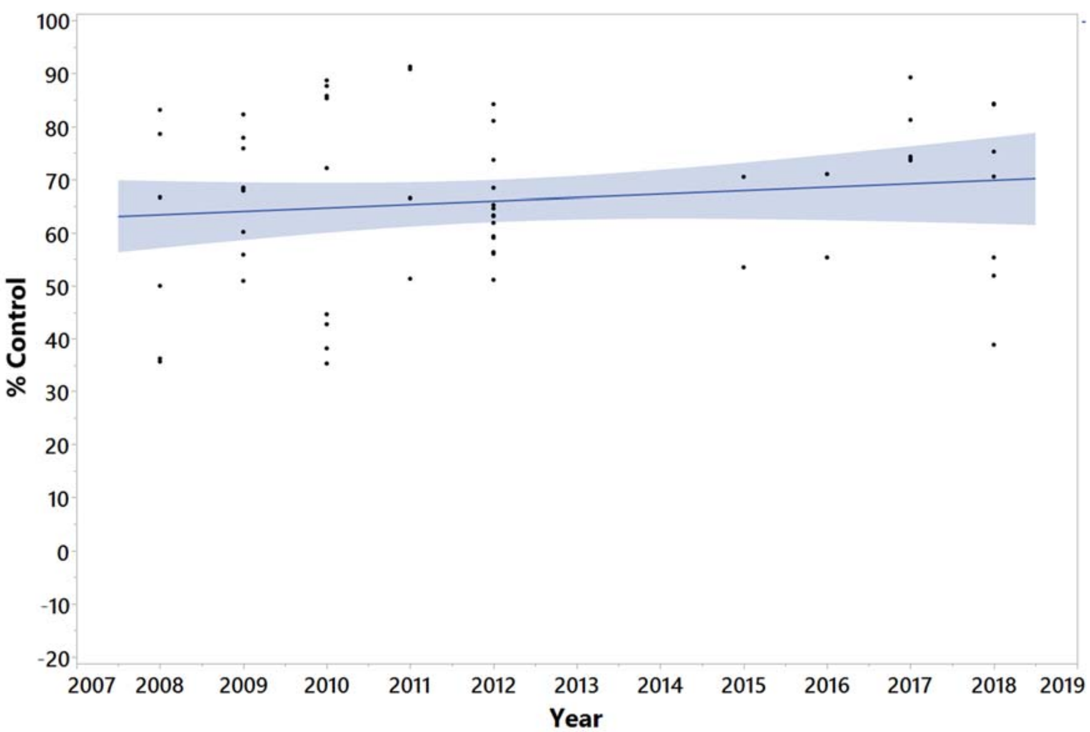

Fig. 6. Benzoylurea (novaluron 0.039 lb ai/ac) efficacy for control of tarnished plant bug over time (*P* = 0.72) in Arkansas.

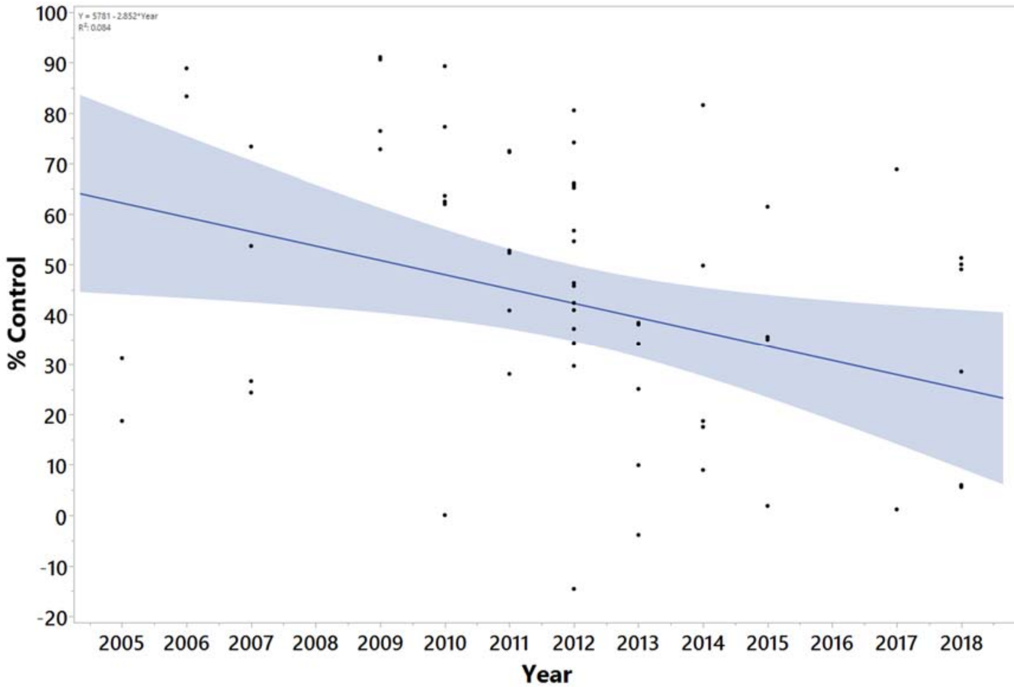

Fig. 7. Pyrethroid (bifenthrin 0.1 lb ai/ac, gamma-cyhalothrin 0.015 lb ai/ac, lambda-cyhalothrin 0.03 lb ai/ac, zeta-cypermethrin 0.025 lb ai/ac) efficacy for control of tarnished plant bug over time (*P* = 0.02) in Arkansas.

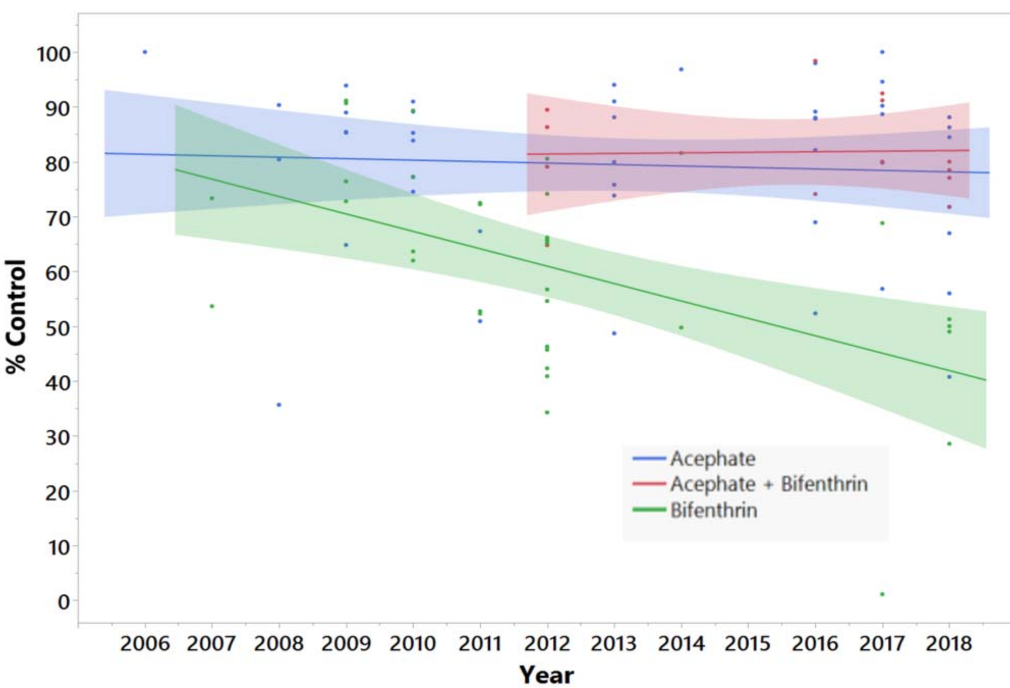

Fig. 8. Efficacy for control of tarnished plant bug of acephate (0.75 lb ai/ac), bifenthrin (0.1 lb ai/ac), and acephate (0.75 lb ai/ac) + bifenthrin (0.1 lb ai/ac) over time in Arkansas.

Comparison of *Bacillus thuringiensis* Technologies, With and Without Diamide Applications, for Control of *Helicoverpa Zea* in Arkansas Cotton

K. McPherson[1], G. Lorenz[1], B. Thrash[1], W. A. Plummer[1], N.M. Taillon[1], A.J. Cato[2], and N. Bateman[3]

Abstract

The cotton bollworm (*Helicoverpa zea,* Boddie) is a major pest of cotton in Arkansas and can cause significant yield losses if not controlled. An increasing amount of fruit damage has been observed in dual gene cotton cultivars in the last several years. A study was conducted in Drew County, Arkansas, to evaluate the efficacy of dual gene and triple gene *Bacillus thuringiensis (Bt)* cotton cultivars in sprayed and unsprayed conditions. 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

The cotton bollworm (BW) (*Helicoverpa zea,* Boddie) is a major pest of flowering cotton in the mid-South. In 2017, 100% of Arkansas cotton acres were infested by the BW. Of those acres, 98% were planted in *Bacillus thuringiensis (Bt)* cotton cultivars (Cook, 2017). A meta-analysis of cotton data in the mid-South suggests that Bollgard 2 and WideStrike efficacy have declined in recent years due to resistance of BW to several *Bt* toxins (Fleming et. al., 2018). With the high technology fees associated with these traits and the growing concern of *Bt* resistance, it is important to monitor the efficacy of different traits for control of caterpillar pests.

Recent studies have indicated that dual gene *Bt* cultivars such as WideStrike, TwinLink, and Bollgard 2 may not provide the protection needed to prevent fruit damage from BW and can benefit from supplemental foliar applications in years when BW populations are high (Taillon et al., 2015; 2016; 2017). In 2013, the average cost of insect control related technology fees in transgenic cotton in Arkansas was \$29.48/acre, this decreased to \$9.32/acre in 2017. Within the same period, supplemental foliar insecticide application costs increased from \$2.95 to \$15.00/acre (Williams, 2014; Cook, 2018). In 2017, around 75% of cotton acres in Arkansas received a supplemental foliar application for control of BW (Cook, 2018). Currently, the threshold in Arkansas for BW in dual gene transgenic cotton cultivars is 6% damaged fruit (squares + bolls) with worms present, or eggs present on 25% of plants (Studebaker et al., 2018). In 2017, triple gene cultivars such as WideStrike 3, TwinLink Plus, and Bollgard 3 provided a superior level of control without requiring a supplemental foliar application (Taillon et al., 2017). The objective of this study was to evaluate dual and triple gene *Bt* cotton cultivars for BW injury and to determine the impact of a supplemental foliar insecticide application in the *Bt* cotton cultivars.

Procedures

A trial was conducted on a grower's field in Drew County, Arkansas in 2018. Plot size was 12.5 ft. (4 rows) by 40 ft., in a randomized complete split block design with 4 replications. Cultivars included: Non-*Bt* (DP 1822XF); WideStrike (PHY 333WRF); WideStrike 3 (PHY 330W3FE); TwinLink (ST 5122GLT); TwinLink Plus (ST 5471GLTP); Bollgard 2 (DP 1518B2XF); and Bollgard 3 (DP 1835B3XF) (Table 1). Each of the tested cultivars contained a sprayed and unsprayed plot. Sprayed plots were treated with a single foliar application of Prevathon (chlorantraniliprole) at 20 oz/ac on 24 July. Insecticide application was made using a Mudmaster high clearance sprayer fitted with TXVS-6 nozzles at 19.5-inch spacing with a spray volume of 10 gal/ac at 40 psi. Damage was rated by sampling 25 squares, 25 flowers, and 25 bolls per plot. Ratings were taken 6, 13, and 21 days after application (DAA). The data were processed using Agriculture Research Manager 2018 (Gylling Data Management, Inc., Brookings, S.D.) with 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 were performed only when analysis of variance Treatment P (F) was significant at mean comparison of significant level.

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[3] Assistant Professor/Crop Entomologist, Department of Entomology, University of Arkansas Rice Research and Extension Center, Stuttgart.

Results and Discussion

All plots had less damage than the untreated non-*Bt* cultivar for each sampling date except for the unsprayed WideStrike cultivar 21 days after application (DAA) (Figs. 1–3). At 6 DAA, all *Bt* cultivars, sprayed and unsprayed, as well as the sprayed non *Bt* cultivar had less damage than the unsprayed WideStrike cultivar (Fig. 1). When sprayed, the WideStrike cultivar was no different than the sprayed non-*Bt* cultivar. All other *Bt* cultivars, sprayed and unsprayed were at or below threshold. At 13 DAA, similar results were observed; however, damage in the TwinLink and Bollgard II cultivars was no different than the sprayed non *Bt* cultivar and sprayed WideStrike cultivar and was above threshold (Fig. 2). At 21 DAA, the unsprayed WideStrike cultivar was no different than the unsprayed non-*Bt* cultivar (Fig. 3). The unsprayed Bollgard II cultivar and sprayed WideStrike cultivar had more damage than the sprayed TwinLink cultivar, sprayed BollGard II cultivar, and the triple gene cultivars–sprayed and unsprayed.

There was high BW pressure in this trial as indicated by the level of damage in the non-*Bt* cultivar (Figs. 1–3). In the first two sample dates, the unsprayed non-*Bt* cultivar averaged 47% fruit damage. As a result, there was not enough fruit left on the last sample date to accurately sample damaged fruit in the unsprayed non *Bt* plots. This caused the data to appear as if the non *Bt* had less damage than was actually present. At all three sample dates, the WideStrike cultivar, sprayed and unsprayed, exceeded the 6% threshold averaging 27% fruit damage in the unsprayed plots and 13% in sprayed plots. In the unsprayed WideStrike 3 cultivar, the damage level never reached the 6% damage threshold and provided much greater control than both sprayed and unsprayed WideStrike cultivar plots. Unsprayed Bollgard II cultivar averaged 11% damaged fruit across all three sampling dates indicating the need for a supplemental foliar application for BW control.

Practical Applications

Cotton bollworms are developing resistance to the dual gene *Bt* toxins. A foliar insecticide application reduced damage in all dual gene cultivars in this trial. However, the triple gene cultivars did not benefit from a foliar insecticide application for control of BW, even under the intense BW pressure experienced in this study. Based on these results, growers planting dual gene cultivars should budget at least one application of a diamide to prevent yield loss. However, triple gene cultivars appear to provide adequate control but should still be monitored to ensure adequate control. When selecting cultivars, growers should consider yield potential first and then technology, but be aware that dual gene cultivars may need a supplemental foliar application for worm control.

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Appreciation is expressed to A.J. Hood for providing the land where this research was conducted.

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Table 1. Cotton cultivars used during cotton bollworm efficacy studies in 2018 (Drew County, Arkansas).

Cotton Cultivars by Transgenic Trait Package		
Conventional	**Dual Gene**	**Triple Gene**
Non-*Bt* (DP 1822XF)	WideStrike (PHY 333WRF)	WideStrike 3 (PHY 330W3FE)
	TwinLink (ST 5122GLT)	TwinLink Plus (ST 5471GLTP)
	Bollgard 2 (DP 1518B2XF)	Bollgard 3 (DP 1835B3XF)

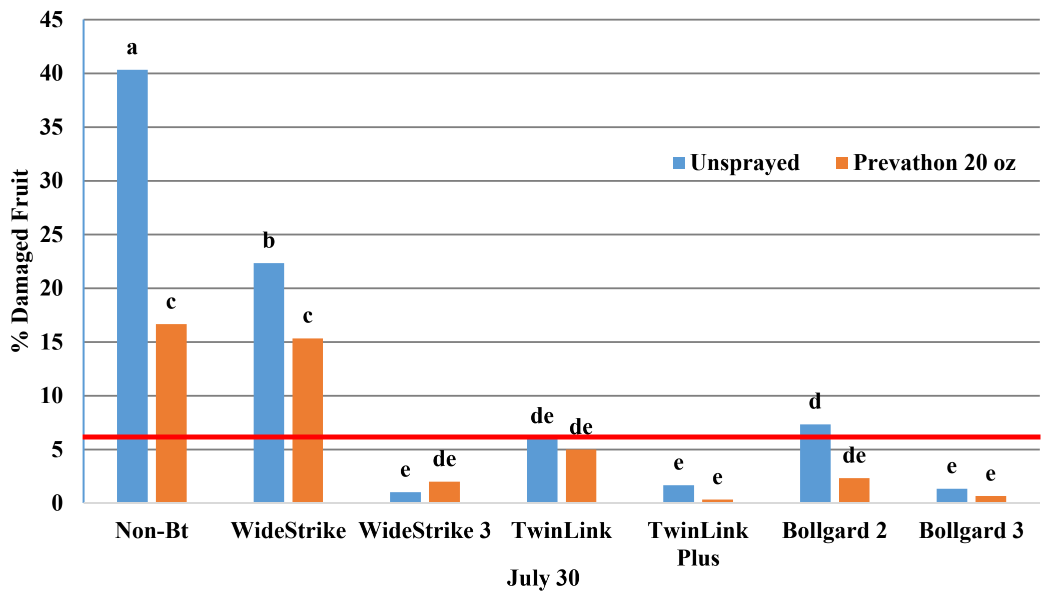

Fig. 1. Percent of cotton bollworm damaged fruit 6 days after application of Prevathon at 20 oz/ac (red line denotes 6% threshold); Drew County, Arkansas, 2018.

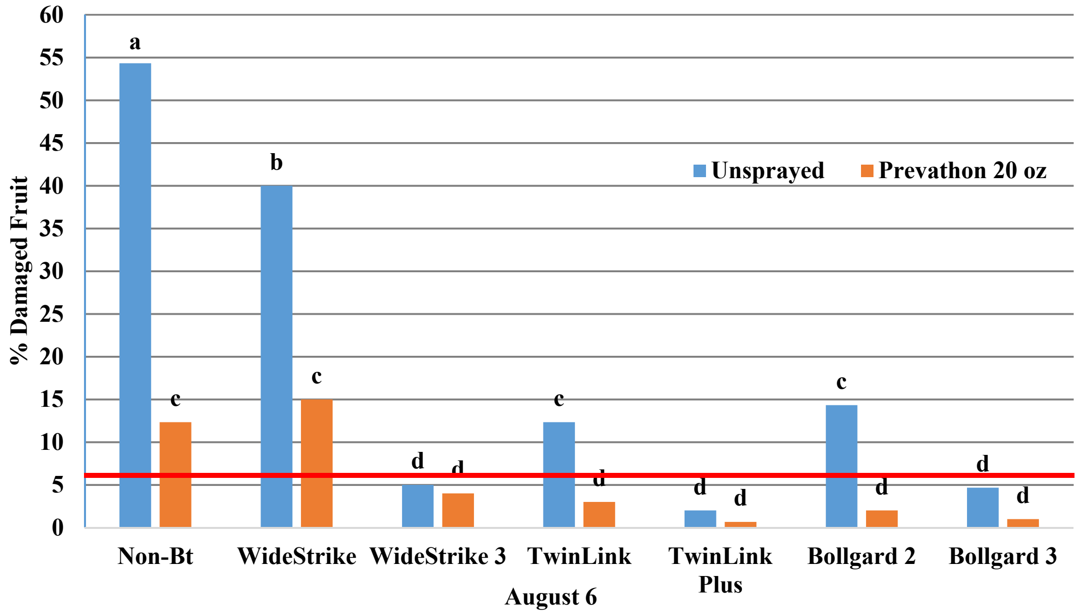

Fig. 2. Percent of cotton bollworm damaged fruit 13 days after application of Prevathon at 20 oz/ac (red line denotes 6% threshold); Drew County, Arkansas, 2018.

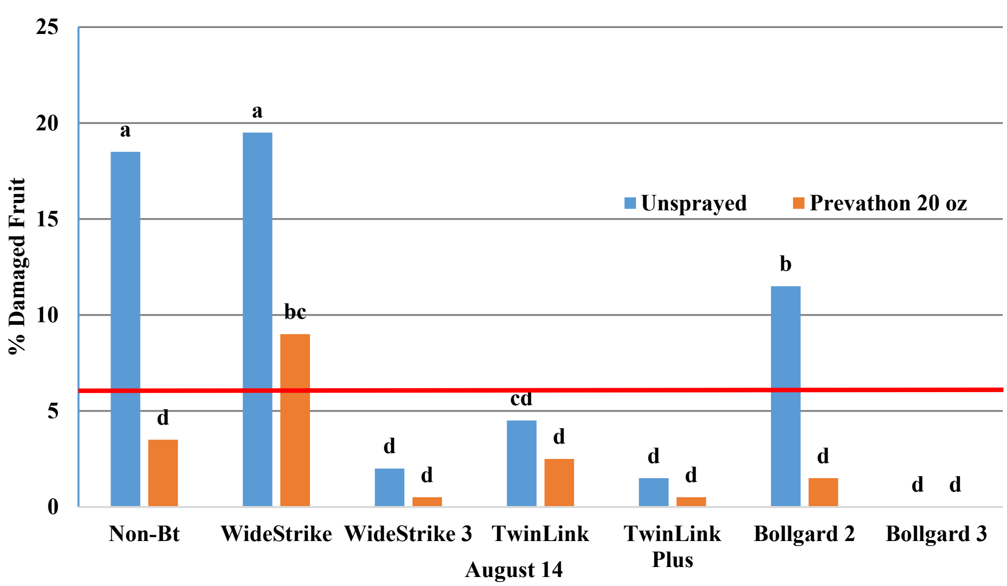

Fig. 3. Percent of cotton bollworm damaged fruit 21 days after application of Prevathon at 20 oz/ac (red line denotes 6% threshold); Drew County, Arkansas, 2018.

Efficacy of Selected Insecticides for Control of *Helicoverpa Zea* in Non-*Bacillus thuringiensis* Cotton

A. Plummer[1], G. Lorenz[1], B. Thrash[1], N. M. Taillon[1], K. McPherson[1], A.J. Cato[2], and N. Bateman[3]

Abstract

Two tests were conducted in 2018 on grower fields in Jefferson and Drew County, Arkansas to evaluate the efficacy and residual control of selected foliar insecticides and rates on cotton bollworm in non-*Bacillus thuringiensis (Bt)* cotton. Selected insecticides included Prevathon, Besiege, Intrepid Edge, Brigade + Prevathon, Brigade + Acephate and an untreated check. Results indicate that higher labeled rates of Prevathon provided an increase in residual control when compared to the lower labeled rate (14 oz/ac).

Introduction

In recent years, the cotton bollworm, *Helicoverpa zea* (Boddie), has been the most damaging insect pest of cotton in Arkansas and has only recently been surpassed by the tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois). In 2017, 100% of Arkansas cotton acres were infested with cotton bollworm, and 75% of these acres required supplemental insecticide treatments (Cook, 2018). Although *Bacillus thuringiensis (Bt)* cotton is still very effective for control of tobacco budworm, *Heliothis virescens* (F.), the amount of *Bt* cotton acreage requiring treatment for cotton bollworm has been increasing in recent years. This has led to development of a new treatment threshold for the mid-South of 6% damaged fruit, with bollworms present; or eggs present on 25% of plants (Studebaker et al., 2018). High costs associated with technology fees for cotton bollworm control has encouraged growers and consultants to look for ways to reduce costs. Planting conventional (non-*Bt*) cotton and using foliar insecticides for cotton bollworm control may be a more cost effective way to grow cotton in the mid-South.

Procedures

Tests were conducted in 2018 on grower fields in Jefferson and Drew County, Arkansas, on a non-*Bt* cultivar (DP 1822XF). Plot size was 12.5 ft (4 rows) by 40 ft. Treatments were arranged in a randomized complete block design with 4 replications. Treatments included: untreated check (UTC), Prevathon (*chlorantraniliprole*) 14 and 20 oz/ac, Prevathon 20 oz/ac + Brigade 6.4 oz/ac, Prevathon 14 oz/ac + Brigade 4.5 oz/ac, Besiege (*chlorantraniliprole + lambda-cyhalothrin*) 7 and 10 oz/ac, Intrepid Edge (*methoxyfenozide + spinetoram*) 8 oz/ac, and additionally at Jefferson County: Brigade 6.4 oz/ac + Acephate 97UP (*acephate*) 0.075 lb/ac. Insecticides were applied with a Mud Master fitted with 80-02 dual flat fan nozzles with 19.5–inch spacing. Spray volume was 10 gal/ac, at 40 psi. Damage ratings at Jefferson County were taken 5, 8, 13, and 19 days after application and Drew County were taken 5, 11, 18, and 26 days after application by sampling 25 squares, flowers, and bolls per plot. Plots were harvested using a Case two row plot picker. Data were processed using Agriculture Research Manager Version 2018.5 (Gylling Data Management, Inc., Brookings, S.D.). Analysis of variance was conducted and Duncan's New Multiple Range Test ($P = 0.10$) to separate means.

Results and Discussion

Jefferson County

All treatments reduced bollworm damage compared to the UTC at 5 days after application (DAA) (Fig. 1). This trend continued through all observation dates. Prevathon 20 oz/ac, Brigade 6.4 oz with Prevathon 20 oz, and Brigade 4.5 oz with Prevathon 14 oz had less damage than the Intrepid Edge 8 oz. Prevathon 20 oz was the only treatment with fruit damage levels at the 6% damage threshold, all other treatments were above threshold. At 8 DAA, Brigade 6.4 oz with Prevathon 20 oz, Brigade 4.5 oz with Prevathon 14 oz, and Besiege 7 and 10 oz had less damage than Prevathon 14 oz and Intrepid Edge 8 oz (Fig. 2). Then at 13 DAA, all

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[2] Graduate Research Assistant, Department of Entomology, University of Arkansas System Division of Agriculture, Fayetteville.
[3] Assistant Professor/Crop Entomologist, Department of Entomology, University of Arkansas Rice Research and Extension Center, Stuttgart.

treatments, except for Prevathon 14 oz had less damage than Intrepid Edge 8 oz. Intrepid Edge, Prevathon 14 oz/ac, and Brigade 6.4 oz with Acephate 0.075 lb had fruit damage at or above threshold (Fig. 3). Lastly at 19 DAA, all treatments except Intrepid Edge 8 oz had less damage than Brigade 6.4 oz with Acephate 0.075 lb and were below threshold (Fig. 4).

Drew County

All treatments had less damage than the untreated check at 5, 11, and 18 DAA sample dates (Fig. 5–7). At 26 DAA, only Besiege 10 oz/ac, Brigade 6.4 oz/ac with Prevathon 20 oz/ac, and Prevathon 20 oz/ac had lower damage than the UTC (Fig. 8). At 5 DAA, Prevathon 20 oz/ac, Brigade 6.4 oz/ac with Prevathon 20 oz/ac and Besiege 10 oz/ac had less fruit damage than Intrepid Edge 8 oz/ac and were below threshold; Besiege 10 oz/ac had less damage than Besiege 7 oz/ac, Brigade 4.5 oz/ac with Prevathon 14 oz/ac, Prevathon 14 oz/ac (Fig. 5). Then at 11 DAA, Brigade 4.5 oz/ac with Prevathon 14 oz/ac, Prevathon 14 and 20 oz/ac, and Besiege 7 oz/ac were at or below threshold. (Fig. 6). Prevathon 14 and 20 oz/ac and Besiege 7 oz/ac had less damage than Intrepid Edge 8 oz/ac. No differences were observed between all treatments at 18 DAA (Fig. 7). Lastly, 26 DAA, Besiege 10 oz/ac, Brigade 6.4 with Prevathon 20 oz/ac and Prevathon 20 oz/ac had less fruit damage than the UTC (Fig 8). Foliar insecticide applications increased yield by 230–520 lb seed cotton/acre above the UTC (Fig. 9).

Practical Applications

In this experiment Intrepid Edge and Brigade with Acephate did not provided adequate control of bollworms at any sample date. The addition of Brigade to Prevathon 14 and 20 oz/ac did not provide any additional control. Prevathon 20 oz/ac and Prevathon 20 oz/ac with Brigade 6.4 oz/ac were the only treatments that had residual control past 26 days.

Acknowledgements

We would like to thank Chuck Hooker and A.J. Hood for allowing us to conduct research on their land and DuPont, Syngenta, and Dow for funding this research. Support also provided by the University of Arkansas System Division of Agriculture.

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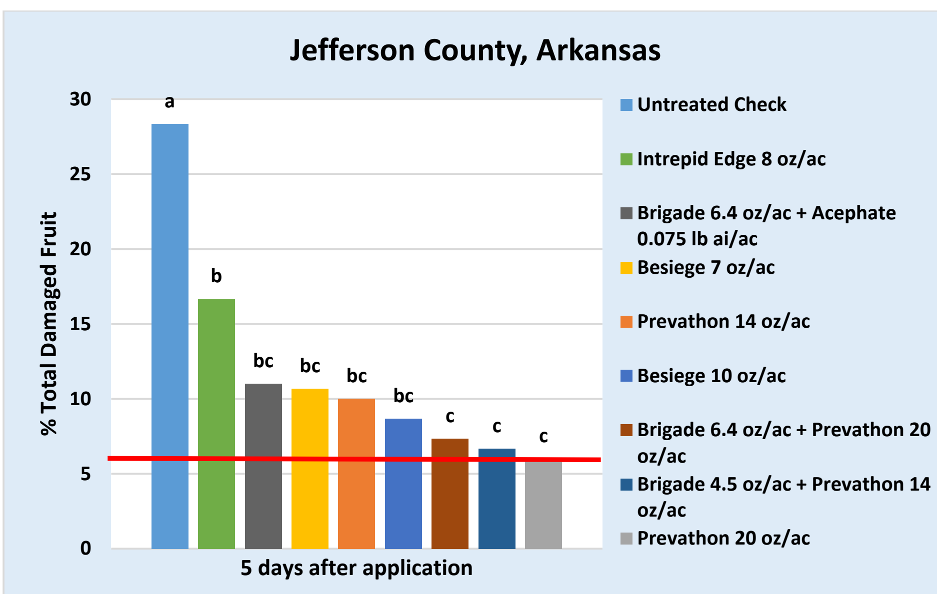

Fig 1. Assessment of bollworm damaged fruit 5 days after application of foliar insecticide on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in 2018.

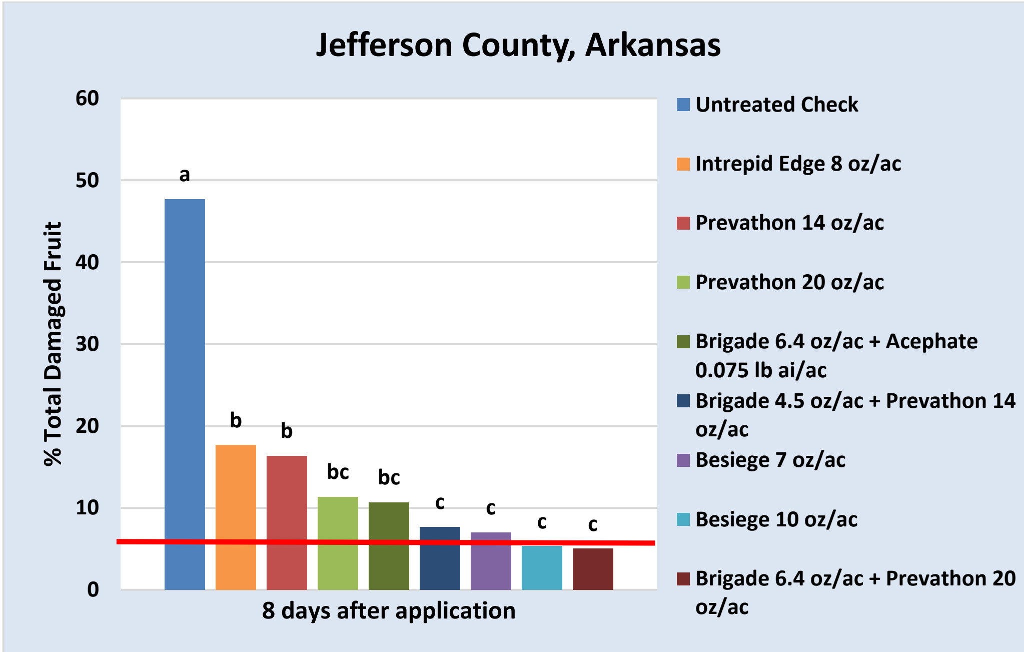

Fig. 2. Percent bollworm damaged fruit 13 days after application of Prevathon at 20 oz/ac (red line denotes 6% threshold); Drew County, Arkansas, 2018.

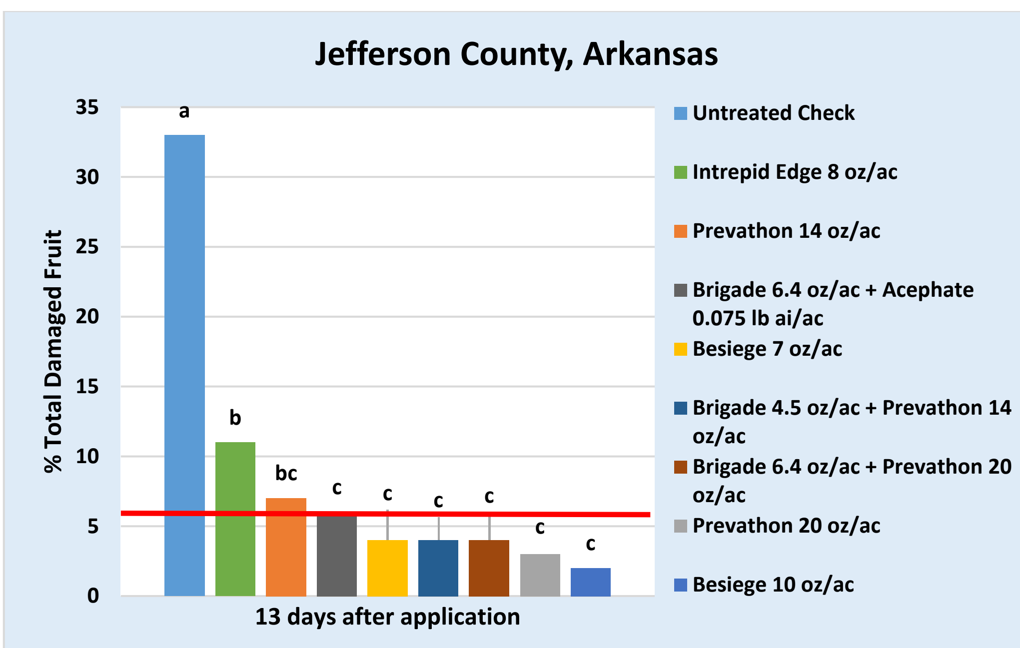

Fig 3. Assessment of bollworm damaged fruit 13 days after application of foliar insecticide on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in 2018.

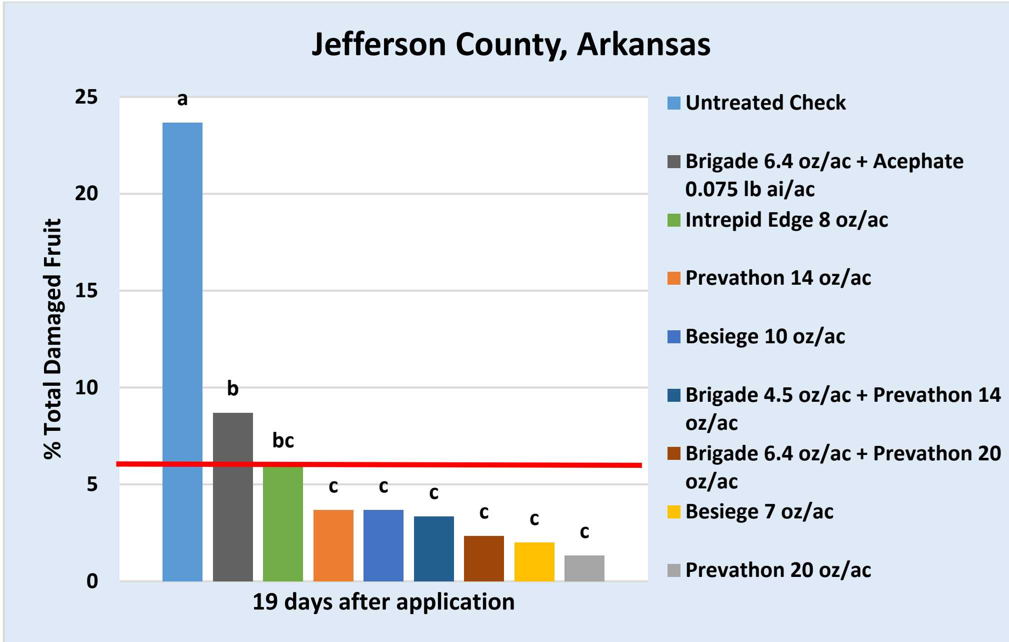

Fig 4. Assessment of bollworm damaged fruit 19 days after application of foliar insecticide on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in 2018.

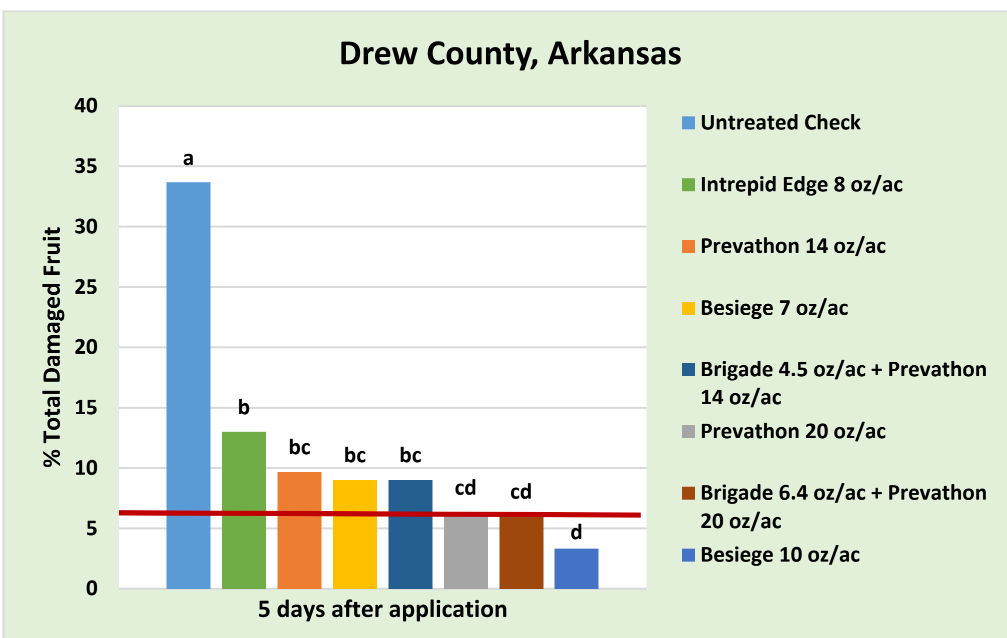

Fig. 5. Assessment of bollworm damaged fruit 5 days after application of foliar insecticide on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in 2018.

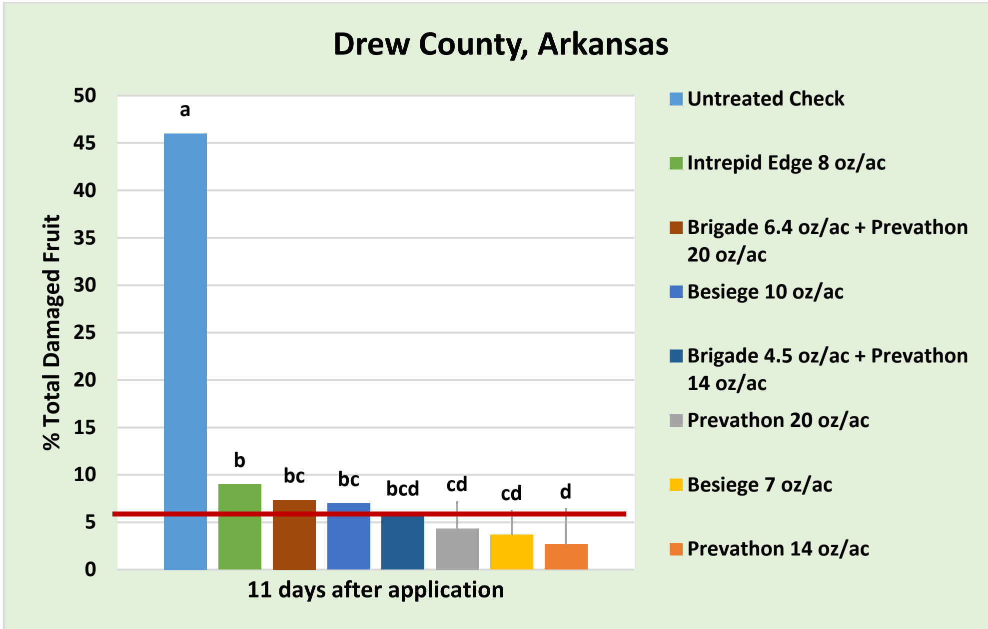

Fig. 6. Assessment of bollworm damaged fruit 11 days after application of foliar insecticide on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in 2018.

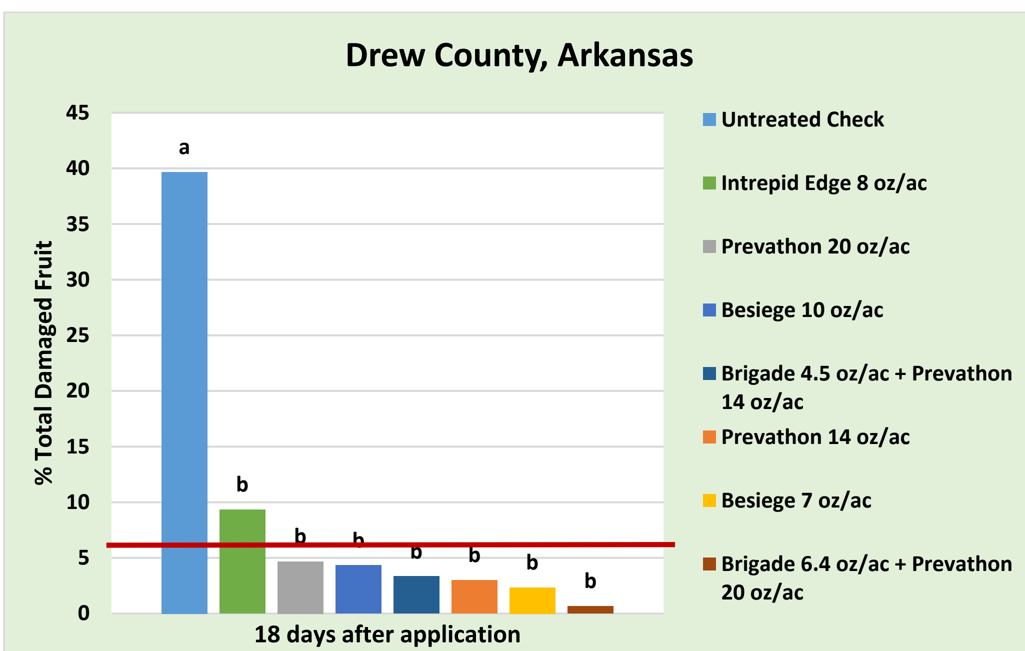

Fig. 7 Assessment of bollworm damaged fruit 18 days after application of foliar insecticide on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in 2018.

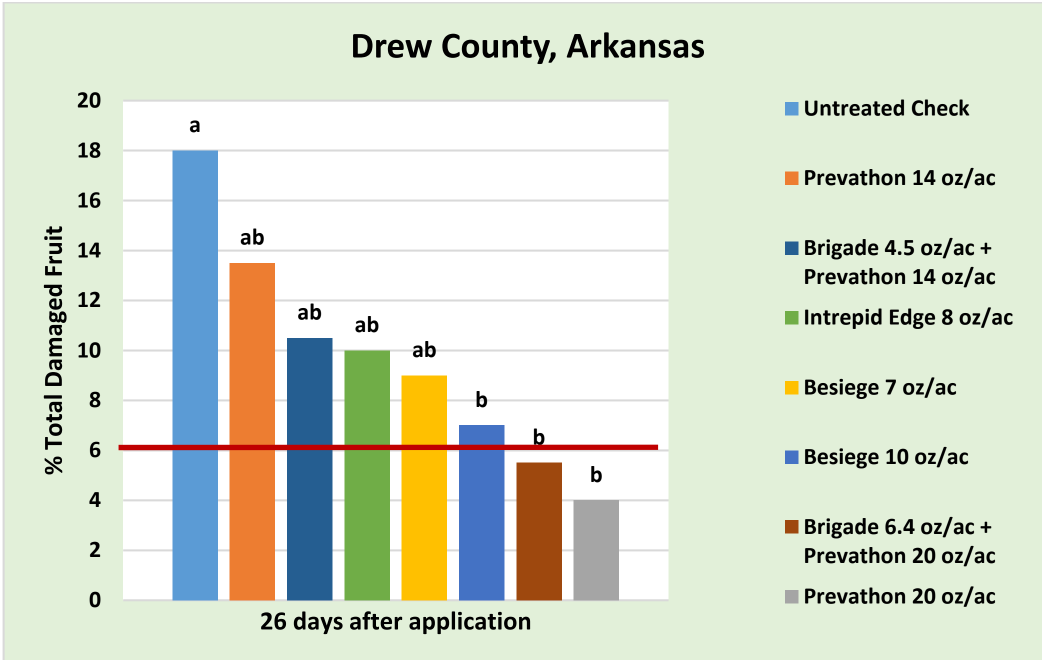

Fig. 8. Assessment of bollworm damaged fruit 26 days after application of foliar insecticide on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in 2018.

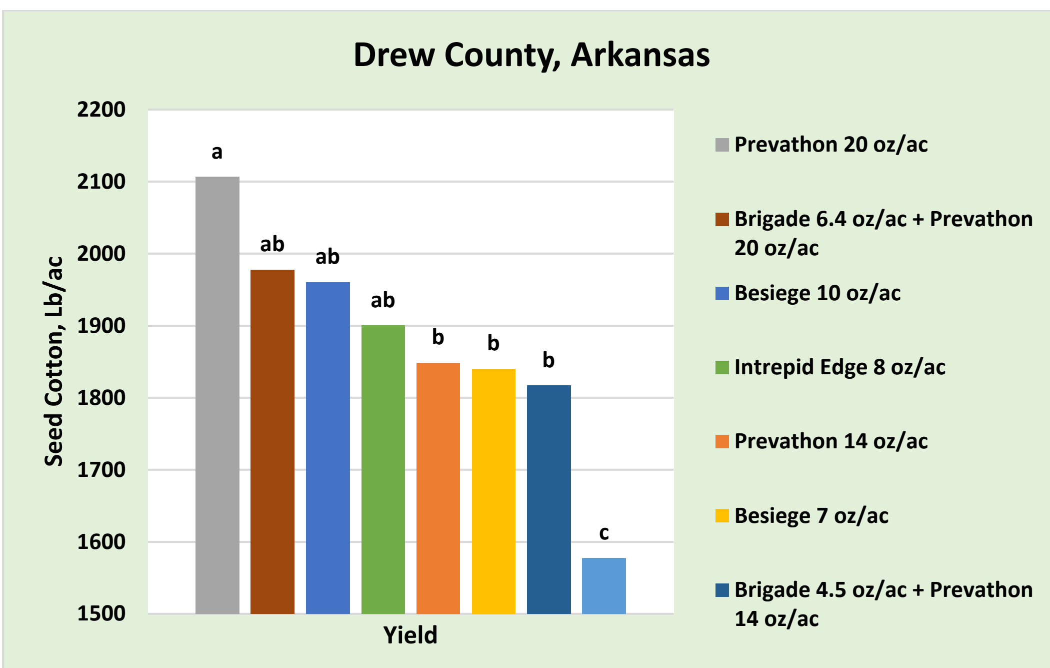

Fig. 9. Seed cotton yield of different insecticide treatments on a non-*Bacillus thuringiensis (Bt)* cotton cultivar in Drew County, Arkansas in 2018.

Monitoring Bollworm Populations in Arkansas Using ArcMap

C. Spinks[1] and G. Studebaker[1]

Abstract

Using federally funded grants, extension row crop entomology specialists and county agents throughout the state of Arkansas work together each growing season to monitor the cotton bollworm, *Heliocoverpa zea* (Bodie), using pheromone traps as part of the Arkansas Integrated Pest Management (IPM) Program. Each week of the growing season, county agents check traps placed across the respective counties to represent areas with potential for infestation. Historically, these data have been collected and put into chart form, which is posted on the University of Arkansas System Division of Agriculture's Cooperative Extension website. Though effective at communicating bollworm numbers, this method is not easy to navigate or quickly understand given frequent need to view multiple counties. To provide a better visual, statewide representation of bollworm populations and movement from week to week, we have begun to utilize the spatial program ArcMap. Using ArcMap, we are able to provide growers with a more accurate and better representation of the movement and population dynamics of the cotton bollworm. Weekly updated ArcMaps showing populations statewide give growers an idea of when to anticipate a flight of bollworms in their fields with one click. These ArcMaps will potentially prevent economic injury level infestations and save growers on unnecessary insecticide application costs while also remaining quick and convenient.

Introduction

Each year, the cotton bollworm (*Helicoverpa zea*, Bodie), infests 100% of all cotton planted in Arkansas (Taillon et al., 2018). Estimated economic loss in 2015 from bollworm has added up to more than $1.7 million (Williams, 2016). Through the federally funded Arkansas Integrated Pest Management (IPM) program, bollworm populations are monitored on a county level. County agents check bollworm pheromone traps on a weekly basis in their respective counties and submit the data to the IPM coordinator. Historically, these data have been put into graph form and posted online for growers to utilize when making pest management decisions. Though the current visual representation of these bollworm population data have been effective, the use of ArcMap has given us a better, easier means to communicate with our growers the population dynamics on a statewide level with a single image. ArcMap is the main component of the geospatial processing program ArcGIS and is used to analyze geospatial data. With ArcMap, we are able to generate maps with a data frame composed of geospatial data, which is composed of trap coordinates and corresponding trap moth catch numbers.

Procedures

At the start of the 2018 growing season, county agents participating in the Arkansas Integrated Pest Management Program placed Hartstack bollworm traps (Hartstack et al., 1979) around the cotton and soybean growing areas of their respective counties. Ideally, these traps were to be placed throughout the entire county to achieve statistical significance with ArcMap. Each week, within a 5-day period, county agents were to check the bollworm traps and report the number of bollworm moths in each trap. The traps were emptied of moths every week and the pheromone changed every other week throughout the growing season.

Data from each county were reported with a trap location name, county, GPS coordinates for each trap, and the number of bollworm moths found in each trap. These data were logged into Open Office 4.1.5 by week and uploaded as .dbf files in ArcMap 10.4.1. These data were then used to generate state maps highlighting each county for each week. These maps are generated using the GPS coordinates provided by county agents, which are then linked to GPS coordinates readily available by the program, resulting in a base layer that is used for the final map. The moth catch data are then linked with the GPS coordinates and results in a top layer map that highlights reported areas and their corresponding trap catch numbers. The end result is a multilayered map that is color coded based on the number of moths reported for a given area. Each map created also has a corresponding map legend. These maps are often referred to as "heat maps," as they give visual representation to areas of moth infestation often referred to as "hot spots."

[1] Program Associate and Extension Entomologist, respectively, Northeast Research and Extension Center, Keiser.

Results and Discussion

Weekly maps for the latter part of June and early July show that bollworm populations remained relatively heavy in the central part of the state weeks 15 June through 6 July (Figs. 1–4). Bollworm populations drastically increased weeks 6 July through 15 July (Figs. 4 and 5). This can be attributed to bollworm populations cycling into the adult moth phase. Conversely, bollworm populations drastically decrease the following weeks (Figs. 6 and 7) as those populations are nearing the end of their life cycles. Although the populations were lower in the northern part of the state for most of June and July, areas with an increase in moth numbers were noted in several areas for the weeks of 22 June through 27 July (Figs. 2–7). Generally, the maps align with what is usually noted with bollworm populations and their life cycles. Areas of intensity begin the season with lower adult moth trap catches, and as the population moves into the adult stage of their life cycle, increased reported moth numbers are seen. The maps generated in ArcMap give a visual representation of bollworm populations on a multi-county scale. They are generated based on averages of moth trap catches from the different locations in the county and give us a better idea of what to expect in the following weeks with regard to population movement and numbers. Moving forward, several adjustments must be made to fully represent each county and to ensure the best possible map is generated with the data obtained.

Practical Applications

Though only presented currently at county production meetings, the heat maps generated with ArcMap have given Arkansas growers a better, statewide visual representation of bollworm population dynamics as opposed to the previous graphs, which are only presented on the county level. These maps have potential to help growers better understand bollworm populations, predict flights into their areas, and plan bollworm management strategies. In the future, focus will be on optimal trap placement, as well as trap catch reporting to produce the best visual representation of bollworm data to growers.

Acknowledgements

The authors would like to thank the county agents with University of Arkansas System Division of Agriculture Research and Extension for collecting all the data used in this project, as well as the National Institute of Food and Agriculture for funding to conduct this research.

This work is supported by the Crop Protection and Pest Management Program [grant no. 2017-70006-27279/project accession no. 1013890] from the USDA National Institute of Food and Agriculture.

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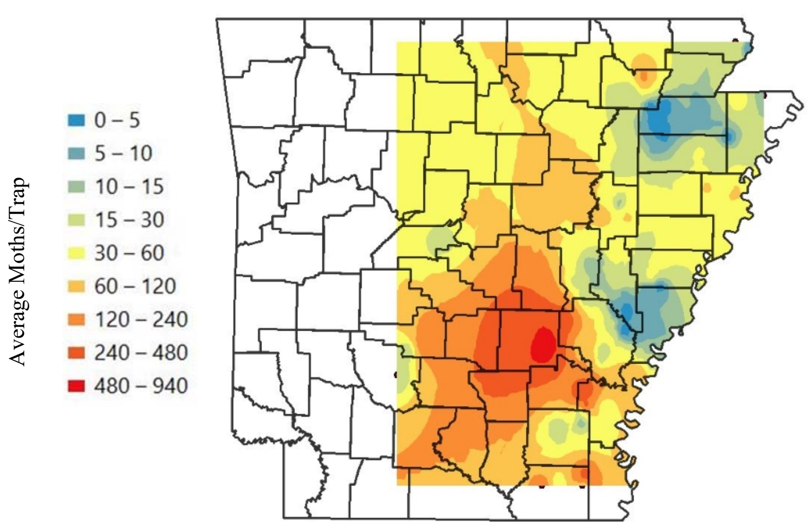

Fig 1. Bollworm populations in Arkansas as established by trap counts and ArcMap for the week of 15 June 2018.

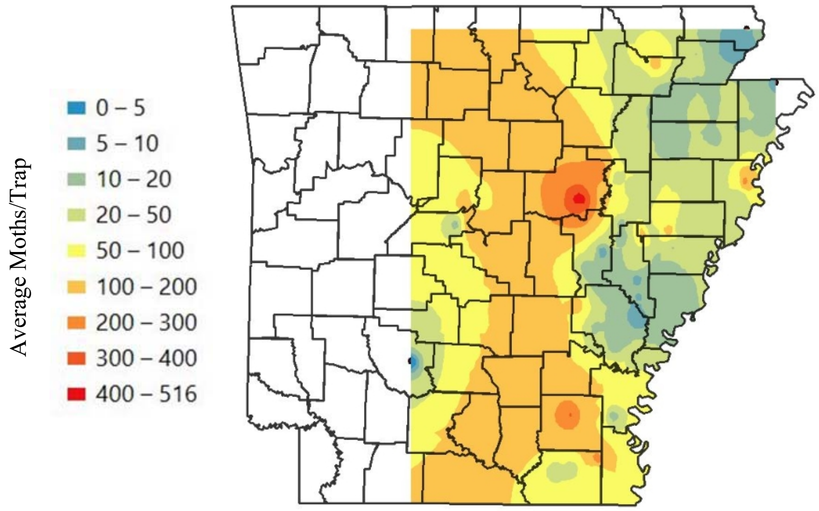

Fig. 2. Bollworm populations in Arkansas as established by trap counts and ArcMap for the week of 22 June 2018.

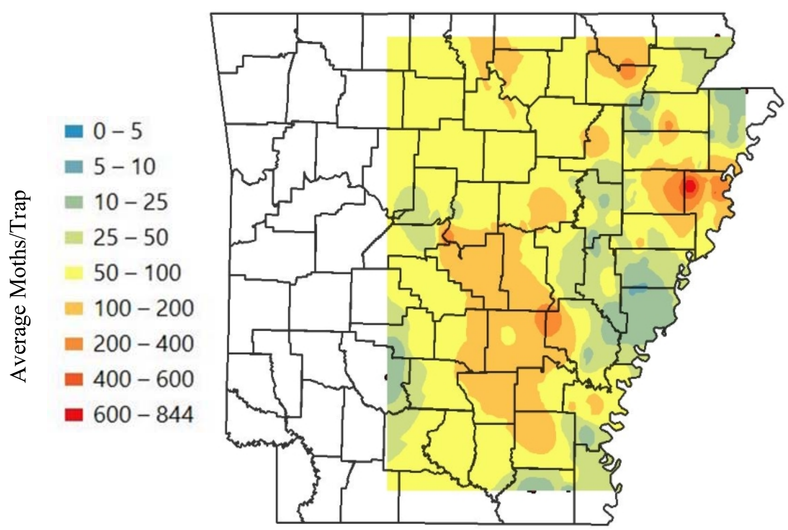

Fig. 3. Bollworm populations in Arkansas as established by trap counts and ArcMap for the week of 29 June 2018.

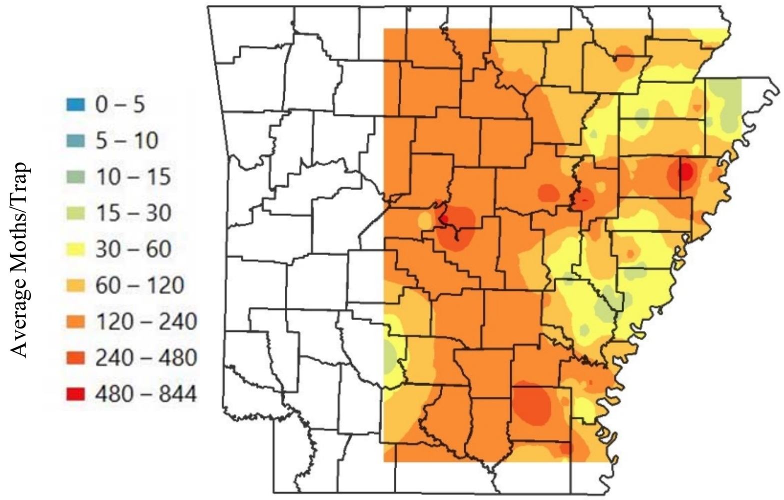

Fig. 4. Bollworm populations in Arkansas as established by trap counts and ArcMap for the week of 6 July 2018.

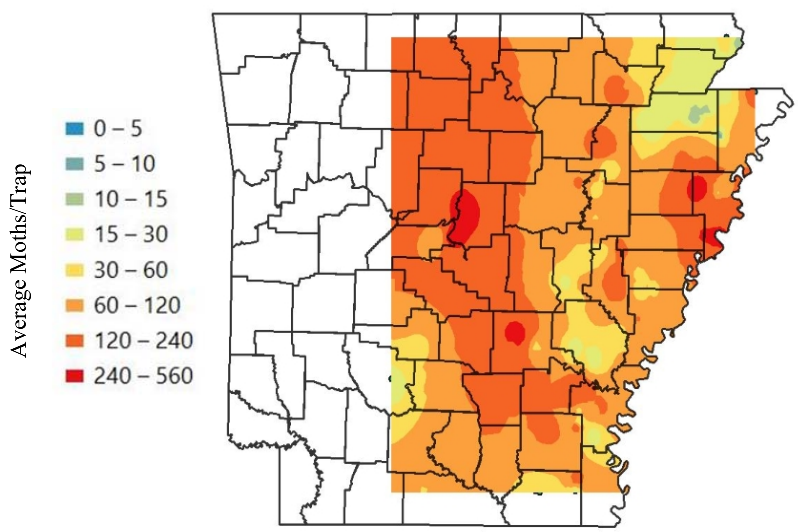

Fig. 5. Bollworm populations in Arkansas as established by trap counts and ArcMap for the week of 13 July 2018.

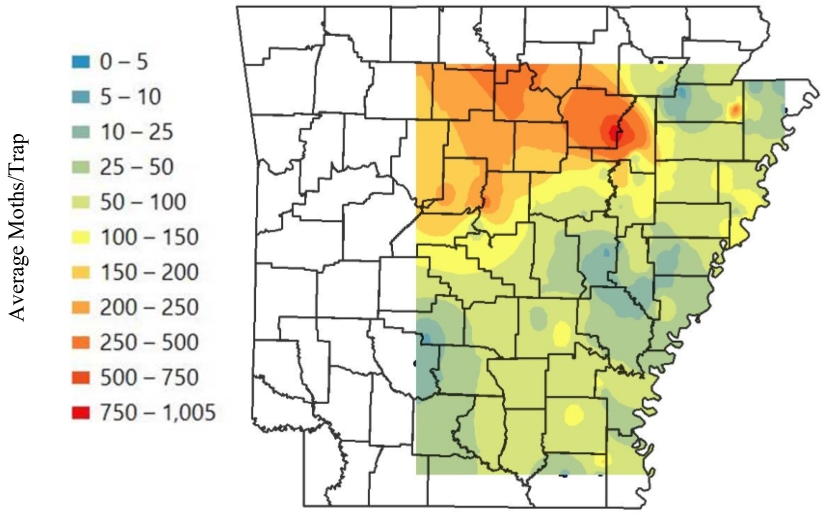

Fig. 6. Bollworm populations in Arkansas as established by trap counts and ArcMap for the week of 20 July 2018.

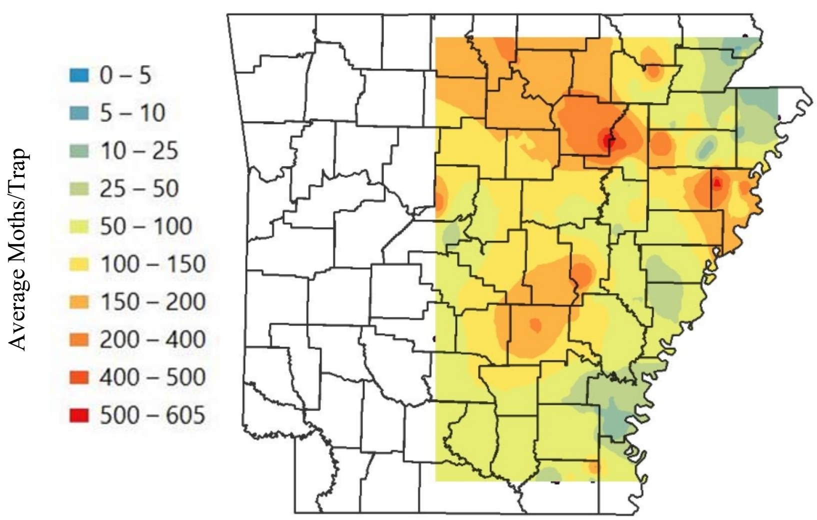

Fig. 7. Bollworm populations in Arkansas as established by trap counts and ArcMap for the week of 27 July 2018.

Integrated Management of Target Leaf Spot in Cotton

B. Robertson[1], J. Davis[2], R. Benson[2], and A. Free[3]

Abstract

In Arkansas, target leaf spot (TLS) on cotton was observed statewide in 2016. Significant defoliation and boll drop were observed in northeast Arkansas. The objective of this study is to evaluate the efficacy and efficiency of applications of the fungicide, (fluxapyroxad + pyraclostrobin), on the disease damage, growth and yield of cotton infested with TLS caused by *Corynespora cassiicola* in various plant structures. An on-farm study site was selected based on historical occurrence of TLS. Georeferenced data including yield, plant height, canopy coverage, occurrence of TLS, and defoliation as a result of TLS were collected and overlaid with other imagery and data collected during the season. Fungicide applications were made with the producer's sprayer equipped using different nozzles to investigate the impact of droplet size and effective coverage on disease control using two different application techniques. Differences in plant height and canopy coverage was observed and recorded with GPS coordinates. Plant height ranged from 18 inches to 42 inches and plant canopy coverage ranged from 50% to 95% late-September. The occurrence of TLS in Arkansas and this study was very light in 2018. Very little difference was observed across sprayer treatments for TLS. Differences in effective coverage were observed. However, it is very difficult to penetrate a dense canopy. While the risk of TLS impacting yield is 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, the expected yield differences these consultants expected between treated and untreated strips were not observed. The severity of TLS appeared to be influenced by rankness of plants. Where cotton canopies did not lap, 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 objective of this study is to evaluate the efficacy and efficiency of applications of the fungicide, (fluxapyroxad + pyraclostrobin), on the disease damage, growth and yield of cotton infested with TLS caused by *Corynespora cassiicola* in various plant structures.

Procedures

An on-farm study site near Manila in a pivot-irrigated cotton, DP 1518 B2XF, field with a Routon-Dundee-Crevasse Complex soil type was selected based on the previous occurrence of TLS resulting in greater than 60% leaf defoliation of cotton. 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 yield, plant height, canopy coverage, occurrence of TLS, and defoliation as a result of TLS were collected and overlaid with other imagery and data collected during the season. Fungicide applications were made with the producer's sprayer equipped with different nozzles to in order to investigate the impact of droplet size and effective coverage on disease control using two different application techniques. One technique, best management practices (BMP), was to apply fungicide treatments in 15 gal/ac spray solution at a speed of 10 mph with a 24-inch boom height. The other technique involved speeding the sprayer to deliver 10 gal/ac while using a boom height of 4 to 6 foot above the canopy (neighbor). Each sprayer treatment also included nozzles to deliver a medium (M), very coarse (VC), and ultra-course (UC) droplet. Spray papers were used to evaluate effective coverage. Mature cotton was machine harvested.

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[1] Professor/Cotton Extension Agronomist, University of Arkansas Cooperative Extension Service, Newport.
[2] Application Technologist and County Extension Agent, respectively, University of Arkansas Cooperative Extension Service, Batesville.
[3] Cotton Research Verification Sustainability Program Coordinator/Professor, University of Arkansas Cooperative Extension Service, Newport.

Results and Discussion

Differences in plant height and canopy coverage were observed and recorded with GPS coordinates. Plant height ranged from 18 inches to 42 inches and plant canopy coverage ranged from 50% to 95% late-September. Fungicide treatments were made to and observed across the range of plant canopy types. The occurrence of TLS in Arkansas and this study was very light in 2018. The incidence of TLS did not exceed 5% of the total leaf area of the plant and defoliation did not exceed 15% of total leaves. Very little differences were observed across sprayer treatments for TLS. Differences in effective coverage were observed. Effective coverage for the 15 gal/ac treatment was double that of the 10 gal/ac treatment (Fig. 1). As shown by these data, it is very difficult to penetrate a dense canopy. The smallest droplets, traveling at slowest speed had the greatest penetration.

Lint yield did not differ statistically for fungicide treatment compared to the untreated control (data not shown). Yields ranged from a low of 744 lb lint/ac to a high of 1994 lb lint/ac across the range of all plant canopy types from the areas of least yield potential to areas in the field with high yield potential.

Practical Applications

While the risk of TLS impacting yield is 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. Since fungicide treatments are costly, any decrease in efficacy of the product as a result of poor application techniques must be avoided.

Acknowledgements

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

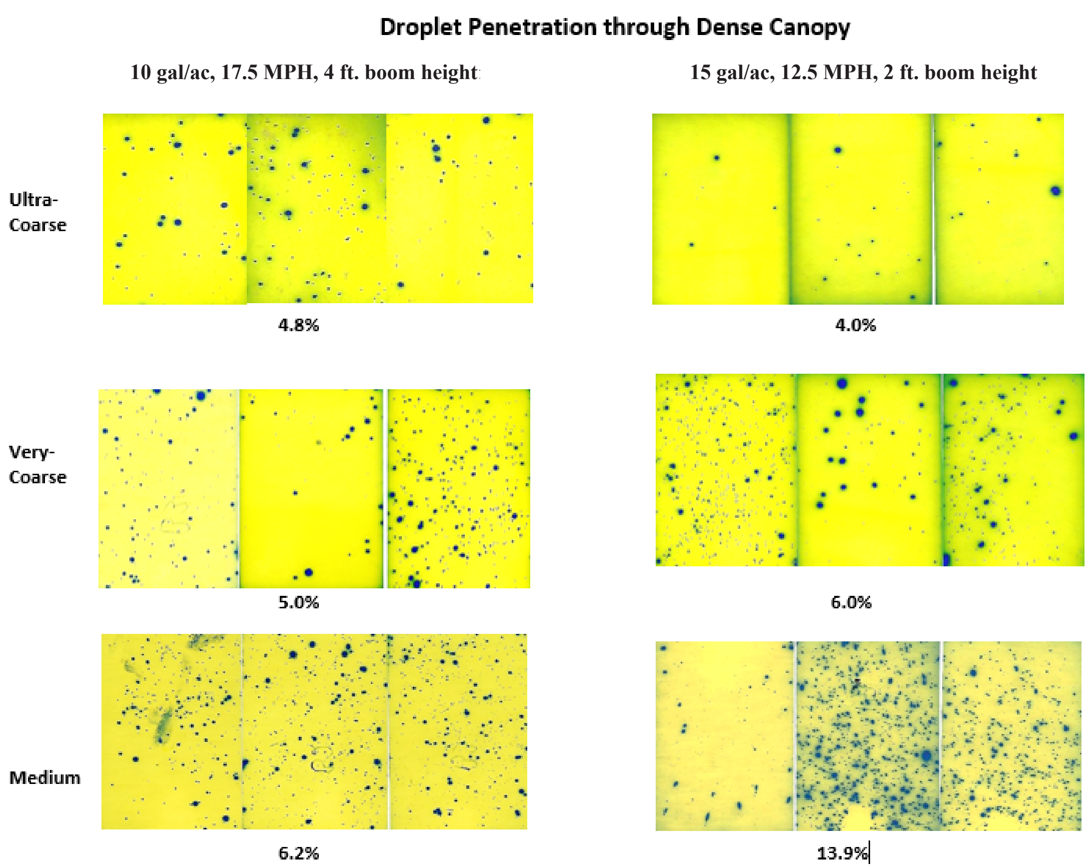

Fig. 1. Droplet penetration through dense cotton density using different nozzle types and ground speed at Manila in 2018.

Efficacy of Pre-emergence Cotton Herbicides on Protoporphyrinogen Oxidase Resistant Palmer Amaranth

W. Coffman[1], T. Barber[2], J.K. Norsworthy[1], G.L. Priess[1], and Z.D. Lancaster[1]

Abstract

Palmer amaranth (*Amaranthus palmeri*) resistant to protoporphyrinogen oxidase (PPO)-inhibiting herbicides is now a common problem growers face in northeast Arkansas. Prior research was mainly focused on controlling PPO-resistant Palmer amaranth in soybean, with little focus on the efficacy of cotton herbicides. In order to assess the efficacy of common pre-emergence (PRE) herbicides used in cotton, non-crop field experiments were conducted on-farm at Marion, Arkansas and near Crawfordsville, Arkansas in 2018. Dry conditions at Marion limited new Palmer amaranth emergence after application, therefore control was higher for this location. A single factor of herbicide treatment was examined. Reflex controlled PPO-resistant Palmer amaranth 36% at Crawfordsville and 60% at Marion 4 weeks after application (WAA). Preliminary results indicate that Brake + Cotoran was the best option for control of PPO-resistant Palmer amaranth, providing control levels 4 WAA of 76% at Crawfordsville and 85% at Marion.

Introduction

Palmer amaranth is the most competitive weed in Arkansas cotton. A broader range of herbicides are available for use in cotton than in soybean, however, herbicide-resistant Palmer amaranth still limits effective pre-emergence (PRE) herbicide options for cotton growers. The recent confirmation of Palmer amaranth with metabolic resistance to Reflex and Dual Magnum is concerning because resistance to other herbicide modes of action could be building in these populations (Varanasi et al., 2018; Brabham et al., 2019).

Procedures

A non-crop field experiment was conducted at two on-farm locations in 2018, in Marion, Arkansas and near Crawfordsville, Arkansas. Pre-emergence cotton herbicide treatment was the factor examined, with a total of 16 herbicide treatments being evaluated, as well as an untreated check (Table 1). Herbicides were applied to freshly tilled, non-crop plots at both locations. Conditions were extremely dry at Marion prior to application and following a single rainfall event, which activated the herbicide treatments. Crawfordsville, however, had rainfall prior to application and received sporadic rainfall throughout the duration of the experiment, following activation of the herbicide treatments. Visible weed control ratings were assessed 4 weeks after application (WAA) at both locations on a scale of 0% to 100%, with 0% being no control of Palmer amaranth and 100% being complete control. Data were analyzed using the GLIMMIX procedure in SAS 9.4 at $\alpha = 0.05$. Data were analyzed separately between locations due to an interaction between experimental location and treatment. Orthogonal contrasts were also conducted ($\alpha = 0.05$) to assess trends observed in the data.

Results and Discussion

The protoporphyrinogen oxidase (PPO)-inhibiting herbicide Reflex provided 36% control at Crawfordsville and 60% at Marion (Fig. 1). The treatment of Brake + Xtendimax controlled Palmer amaranth 95% under dry conditions at Marion, which was the highest level of control observed for this location. Brake + Cotoran provided the highest level of control at Crawfordsville (76%); however, it was not different from the treatments of Cotoran + Caparol or Cotoran + Warrant (both 68%). Results of contrast analyses for these locations indicate that herbicide mixtures control PPO-resistant Palmer amaranth at higher levels than the use of a single herbicide. At Crawfordsville, Palmer amaranth was controlled 44%, averaged over all single herbicide treatments (excluding Reflex), compared to 55%, averaged over all herbicide mixtures ($P < 0.0001$). The Marion location showed the same trend, where control averaged over all single herbicide treatments (excluding Reflex) was 75%, compared to a mean of 82% control with herbicide mixtures ($P = 0.0002$).

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Further contrast analyses were conducted to determine if higher levels of control were obtained with mixtures including the herbicide Cotoran compared to those mixtures which did not contain Cotoran (Table 2). At Crawfordsville, mean control of mixtures containing Cotoran was 70%, whereas mixtures without Cotoran provided a mean of 48% control ($P < 0.0001$). Mean control of mixtures containing Cotoran at Marion was 85%, whereas mixtures without Cotoran provided a mean control level of 80% ($P = 0.0542$).

Practical Applications

Preliminary results suggest that PPO-resistant Palmer amaranth can be controlled with common PRE herbicides in cotton. Herbicide mixtures should be used to control PPO-resistant Palmer amaranth pre-emergence. For best results, herbicide mixtures should contain Cotoran, in combination with another effective herbicide. It is important to use effective PRE herbicides in order to limit the amount of Palmer amaranth that must be controlled in subsequent post-emergence herbicide applications.

Acknowledgements

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Varanasi V.K., C. Brabham, J.K. Norsworthy, H. Nie, B.G. Young, M.M. Houston, T. Barber, and R.C. Scott. 2018. A statewide survey of PPO-inhibitor resistance and the prevalent target-site mechanisms in Palmer amaranth (*Amaranthus palmeri*) accessions from Arkansas. Weed Sci. 66:149-158.

Table 1. Pre-emergence herbicide products used in 2018 field experiments at Crawfordsville and Marion, Arkansas[a].

Herbicide Product	Common Name	Rate
		lb ai/ac
Untreated		
Reflex	fomesafen	0.25
Brake	fluridone	0.15
Caparol	prometryn	1
Cotoran	fluometuron	1
Direx	diuron	0.5
Warrant	acetochlor	1.125
Xtendimax 1/2X	dicamba	0.5
Xtendimax 1X	dicamba	1
Brake + Caparol	fluridone + prometryn	0.15 + 0.75
Brake + Cotoran	fluridone + fluometuron	0.15 + 0.75
Brake + Direx	fluridone + diuron	0.15 + 0.5
Brake + Warrant	fluridone + acetochlor	0.15 + 0.9375
Brake + Xtendimax	fluridone + dicamba	0.15 + 0.5
Cotoran + Caparol	fluometuron + pormetryn	0.5 + 0.5
Cotoran + Warrant	fluometuron + acetochlor	0.75 + 0.9375
Warrant + Xtendimax	acetochlor + dicamba	1.125 + 0.5

[a] Rates of Xtendimax listed in lb ae/ac.

Table 2. Significance of contrast statements between standalone herbicides and herbicide mixtures, and mixtures containing Cotoran and mixtures containing no Cotoran.

	Palmer amaranth control 4 WAA			
Contrast	**Crawfordsville**	**Means**	**Marion**	**Means**
Single herbicide vs herbicide mixture	< 0.0001*	44 vs 55	0.0002*	75 vs 82
Mixtures including Cotoran vs mixtures with no	< 0.0001*	70 vs 48	0.0542	85 vs 80

[a] Abbreviations: WAA, weeks after application; Crawfordsville, on-farm location near Crawfordsville, Arkansas; Marion, on-farm location in Marion, Arkansas.
[b] Significant *P* values (α = 0.05) are indicated by (*).
[c] Fomesafen was not included in contrast for single herbicide.

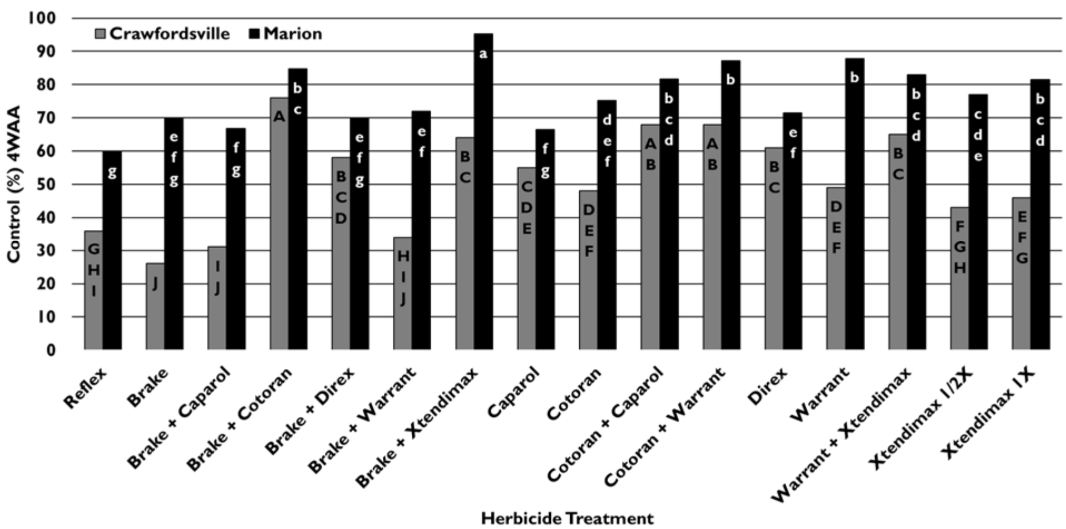

Fig. 1. Means of percent control of Palmer amaranth 4 weeks after application (4 WAA). Gray bars represent the Crawfordsville location and black bars represent the Marion location. Bars containing the same letters of the same case are not significantly different (α = 0.05).

A Systems Approach to Weed Management in Enlist™ Cotton

H.E. Wright[1], J.K. Norsworthy[1], J.T. Richburg[1], and L.T. Barber[2]

Abstract

Palmer amaranth, annual grasses, and morningglories are some of the most troublesome weeds in mid-South cotton production. With the introduction of Enlist ™ cotton, 2,4-D can be used to control some of these troublesome weeds. An experiment was conducted in 2018 using a program approach to evaluate weed control with Enlist One™ and Enlist Duo® as an early-post-emergence (EPOST) or mid-post-emergence (MPOST) application. This experiment was located at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas where 7 weed control programs and a nontreated control were evaluated. Visible crop injury and weed control ratings were taken 2 and 4 weeks after each application and analyzed for treatment differences. No significant injury was observed from any treatment at 2 or 4 weeks after MPOST. Treatments containing a residual herbicide in either POST application controlled Palmer amaranth ≥92% 2 weeks after the MPOST application. Treatments containing Enlist One or Enlist Duo provided ≥88% pitted morningglory control 2 weeks after MPOST. Results from this experiment indicate Enlist One and Enlist Duo show utility as part of a POST herbicide program and provide a much-needed option for controlling troublesome weeds in Enlist cotton production systems.

Introduction

Palmer amaranth, morningglories, and annual grasses have been noted as the most problematic weeds in mid-South cotton production (Riar et al., 2013). There are several herbicide options to control Palmer amaranth and morningglory species, including 2,4-D (Norsworthy et al., 2008; Siebert et al., 2004). The Enlist™ trait allows 2,4-D to be used in Enlist cotton and was released in 2016 (Anonymous, 2018). Previous formulations of 2,4-D have injured cotton through off-target movement. However, Enlist One™ and Enlist Duo® utilize the choline formulation of 2,4-D along with a drift retardant, allowing these formulations to be used safely around non-Enlist cotton (Sosnoskie et al., 2015). A study was conducted to compare weed control programs utilizing Enlist One and Enlist Duo for troublesome weeds in Enlist cotton.

Procedures

A field trial was initiated in 2018 at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas. This experiment was conducted as a randomized complete block design that contained 7 herbicide treatments and a nontreated control with 4 replications. Enlist cotton cultivar PHY 330 W3FE was planted at 48,000 seeds per acre on 10 May 2018, into 38-inch wide beds. Plots were 4 bedded rows wide and 25 feet long. Treatments included Cotoran® at planting, Roundup WeatherMAX®, Enlist Duo, EverpreX™, Liberty®, and Enlist One in various combinations early-post-emergence (EPOST) and mid-post-emergence (MPOST). A complete list of treatments can be found in Table 1. All herbicide applications were made with a CO_2-pressurized backpack sprayer at 15 gallons per acre. Visible weed control and crop injury ratings were taken 2 and 4 weeks after each after application. Data were analyzed using JMP Pro 13.2 and subjected to analysis of variance. Means were separated using Fisher's protected least significant difference ($\alpha = 0.05$). Additionally, orthogonal contrasts were conducted.

Results and Discussion

Treatments utilizing residual herbicides in POST applications provided >92% Palmer amaranth control 2 weeks after MPOST (Fig. 1). Barnyardgrass control decreased from 2 to 4 weeks after MPOST in treatments where Liberty was used in the first application, indicating the need for an effective barnyardgrass control and a residual herbicide in POST applications (Fig. 2). Orthogonal contrasts showed Palmer amaranth control 2 and 4 weeks after EPOST was improved by the addition of Liberty in the EPOST application (data not shown). Additionally, late season Palmer amaranth control was not different between Enlist One or Enlist Duo ap-

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plied MPOST. Treatments that included Enlist One or Enlist Duo also controlled pitted morningglory ≥88% 2 weeks after MPOST, and no observable injury occurred for any treatment at 2 or 4 weeks after MPOST (data not shown).

Practical Applications

Enlist One and Enlist Duo show utility in an early- or mid-post-emergence application and are viable options to control troublesome weeds in Enlist cotton. Enlist One and Enlist Duo may be used in a herbicide program as an effective site of action to reduce the risk of developing resistance (Norsworthy et al., 2012). Improved weed control and no crop injury indicate the Enlist system will be a successful tool for weed management in cotton. Future research should continue to evaluate weed control using the Enlist system in Enlist cotton.

Acknowledgements

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Table 1. List of herbicides, rates, and timings evaluated for weed control and crop injury.

Treatment	Herbicide	Rate (fl oz/ac)	Timing[a]
1	None	-	-
2	Cotoran	32	PRE
3	Cotoran	32	PRE
	Roundup WeatherMAX	28.4	EPOST
	Roundup WeatherMAX	28.4	MPOST
4	Cotoran	32	PRE
	Enlist Duo	75	EPOST
	Liberty + Enlist One + EverpreX	29 + 32 + 16.2	MPOST
5	Cotoran	32	PRE
	Enlist One + EverpreX + Liberty	32 + 16.2 + 29	EPOST
	Enlist Duo	75	MPOST
6	Cotoran	32	PRE
	EverpreX + Liberty	16.2 + 29	EPOST
	Liberty + Roundup WeatherMAX	29 + 28.4	MPOST
7	Cotoran	32	PRE
	Enlist One + EverpreX + Liberty	32 + 16.2 + 29	EPOST
	Enlist One + Liberty	32 + 29	MPOST
8	Cotoran	32	PRE
	EverpreX + Liberty	16.2 + 29	EPOST
	Enlist Duo	75	MPOST

[a] Abbreviations: PRE- pre-emergence; EPOST- early-post-emergence; MPOST- mid-post-emergence.

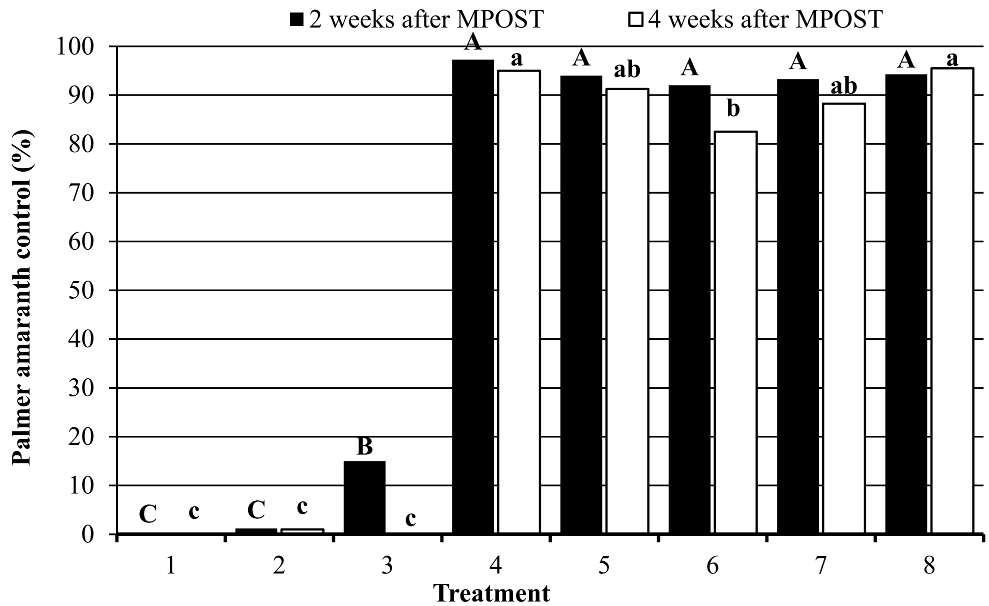

Fig. 1. Visible control ratings for Palmer amaranth (%) 2 and 4 weeks after mid-post-emergence (MPOST) application. Letters are used to separate means using Fisher's protected least significant difference. Means with the same letter are not statistically different. Uppercase letters denote letter separations for 2 weeks after MPOST and lowercase letters denote letter separation for 4 weeks after MPOST.

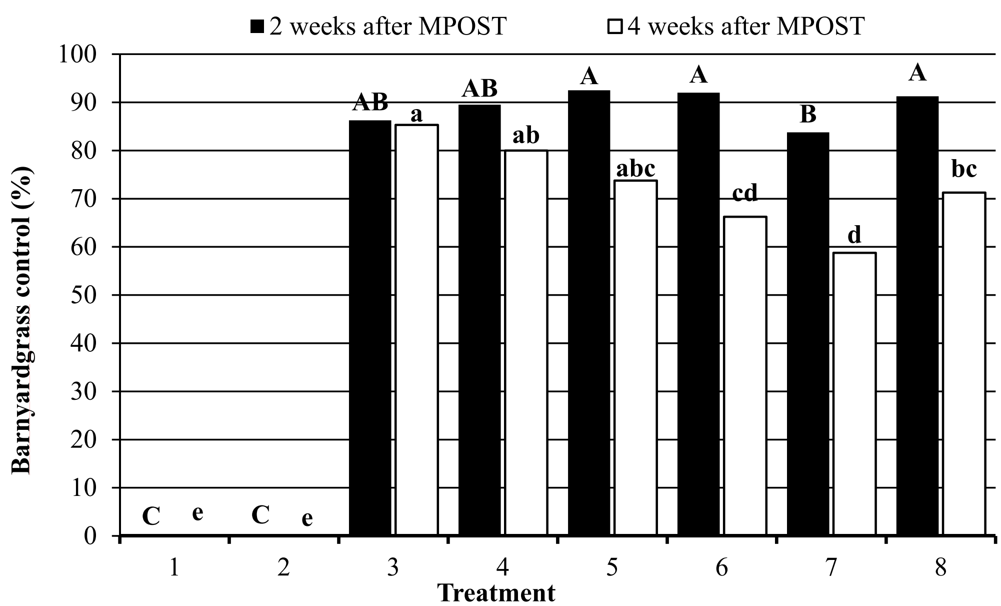

Fig. 2. Visible control ratings for barnyardgrass (%) 2 weeks after mid-post-emergence (MPOST) application. Letters are used to separate means using Fisher's protected least significant difference. Means with the same letter are not statistically different. Uppercase letters denote letter separations for 2 weeks after MPOST and lowercase letters denote letter separation for 4 weeks after MPOST.

Evaluation of Interline™ Mixtures in Enlist™ Cotton

J.A. Patterson[1], J.K. Norsworthy[1], Z.D. Lancaster[1], and L.T. Barber[2]

Abstract

A field experiment was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research station near Marianna, Arkansas in 2018. There were three objectives for this experiment. The first objective was to evaluate weed control differences between treatments containing a chloroacetamide herbicide and those without. The second objective was to compare weed control with Intermoc™ to Interline + Moccasin II PLUS and Interline + Dual Magnum. The last objective was to determine if the addition of Enlist One to Interline mixtures improves weed control. Orthogonal contrasts showed that chloroacetamide-containing treatments were similar in control to those without ($P = 0.2624$). Additionally, orthogonal contrasts showed that Intermoc-containing treatments were similar in control to Moccasin II PLUS or Dual Magnum-containing treatments ($P = 0.9840$). Lastly, orthogonal contrasts showed that the addition of Enlist One to herbicide programs improved Palmer amaranth control ($P = 0.0039$). At three weeks after the post-emergence application, Interline + Enlist One + Dual Magnum-containing treatments provided 95% Palmer amaranth control. No more than 3% crop injury was observed across all treatments. Results from this experiment indicate growers would benefit from the addition of Enlist One to Interline or Intermoc mixtures if Palmer amaranth is present.

Introduction

Palmer amaranth (*Amaranthus palmeri* S. Wats.) 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 made to alleviate Palmer amaranth from reaching reproductive maturity. As a result of technological advances in trait development, glufosinate-resistant crops, such as cotton, enable use of this broad-spectrum herbicide over-the-top of the crop. In recent years, glufosinate has become a popular foundational herbicide to control Palmer amaranth and other weeds in cotton. Additionally, with the development and release of Enlist™ cotton, growers are now able to utilize 2,4-D choline as a post-emergence weed control option, further broadening and strengthening the spectrum of the weed control programs (Manuchehri et al., 2017).

Procedures

An experiment was initiated in 2018 at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas. The experiment was implemented as a randomized complete block design with four replications. Enlist cotton cultivar PHY 330W3FE was planted into 38-inch wide beds at a rate of 44,000 seeds/acre. The post-emergence herbicides used in this experiment were Interline (glufosinate), Moccasin II PLUS (*S*-metolachlor), Warrant (acetochlor), Outlook (dimethenamid-P), Dual Magnum (*S*-metolachlor), Intermoc (glufosinate + *S*-metolachlor), and Enlist One (2,4-D choline). All treatments received a pre-emergence application of Cotoran (fluometuron) at 32 fl oz/ac. A complete list of treatments can be found in Table 1. All herbicide applications were made utilizing a CO_2-pressurized backpack calibrated to deliver 15 gal/ac. Visible weed control ratings as well as visible injury ratings were taken at 14 and 21 days after the early post-emergence (EPOST) application. All data were analyzed using JMP Pro 14 and subjected to analysis of variance. Orthogonal contrasts were conducted, and means were separated utilizing Fisher's protected least significant difference ($P = 0.05$).

Results and Discussion

Palmer amaranth control at 21 days after the EPOST application was numerically less than ratings taken 7 days earlier across all treatments (Fig. 1). At 21 days after the EPOST application, Enlist One + Dual Magnum-containing treatments provided better Palmer amaranth control than all other treatments at 95%. Less than 3% crop injury was observed across all treatments (data not shown). Orthogonal contrasts showed increased Palmer amaranth control in

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treatments containing Enlist One (P = 0.0039). Additionally, orthogonal contrasts showed that chloroacetamide-containing treatments were similar in control to those without (P = 0.2624) and that Intermoc-containing treatments and treatments with Moccasin II PLUS or Dual Magnum were similar (P = 0.9840).

Practical Applications

Enlist One herbicide shows potential for being a viable post-emergence Palmer amaranth control option in Enlist cotton. When Palmer amaranth is present, Moccasin II PLUS can be substituted for Dual Magnum, a similar active ingredient, without sacrificing weed control in Enlist One-containing programs. Effective Palmer amaranth control and minimal crop injury suggest that the Enlist system is a feasible option for weed control in cotton.

Acknowledgements

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Table 1. List of herbicides, rates, and timings. All treatments, except the nontreated, received Cotoran at 32 fl oz/ac pre-emergence.

Treatment	Herbicides	Rate (fl oz/ac)	Timing[a]
1	None	--	--
2	Interline	32	EPOST
3	Interline + Moccasin II PLUS	32 + 21	EPOST
4	Interline + Warrant	32 + 30	EPOST
5	Interline + Outlook	32 + 21	EPOST
6	Interline + Dual Magnum	32 + 21	EPOST
7	Intermoc	70	EPOST
8	Interline + Enlist One	32 + 32	EPOST
9	Interline + Enlist One + Moccasin II PLUS	32 + 32 + 21	EPOST
10	Interline + Enlist One + Warrant	32 + 32 + 30	EPOST
11	Interline + Enlist One + Outlook	32 + 32 + 21	EPOST
12	Interline + Enlist One + Dual Magnum	32 + 32 + 21	EPOST
13	Intermoc + Enlist One	70 + 32	EPOST

[a] Abbreviations: EPOST = early-post-emergence.

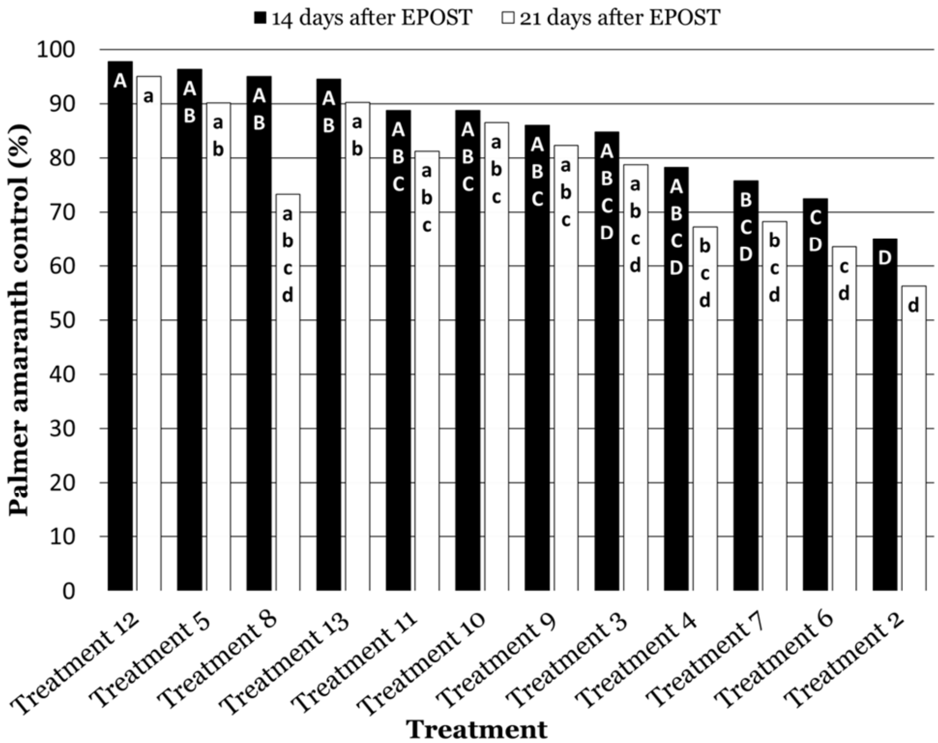

Fig. 1. Visible Palmer amaranth control ratings 14 and 21 days after early-post-emergence (EPOST) application. See Table 1 for explanation of herbicide treatments. Uppercase letters are for comparing treatments at 14 days after treatment and lowercase letters are for 21 days after treatment.

Interaction Between 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 Xtend™ crops. Greenhouse experiments were conducted to quantify Palmer amaranth groundcover following a dicamba and dicamba + glufosinate application and to assess if dicamba followed by glufosinate reduces efficacy of the later herbicide. Reductions of 68% and 55% Palmer amaranth groundcover occurred 240 minutes after dicamba and dicamba + glufosinate application, respectively. Based on Palmer amaranth groundcover measured over time after application, the addition of glufosinate to dicamba hinders the activity of dicamba, at least within a few days of application. A reduction of Palmer amaranth groundcover following a dicamba application may result in difficulty controlling escapes with sequential applications because of the diminished surface area available for spray interception, especially when applying a contact herbicide.

Introduction

The commercial launch and extensive adoption of XtendFlex™ cotton, resistant to dicamba, glufosinate, and glyphosate enables producers to use these herbicides over-the-top of the crop. 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 six SOA (Heap, 2019). Prior research has shown that utilizing two effective SOA in mixture or rotation will reduce the likelihood of target-site resistance evolving to herbicides (Norsworthy et al., 2012). However, label restrictions on the new dicamba products prohibit the mixture of dicamba and glufosinate (Anonymous, 2018). In addition to label restrictions, Meyer (2018) found that dicamba and glufosinate in mixture resulted in antagonism. They also observed that coverage of the contact herbicide glufosinate greatly impacted the efficacy of weed control. Therefore, it is essential to determine if changes in Palmer amaranth groundcover following a dicamba and dicamba + glufosinate have the potential to impact efficacy of sequential applications.

Procedures

One greenhouse experiment was completed at the University of Arkansas System Division of Agriculture's Agricultural Research Station at Fayetteville, Arkansas in 2018. The experiment was designed as a completely randomized block design with three replications. A Palmer amaranth biotype resistant to Group 2, 9, and 14 herbicides (Varanasi et al., 2018) was planted in 50 cell trays. Later, Palmer amaranth was thinned to 1 plant per cell or 50 plants/tray. Each tray was considered a plot. Dicamba (0.5 lb/ac) and dicamba (0.5 lb/ac) + glufosinate (0.53 lb/ac) were applied to 6-leaf Palmer amaranth. Photographs that captured the entire tray were taken 0, 30, 60, 90, 120, 180, 240, 420, 1000, and 1100 minutes after application. Photographs were imported into Field Analyzer (https://www.turfanalyzer.com/) where the proportion of green pixels in each tray were calculated. The percentage of green pixels are representative of Palmer amaranth groundcover (Purcell, 2000).

The groundcover percentage was regressed by minutes in JMP 14.1 Pro (SAS Institute Inc., Cary, N.C.). The line of best fit was a bi-exponential 4P growth curve (y = scale 1 × EXP (- Decay Rate 1 × Time) + Scale 2 + EXP(-Decay Rate 2 × Time)). Fit of the curve was confirmed utilizing the AIC_c, Weighted AIC_c, SSE, and R^2. Inverse predictions were made of percent groundcover at chosen time periods after application. Differences between the reduction in percent groundcover caused by dicamba and dicamba + glufosinate were determined with using standard errors.

Results and Discussion

Applications of dicamba will rapidly reduce groundcover of Palmer amaranth. It took 30 minutes for dicamba alone to reduce Palmer amaranth groundcover by 19%, thus dis-

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playing the fast action of the herbicide (Fig. 1; Table 1). Two hours after a dicamba application, Palmer amaranth groundcover was reduced by 55%. Palmer amaranth groundcover was ultimately reduced by 70% at 420 minutes after applying dicamba. Although no sequential herbicide application was evaluated in this research, reductions in Palmer amaranth groundcover following dicamba has the potential to impact sequentially applied herbicides, specifically contact herbicides like glufosinate. The application of dicamba + glufosinate resulted in a slower reduction in Palmer amaranth groundcover at every time period, except 30, 60, 1000, and 1100 minutes after application (Table 1). From these data, the antagonistic interaction between dicamba and glufosinate discovered by Meyer (2018) may be evident based on the delay in Palmer amaranth groundcover reduction with the addition of glufosinate.

Practical Applications

An emphasis has been placed on slowing the evolution of herbicide resistance in weeds by using multiple SOA. However, wide adoption of XtendFlex™ cotton and hindering label restrictions that prohibit mixing dicamba and glufosinate, forces the two herbicides to be applied separately. Applications of dicamba followed by glufosinate may result in decreased efficacy because dicamba substantially reduces the likelihood for adequate coverage with glufosinate, a contact herbicide. Essentially, plants treated with dicamba intercept a reduced rate of herbicides applied subsequently, increasing the likelihood for resistance to evolve to the later herbicide.

Acknowledgements

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Table 1. Prediction of Palmer amaranth percent groundcover at time intervals after applications of dicamba and dicamba + glufosinate.

	Dicamba		Dicamba + glufosinate	
Time after application	Groundcover	Standard error	Groundcover	Standard error
minutes	%		%	
0	100	2.42	100	2.39
30	81	1.40	78	1.29
60	64	1.35	64	1.31
90	53	1.30	57	1.28
120	45	1.18	52	1.17
180	36	1.00	47	1.00
240	32	1.07	45	1.02
420	30	1.18	41	1.11
1000	35	2.12	30	2.10
1100	36	2.61	29	2.58

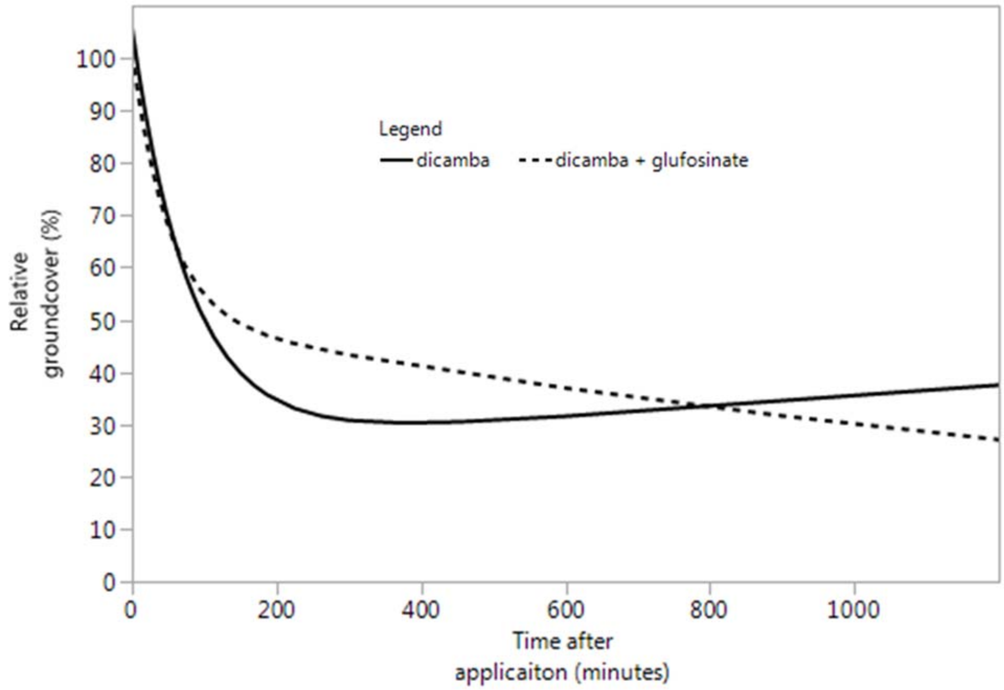

Fig. 1. The bi-exponential growth curves (y = Scale 1 × EXP(- Decay Rate 1 × Time) + Scale 2 + EXP (- Decay Rate 2 × Time) display the effect of the treatments (dicamba and dicamba + glufosinate) on Palmer amaranth groundcover (%) over time (minutes).

Efficacy of Brake Applied Alone and in Combination with Other Residual Herbicides in Cotton

M.C. Castner[1], J.K. Norsworthy[1], L.T. Barber[2], Z.D. Lancaster[1], and J.T. Richburg[1]

Abstract

Mid-South growers continue to face limited post-emergence (POST) weed control options for Palmer amaranth (*Amaranthus palmeri* S. Wats) in cotton production. With few POST options available, there is a strong need to reduce selection for herbicide resistance by beginning weed-free with the intensive use of pre-emergence (PRE) herbicides. The addition of Brake (fluridone) as a PRE herbicide option in cotton has been shown to be effective on Palmer amaranth, and when used in combination with other PRE herbicides, may improve the spectrum of control and extend residual activity. To evaluate the efficacy of Brake on Palmer amaranth, an experiment was conducted near Marianna, Arkansas in 2018. All Brake-containing treatments demonstrated greater efficacy than the Cotoran (fluometuron) plus Caparol (prometryn) weed control standard, as well as provided extended residual control.

Introduction

Mid-South growers are often faced with limited post-emergence (POST) weed control options for controlling resistant Palmer amaranth populations in cotton production. According to the international survey of herbicide resistant weeds, Palmer amaranth has developed resistance to six sites of action (SOA) throughout the United States (Heap, 2018). In order to combat and manage those resistant populations, growers are encouraged to reduce selection pressure of POST-applied herbicides by beginning weed-free through the intensive use of pre-emergence (PRE) herbicides. Overlapping residual herbicides with POST applications have proven to be effective against Palmer amaranth, and when in combination with other PRE herbicides, could extend the longevity of Brake (Norsworthy et al., 2012).

Procedures

This experiment was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas in 2018 on a Zachary silt loam soil. XtendFlex cultivar, DG 3385 B2XF was planted on 10 May at 48,000 seeds/acre into a conventionally tilled and bedded system. Each plot was 12.6 (4 rows) by 25 ft with four replications. At planting, all plots received a broadcast application of Gramoxone SL 2.0 (paraquat) to eliminate any remaining vegetation. Following the burndown application, all treatments were applied PRE to further evaluate Palmer amaranth efficacy and residual activity of Brake and Brake-containing mixtures in comparison to a Cotoran plus Caparol standard. A combination of Liberty (glufosinate) at 29 fl oz/ac (0.53 lb ai/ac) and Dual Magnum (*S*-metolachlor) at 16 fl oz/ac (0.953 lb ai/ac) were applied 18 days after planting to continue assessing residual weed control from the initial treatments. Ratings of visible crop injury and percent weed control were taken at weekly intervals following the last application until 10 weeks after treatment. Weed control ratings were fit with a mechanistic growth curve. Inverse predictions were made to find the number of days herbicide treatments provided greater than or equal to 60%, 70%, and 80% control (Fig. 1). Confidence limits of 0.95 were used to determine differences between prediction estimates (Table 1). All data were analyzed in JMP Pro 14, and means were separated using Fisher's protected least significant difference ($\alpha = 0.05$).

Results and Discussion

At 21 days after treatment (DAT) mixtures containing Cotoran, or mixtures that did not include Brake demonstrated lower of Palmer amaranth control (Fig. 2). Brake applied alone and when applied in combination with Reflex, provided greater efficacy (94%) than Brake applied with Cotoran (88%) or in comparison to the non-Brake-containing Cotoran plus Caparol standard (83%). To quantify residual activity for each PRE treatment, a mechanistic growth curve (Fig. 1) was fitted using inverse predictions at a 0.95 confidence interval. The analysis showed all treatments containing Brake provided extended residual Palmer amaranth control compared to the Cotoran plus Caparol standard. Brake-containing treatments demonstrated ≥80% Palmer

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amaranth control from 50 to 65 DAT, which is a increase when compared to treatments without Brake. Treatments without Brake showed a lack of extended residual activity, with 80% or more control for only 36 days (Fig. 1, Table 1).

Practical Applications

From a cotton production standpoint, Brake not only delivers exceptional Palmer amaranth control, but also provides growers another effective SOA with extended residual activity. By starting clean and utilizing Brake as a key component in an integrated weed control approach, growers can significantly reduce selection pressure on POST applications and increase the sustainability of current PRE weed control programs in Arkansas.

Acknowledgements

The authors would like to thank SePRO Corporation, Carmel, Indiana for funding this research and providing Brake herbicide for evaluation, the University of Arkansas System Division of Agriculture for providing additional resources necessary to complete this research, and the Lon Mann Cotton Research Station for assistance in planting and maintaining research plots.

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Table 1. The number of days predicted for Palmer amaranth (PA) to reach 60%, 70%, and 80% control. Differences between treatments can be determined if the 95% confidence intervals of the mean do not overlap.

			Confidence limits	
Treatment[a]	Specified PA Ratings	Predicted	Lower	Upper
	%	----------------------	days[b]	--------------------
Brake + Cotoran 16 fl oz	60	69	62	77
Brake + Cotoran 24 fl oz	60	67	62	72
Brake + Direx	60	70	65	76
Brake	60	74	62	86
Brake + Reflex	60	71	65	76
Brake + Warrant	60	69	65	73
Cotoran + Caparol	60	59	55	64
Brake + Cotoran 16 fl oz	70	60	55	65
Brake + Cotoran 24 fl oz	70	59	54	63
Brake + Direx	70	64	60	68
Brake	70	71	63	78
Brake + Reflex	70	66	62	69
Brake + Warrant	70	64	60	67
Cotoran + Caparol	70	48	43	54
Brake + Cotoran +	80	48	40	55
Brake + Cotoran 24 fl oz	80	47	41	54
Brake + Direx	80	55	48	61
Brake	80	65	61	70
Brake + Reflex	80	58	53	64
Brake + Warrant	80	56	51	62
Cotoran + Caparol	80	36	29	42

[a] All treatments applied at their respective labeled rates unless indicated by a rate in fl oz/ac.

[b] Number of days for Palmer amaranth to reach the predicted percent control.

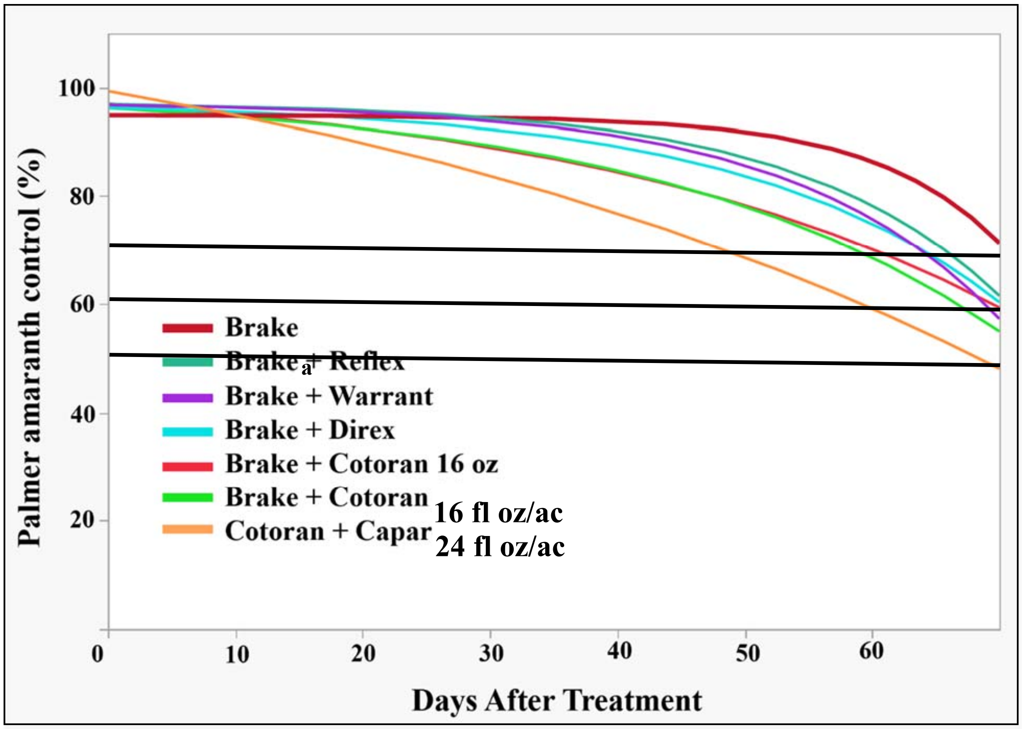

Fig. 1. Percent Palmer amaranth control data (from ratings at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas in 2018) were fit with a mechanistic growth curve (y = a (1 – b × EXP (- c × days)) where a = asymptote, b = scale, and c = growth. Inverse predictions were made from the fitted lines estimating the number of days for Palmer amaranth control to reach 60, 70, and 80 percent. See Table 1 for estimated number of days. All treatments applied at their respective labeled rates unless indicated by a rate in fl oz/ac.

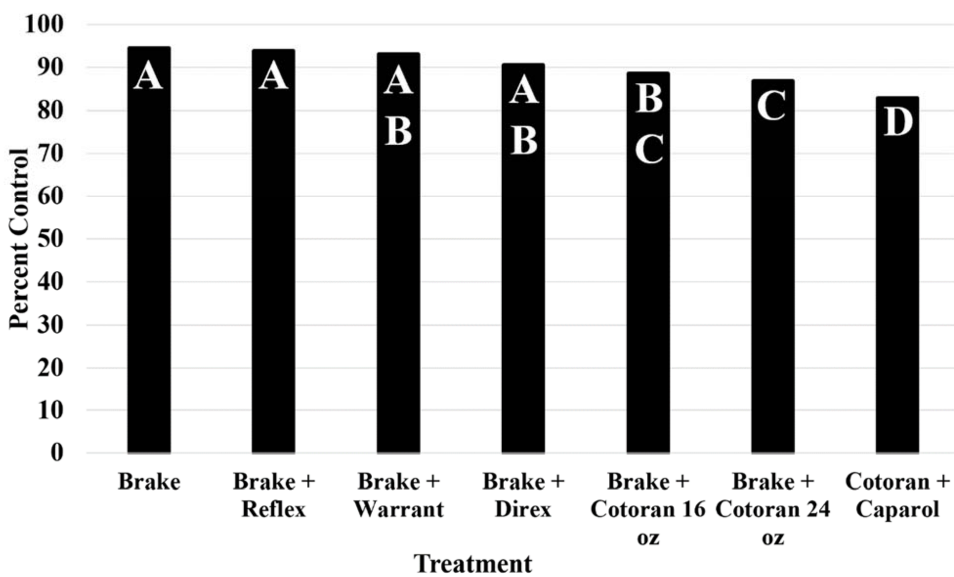

Fig. 2. Efficacy of Brake and Brake-containing mixtures on Palmer amaranth control compared to a Cotoran plus Caparol standard at 21 days after treatment at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in 2018 near Marianna, Arkansas Means followed by the same letter are not significantly different based on Fisher's protected least significant difference (*P* = 0.05).

Loyant as a Potential Post-Direct Option in Cotton

R.C. Doherty[1], T. Barber[2], Z.T. Hill[1], and A. Ross[3]

Abstract

With the continued spread of herbicide-resistant Palmer amaranth throughout Arkansas, cotton weed control continues to be challenging. New technologies such as Enlist™ and XtendFlex™ cotton traits provide opportunity for the use of auxin-based herbicide programs, but some Palmer amaranth resistance to these herbicides has been recently discovered in Kansas. Loyant (florpyrauxifen-benzyl) is a new auxin herbicide labeled in rice and is effective in controlling a range of weed species including Palmer amaranth. Two trials were conducted in 2017 at the University of Arkansas System Division of Agriculture's Lonn Mann Cotton Research Station in Marianna and the Rohwer Research Station in Rohwer, Arkansas and in 2018 at Marianna and Tillar, Arkansas, to determine if Loyant could fit in a post-direct program for control of problem weeds in cotton at a layby timing and to determine the rate of Loyant necessary to achieve this control. Cotton injury observed from post-directed applications of Loyant was minimal through both years of research. 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.

Introduction

Glyphosate, PPO (Protoporphyrinogen oxidase inhibitor), and ALS (acetolactate synthase) -resistant Palmer amaranth remains a major concern for cotton growers in Arkansas. Herbicide programs that utilize multiple modes of action applied timely are essential in controlling this troublesome weed (Barber et al., 2018). Enlist™ technology provides 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, 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 at the University of Arkansas System Division of Agriculture's Lonn 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. In 2018, 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. Cultivars PHY 340 W3FE and PHY 330 W3FE were planted in 2017 and 2018, respectively. The trials were arranged in a randomized complete block design with four replications. All treatments received Brake FX pre-emergence 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 and 2). 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 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.

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 cotton injury was caused by any treatment, other than Xtendimax, at either location in 2017. Cotton yield was impacted by Xtendimax plus Round-Up PowerMax, which was expected and

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resulted in a seedcotton yield loss of 552 and 1173 lb/ac, at Marianna and Rohwer respectively (Fig. 1). Yields of all other treatments were equal at the respective locations.

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).

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 little or no injury to cotton. This system must also include early season residuals applied pre-emergence and early-post-emergence to insure 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.

Acknowledgements

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

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Table 1. 2017 Post-directed herbicide treatments at the University of Arkansas System Division of Agriculture's Lonn Mann Cotton Research Station, Marianna and the Rohwer Research Station, Rohwer, Arkansas locations.

Herbicide	Rate in oz product/acre	Timing
Brake FX	40	Pre-emergence
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 University of Arkansas System Division of Agriculture's Lonn Mann Cotton Research Station, Marianna and Tillar, Arkansas locations.

Herbicide	Rate in oz product/acre	Timing
Brake FX	40	Pre-emergence
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

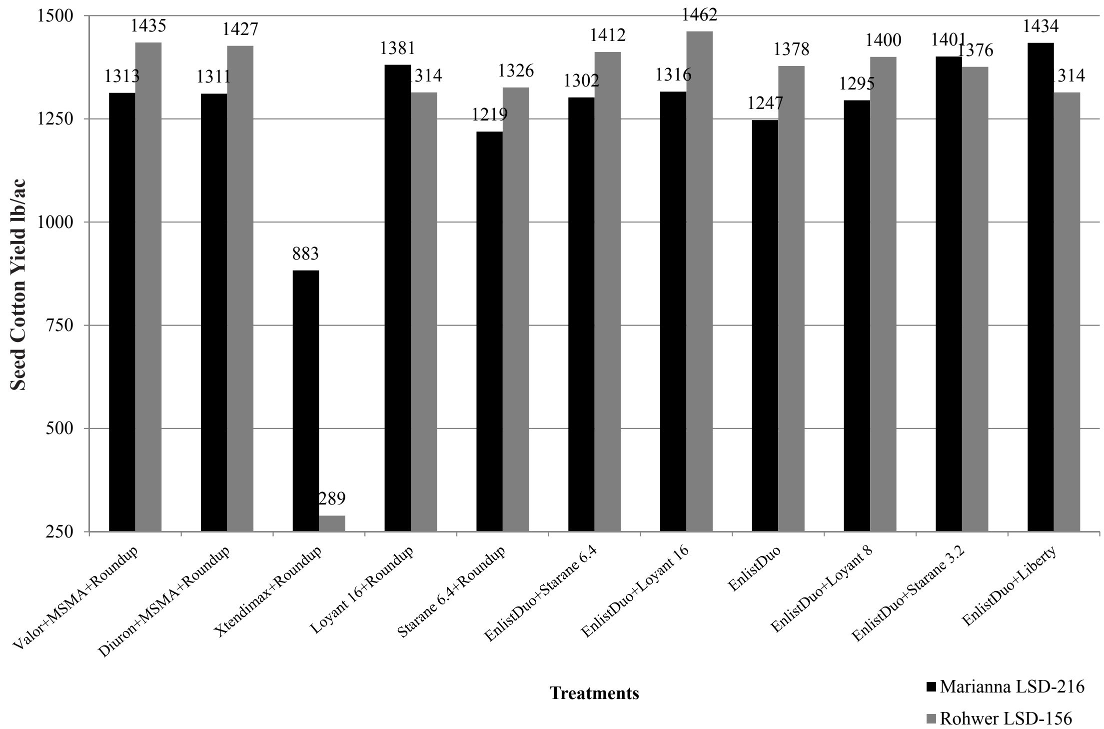

Fig. 1. 2017 seed cotton yield at Marianna and Rohwer Arkansas following various herbicide programs applied at layby. Abbreviations: LSD = least significant difference.

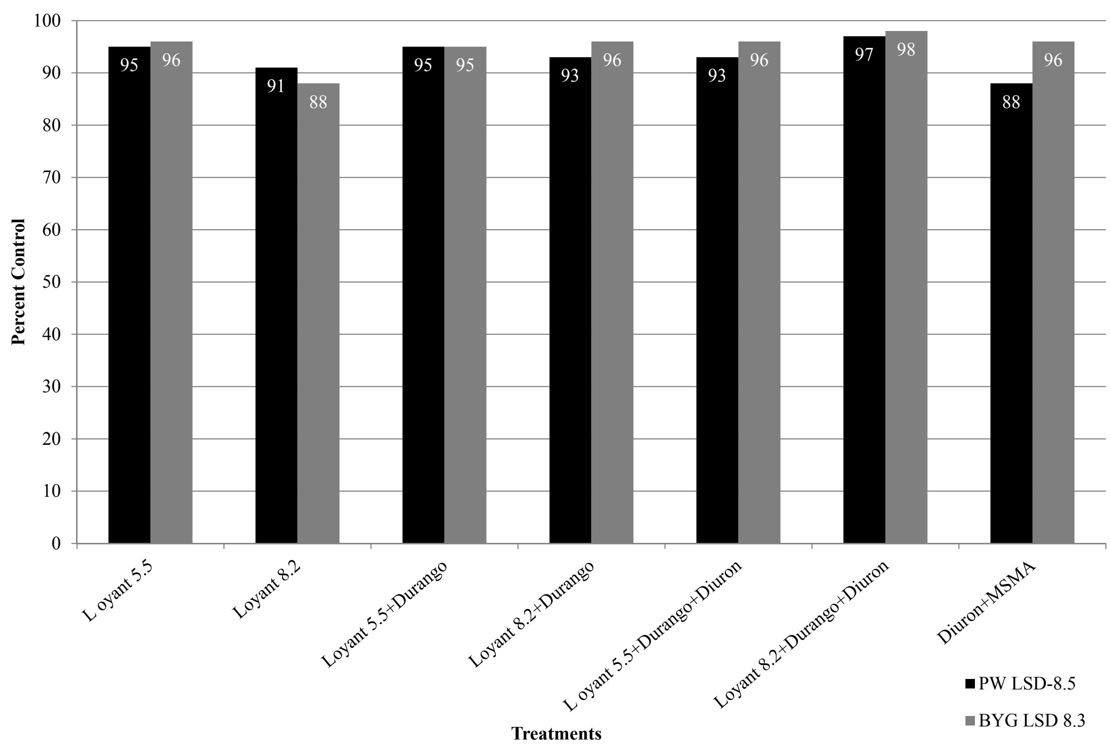

Fig. 2. 2018 Weed Control 20 days after Layby at Marianna, Arkansas. Abbreviations: PW = pigweed, BYG = barnyardgrass, LSD = least significant difference.

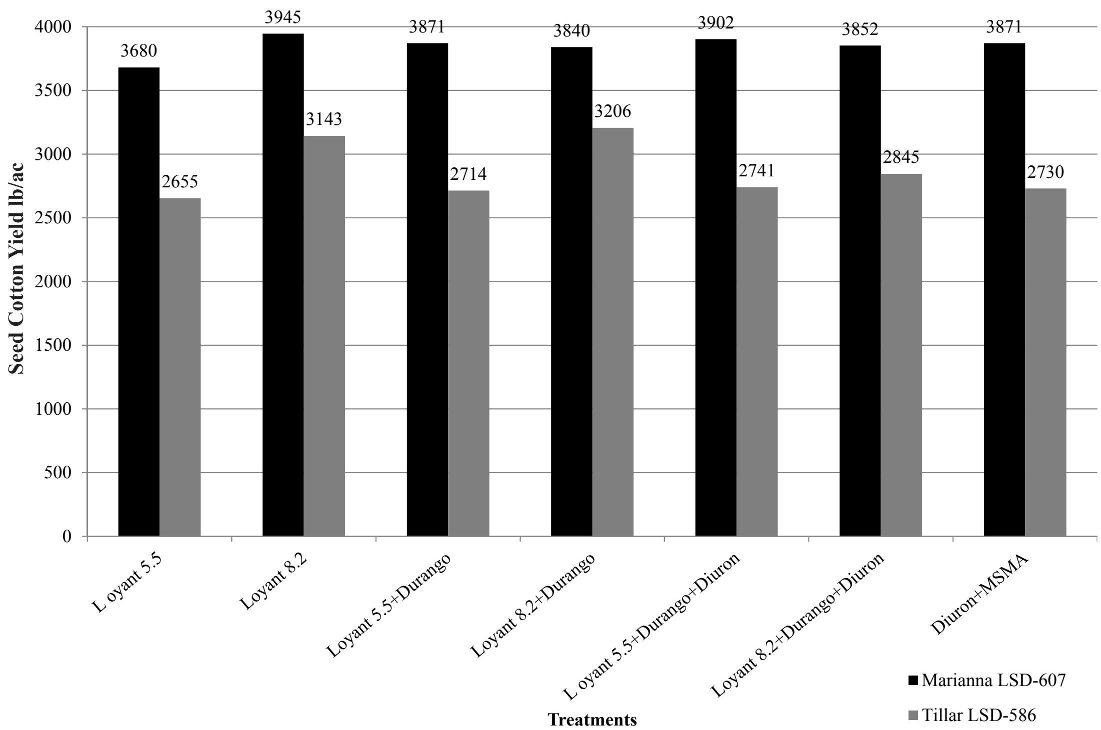

**Fig. 3. 2018 seed cotton yield at Marianna and Rohwer, Arkansas.
Abbreviations: LSD = least significant difference.**

Consequences of Skipping Late-Season Herbicide Applications in Cotton

J.T. Richburg[1], J.K. Norsworthy[1], L.T. Barber[2], M.C. Castner[1], and Z.D. Lancaster[1]

Abstract

An experiment was conducted near Marianna, Arkansas to evaluate the effects of skipping late-season herbicide applications in cotton. A four-pass program, consisting of effective modes of action and residual herbicides, was used as a standard comparison for treatments that skipped either a late post-emergence application or a layby application. Results indicate that skipping a late post-emergence application may result in lower Palmer amaranth control than skipping a layby application. Yield was not affected by skipping either late-season herbicide application; however, to ensure an efficient harvest and to strive for a zero-tolerance policy, timely late-season post-emergence applications should be made.

Introduction

Keeping cotton weed-free throughout the season results in higher yields (Klingaman and Oliver, 1994). In Arkansas, a standard cotton weed control program generally consists of at least four different herbicide applications throughout the year. This includes a burndown plus a pre-emergence (PRE) application at planting, an early post-emergence (POST) application 14–21 days later, a late post-emergence application 14–21 days after the early post-emergence application, followed by a layby application around bloom. Although weed control is possible by relying solely on effective post-emergence herbicides, to combat weed resistance and deplete the soil seedbank, residual herbicides should be used (Norsworthy et al., 2012). The timeliness of herbicide applications is vital to their success. Hence, herbicide applications should be timed so that residual activity may overlap and lessen the chances of weeds competing with cotton. However, because of unforeseen conditions, growers sometimes cannot make timely herbicide applications. Therefore, research was initiated to further understand the consequences of skipping late-season herbicide applications.

Procedures

This study was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station near Marianna, Arkansas in 2018. Cotton cultivar, Dyna-Gro 3385B2XF, was planted at 55,000 seeds/acre into conventionally tilled, raised beds. Plot size was 12.6 (4 rows) by 25 ft. The study was designed as a randomized complete block with 4 replications. All plots, except the nontreated, received an application of Gramonxone SL 2.0 (paraquat) at 64 oz/ac + Brake (fluridone) at 16 oz/ac + Cotoran (fluometuron) at 24 oz/ac pre-emergence followed by Liberty (glufosinate) at 29 oz/ac + Dual Magnum (*S*-metolachlor) at 16 oz/ac early post-emergence. Treatments one and three received a late post-emergence application (21 days after early post-emergence) of Liberty at 29 oz/ac + Roundup PowerMax II (glyphosate) at 32 oz /ac + Warrant (acetochlor) at 48 oz/ac. Lastly, treatments one and two received a layby application of Roundup PowerMax II at 32 oz/ac + Direx (diuron) at 32 oz/ac. To summarize, treatment one received a season-long program consisting of all four application timings, treatment two received all applications, except the late post-emergence application, and treatment three received all applications, except the layby application. Palmer amaranth control was rated 7, 14, 28, and 35 days after the late post-emergence (DALP) application. Seedcotton yield was picker harvested from the two center rows of each plot. All data were subjected to an analysis of variance in SAS Version 9.4 statistical software (SAS Institute Inc, Cary, N.C.). Means were separated using Fisher's protected least significant difference ($\alpha = 0.05$).

Results and Discussion

At 7 DALP, no differences occurred among treatments (Fig. 1). However, by 14 DALP, Palmer amaranth control in plots that did not receive a late post-emergence application was inferior to plots that did. Palmer amaranth control at 28 DALP (14 days after the layby application) showed similar results, with plots not receiving the late post-emer-

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gence application having lower control than those that did. Plots that did not receive a layby application had Palmer amaranth control comparable to the full-season program. Though treatment two illustrated poorer control than other treatments, no differences in yield were detected (data not shown). Since the cotton was one week from cutout by the time Palmer amaranth control declined, weeds were not as competitive with cotton and therefore no yield loss ensued.

Practical Applications

Though yield loss did not occur, other potential drawbacks did. For example, weeds in plots that did not receive a late post-emergence application grew for 30+ days before harvest. This resulted in Palmer amaranth overtopping the cotton canopy and making harvest difficult in some plots. These Palmer amaranth plants also produced a seed head. In order to deplete the soil seedbank and slow the evolution of resistance, a zero-tolerance threshold should be implemented. Applications should be made as timely as possible. Regular scouting from planting to harvest will ensure that weeds are documented and treated where escapes occur.

Acknowledgements

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

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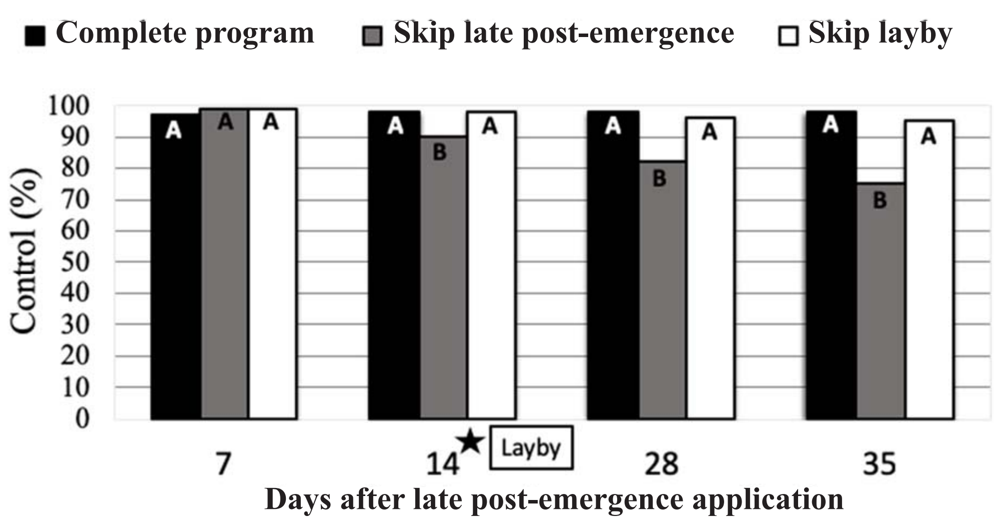

Fig. 1. Assessment of Palmer amaranth control at 4 different timings. Bars not containing the same letter are significantly different within a rating timing (α = 0.05).

Within-Field Variability: A Case Study to Evaluate Factors Affecting Maturity and Yield in a Commercial Cotton Field in Northeast Arkansas

J. Krob[1], J.W. Nowlin[1], and T.G. Teague[1]

Abstract

Mid-South cotton producers are receptive to expanding use of geospatial technology and site-specific management practices; however, to make profitable use of those precision tactics, they must understand sources of within-field variability of lint yield. In this 2018 exploratory case study, our goal was to identify the major factors contributing to spatial variability in maturity and yield in a 40-acre, center-pivot irrigated, cotton field in Northeast Arkansas. Our evaluations included collection and analysis of in-season plant and soil moisture monitoring data, as well as yield monitor-measured yields and crop budget analyses. We observed that spatial and temporal variation in plant growth, maturity, and productivity was associated primarily with heterogeneous soil textures and irrigation patterns. Spatial patterns of pest pressure related to tarnished plant bug were associated with variable fruiting dynamics of plants growing across irrigated and rainfed field areas in either coarse sand or loamy sand soil textures. Lint yields and estimates of net returns were combined to produce a profitability map which showed 20% of the field area produced negative net returns over variable costs. Possible site-specific management options including use of variable seeding and fertility, as well as modifications in pesticide application timing are included in the discussion.

Introduction

Successful implementation of precision agriculture approaches can improve production efficiency, reduce overall production costs, and lead to a more sustainable cotton production system. To exploit existing equipment capacity and access to geospatial technology, mid-South producers are interested in employing precision tactics such as site-specific practices and zone management, but there is a lack of practical and validated rules and guidelines for efficient implementation. The focus of this case study research was to improve understanding of sources and consequences of within-field variability. Our aim is to identify practical opportunities for producers to employ site-specific practices to increase production efficiency.

The study took place in a center-pivot sprinkler irrigated 40-acre commercial cotton field in Mississippi County near Leachville, Arkansas. The production area lies in the Mississippi River floodplain and is characterized by alluvial soils. Fields in this Northeast Arkansas region are laced with sand blows associated with multiple historic seismic events in the New Madrid fault zone. Mid-South cotton fields with center-pivot sprinkler irrigation generally have irrigated circles and non-irrigated (rainfed) corners. Heterogeneous soils as well as soil moisture differences related to irrigation each can contribute to variable crop growth and development.

Procedures

Cotton (cv. NG 3522B2XF) was planted 15 May 2018 at a rate of 3 seeds per ft of row on raised beds with 38-inch row spacing (~41,000 seed/acre). All production inputs (fertility, crop protection, harvest aid products) were the standard practices by the cooperating producer and followed the University of Arkansas System Division of Agriculture's Cooperative Extension recommendations. Plant, pest, and soil monitoring was conducted throughout the season at georeferenced sample points in rainfed and irrigated cotton in areas with either coarse or loamy sand soil textures (Fig. 1). Sampling included weekly plant monitoring using COTMAN™ protocols (Oosterhuis and Bourland, 2008) and soil moisture monitoring with Watermark® sensors (www.irrometer.com). Soil moisture stations were set at five different sample sites in the field with two pairs of sensors at each sample station positioned between plants at 6- and 12-inch depths. Yield assessments were made with measures of hand-picked harvest data (10 ft of row) and evaluation of yield monitor-measured yields. Crop budgets were generated using the University of Arkansas Cooperative Extension Interactive Crop Enterprise Budget in Excel (www.uaex.edu/farm-ranch/economics-marketing/farm-planning/budgets/crop-budgets.aspx) to estimate net returns over variable costs. These data were used to develop a profitability map using ArcGIS 10.6.1 (www.esri.com).

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Results and Discussion

Temperatures and rainfall were sufficient for good growing conditions after planting and during seedling development. Stand counts for all sample points made at 34 days after planting (DAP) indicated no difference in plant stand density among different soil textures or irrigation sample points (data not shown). Precipitation amounts in May and June were below average, and higher than average levels were recorded in July and August (Table 1). The field received seven irrigations. Soil moisture and plant available water was lower in the rainfed corners during the season compared to the irrigated sections of the field (Fig. 2). Watermark sensor functionality can be sporadic in sand-dominated soils if soil surrounding the sensor dries; measurements from sensors located in rainfed sites show total dry-down despite some precipitation in early season.

Seedlings growing in loamy sand produced greater biomass by 25 DAP compared to plants in coarse sand (Table 2). The COTMAN™ target development curve shows the standard (expected) plant development. Mainstem squaring nodes ascend at a pace of one node every 2.7 days through first flower (60 DAP), and then descend with physiological cutout (NAWF = 5) occurring at 80 days (Oosterhuis and Bourland, 2008). Results from our COTMAN monitoring showed that the pace of plant mainstem nodal development lagged for plants in coarse compared to loamy sand soils in both irrigated and rainfed field areas (Fig. 3). First flowers were observed by 54 DAP, and plants in the irrigated loamy sand produced an average of 8 squaring nodes compared to only 5 to 7 produced by plants in coarse sand or in the rainfed loamy areas of the field, respectfully. Premature cutout was associated with rainfed plants and plants in coarse sand areas. Mean number days from planting to physiological cutout (days to cutout) was 67, 80, 54 and 69 days for plants in the irrigated coarse sand, irrigated loamy sand, rainfed coarse sand, and rainfed loamy sand, respectively.

COTMAN results also showed that square retention varied among soil textures and with irrigation. Tarnished plant bug infestation patterns and feeding preferences were reflected in square shed rates (% shed of first position squares on mainstem sympodia). Plants with high biomass growing in loamy sand had highest % shed compared to less vigorous plants in coarse sand (Table 3). Tarnished plant bug adult movement into the field was apparent in drop cloth sampling at 35 DAP (Table 4). Plants in coarse sand had produced few, if any, squares at that time.

Gin records provided by the cooperating producer indicated that overall average yield for the field was 1241 lb lint/ac with 40.46% turnout and loan value $659.70/ac. Handpicked lint yield at our sample points showed variability in lint production among plants in different soil textures with 1338 lb/ac associated with irrigated loamy sand compared to 890 and 922 lb/ac harvested from plants in the irrigated coarse sand and rainfed coarse sand, respectively. When spatially referenced yield values from yield monitor data were delineated into classes using ArcGIS, clustered spatial patterns were observed. Lowest production was observed in rainfed coarse sand compared to irrigated loamy sand areas of the field; irrigation also increased yields (Table 5). A partial budget analysis was performed to calculate returns to operating expenses. Returns for mean yields were based on $0.70/lb price with land rent included as 25% share rent. Fixed costs were not included in the analysis. A standard operating cost was calculated at $500.86/acre. Budget results showed economic losses or reduced returns in coarse sand areas of the field. Approximately 21% (8.4 acres) of the field generated losses. Cotton grown in loamy sand had positive returns. Spatial variability in net returns and losses is apparent in the profitability map (Fig. 4).

Practical Applications

Crop managers may improve resource use efficiency in variable fields with adoption of precision agriculture approaches including use of management zones. From a practical standpoint, management zones should occur in a predictable spatial pattern plus be large enough to occupy a management-worthy area within a field (e.g., large enough for production-scale equipment). Research by Teague et al. (2014) has shown that in fields with center-pivot irrigation systems, rainfed and irrigated areas are easy-to-implement zones that can be appropriate for differential termination timing of insecticides in late season. Managers also may opt to reduce costly inputs in field areas of low productivity (e.g., sand blows) compared to areas of high productivity. For example, reduced seeding rates may be appropriate in coarse sand areas (Teague, 2016; Teague et al., 2019). With high costs of inputs and land rent, profit margins are very narrow for mid-South cotton production. Reduced inputs in less productive field areas is one option for producers to improve efficiency and profitability.

Acknowledgements

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Table 1. Monthly precipitation (inches) measured at the study site for the 2018 season compared with 30-year county average – Leachville, Arkansas.

Month	30-year Average	2018	Departure
	---inches---		
May	5.37	4.00	-1.37
June	3.99	3.61	-0.38
July	4.04	1.89	-2.15
August	2.36	7.76	5.40
Total Season	15.76	17.26	1.50

Table 2. Plant biomass measurements taken from 10-plant samples collected 25 days after planting (6 June) at georeferenced sites - 2018, Leachville, Arkansas.

	Irrigated		Rainfed	
Category	Coarse sand	Loamy sand	Coarse sand	Loamy sand
No. of true leaves	3.3	5.0	4.0	4.0
Leaf Area Index (m^2/m^2)	382	934	927	1042
Height (cm)	1	17	17	17
Plant dry wgt (g)	6	15	14	13

Table 3. First position square shed (%) observed in COTMAN sample data (%) associated with tarnished plant bug (*Lygus lineolaris)* feeding damage in the 2018 geospatial variability case study, Leachville, Arkansas.

	Irrigated		Rainfed	
Days after planting	Coarse sand	Loamy sand	Coarse sand	Loamy sand
	---%---			
33	0	0	0	0
41	7.1	16.5	11.4	7.5
45	5.4	31.4	19.6	18.4
54	20.8	40.3	17.0	36.0
61	14.9	41.9	10.0	31.7
66	6.7	38.9	7.0	39.7

Table 4. Consultant scouting notes submitted to the producer for tarnished plant bug counts and for insecticide applications – 2018 Leachville, Arkansas.

Days after planting	Tarnished plant bugs		Insecticide
	Adults	Nymphs	
	-----No. per 12 ft of row----		-----------lb (ai) per acre----------
31	1	0	no spray
38	5	0	thiamethoxam (0.0625)
45	3	8	sulfoxaflor (0.047)
52	-	-	sulfoxaflor (0.062) + novaluron (0.039)
59	0	13	sulfoxaflor (0.054)
66	2	2	no spray
73	0	16	acephate (0.83) + bifenthrin (0.04)
80	2	6	acephate (0.83) + lambda-cyhalothrin (0.035)

Table 5. Mean cotton lint yields (lb/ac) determined from yield monitor and estimated returns to operating expenses determined using the Arkansas Cooperative Extension Interactive Crop Enterprise Budget in Excel, 2018, Leachville, Arkansas.

Category	Irrigated		Rainfed	
	Coarse Sand	Loamy Sand	Coarse Sand	Loamy Sand
Lint yield (lb/ac)	1096	1455	435	1025
Net returns above variable costs ($/ac)	66.35	246.96	-271.36	28.13

Fig. 1. Georeferenced sample points (left) were classified based on in-field sampling and visual assessments using historical imagery; two of our classes (right): irrigated or rainfed and coarse sand (CS) or loamy sand (LS), 2018, Leachville, Arkansas.

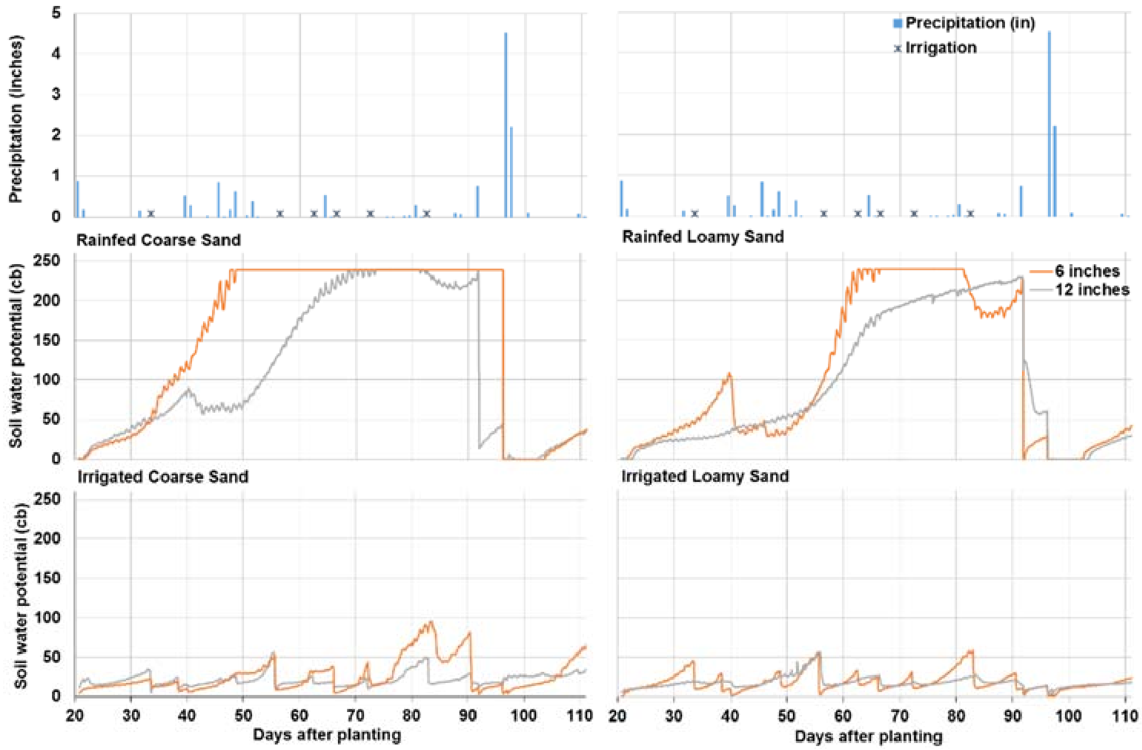

Fig. 2. Season-long soil moisture readings from Watermark sensors; top figure shows precipitation and irrigation events--2018 geospatial variability case study, Leachville, Arkansas.

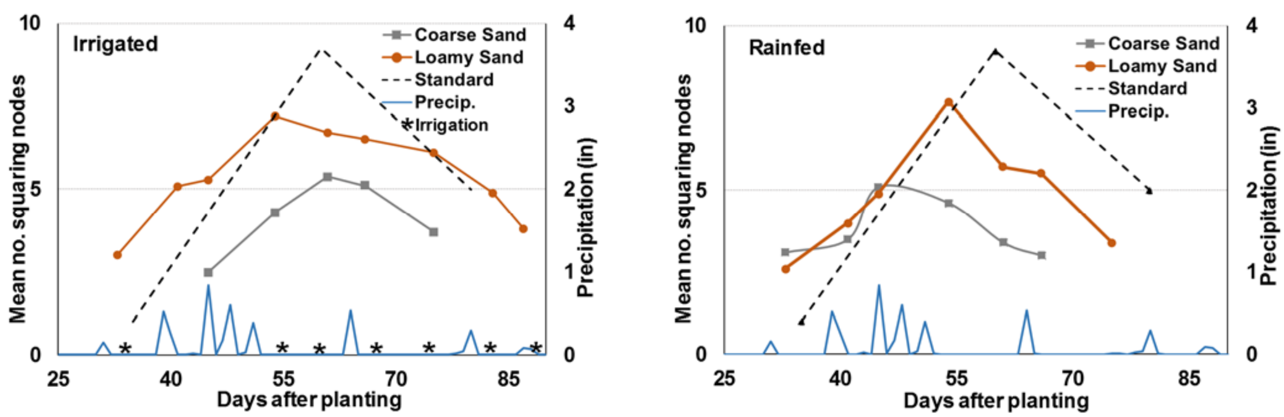

Fig. 3. COTMAN growth curves for plants in irrigated and rainfed field areas in coarse sand and loamy sand soil textures in the 2018 geospatial variability case study, Leachville, Arkansas.

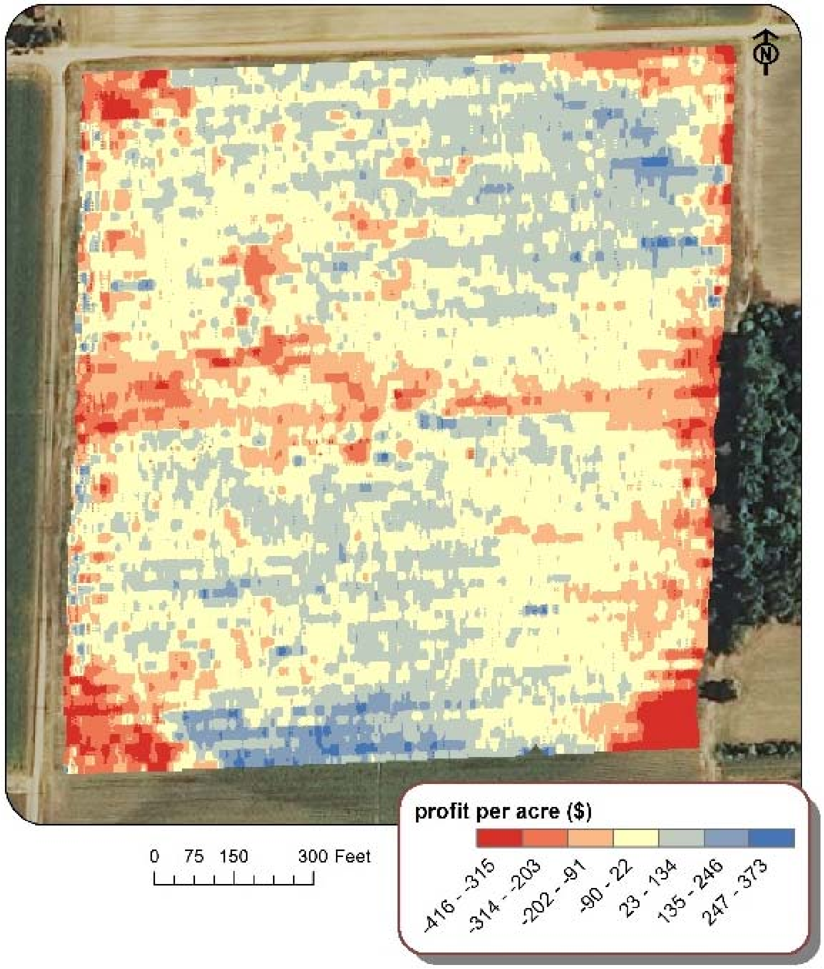

Fig. 4. Profitability map showing spatial variability of net returns over variable costs; lowest revenue was associated with rainfed field areas (pivot corners) and areas with coarse sand soil texture (sand blows) -2018 geospatial variability case study, Leachville, Arkansas.

Impact of Cover Crop Termination on Soil Health and Lint Yield of Cotton

B. Robertson[1], A. Free[1], and C. Manuel[1]

Abstract

Utilization of cover crops and reducing tillage are two practices that can have a significant impact toward improving soil health. Issues with cover crops that present most growers concern 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 above ground 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) mid-boot, 3) late-boot, 4) full panicle exertion, and 5) anthesis. Termination timing did influence above ground 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 above-ground biomass and root mass ratings. However, the treatment yielded significantly less than the termination timing two weeks prior to planting. It is possible to terminate cereal rye two weeks prior to planting cotton to achieve benefits associated with a cover crop while avoiding pest issues associated with the "green bridge".

Introduction

Utilization of cover crops and reducing tillage are two practices that can have a significant impact toward improving soil health. Many measurements can be used as indicators of improved soil health. Water infiltration can be used as an indirect measure of soil health. As soil health improves, water infiltration rates often increase as well. Maintaining living roots in a field for as many months as possible sustains soil microbe populations, which are important in improving soil health. Two issues with cover crops that concern most growers include 1) a "green bridge" for pests from the cover crop to the economic crop, and 2) planting and obtaining a good stand through the residue. The objective of this study was to investigate the timing of cereal rye cover crop termination, so as to provide 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 conducted in 2018 near Forrest City on a pivot-irrigated Loring silt loam soil was utilized to evaluate five termination timings of cereal rye. The timings were based on the growth stage of cereal rye to include 1) early-boot, 2) mid-boot, 3) late-boot, 4) full panicle exertion, and 5) anthesis. Six-row plots were arranged in a randomized complete block design with four replications in a producer field of DP 1725 B2XF planted on 6 May 2018 and harvested 29 October 2018. Visual root ratings from hand split soil cores at 6-inch intervals down to a 3 foot depth were recorded at planting to assess cover crop root density and depth with a rating of 1 representing no visible roots and a rating of 5 indicating 50% of exposed area composed of roots. Water-mark soil moisture sensors placed at a depth of 6, 12, and 18 inches were utilized to evaluate water infiltration in each termination timing. Lint yield was calculated from seedcotton weights from machine picked six-row plots 400 foot in length. Turnout was calculated from a grab sample pulled from each plot and ginned on a table top gin.

Results and Discussion

Visual ratings on a scale of 1 to 5 for each 6-inch section of a soil core sampled down to three foot in depth varied by treatment (Fig. 1). Root mass was denser and extended deeper into the soil as the cereal rye cover crop was terminated later.

Water infiltration at deeper depths was improved as rooting of cover crop increased (Figs. 2 and 3). Deeper water infiltration should provide deeper effective rooting for water and nutrient uptake by the plant.

Lint yield was significantly impacted by termination timing in this one-year study (Fig. 4). The lowest yields were observed where biomass and root mass was the lowest at early-boot. Termination of anthesis also resulted in lower

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yields. 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 above ground biomass, root mass, and depth of rooting with greater quantities being produced as termination was delayed. Termination during mid-boot to heading resulted in the highest numerical yields. These timings ranged from 2 to 4 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 significantly less than the termination timing 2 weeks prior to planting. It is possible to terminate cereal rye 2 weeks prior to planting cotton to achieve benefits associated with cover crop while avoiding pest issues associated with the "green bridge".

Acknowledgements

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

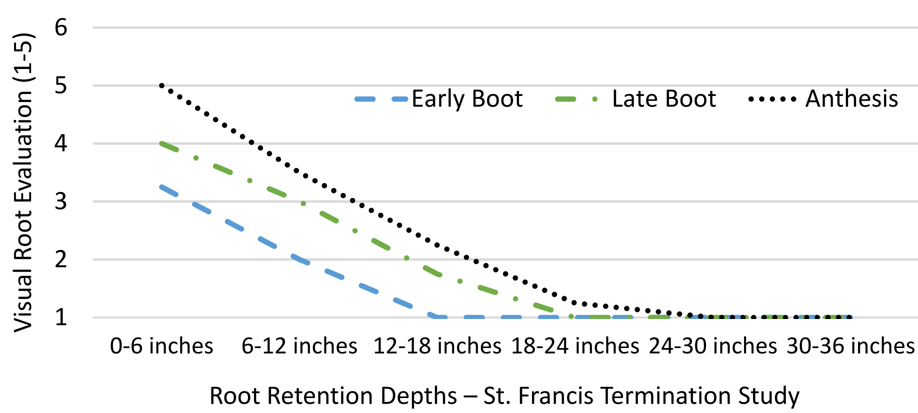

Fig. 1. Visual evaluation at cotton planting of root mass at six soil depths after terminating cereal rye at early boot, late both and anthesis. A rating of 1 represents no visible roots and a rating of 5 indicates 50% of exposed area composed of roots. Test was conducted in St. Francis County on a Loring silt loam soil type.

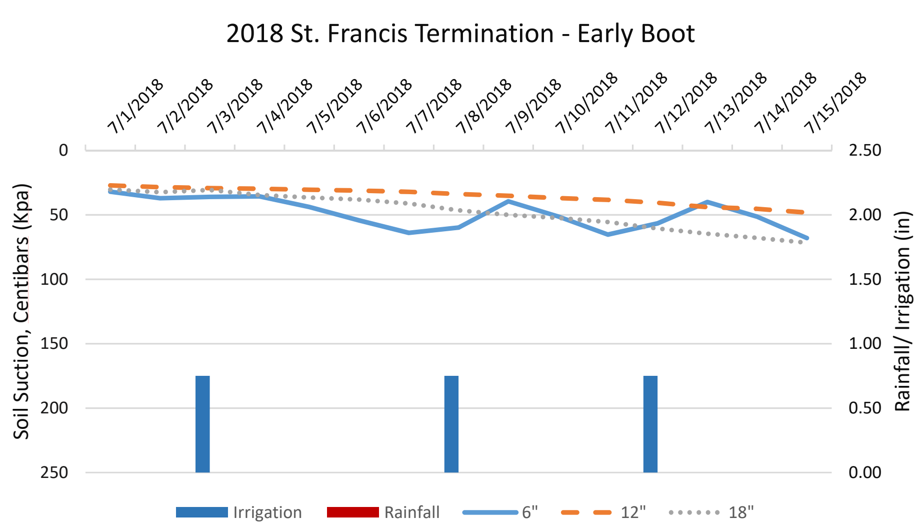

Fig. 2. Water infiltration at three depths in response to irrigation events observed with cereal rye cover crop termination at early boot. Test was conducted in St. Francis County on a Loring silt loam soil type.

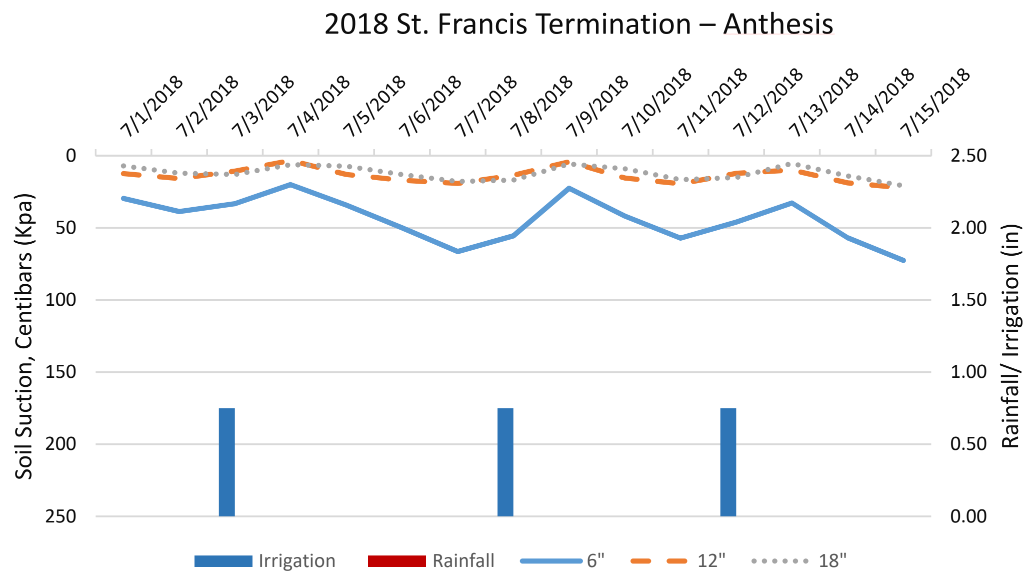

Fig. 3. Water infiltration at three depths in response to irrigation events observed with cereal rye cover crop termination at anthesis. Test was conducted in St. Francis County on a Loring silt loam soil type.

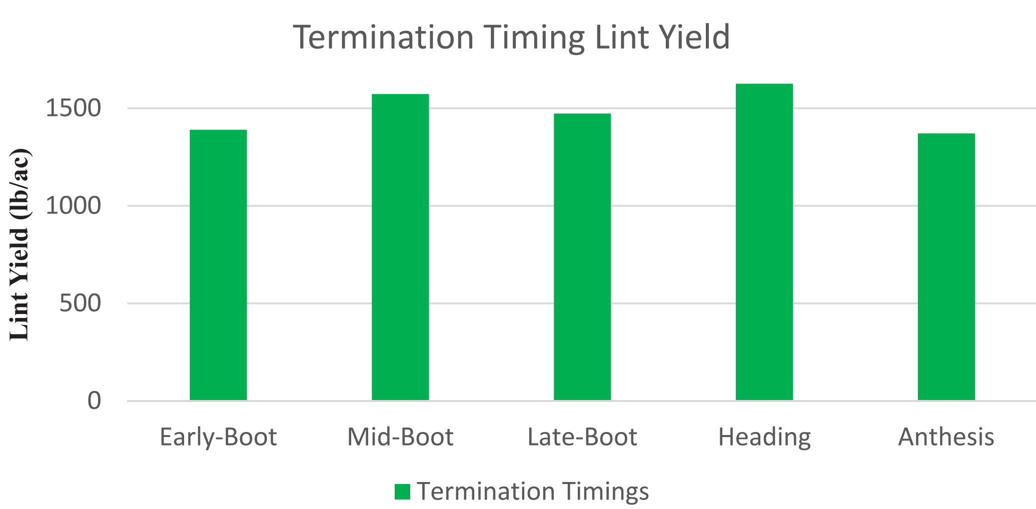

Fig. 4. Lint yield as impacted by cereal rye cover crop termination timings. Test was conducted in St. Francis County in 2018 on a Loring silt loam soil type.

Evaluation of Cotton Yield to In-Season Soil-Applied Potassium

B. Robertson[1], A. Free[1], and C. Manuel[1]

Abstract

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 is to evaluate application timing and rates of K on cotton yield and quality. The on-farm study site was a conventional-tilled, furrow irrigated field. The producer's standard fertility program consisted of three applications at pre-plant, at 4 to 6 leaf, and at 1 week prior to first flower. Two additional treatments consisted of shifting the in-season K applications to either the 4 to 6 leaf or the one week prior to first flower timing. The fourth and final treatment consisting of no in-season applications represented the current University of Arkansas System Division of Agriculture's Cooperative Extension Service recommendation. While no statistical yield differences were observed, it appears that a trend for improved yields may be obtained when shallow rooting conditions exist especially during boll fill.

Introduction

The increased yield potential of new varieties and better management by growers have pushed cotton yields in Arkansas to 3–4 bales/acre. 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 has increased on highly productive soils over the past decade especially in soils with shallow rooting. Providing insufficient K could decrease yields and fiber quality and lead to decreased grower profits. The objective of this study is to evaluate application timing and rates of K on cotton yield and quality. Based on these findings, soil K recommendations will be re-evaluated and modified as appropriate to optimize yields.

Procedures

A three-year, on-farm study site near Judd Hill on a Hayti soil type was selected based on cooperators desire to address their questions on K needs of cotton on their soil and yields. The study site was a conventional-tilled, furrow irrigated field. The study was conducted using a randomized complete block design with 4 replications. Plots were 6 rows (38-inch centers) 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). Two additional treatments consisted of shifting the in-season K applications to either the 4- to 6-leaf or the one week prior to first flower timing. The fourth and final treatment consisting of no in-season applications represented the current University of Arkansas System Divison of Agriculture's Cooperative Extension Service recommendation.

Seedcotton was hand-picked from four plants (one hill) in each plot, then ginned on a table-top gin to calculate percent lint and provide samples for HVI fiber analysis. Plots were machine harvested to calculate seedcotton and lint yields.

Results and Discussion

While not statistically different, a trend was observed for increased yield associated with in-season K applications in 2016 and 2017 when dry conditions were observed during much of boll fill (Table 2). The lack of water infiltration below six inches with the furrow irrigation resulted in a shallow rooting/uptake situation (data not shown). No advantage was observed in 2018 when above average rainfall was received during boll fill allowing the plants to have much deeper effective rooting zone.

Practical Applications

While no statistical yield differences were observed in this study, a trend for improved yields may exist when the effective rooting depth is restricted during boll fill, which results from poor irrigation water infiltration below six inches. In 2018, rainfall received during boll fill was more than double the average of almost 13 inches. This level of rainfall most likely resulted in a much greater effective rooting depth than that normally seen in Arkansas. More research is needed to fully evaluate the impact of soil moisture in plant response to soil-applied K.

Acknowledgements

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

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

Table 1. The producer's standard fertility program utilized all three years of the study.

	Application Timing			
Nutrient	**Pre-plant (lb/ac)**	**4 to 6 Leaf (lb/ac)**	**1 week prior First Flower (lb/ac)**	**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. Lint yield by treatment across the three years of the study.

	Lint Yield (lb/ac)			
K Timing	**2016**	**2017**	**2018**	**Average**
In-season Early + Late	1627	1643	1640	1637
In-season Early Only	1572	1588	1590	1583
In-season Late Only	1459	1650	1745	1618
Pre-plant Only	1413	1581	1740	1578

Evaluation of Soar® Bloom Spray in Cotton

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

Abstract

Cotton producers are looking for ways to improve production and increase yield to help offset low commodity prices. Producers are exposed to a wide range of foliar applied products to enhance yields. Biostimulant products such as Soar® Bloom Spray are marketed to increase uptake of nutrients, and enhance marketable yields on most crops. However, field responses from these products are often erratic. The objective of this study was to evaluate the effects of Soar Bloom Spray on cotton yield in a production field in Arkansas.

Introduction

Recent adoption of yield mapping equipment has allowed producers to identify low yielding areas within production fields. It is not clear if foliar products should be used to boost production in low yielding zones or to preserve and enhance yield potential in all yield zones. The boll load or lack thereof can be an important factor in determining the positive outcome from foliar products.

Good early rooting of cotton is generally experienced in Arkansas. Because of the fragipan nature of our soils, soluble salts accumulate in the profile and pH drops as soils dry in-season. Aluminum toxicity greatly impacts roots deeper than about 6 inches. The chemical interaction with the lack of soil structure results in a chemical hardpan developing around 6 inches that is firmly in place by first flower. When we initiate irrigation after our hardpan has developed, we see poor water infiltration with a single irrigation or rainfall event deeper than 6 inches. As a result, our plants are forced to meet water and nutritional demands at peak needs with a 6 inch effective root zone.

The label of Soar® Bloom Spray states that it is a balanced combination of chelated micronutrients, *Ascophylum nodosum* (seaweed), humic and fulvic acids that activate the production of beneficial enzymes and catalysts within the plant. These biologically active seaweed-based compounds aid in breaking down complex starch molecules (oligosaccharins) providing more available energy to be used in active transport and absorption of minerals. High quality humic and fulvic acids have also been added to the blend to optimize the assimilation and translocation of nutrients. This synergistic mix has been specially formulated to correct and prevent mineral deficiencies and stimulate plant growth, especially during periods of environmental stress. Plant response to this next generation of biostimulant chemistry can result in increased uptake of nutrients, and higher marketable yields on most crops.

Procedures

A replicated field study conducted in 2018 near Forrest City on a pivot-irrigated Loring silt loam soil was utilized to evaluate Soar Bloom spray on DP 1725 B2XF planted on 6 May 2018 and harvested 29 October 2018. Production inputs were based on weekly field inspections and followed University of Arkansas System Division of Agriculture's Cooperative Extension Service recommendations for cotton production. All practices, with the exception of Soar Bloom Spray were consistent across all plots in this study.

Treatment consisted of two in-season foliar applications at the rate of 2.0 qt/ac at pinhead square (PHS) and again at first flower (FF) compared to an untreated control. Each plot consisted of 6 rows (38-inch centers) the length of the field (700 feet). Plots were arranged in a randomized complete block and included six replications. Two study areas were evaluated. One was a conventionally tilled area and the other was a no-till area, which included cereal rye cover crops in an effort to improve soil health. Soar Bloom Spray was applied using a self-propelled plot sprayed calibrated to deliver 15 gal/ac. Lint yield calculated from seedcotton weights from machine picked six-row plots. Turnout was calculated from a grab sample pulled from each plot and ginned on a table top gin. Lint samples were submitted to the Cotton Classing office in Dumas, Arkansas for HVI analysis.

Results and Discussion

Yields from the conventionally tilled study area averaged 1811 lb lint/ac. Yields from the cover crop study were 1530 lb lint/ac. The major difference between the two studies was final plant stand and crop stress. No-till with cover study area averaged between 1.0 and 1.5 plants per foot of row. The conventionally tilled study was in the optimum range of 2.0 to 2.25 plants per foot of row. Both study areas were under the same pivot. Irrigation timings and rates were based

[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.

on the needs of the conventionally tilled area as that represented the vast majority of the fields on the farm that the pivot serviced. Plants in the no-till cover study area were extremely vigorous and much greener than the rest of the field indicating soil moisture and/or nutrient levels were above optimum levels.

Yield response of Soar Bloom Spray did not differ statistically from the control in either test. Soar Bloom Spray treated plots numerically out yielded the untreated check (UTC) by 12 lb lint/acre in the tilled site while the UTC out yielded the treated plot by 8 lb lint/acre in the no-till plot with cover crop. No statistical difference for fiber quality parameters were observed between the Soar Bloom Spray treatment and the untreated control in either study.

Practical Applications

While yields in the study areas differed by about 300 lb lint/acre, both study areas exhibited yields in excess of the state average yield of 1150 lb lint/acre. No statistical yield differences were observed in either study. Expanded testing of Soar Bloom Spray on field areas with historically low yields may help develop strategies, which may improve the efficacy of this product in Arkansas.

Acknowledgements

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

Seasonal Nutrient Losses in Runoff from Cotton

M. Daniels[1], A. Sharpley[2], B. Robertson[3], P. Webb[1], L. Riley[1], A. Free[3], and M. Freyaldenhoven[1]

Abstract

Edge-of-field monitoring of the loss of nutrients in runoff from four fields in a cotton–corn rotation was conducted from 2013 to 2017. Nitrate + Nitrite-Nitrogen (NO_3-N), total N (TN), soluble reactive phosphorus (SRP) and total P (TP) concentrations and mass losses were measured for individual discharge events initiated by both irrigation and rainfall. Cereal rye as a cover crop was planted in two of the fields each fall and terminated weeks before planting in the spring. Total N and TP mass losses from planting to harvest were 3.7% and 4.0%, of total N and P applied as fertilizer, respectively. Total nutrient loss increased linearly with increase in runoff volume from planting to harvest.

Introduction

Cotton producers along with other row crop producers in the Lower Mississippi River Basin (LMRB) are under increased scrutiny to demonstrate that current cotton production systems are environmentally viable with respect to water quality and sustainability (Daniels et al., 2018). These concerns are manifested from regional issues such as hypoxia in the Gulf of Mexico (USEPA, 2018a). Nutrient enrichment remains a major impairment of water quality to the designated uses of fresh and coastal waters of the USA (Schindler et al., 2008). Nutrient runoff from cropland is receiving greater attention as a major source of nutrients from nonpoint sources (Dubrovsky et al., 2010; USEPA, 2018b). This is especially true in the Mississippi River Basin (MRB), as recent model estimates suggest that up to 85% of the phosphorus (P) and nitrogen (N) entering the Gulf of Mexico originates from agriculture (Alexander et al., 2008).

The nutrient runoff effectiveness of conservation practices (CP) on private farms in Arkansas is being evaluated by the Arkansas Discovery Farm Program (Sharpley et al., 2015, 2016). Arkansas Discovery Farms (ADFs) are privately owned farms that have volunteered to help with on-farm research, verification, and demonstration of farming's impact on the environment and natural resource sustainability. The specific objectives for this paper were to 1) determine the cumulative nutrient loss in runoff from May through October and 2) determine the relationship between cumulative nutrient loss and cumulative runoff volume.

Procedures

The study site was located on C.B. Stevens farm in Desha County, Arkansas. Edge-of-field runoff monitoring stations were established below four fields in a cotton and corn rotation for at least the prior 10 years. Cotton or corn on all fields were grown on beds and furrow-irrigated designed with computerized hole selection. During the study period, cotton was grown in all fields in all years with the exception of field DUM3 in 2014 and DUM1 in 2015 where corn was grown. Minimum tillage and stale seedbed was utilized in all four fields in all years. Fertilizer was applied each year after stand establishment and 32% liquid urea N was knifed into the soil (118 lb/ac of N for cotton; 270 lb/ac for corn of N). Phosphorus was broadcast as di-ammonium phosphate (DAP; 18-46-0; 30 lb/ac of P_2O_5 for cotton and 50 lb/ac of P_2O_5 for corn) resulting in remainder of the N application.

At the lower end of each field, automated, runoff water quality monitoring stations were established to: 1) measure runoff flow volume, 2) collect water quality samples of runoff for water quality analysis and 3) measure precipitation. A 60-degree, V-shaped, 8-inch trapezoidal flume that was pre-calibrated and gauged was installed at the outlet of each field (Tracom, Alpharetta, Georgia). The ISCO 6712, an automated portable water sampler (Teledyne ISCO, Inc., Lincoln, Nebraska), was used to interface and integrate all the components of the flow station. All samples were analyzed at the Arkansas Water Resources Lab (Arkansas Water Resources Center, 2018), an EPA-certified laboratory, for total nitrogen (TN), nitrate + nitrite (NO_3^-), total phosphorus (TP) and soluble reactive phosphorus (SRP).

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[2] Professor, Department of Crop, Soil, and Environmental Sciences, University of Arkansas System Division of Agriculture, Fayetteville.
[3] Cotton Research Verification/Sustainability Program Coordinator and Professor/Cotton Extension Agronomist, respectively, University of Arkansas System Division of Agriculture's Newport Extension Center, Newport.

Results and Discussion

Nitrogen and phosphorus nutrient losses in runoff collected during the time between planting and harvest varied among years and fields (Tables 1 and 2). Nitrate-N loss from planting to harvest, ranged from 0.06 to 8.13 lb/ac across all fields and years, while TN ranged from 0.46 to 15.1 lb/ac. Over the same period, SRP ranged from 0.04 to 1.97 lb/ac and TP from 0.38 to 12.1 lb/ac. Average TN and TP losses for years and fields were 3.7% and 4.0%, respectively of N and P applied as fertilizer. The range of percentage loss was from 0.4% to 14.0% of N applied and 0.4% to 8.0% P applied (Tables 1 and 2). Field DUM3 in 2014 and DUM1 in 2015 were planted in corn and total N applied as fertilizer was approximately 40% more than for cotton to better meet N needs of corn, yet TN losses from these two fields were not proportionately higher as compared to cotton fields in those years.

Nutrient loss increased linearly for all nutrient constituents as total runoff increased during the monitoring period (Figs. 1 and 2). Linear regression coefficients suggest that NO_3-N and TN increased by 0.34 and 0.76 lb/ac per inch of runoff, respectively, while SRP and TP increased by 0.14 and 0.18 lb/ac per inch of runoff, respectively. The linear relationships were stronger for SRP and P than for NO_3-N and TN.

Results from this study indicate that only 3.7% and 4% of N and P applied as fertilizer was lost in runoff during the monitoring period. These totals losses did not include non-growing season losses due to missing data during that time so they obviously may be low. However, when calculating N and P uptake by the crop based on yield and losses totaled during May to October, these amounts were very similar to application rates, which may imply that the bulk of losses were accounted for during the May to October period.

Practical Applications

Cotton farmers need assurances that their practices have minimum effects on surrounding water bodies. Runoff volume and cumulative nutrient losses from four cotton fields were highly variable. Cumulative nutrient losses relative to nutrients applied as fertilizer were small. Cumulative nitrogen and phosphorus loss increased linearly with cumulative runoff volume. This implies that increasing infiltration and reducing runoff is an important consideration to keeping nutrients in the field and available for plant use.

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Table 1. Total runoff and nitrate-N (NO_3-N) and total nitrogen (TN) losses from May through October relative to N as fertilizer applied from four fields on C.B. Stevens Farm, Dumas, Arkansas.

Site	Crop	Year	Total Runoff[a]	N Applied as Fertilizer	NO_3-N	Total N	% N Loss in Runoff	Mass loss per unit area per cm of runoff
			inches	--------------------lb/ac--------------------			%	lb/acre-inch
DUM1	cotton	2014	4.51	110	0.95	2.36	2.14	0.52
	corn	2015	1.70	255	0.33	1.09	0.43	0.64
	cotton	2016	0.46	105	0.48	0.73	0.69	1.57
DUM2	cotton	2013	14.27	108	8.13	15.10	14.02	1.06
	cotton	2014	7.85	110	4.79	8.28	7.50	1.05
	cotton	2015	5.31	117	1.92	3.48	2.98	0.66
	cotton	2016	0.69	105	0.20	0.45	0.43	0.66
	cotton	2017	14.55	115	5.32	14.17	12.34	0.97
DUM3	cotton	2013	8.21	108	0.71	1.71	1.59	0.21
	corn	2014	7.39	268	3.22	6.32	2.36	0.86
	cotton	2015	4.46	117	1.47	3.13	2.69	0.70
	cotton	2016	1.61	108	0.17	0.53	0.50	0.33
	cotton	2017	10.40	115	4.45	9.14	7.96	0.88
DUM4	cotton	2013	13.51	108	1.12	3.28	3.05	0.24
	cotton	2014	5.73	110	0.45	2.19	1.98	0.38
	cotton	2015	0.71	117	0.14	0.46	0.40	0.65
	cotton	2016	1.91	105	0.06	0.48	0.46	0.25
	cotton	2017	12.80	115	1.86	6.04	5.26	0.47

[a] Observed total runoff from 1 May to 31 October of each year.

Table 2. Total runoff and soluble reactive P (SRP) and total P (TP) loss from May to October relative to P as fertilizer applied from four fields on C.B. Stevens Farm, Dumas, Arkansas.

Site	Crop	Year	Total Runoff[a]	P Applied as Fertilizer	SRP	Total P	% Loss in Runoff	Mass loss per unit area per cm of runoff
			inches	----------------lb/ac--------------			%	lb/acre-inch
DUM1	cotton	2014	4.51	30	0.25	0.61	2.00	0.13
	corn	2015	1.70	54	0.04	0.28	0.59	0.17
	cotton	2016	0.46	39	0.04	0.17	0.49	0.36
DUM2	cotton	2013	14.27	30	1.97	3.23	12.10	0.23
	cotton	2014	7.85	34	0.91	1.31	4.32	0.17
	cotton	2015	5.31	34	0.36	1.03	3.41	0.19
	cotton	2016	0.69	39	0.04	0.13	0.38	0.19
	cotton	2017	14.55	39	1.58	1.80	5.18	0.12
DUM3	cotton	2013	8.21	30	0.77	1.45	5.43	0.18
	corn	2014	7.39	34	0.97	1.04	3.44	0.14
	cotton	2015	4.46	34	0.19	1.27	4.21	0.29
	cotton	2016	1.61	39	0.20	0.36	1.05	0.23
	cotton	2017	10.40	39	2.32	2.94	8.46	0.28
DUM4	cotton	2013	13.51	30	1.40	2.41	9.03	0.18
	cotton	2014	5.73	34	0.61	1.17	3.88	0.20
	cotton	2015	0.71	34	0.04	0.12	0.38	0.16
	cotton	2016	1.91	39	0.25	0.39	1.13	0.21
	cotton	2017	12.80	39	1.64	2.39	6.90	0.19

[a] Observed total runoff from 1 May to 31 October of each year.

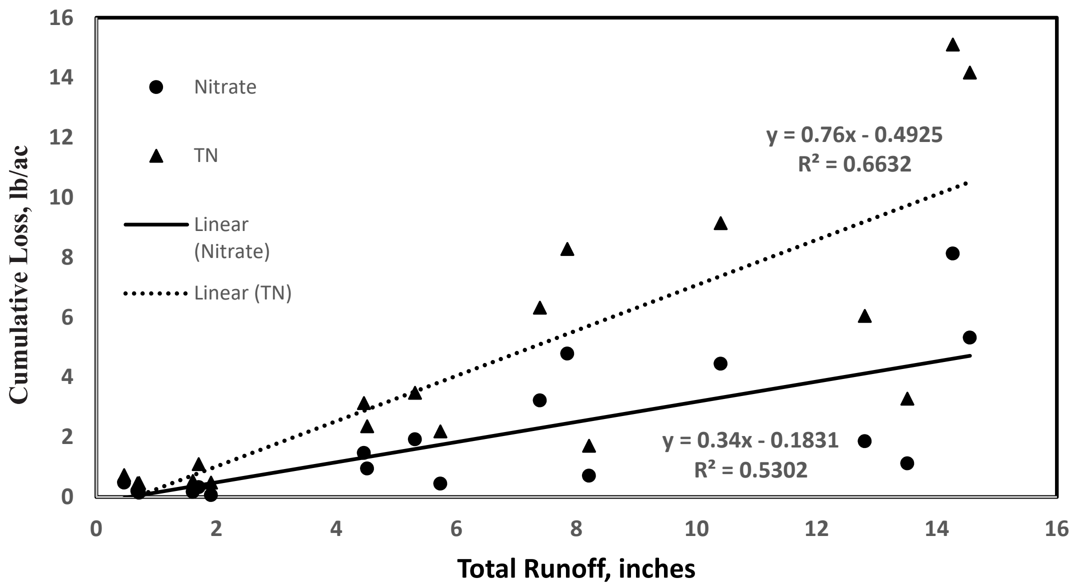

Fig. 1. The relationship between cumulative total nitrogen (T) and nitrate-N losses from May through October to total runoff from four fields on C.B. Stevens Farm, Dumas, Arkansas, in 2014–2017 Cumulative loss for runoff and nutrients was observed from 1 May to 31 October of each year.

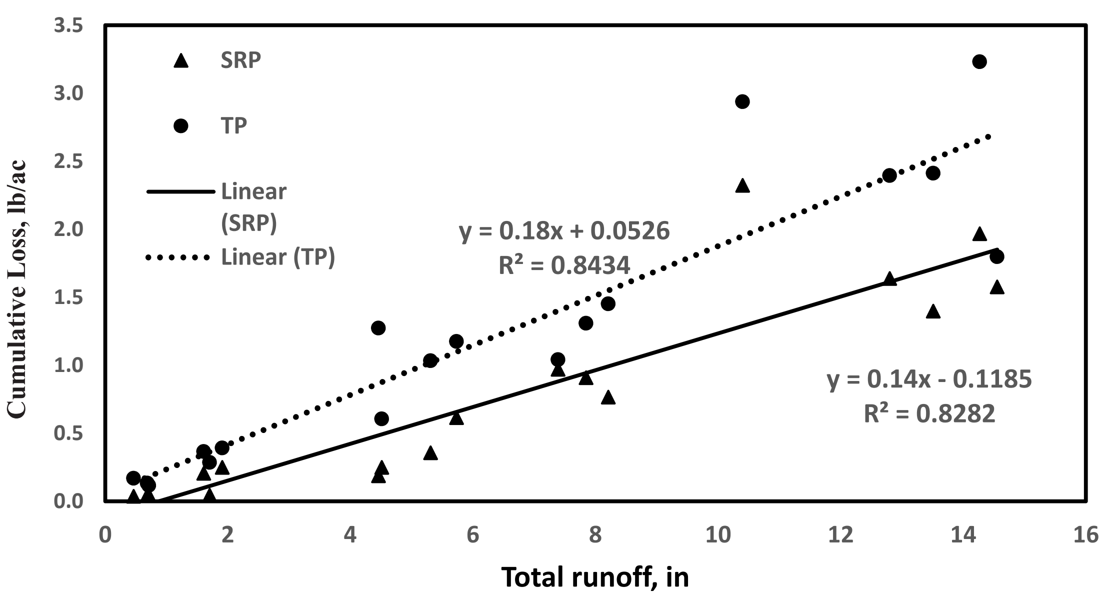

Fig. 2. The relationship between cumulative soluble reactive phosphorus (SRP) and total phosphorus (TP) losses from May through October to total runoff from four fields on the C.B. Stevens Farm, Dumas, Arkansas, in 2014–2017. Cumulative loss for runoff and nutrients was observed from 1 May to 31 October of each year.

Nutrient Losses Associated with Irrigation and Rainfall Runoff Events and Seasonal Field Conditions in Cotton

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Abstract

Edge-of-field monitoring of the loss of nutrients in runoff from four fields in a cotton–corn rotation was conducted from 2013 to 2017. Nitrate + Nitrite-Nitrogen (NO_3-N), total N (TN), soluble reactive phosphorus (SRP) and total P (TP) concentrations and mass losses were measured for individual discharge events initiated by both irrigation and rainfall. Cereal rye as a cover crop was planted in two of the fields each fall and terminated weeks before planting in the spring. Median runoff volumes per event ranged from 0.24 to 0.41 inches across the four fields. Median NO_3-N losses ranged from 0.03 to 0.9 lb/ac while TN ranged from 0.1 to 0.21 lb/ac. Soluble reactive P and TP losses ranged from 0.01 to 0.02 lb/ac and from 0.02 to 0.04 lb/ac, respectively. Mean nutrient losses were compared to contrast losses from irrigation and rainfall events and for field condition relative to time of year.

Introduction

Cotton producers along with other row crop producers in the Lower Mississippi River Basin (LMRB) are under increased scrutiny to demonstrate that current cotton production systems are environmentally viable with respect to water quality and sustainability (Daniels et al., 2018). These concerns are manifested from regional issues such as hypoxia in the Gulf of Mexico (USEPA, 2018) and critical groundwater decline in lower Mississippi Alluvial Aquifer (Reba et al., 2017; Czarnecki et al., 2018). The nutrient runoff effectiveness of conservation practices (CP) on private farms in Arkansas is being evaluated by the Arkansas Discovery Farm Program (Sharpley et al., 2015; 2016). Arkansas Discovery Farms (ADFs) are privately owned farms that have volunteered to help with on-farm research, verification, and demonstration of farming's impact on the environment and natural resource sustainability. The specific objectives for this paper were to 1) contrast nutrient losses from runoff generated from irrigation and runoff generated from rainfall and 2) contrast nutrient losses during the growing season with the non-growing season for fields with a cereal rye crop and no cover crop.

Procedures

The study site was located on C.B. Stevens Farm in Desha County, Arkansas. Edge-of-field runoff monitoring stations were established below four fields in a cotton and corn rotation for at least the prior 10 years. Cotton or corn were grown on beds and furrow-irrigated designed with computerized hole selection. During the study period, cotton was grown in all fields in all years with the exception of field DUM3 in 2014 and DUM1 in 2015 where corn was grown. Minimum tillage and stale seedbed was utilized in all four fields. Fertilizer was applied after stand establishment and 32% liquid urea N was knifed into the soil (118 lb/ac of N for cotton; 270 lb/ac for corn of N). Phosphorus was broadcast as di-ammonium phosphate (DAP; 18-46-0; 30 lb/ac of P_2O_5 for cotton and 50 lb/ac of P_2O_5 for corn) resulting in remainder of the N application.

At the lower end of each field, automated, runoff water quality monitoring stations were established to: 1) measure runoff flow volume, 2) collect water quality samples of runoff for water quality analysis and 3) measure precipitation. A 60-degree, V-shaped, 8-inch trapezoidal flume that was pre-calibrated and gauged was installed at the outlet of each field (Tracom, Alpharetta, Georgia). The ISCO 6712, an automated portable water sampler (Teledyne ISCO, Inc., Lincoln, Nebraska), was used to interface and integrate all the components of the flow station. All samples were analyzed Arkansas Water Resources Lab (Arkansas Water Resources Center, 2018), an EPA-certified lab, for total nitrogen (TN), nitrate + nitrite (NO_3^-), total phosphorus (TP) and soluble reactive phosphorus (SRP).

Each field was statistically analyzed separately as we observed large hydrological differences between fields and fields were irrigated on different dates. To obtain some in-

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sight on the effect of cover crops, we separated runoff events into differences as affected by growing season (G) defined arbitrarily as May 1 to October 3, and the Non-Growing season (NG) defined as November 1 to April 30. We further delineated runoff into those events generated by precipitation (Precip) or irrigation (Irr). The combination of these classes provided: 1) runoff generated by irrigation during the growing season (G-Irr), 2) runoff generated by precipitation during the growing season (G-Precip) and 3) runoff generated by precipitation during the non-growing season (NG-Precip; i.e., November through April). Due to equipment malfunction, data were not collected from DUM1 in 2013. Due to the installation of an elevated turnrow in an adjacent field in early 2017, erosion from the installation contaminated our samples from the study field. Thus data were not collected in 2017, andDUM1 data were not included in all statistical analyses.

Results and Discussion

Runoff volume was summarized for all individual events regardless of year for each field (Table 1). Runoff volume across events was highly variable for each field as the standard deviation was greater than the mean in three fields (Table 1). As a result, median runoff volumes were chosen to describe central tendency and ranged from 0.24 to 0.42 inches from fields DUM1 to DUM2, respectively. Maximum runoff volumes ranged from 2.52 to 5.39 inches from DUM3 and DUM1, respectively.

Similar to runoff volumes, N losses summarized across all years were highly variable among fields as standard deviations approached or exceeded means for mass losses (Table 2). In terms of mass loss, NO_3-N losses ranged from 0.03 to 0.09 lb/ac while TN ranged from 0.1 to 0.2 lb/ac across the four fields. Similar to runoff volume and nitrogen, SRP and TP varied among fields (Table 3). Median mass loss per event for SRP and TP ranged from 0.006 to 0.025 lb/ac and 0.025 to 0.049 lb/ac, respectively.

Mean concentrations for NO_3-N and TN from precipitation-derived runoff events were significantly higher in field DUM2, but were not significantly different for DUM3 and DUM4 (Table 4). Nitrogen losses were significantly greater in DUM2 and DUM3, but not DUM4, for precipitation events in the growing season than non-growing season. This reflects a reduction in N concentration with cover crops (DUM2 and DUM3) as compared to DUM4 where cover crops were not established after the cotton was harvested.

Significant differences in SRP and TP were consistent for concentration and loads (mass loss) among fields and observation periods. Soluble reactive P and TP concentrations in runoff were significantly lower during irrigation-induced runoff events compared with rainfall-runoff events (Table 5). However, there was no difference in SRP or TP in runoff from precipitation-derived events regardless of whether cotton was actively growing or not, even in fields with a cover crop present. The lone exception was that the SRP load per event in field DUM3 was significantly higher in non-growing season than during the growing season even in the presence of a cover crop. While not significantly different, SRP and TP losses were numerically higher in the non-growing season where cover crops were present in fields DUM 2 and 3. It is possible that P losses associated with irrigation-derived events were less than rainfall events due to less detachment and transport of sediment during irrigation than rainfall-runoff

Neither irrigation nor time of year (growing season and non-growing season) had a significant effect on mass loss of NO_3-N and TN in any of the three fields. While significant differences in NO_3-N and TN concentrations were observed, losses per unit area were not significantly different for any observation period or fields (Table 4). The large variability associated with runoff volumes (Table 1) likely masked any statistical difference in nutrient losses per unit area. Unlike N, mass-based unit area losses of P were statistically different as irrigation derived losses were at least 2.5 times lower than precipitation derived losses during both growing season and non-growing seasons (Table 5).

Practical Applications

Cotton farmers need assurances that their practices have minimum effects on surrounding water bodies. Runoff volume and nutrient losses from four cotton fields were highly variable. Nutrient losses were relatively small on an event basis. Phosphorus loss in terms of mass per unit area was significantly less than for that associated with runoff derived from rainfall. Rainfall runoff can cause soil particle detachment and have increased water velocity down furrows compared to trickling irrigation water. Fields DUM2 and DUM3 both had cover crops and nitrogen concentration in runoff water that were significantly smaller during the time that cover crops were growing, while there was no difference in DUM4, which did not have cover crops. Overall the losses are sufficiently small so that differences in management practices are hard to quantify by comparing runoff on an event basis. Little data for nutrient losses from cotton fields exist. These data will inform policy makers and modelers when trying to identify sources of nutrients.

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Table 1. Summary of runoff volume in four fields on C.B. Stevens Farm in 2014–2018.

Field	Number of Events	Median	Mean	Standard Deviation	Minimum	Maximum
		inches				
DUM1	70	0.24	0.44	0.83	0.00	5.39
DUM2	119	0.42	0.60	0.41	0.01	2.72
DUM3	108	0.34	0.40	0.39	0.01	2.52
DUM4	107	0.33	0.48	0.54	0.00	2.87

Table 2. Mean and median concentrations and mass loss of Total Nitrogen (Total N) and Nitrate + Nitrite–N (NO_3^-N) per event in four fields on C.B. Stevens Farm, Dumas, Arkansas, in 2014–2018 (3 years for DUM1; 5 years for DUM2, DUM3 and DUM4).

	Total N					NO_3^-- N				
Field	Mean	Median	S.D.	Min	Max	Mean	Median	S.D.	Min	Max
	lb/ac									
DUM1	0.61	0.19	1.33	0.00	8.82	0.28	0.05	0.89	0.00	6.84
DUM2	0.45	0.20	0.61	0.00	4.34	0.23	0.09	0.35	0.00	1.90
DUM3	0.21	0.11	0.40	0.00	3.40	0.10	0.04	0.27	0.00	2.39
DUM4	0.17	0.10	0.23	0.00	1.64	0.05	0.03	0.08	0.00	0.64

Table 3. Mean and median concentrations and mass loss of Total phosphorus (Total P) and soluble reactive phosphorus (SRP) in four fields on C.B. Stevens Farm, Dumas, Arkansas, in 2014—2018 (3 years for DUM1; 5 years for DUM2, DUM3 and DUM4).

	Total P					SRP				
Field	**Mean**	**Median**	**S.D.**	**Min.**	**Max.**	**Mean**	**Median**	**S.D.**	**Min.**	**Max.**
	-----lb/ac-----									
DUM1	0.09	0.025	0.222	0.001	1.62	0.029	0.006	0.056	0	0.325
DUM2	0.108	0.039	0.152	0	0.967	0.065	0.023	0.091	0	0.456
DUM3	0.102	0.049	0.156	0	1.073	0.06	0.018	0.093	0	0.461
DUM4	0.109	0.042	0.171	0	1.099	0.063	0.025	0.098	0	0.615

Table 4. Mean nitrogen loss by event in runoff for different field conditions and type of runoff in three fields on C.V. Stevens Farm in 2014–2018.

Field	Condition	Nitrate	Total N	Nitrate	Total N
		-------------mgL------------		--------------lb/ac------------	
	Growing - Irrigation	0.96 B[a]	2.37 B	0.11	0.26
DUM2	Growing - Precip.	3.25 A	7.77 A	0.27	0.61
	Non-grow - Precip.	1.59 B	3.47 B	0.18	0.38
	Growing - Irrigation	0.42 A	3.02 A	0.14	0.20
DUM3	Growing - Precip.	0.31 A	3.16 A	0.08	0.16
	Non-grow - Precip	0.12 B	1.56 B	0.04	0.15
	Growing - Irrigation	0.15	1.38 B	0.04	0.04
DUM4	Growing - Precip.	0.19	1.61 BA	0.02	0.05
	Non-grow - Precip	0.55	2.16 A	0.04	0.16

[a] Numbers followed by different letters indicates significant difference at *P* = 0.05. No letters indicate no significant difference.

Table 5. Mean phosphorus by event in runoff for different field conditions and type of runoff generation in three fields on C.V. Stevens Farm in 2014-2018.

Field	Condition	Soluble Reactive P	Total P	Soluble Reactive P	Total P
		---------------mgL------------		--------------lb/ac----------	
	Growing - Irrigation	0.12 B[a]	0.32 B	0.02 B	0.03 B
DUM2	Growing - Precip.	0.42 A	0.85 A	0.05 A	0.08 A
	Non-grow - Precip.	0.49 A	1.02 A	0.06 A	0.12 A
	Growing - Irrigation	0.11 B	0.55 B	0.01 C	0.04 B
DUM3	Growing - Precip.	0.56 A	1.15 A	0.05 B	0.09 A
	Non-grow - Precip.	0.77 A	1.21 A	0.10 A	0.12 A
	Growing - Irrigation	0.14 B	0.34 B	0.02 B	0.03 B
DUM4	Growing - Precip.	0.54 A	1.08 A	0.07 A	0.12 A
	Non-grow - Precip.	0.70 A	1.64 A	0.09 A	0.16 A

[a] Numbers followed by different letters indicates significant difference at *P* = 0.05. No letters indicate no significant difference.

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