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Summaries of Arkansas Cotton Research 2021

Fred Bourland

Summaries of Arkansas Cotton Research 2021

Edited by Fred Bourland

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Cover Photo: Cotton planting day in a replicated, cover crop system evaluation in on-farm research with Wildy Family Farms at the Cooperative Research Farm at the Manila Airport Complex. Sustainable cotton systems compared were either a fall-seeded, terminated, cereal rye winter cover crop or spring-seeded, black oats cover crop system.
Photograph by Tina Teague, Professor, College of Agriculture, Arkansas State University, Jonesboro.

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

Arkansas Agricultural Experiment Station (AAES), University of Arkansas System Division of Agriculture, Fayetteville. Deacue Fields, Vice President for Agriculture. Jean-François Meullenet, AAES Director and Senior Associate Vice-President for Agriculture–Research. WWW/CC2022.

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Summaries of Arkansas Cotton Research 2021

Fred Bourland, Editor

University of Arkansas System
Division of Agriculture
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Fayetteville, Arkansas 72704

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Cotton Incorporated and the Arkansas State Support Committee

The *Summaries of Arkansas Cotton Research 2021* is published with funds supplied by the Arkansas State Support Committee through Cotton Incorporated.

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

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

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

Table 1. Funding for cotton production research in Arkansas in 2020 and 2021.

Researcher	Short Title	2020	2021
Robertson	Cotton Research Verification/Applied Research	$50,000	$50,000
Bourland	Breeding	$26,000	$26,000
Robertson	Increasing Profitability by Reducing Input Costs	$0	$30,000
Faske	BMP for Root-Knot Nematodes and Target Spot	$13,598	$13,598
Rojas	Seed treatment efficacy and cotton seedling	$0	$7,000
Thrash	Impact of water quality on insecticide	$0	$10,000
Lorenz	2 and 3 gene *Bt* and Non-*Bt* for Arkansas	$20,000	$20,000
Barber	Integrated Pest Management for Weeds	$31,351	$31,351
Total		**$140,949**	**$187,949**

Acknowledgments

The organizing committee would like to express appreciation to Christina Jamieson for help in formatting this research series for publication.

Disclaimer

Summaries of
Arkansas Cotton Research
— 2021 —

Review of the 2021 Arkansas Cotton Crop

While the basic growth and development of the cotton plant have not changed significantly in recent history, the business of cotton production is ever-changing. The last two years have seen us plant a crop just about as late as we thought possible, yet extended favorable conditions at season's end have been our salvation, helping to lead us to record yields. The economic environment over the last few years has been such that farmers need to produce record or near-record yields to advance. Unfortunately, production levels at the state yield average barely cover out-of-pocket expenses.

Great uncertainties exist for the upcoming 2022 season as it appears "business as usual" is out the door. While record prices are being seen for cotton lint, record increases in production inputs have far exceeded the pace of the increase of lint value. While we can lock in our lint price, input availability and cost are in question. Without judicious management and use of inputs, many feel it could be possible to not pay out even with cotton over $1.00 per pound. The need for recommendations of unbiased research-based cotton production practices is perhaps as great now as it has ever been. We are fortunate in Arkansas that publications such as this contain the latest research that validates and serves to fine-tune existing recommendations and is freely available to all.

Overview

Cotton acreage in Arkansas has increased from an all-time low of 210,000 acres in 2015 and has basically leveled off to around 500,000 acres. Arkansas producers planted 480,000 acres, down from the intentions of 490,000 released in March by USDA-NASS https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Releases/Prospective_Plantings/2021/arplant21.pdf. Producers harvested 475,000 acres in 2021, down 9 percent from 2020. The yield averaged 1,263 pounds per harvested acre, a new Arkansas yield record and up 84 pounds from last year. Production was approximately 1.25 million bales https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Releases/Annual_Summary/2021/arannsum21.pdf. Our current five-year average is 1,187 lb lint/ac. Arkansas currently ranks third in cotton production behind Texas and Georgia https://downloads.usda.library.cornell.edu/usda-esmis/files/k3569432s/sn00c1252/g158cj98r/cropan22.pdf.

Planting

Essentially all cotton plantings in 2021 contained traits for enhanced insect and weed control. The Cotton Varieties Planted report released by Agricultural Marketing Service was discontinued in 2021. Therefore, no official estimate is available for cotton plantings in 2021. An informal survey of crop consultants statewide was conducted by the University of Arkansas System Division of Agriculture in late June for the purpose of submitting to the Cotton Varieties Planted publication. Results of the unofficial survey indicated that 12 varieties accounted for just over 90 percent of the acres planted statewide in 2021 and are as follows:

Variety	Planted Acres (%)
DP 2038 B3XF	18.2
DP 2020 B3XF	14.1
DP 2012 B3XF	13.7
NG 4936 B3XF	11.3
DP 1646 B2XF	10.6
ST 4990 B3XF	10.1
ST 4993 B3XF	3.5
PHY 400 W3FE	2.4
DP2127 B3XF	2.3
NG 3195 B3XF	1.5
ST 5091 B3XF	1.5
ST 4550 GLTP	1.5

Based on this survey, it is estimated that 95% of the cotton varieties planted in 2021 contained XtendFlex® herbicide-tolerant traits (XF). Plantings of varieties containing the Enlist™ weed control system traits (FE) were estimated at 3.5% in 2021. The remaining 1.5% of the cotton acres were planted to cotton with traits for herbicide tolerance to only glyphosate and glufosinate.

A big shift occurred to three-gene *Bt* varieties in 2021. Varieties containing three-gene *Bt* traits increased to just less than 90% of the acres statewide. The three most widely planted varieties, DP 2033 B2XF, DP 2020 B3XF, and DP 2012 B3XF, accounted for 46% of acres. In 2020, DP 1646 B2XF accounted for 49% of acres.

Cotton planting progress essentially mirrored that of 2020. In 2021, the early planting window, which we generally have in April, never materialized. Subsequently, we only planted about 7% of our crop in April compared to our five-year average of 17% for this timeframe (https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Progress_&_Condition/2021/index.php). Planting progressed slowly and trailed behind the five-year average to the very end of planting due to numerous rainfall events. We were only 45% planted in mid-May at the end of our optimum planting window compared to the five-year average of 60% for the same period. While not planned, some producers' planting windows extended into June.

Fruiting and Harvest

The condition of most of the crop was good to excellent all season long. Reports by the United States Department of Agriculture National Agricultural Statistics Service (https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Progress_&_Condition/2021/index.php) indicate the percentage of the acres statewide receiving a rating of excellent never dropped to less than 30% once the crop started flowering. The percent of the crop rated good and excellent was greater than 80% essentially the entire season. The absence of extremely high temperature and the occurrence of relatively high rainfall provided excellent growing conditions throughout the season, especially north of I-40.

While planting progress mirrored 2020, the progress of squaring in 2021 was consistently behind that observed in 2020. Flowering followed the same trend. Our crop continued to be behind that of 2020 through boll opening. Boll opening estimates on the first of September were just over 50% of that observed in 2020. Boll opening did not catch up to that observed in 2020 and that of our five-year average until the end of September.

Rainfall amounts in 2021 were much closer to what is expected compared to the last couple of years. However, the distribution was not. The first six out of seven months were wetter than usual, and the last four out of six months were dry to very dry. A drought was ongoing in central and southern Arkansas as 2021 ended. Temperatures were largely below average through the first half of the year and warmer than normal during the second half.

While 2021 will not be remembered statewide for excessive rain, there was a record-breaking amount across the southeast in June. Rohwer received 9.25 inches of rain on 8 June and another 9.97 inches the next day. A total of 19.22 inches on the 8th/9th of June was the second-largest two-day amount in Arkansas https://www.weather.gov/lzk/2021.htm. Subsequent flooding caused much cotton to be lost, including all cotton research plots at the Rohwer Research Station. Excessive rains occurred in much of central and southeast Arkansas in 2021, resulting in a large amount of variability of lint yield in these regions.

Harvest progress trailed behind that of last year and the five-year average through the end of October. This was due primarily to a late crop and late initiation of harvest aids. Approximately 25% of the crop was not harvested as we reached our target harvest completion date of 1 November. Harvest for some fields was not completed until mid- to late-November. The dryer and warmer than usual weather helped ensure a record-breaking average lint yield of 1263 lb lint/ac of a late crop.

Inputs

In our 2021 Cotton Research Verification Sustainability Program (CRVSP), the average operating cost for cotton was $610.03/ac. Protection chemicals averaged $133.30/ac and were 28% of operating expenses. Seed and associated technology fees averaged $134.56/ac, or 28% of operating expenses, and included 6 fields with a cover crop. Fertilizer and nutrient costs averaged 14% of operating expenses and were $66.43/ac. Tarnished plant bug (TPB) numbers were similar to the 2020 CRVSP fields. Fields were treated an average of 3.75 times compared to 3.33 times in 2020. Each field had an average of 1.25 burndowns and 2.67 herbicide applications for the 2021 season. The average costs for herbicides and insecticides were $56.99 and $47.54, respectively. Pest control represents a big expense and can impact yields greatly.

Costs do not include land costs, management, or other expenses and fees not associated with production. The price received for cotton of $0.62/lb is the estimated Arkansas annual average for the 2021 production year. The average cotton yield for these verification fields was 1,260 lb lint/ac. The average operating costs were $0.39/lb lint, while total expenses averaged $0.50/lb lint.

Yield and Quality

The NASS Annual Summary report projected that producers would harvest 1,263 lb lint/ac. (https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Releases/Annual_Summary/2021/arannsum21.pdf). We currently have 29 active gins in the state. Fiber quality was very good in 2021.

Approximately 95% of bales classed for Arkansas was tenderable, ranking the 4th best across all other cotton-producing states for quality (https://www.ams.usda.gov/mnreports/cnwwqs.pdf). Color grades were very good, with 32.7% of bales receiving color grades of 31 or better, and 65.5% of bales classed received a color grade of 41. Micronaire averaged 4.43, with only 3.4% of Arkansas cotton classed in the discount range for high micronaire. Staple averaged 38.45 and leaf averaged 3.42. Leaf was not a big issue in 2021, with 95.5% of the bales classed receiving a leaf of 4 or less compared to 87.4% and 82.4% in 2020 and 2019, respectively.

Summary

Arkansas ended the 2021 season ranked 3rd nationally in harvested acres (475,000 acres) behind Texas and Georgia, 4th in lint yield on an acre basis (1,263 lb/ac) behind California, Arizona, and Missouri, and 3rd in total production (1,300,000 bales) behind Texas and Georgia. The string of consecutive years with record-breaking or near-record yields is helping to sustain cotton acres. Harvest and ginning capacity are limiting factors for acre expansion. Our current production continues to push our ginning capacity of 29 gins and on-farm picker capacity to the limit. Cotton planting intentions for 2022 reflect an increase of 8% compared to 2021 https://www.nass.usda.gov/Statistics_by_State/Arkansas/Publications/Crop_Releases/Prospective_Plantings/2022/arplant22.pdf.

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

2021 Judd Hill Cooperative Research Station: Overview of Cotton Research

A. Beach,[1] B. Milano,[1] and F.M. Bourland[1]

Background

The University of Arkansas System Division of Agriculture (UADA) 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 UADA to conduct research on other property belonging to the Foundation. Judd Hill is located about 5 miles south of Trumann and 8 miles northwest of Marked Tree. Research at the Judd Hill site has been conducted annually since 2005. The primary soil type at the Judd Hill station is a Dundee silt loam (fine-silty, mixed, active, thermic Typic Endoaqualfs). Furrow irrigation is available on the entire 35-acre block.

Table 1. List of 2021 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 test with 44 entries and conventional test with 16 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests (6 tests evaluating a total of 120 entries)
Fred Bourland	Cotton Breeding	Cotton industry strain tests (total of 772 plots)
Alejandro Rojas	Plant Pathology	2021 National Cottonseed Treatment (NCST) Test
Glenn Studebaker	Entomology	In-furrow seed treatments for control of thrips
Glenn Studebaker	Entomology	Chemical control/variety trial for tarnished plant bug

2021 Conditions and Observations

Accumulative temperatures (DD60s) and rainfall during the 2021 growing season at Judd Hill were similar to historic averages (Table 2). Due to excessive rainfall in April and May, plantings of some tests were delayed. With adequate moisture and good soil temperatures, most plots at Judd Hill achieved excellent stands. Daily high temperatures were relatively mild throughout most of the season, with only four days exceeding 95 °F (Fig. 1). The plants grew well and established excellent boll loads. Insect pressure was light throughout the season. Verticillium wilt at Judd Hill in 2021 was moderate but intense in localized areas. Accumulative DD60s over the season were 7% higher than the historical average and were consistently higher in each month except May. Total rainfall from April through October was similar to the historical average rainfall (Table 2). Harvest was completed in October.

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

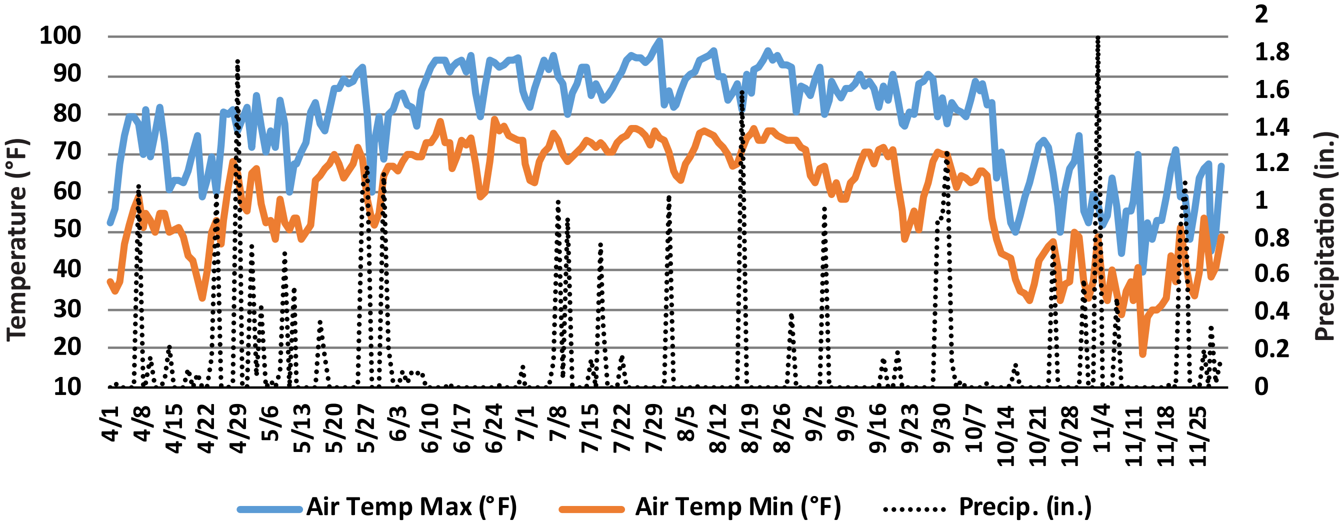

Fig. 1. 2021 Judd Hill temperature and precipitation.

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

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2021	96	270	599	641	642	431	148	2636
Historical avg. DD60s[a]	49	293	522	634	552	348	57	2455
2021 rainfall (in.)	4.8	6.6	0.8	3.6	3.1	3.2	3.0	25.0
Historical 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 = Degree-Day 60.

[b] 30-year average of data collected at the Jonesboro Municipal Airport 1981–2010; http://www.ncdc.noaa.gov/cdo-web/datatools/normals

Acknowledgments

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

2021 Manila Airport Cotton Research Station: Overview of Cotton Research

F.M. Bourland,[1] A. Beach,[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 (see Table 1 for a list of 2021 research at Manila).

Table 1. List of 2021 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 (44 entries)
Bill Robertson	Agronomy	Evaluation of cotton in large-plot on-farm variety testing

2021 Conditions and Observations

Wet conditions delayed the planting of plots at Manila until 18 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. Irrigation events were initiated based on the cooperating producer's standard production practices.

Insect pressure was generally light in 2021. Incidences of bacterial blight and target spot diseases were very light. Harvest was completed by late November. Despite the late planting date, the average lint yield obtained in the 2021 Arkansas Cotton Variety Test at the Manila Airport was the highest achieved since we began conducting the test at this location in 2014 and was the highest of all 2021 locations.

Weather Data

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

Acknowledgments

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

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[1] Professor and Program Technician, respectively, 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.

2021 Northeast Research and Extension Center: Overview of Cotton Research

A. Beach,[1] B. Milano,[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 multiple disciplines, including breeding, variety testing, control of insects, diseases, weeds, soil fertility, irrigation, and agricultural engineering. Innovative practices evaluated at Keiser have included narrow row culture, mechanical harvest (pickers, strippers, and the cotton combine), and the cotton caddy (forerunner to the 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 our other cotton stations and one that has a very low incidence of Verticillium wilt. Since cotton normally does not require the application of mepiquat chloride on this soil type, plants develop unaltered heights at this station.

Table 1. List of 2021 cotton research at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser.

Project leader	Discipline	Title
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (transgenic test, 44 entries and conventional test, 16 entries)
Fred Bourland	Cotton Breeding	National Cotton Variety Test (8 entries), Regional High Quality Strain Test (19 entries) and Regional Breeders' Network Test (28 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests (6 tests evaluating a total of 120 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
Fred Bourland	Cotton Breeding	Evaluation of cotton industry strain tests (68 entries in 272 plots)
Fred Bourland	Cotton Breeding	Evaluation of resistance to tarnished plant bug (TPB) in small plots (136 entries in 928 plots)
Jason Norsworthy	Weed Science	Control of weeds in cotton
Glenn Studebaker	Entomology	Tarnished plant bugs (TPB): Verification of TPB resistance in cultivars and TPB standardized efficacy study
Glenn Studebaker	Entomology	Bollworm in cotton: Efficacy of various *Bt* cultivar technologies and Standardized efficacy study with foliar insecticides
Glenn Studebaker	Entomology	Efficacy of seed treatments and in-furrow insecticides on control of thrips
Glenn Studebaker	Entomology	Cotton aphid standardized efficacy study
Glenn Studebaker	Entomology	Spider mite standardized efficacy study
Gus Lorenz and Ben Thrash	Entomology	Regulated trials (1 trial, 24 treatments, 72 plots)

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

2021 Conditions and Observations

Weather data for Keiser aren't reported due to malfunction of weather recording instruments. Temperatures at Keiser were similar to those reported for the Judd Hill station. Similar to conditions experienced in 2018 through 2020, rainfall in April delayed land preparation at Keiser in 2021. The planting of cotton plots was completed in late May. Adequate moisture and good soil temperatures resulted in good stands in most plots. Except for a period from mid-June to early July, frequent rains caused fields to be relatively wet throughout the season. Both insect and disease incidences were low at Keiser in 2021. Defoliants were applied on time using ground application. Mechanical problems with a plot picker delayed harvest completion until mid-November.

Acknowledgments

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

2021 Lon Mann Cotton Research Station: Overview of Cotton Research

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

Background

The Lon Mann Cotton Research Station (LMCRS) 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. 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 2021 cotton research at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station.

Project Leader	Discipline	Title
Alejandro Rojas	Plant Pathology	Seed treatment efficacy and cotton seeding disease prevalence in Arkansas
Tom Barber	Weed Science	Weed management in Enlist cotton systems
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (Transgenic, 44 entries and Conventional, 16 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
Fred Bourland	Cotton Breeding	Genetics of cotton fiber quality: UA48/GA230 Trait Study, 144 plots; Fiber Quality Gene Sequencing, 16 plots; Fiber quality in cotton NAM families, 480 plots
Fred Bourland	Cotton Breeding	Cotton industry strain tests, total of 400 plots
Gus Lorenz Ben Thrash	Entomology	Thrips trials (3 trials, 21 treatments, 84 plots)
Gus Lorenz Ben Thrash	Entomology	Evaluation of Thryvon cotton for control of tobacco budworm, thrips and tarnished plant bug (117 treatments, 468 plots)
Gus Lorenz Ben Thrash	Entomology	Plant bug trials (6 trials, 47 treatments, 188 plots)
Gus Lorenz Ben Thrash	Entomology	Regulated trials (1 trial, 24 treatments, 72 plots)
Gus Lorenz Ben Thrash	Entomology	Lepidoptera (2 trials, 22 treatments, 88 plots)
Jason Norsworthy Tom Barber	Weed Science	Long-term evaluation of integrated weed management strategies in cotton
Jason Norsworthy	Weed Science	Integrated weed management strategies in cotton

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

2021 Conditions and Observations

As occurred in 2019 and 2020, LMCRS experienced frequent rains and relatively mild temperatures through most of the 2021 growing season (Fig. 1). High rainfall in April (Table 1) delayed land preparation and planting on the station, but most cotton plots were planted before mid-May. Adequate stands were obtained in most plots, but some plots in the lower ends of fields were flooded by early May rains. 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 from April through October were normal (within 10% of the historical averages), with the greatest deviation associated with warmer October temperatures. Rainfall during the same period was 18% higher than the historical average, with the greatest deviations associated with higher rainfall in June and July. Plots were furrow-irrigated as needed. Mepiquat chloride (Pix) to control internode elongation and plant height was required at normal rates. Insect pressure was relatively light, with the primary insect pest being plant bugs. Harvest was completed in early October

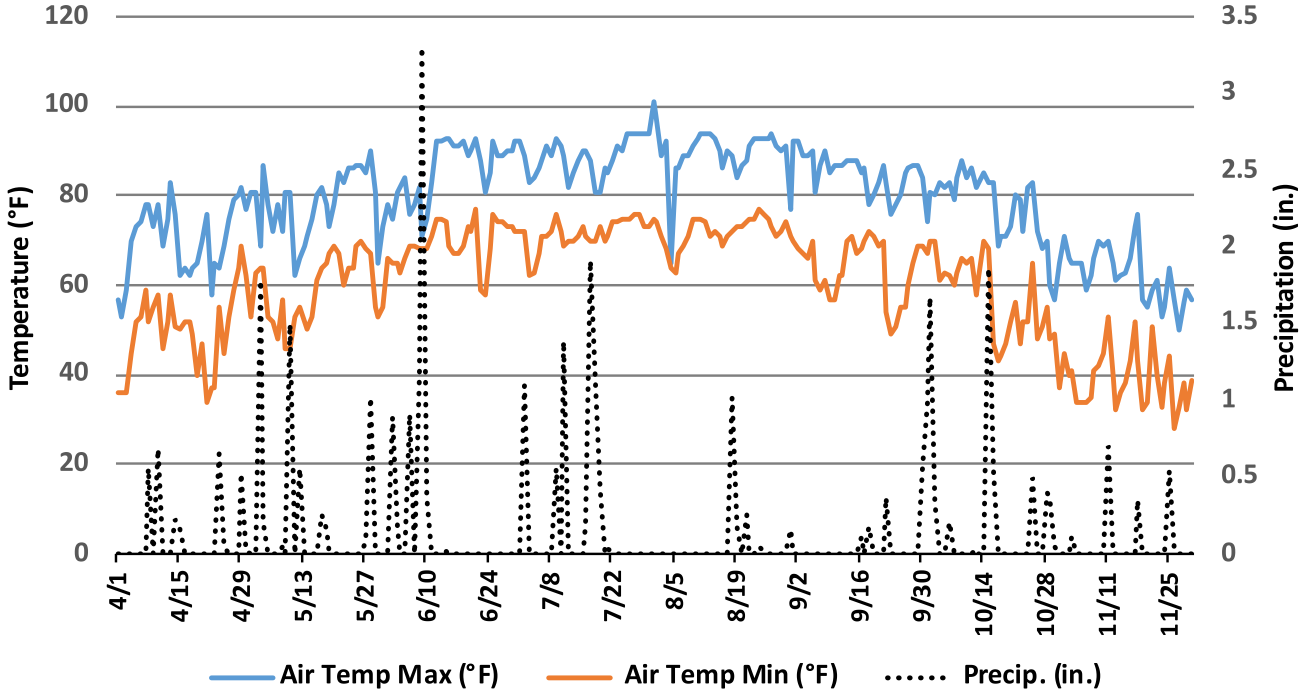

Fig. 1. 2021 temperature and precipitation at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna.

Table 2. Weather conditions at University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2021	99	268	530	634	642	440	248	2860
Historical avg. DD60s[a]	65	339	548	650	594	398	98	2709
2021 rainfall (in.)	2.9	5.6	6.8	6.7	1.7	1.2	6.9	31.9
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 = Degree-Day 60.

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

Acknowledgments

The authors wish to thank the staff at the LMCRS for their assistance in performing research at this station. Support was also provided by the University of Arkansas System Division of Agriculture.

2021 Rohwer Research Station: Overview of Cotton Research

L. Martin[1]

Background

Cotton research has always been a primary focus at the University of Arkansas System Division of Agriculture's Rohwer Research Station, which began operations in 1958. The station includes 635 acres (about 534 acres 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. Cotton research projects conducted at Rohwer in 2021 are listed in Table 1.

Table 1. List of 2021 cotton research at the University of Arkansas System Divison of Agriculture's Rohwer Research Station.

Project Leader	Discipline	Title
Fred Bourland	Cotton Breeding	Arkansas Cotton Variety Tests (Transgenic, 44 entries and Conventional, 16 entries)
Fred Bourland	Cotton Breeding	Cotton Strain Tests (six tests evaluating a total of 120 entries)
Fred Bourland	Cotton Breeding	Cotton breeding trial of 190 Advanced F_6 progenies
Fred Bourland	Cotton Breeding	Cotton observation plots of 960 F_5 preliminary progenies
Terry Spurlock	Plant Pathology	Syngenta Seed Treatment, NPMTI, NCST, Syngenta Foliar

2021 Conditions and Observations

Research trials at Rohwer were planted during the second week of May. Warm temperatures and light rainfall occurred within a few days after planting (Fig. 1). Plant stands were uniform, and no loss of seedlings was noticed. On 8-10 June, the Rohwer station received a total of 19.89 inches of rainfall. The extreme flooding caused approximately 75% plant death in the cotton breeding/variety testing trials. These trials were terminated due to the lack of plant survival on 14 June. Production cotton was replanted on 18 June, after termination of the plots. Defoliation of the replanted cotton began on 5 October, and observations were noted that the majority of cotton plants contained vegetative growth in the top half of plants. The defoliation program was increased in rates and usage of multiple defoliants to achieve desired harvest conditions. The final yield was less than 0.5 bale per acre.

Acknowledgments

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

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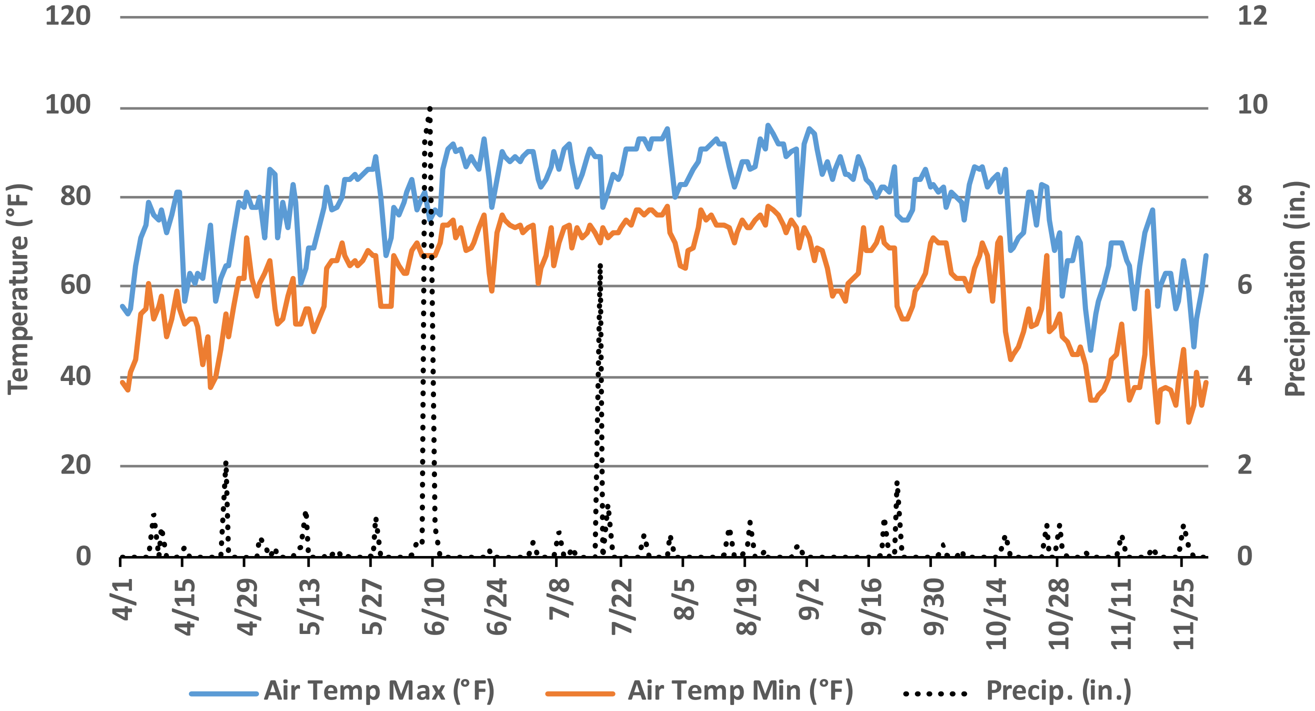

Fig. 1. 2021 temperature and precipitation at the University of Arkansas System Division of Agriculture's Rohwer Research Station.

Table 2. Weather conditions at the University of Arkansas System Division of Agriculture's Rohwer Research Station, Rohwer.

Weather factor	April	May	June	July	Aug.	Sept.	Oct.	Total
DD60s in 2021	108	286	516	626	645	433	263	2857
Historical avg. DD60s[a]	100	354	551	661	618	415	167	2866
2021 rainfall (in.)	4.1	5.6	20.8	9.5	3.0	2.6	2.8	46.4
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 = Degree-Day 60.

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

Cotton Research Verification Sustainability Program: 2021 Economic Report

B. Robertson,[1] A. Free,[1] J. McAlee,[1] B. Watkins,[1] and W. Haigwood[1]

Abstract

The University of Arkansas System Division of Agriculture's Cotton Research Verification Sustainability Program (CRVSP) works with producers to grow cotton more efficiently with the objective of improving profitability. The average return to total specified costs in 2021 was $171.40/ac. The verification field low was -$52.79/ac in the St. Francis FS/NC field, and the high was $515.90/ac in the Judd Hill FS/NC field. Total operating expenses averaged $0.39/lb lint, and total expenses averaged $0.50/lb lint. For cotton to continue being a viable commodity, profitability must continue to 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 343 irrigated fields entered into the program. The success of the cotton program spawned verification programs in rice, soybean, wheat, and corn in Arkansas and similar programs in other mid-South states. In 2014, the CRVP became known as the Cotton Research Verification Sustainability Program (CRVSP). The CRVSP expands beyond that of the traditional verification programs by measuring the producers' environmental footprint for each field and evaluating the connection between profitability and sustainability.

Procedures

The 2021 CRVSP was composed of 12 fields in six locations. Locations included Clay County, Lee County, Lonoke County, St. Francis County, Poinsett County, and Judd Hill Foundation. Two fields were evaluated at each location, providing the opportunity to compare two production strategies. The farmer standard tillage practice was compared to a no-till system with cereal rye cover crop (Table 1).

In the fall of 2020, all no-till cover fields were broadcast seeded with 'Elbon' cereal rye at a target seeding rate of 56 lb/ac. Irrigated fields were either furrow or pivot irrigated. The diversity of the fields in the program reflects cotton production in Arkansas. Field records were maintained, and economic analysis was conducted at the end of the season to determine net return/ac for each field in the program.

Results and Discussion

Most of the cotton in Arkansas was planted in May. Tarnished plant bug (TPB) numbers were similar to past years in the CRVSP fields, which were treated an average of 3.75 times in 2021 compared to 3.33 times and 3.75 times in 2020 and 2019, respectively. The TPB pressure was similar across all fields, which were sprayed 3 to 5 times during the growing season. Each field had an average of 1.25 burndowns and 2.67 herbicide applications for the 2021 season. The average costs for herbicides and insecticides were $56.99 and $47.54, 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 operating costs, as well as total specified costs. Operating costs and total costs/lb lint 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 2.

The price received for cotton of $0.62/lb is the estimated Arkansas annual average for the 2021 production year. The average cotton yield for the verification fields was 1260 lb/ac lint. The average operating cost for cotton in these fields was $483.01/ac. Chemical costs averaged $133.30/ac and were 28% of operating expenses. Seed and associated technology fees averaged $134.56/ac, or 28% of operating expenses. Fertilizer and nutrient costs averaged 14% of operating expenses and were $66.43/ac. The average yield in the verification fields was 1260 lb/ac lint, which was 60 lb/ac over the 2021 enterprise budget. Average operating costs were $0.39/lb lint is equal to the enterprise budget operating costs of $0.39 lb/lint.

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Operating costs ranged from a low of $402.70 in the Poinsett county Farmer Standard No Cover (FS/NC) field to a high of $513.71 in the St. Francis county not till cover (NT/C) field. Returns to operating expenses averaged $310.52/ac across verification fields which was an increase of $92.26/ac over the enterprise budget. The range was from a low of $90.63/ac in the St. Francis FS/NC field to a high of $651.72/ac in the Judd Hill FS/NC field. Average fixed costs were $137.22/ac which led to average total costs of $610.03/ac. The average return to total specified costs was $171.40/ac, compared to $58.10/ac on the enterprise budget. The verification field low was -$52.79 in the St. Francis FS/NC field, and the high was $515.90 in the Judd Hill FS/NC field. Total expenses averaged $0.50/lb lint and were equal to the enterprise budget. While the enterprise budget slightly over-estimated expenses and slightly under-estimated revenue, it still serves as a valuable planning tool for producers. For cotton to continue being a viable commodity, profitability must be improved.

Practical Applications

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

Acknowledgments

The authors would like to acknowledge Cotton Incorporated for its support of this project. The authors would like to thank producers and County Extension agents for their interest and support of this study. Support was also provided by the University of Arkansas System Division of Agriculture.

Table 1. Field location, field name, tillage type with or without cover crop, and irrigation method for 2021 verification fields.

Location	Field name	No-Till Cover crop	Famer Standard till with No Cover	Irrigation Method
Clay	Clay NT/C	X		Furrow
Clay	Clay FS/NC		X	Furrow
Lee	Lee NT/C	X		Furrow
Lee	Lee FS/NC		X	Furrow
Lonoke	Lonoke NT/C	X		Furrow
Lonoke	Lonoke FS/NC		X	Furrow
Poinsett	Poinsett NT/C	X		Furrow
Poinsett	Poinsett FS/NC		X	Furrow
St. Francis	St Francis NT/C	X		Pivot
St. Francis	St. Francis FS/NC		X	Pivot
Judd Hill	Judd Hill NT/C	X		Furrow
Judd Hill	Judd Hill FS/NC		X	Furrow

Table 2. Summary of revenue and Expenses per acre for 12 fields in the 2021 Cotton Research Verification Sustainability Program compared to the online 2021 enterprise budget.

	Field															
Revenue/Expenses	**Clay NT/C[a]**	**Clay FS/NC[a]**	**Judd Hill NT/C**	**Judd Hill FS/NC**	**Lee NT/C**	**Lee FS/NC**	**Lonoke NT/C**	**Lonoke FS/NC**	**Poinsett NT/C**	**Poinsett FS/NC**	**St. Francis NT/C**	**St. Francis FS/NC**	**12 Field Verification Average**	**6 Field NT/C Average**	**6 Field FS/NC Average**	**2021 Enterprise Budget**
Revenue																
Yield (lb)	1355	1364	1458	1824	1423	1377	1062	1141	1215	968	1009	928	1260	1254	1267	1200
Price ($/lb)	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Tot. Crop Rev.	**840.10**	**845.68**	**904.27**	**1130.76**	**882.26**	**835.74**	**658.44**	**707.42**	**753.30**	**600.16**	**625.58**	**575.36**	**779.92**	**777.33**	**782.52**	**744.00**
Cottonseed Value	**224.12**	**225.61**	**241.24**	**301.66**	**235.36**	**227.76**	**175.65**	**188.72**	**200.96**	**160.11**	**166.89**	**153.49**	**208.46**	**207.37**	**209.56**	**198.48**
Expenses																
Seed	212.10	192.40	108.00	93.60	125.16	157.50	122.80	106.60	127.20	109.20	140.16	120.00	134.56	139.24	129.88	123.50
Fertilizer & Nutrients	54.01	54.01	84.23	84.23	67.29	67.29	50.01	50.01	56.98	56.98	86.04	86.04	66.43	66.43	66.43	73.37
Herbicide	27.90	43.11	65.42	65.42	85.61	97.16	44.71	44.71	33.52	39.50	68.38	68.38	56.99	54.26	59.71	94.87
Insecticide	53.94	53.94	58.21	81.10	40.72	40.72	30.76	30.76	49.99	37.07	46.61	46.61	47.54	46.71	48.37	70.36
Other Chemicals	18.71	18.71	29.05	30.65	13.07	13.87	48.98	48.98	28.77	28.77	32.81	32.81	28.77	28.57	28.97	24.38
Custom Applications	31.28	23.78	46.75	39.25	28.00	21.00	56.00	49.00	28.00	28.00	42.00	35.00	35.67	38.67	32.67	14.00
Other Inputs	23.47	23.60	24.97	30.25	24.45	23.79	19.23	20.38	21.45	17.88	18.47	17.30	22.10	22.01	22.20	21.23
Diesel Fuel	9.63	9.84	10.14	9.27	10.07	12.55	7.20	7.20	8.45	8.86	9.31	9.31	9.32	9.13	9.51	12.87
Irrigation Enegry Costs	7.56	7.56	5.67	7.56	11.34	7.56	9.83	9.83	15.12	15.12	6.00	6.00	9.10	9.25	8.94	22.68
Input Costs	**438.60**	**426.95**	**432.44**	**441.33**	**405.71**	**441.44**	**389.52**	**367.47**	**369.48**	**341.38**	**449.78**	**421.45**	**410.46**	**414.26**	**406.67**	**457.26**
Fee's	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50
Repairs and Maintenance[b]	23.27	23.27	23.03	23.27	23.75	23.27	23.56	23.56	24.23	24.23	24.05	22.31	23.48	23.65	23.32	25.19
Labor, Field Act.	7.37	7.53	7.66	6.93	7.75	9.66	5.39	5.39	6.49	6.83	7.20	7.20	7.12	6.98	7.26	10.36
Production Exp.	**490.74**	**479.25**	**484.63**	**493.03**	**458.71**	**495.87**	**439.97**	**417.92**	**421.70**	**393.94**	**502.53**	**472.46**	**462.56**	**466.38**	**458.75**	**514.31**
Interest	10.92	10.66	10.78	10.43	10.21	11.03	9.79	9.30	9.38	8.76	11.18	10.55	10.25	10.38	10.12	11.44
Post Harvest Exp.	224.12	225.61	241.24	301.65	235.36	227.76	175.65	188.72	200.96	160.11	166.89	153.49	208.46	207.37	209.56	198.48
Operating Exp.	**501.66**	**489.91**	**495.41**	**503.46**	**468.92**	**506.90**	**449.76**	**427.22**	**431.08**	**402.70**	**513.71**	**483.01**	**472.81**	**476.76**	**468.87**	**525.75**
Returns to Op. Exp.	**338.46**	**355.79**	**408.88**	**651.72**	**413.35**	**346.86**	**208.69**	**280.22**	**322.24**	**197.48**	**111.89**	**90.63**	**310.52**	**300.59**	**320.45**	**218.26**
Cap. Recovery of Fixed Costs	140.29	144.83	139.52	135.82	150.22	166.62	108.73	108.73	139.38	148.45	143.41	143.41	139.12	136.93	141.31	160.16
Tot. Specified exp.[c]	**641.94**	**634.72**	**634.90**	**614.86**	**619.13**	**673.51**	**558.49**	**535.94**	**570.43**	**551.12**	**657.11**	**628.15**	**610.03**	**613.67**	**606.38**	**685.90**
Returns to Spec. Exp.	**198.16**	**210.96**	**269.37**	**515.90**	**263.13**	**180.23**	**99.95**	**171.48**	**182.87**	**49.04**	**-31.53**	**-52.79**	**171.40**	**163.66**	**179.14**	**58.10**
Operating Exp./lb	0.37	0.36	0.34	0.28	0.33	0.37	0.42	0.37	0.35	0.42	0.51	0.52	0.39	0.39	0.39	0.39
Total Expenses/lb	0.47	0.47	0.44	0.34	0.44	0.49	0.53	0.47	0.47	0.57	0.65	0.68	0.50	0.50	0.50	0.50

[a] Abbreviations: NT/C = no till cover; FS/NC = farmer standard no cover.

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

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

Improving Sustainability: Program to Demonstrate Implementation and Benefits of the U.S. Cotton Trust Protocol and Better Cotton Initiative Better Cotton Program

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Abstract

Cotton produced in the United States is highly prized by the global textile industry for its quality. While American cotton farmers use advanced production methods, they still face sustainability challenges. In response to the documented sustainability demand from retailers and suppliers, Better Cotton Initiative (BCI) launched a Better Cotton program in the United States in 2014. Recently, the U.S. Cotton Industry initiated the U.S. Cotton Trust Protocol (Trust Protocol), a program designed to drive continuous improvement and increase awareness of the benefits of implementing best practices. A field study was established to show standard production practices (conventional tillage without the use of cover crops) compared to a management strategy utilizing cover crops and greatly reduced tillage in an effort to improve soil health and sustainability and to enroll fields into both the Trust Protocol and BCI programs. While altering production practices to improve soil health are generally successful, they do not consistently result in a positive yield response. Once soil health is improved in a field, efforts to reduce expenses to take advantage of the improvements greatly improve the potential to positively impact profitability. Enrolling farms in either program is not a difficult task and should not be a deterrent for producers interested in participating in either of these programs. Documenting our practices is becoming more important to brands and retailers looking to source sustainably produced fibers.

Introduction

The United States is the third-largest cotton-producing country in the world, and its cotton quality is highly prized by the global textile industry. While U.S. cotton producers use advanced production methods, they still face sustainability challenges.

In response to demand from retailers, suppliers, and interested farmer groups, Better Cotton Initiative (BCI) launched a Better Cotton program, https://bettercotton.org/, in the United States in 2014. The BCI program operates a global standard system for sustainable cotton production. To help U.S. farms meet program requirements and set targeted goals for continuous improvement, BCI developed a resource planning template for its seven principles of sustainability. The template emphasizes multi-year objective setting for continuous improvement of production and management systems that farmers can use to evaluate their progress.

Recently, the U.S. Cotton Industry initiated the U.S. Cotton Trust Protocol (Trust Protocol), https://trustuscotton.org/, a program designed to confirm and increase awareness that most U.S. cotton producers are farming responsibly and striving for continuous improvement. The Trust Protocol was developed to help the U.S. cotton production sector reduce its environmental footprint via specific sustainability goals targeted for 2025: 1) a 13% increase in productivity (i.e., reduced land use per pound of fiber); 2) an 18% increase in irrigation efficiency; 3) a 39% reduction in greenhouse gas emissions; 4) a 15% reduction in energy expenditures; 5) a 50% reduction in soil loss; and 6) a 30% increase in soil carbon.

Both BCI and the Trust Protocol programs have similar goals in supporting U.S. farmers in addressing these and other sustainability challenges and improving their performance. This project will help provide data to support “substantial equivalency” between the two programs and would simplify the adoption of both programs for the supply chain. The major limitation currently is scaling up awareness and adoption of the sustainability initiatives. Increasing the working knowledge of sustainability efforts among Extension agents and consultants has a great potential to improve adoption.

The objectives are to 1) establish demonstration fields that show standard production practices (conventional till-

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age without the use of cover crops) compared to a management strategy utilizing cover crops and greatly reduced tillage in an effort to improve soil health and sustainability and to enroll fields into both Trust Protocol and BCI programs; and 2) evaluate changes in operating expenses and profitability and compare to changes in environmental footprint as calculated using the Field to Market Fieldprint Platform.

Procedures

An on-farm study site of 30 ac was selected at the Agricenter International in Memphis, Tennessee. The Agricenter provides multiple opportunities to share educational opportunities for the various segments of the supply chain. One 15-ac field was planted into cover crops with no-tillage (improved soil health and sustainability field), and the other 15-ac field was farmed using conventional tillage without the use of cover crops (standard practice field). The cover crop blend consisting of 25 lb/ac cereal rye, 25 lb/ac black-seeded oats, and 2 lb/ac hairy vetch was broadcasted on the soil surface prior to defoliation in 2020. All production practices were recorded to facilitate the creation of a budget. Seeding rates, in-season pest management, nutrient management, and harvest preparation were adjusted in an attempt to reduce expenses by taking advantage of improved soil health. Field information and inputs were entered into the Field to Market Fieldprint Platform. The study was harvested with an onboard module building cotton picker. Grab samples were collected and ginned to determine lint fraction and fiber quality through high volume instrument (HVI) analysis.

Results and Discussion

Program Enrollment

All commercial cotton fields (50 acres) at the Agricenter were enrolled in both the Trust Protocol and the BCI programs for the 2021 growing season.

Approximately one hour was required to complete the self-assessment forms for each program. Documentation regarding: 1) soil health, water management, and biodiversity composed primarily of conservation plans and contracts with NRCS; 2) nutrient management plan based on routine soil sampling and following nutrient application recommendations; 3) crop protection primarily including approval of chemical storage, application records, scouting reports and pesticide recommendation; and 4) worker well-being as documented in the Agricenter employee handbook were reviewed and organized in preparation of a third-party verification.

The verifier was very knowledgeable of local farming practices, very organized, and clear in his requests. The verifier was satisfied that the documentation needed to fulfill transparency requirements to satisfy the needs of the supply chain was in place and that the Agricenter was in compliance with both programs. The on-site verification for both programs took less than two hours to complete.

Environmental Footprint and Economics

Inputs were adjusted in response to multiple years of diverse cover crops, which contributed to significant improvements in soil health and crop performance. Seeding rates were reduced from 50K seed/ac to 25K seed/ac, which resulted in approximately 1.5 plants per foot of row (38-in. row). Nitrogen fertility was reduced to 60lb N/ac on the improved soil health field. These changes represented modifications of rates near the top of recommended rates to those near the low end of recommended rates for this production system.

Fieldprint platform results showed improved sustainability with the improved soil health field compared to the standard practice field (Table 1). Greenhouse gas emissions and energy use were reduced by over 60% and 70%, respectively. These reductions are well above the 2025 cotton industry goal of reducing greenhouse emissions by 39% and energy use by 15%.

The lower plant population and fertility rate resulted in shorter and easier to manage plants. Trends were seen for increased numbers of beneficial insects season long. However, no differences in pesticide applications were made during the season. A positive yield response was observed with the improved soil health practices (Table 2). Improved net revenue from yield differences and reduced expenses from seeding rates and fertility modifications resulted in a $155.71/ac advantage to the improved soil health field. The standard practice field failed to cover its operating expenses.

Practical Applications

While altering production practices to improve soil health are generally successful, they do not consistently result in a positive yield response. Once soil health is improved in a field, efforts to reduce expenses to take advantage of the improvements greatly improve the potential to positively impact profitability. Greater levels of improved profitability beyond just yield differences are needed to see a shift to the adoption of these practices, which is needed to reach industry sustainability goals.

Enrollment into programs is essential to developing the documentation needed by the supply chain to verify the level of sustainability that currently exists in U.S cotton. This documentation also helps identify areas in which improvements in sustainability can be made. Enrolling farms in either program is not a difficult task and should not be a deterrent for producers interested in participating in either of these programs. Documenting our practices is becoming more important to brands and retailers looking to source sustainably produced fibers.

Acknowledgments

The authors would like to acknowledge Cotton Incorporated and BCI for their support of this project. The authors would also like to thank Agricenter International for their interest and support of this study. Support was also provided by the University of Arkansas System Division of Agriculture.

Table 1. Lint yield and metrics from the Fieldprint calculator used to evaluate sustainability as affected by practices to improve soil health in the 2021 Agricenter International fields.

Parameters	Improved Soil Health Field	Standard Practice Field	% Change Improved vs. Standard
Yield (lb lint/ac)	777	593	23.68
Land Use (ac/lb lint)	0.0013	0.0017	-30.77
Soil Conservation (ton/ac/year)	2.10	9.10	-333.33
Energy use (BTU/lb lint)	5169	8814	-70.52
Greenhouse Gas Emissions (lb CO_2 eq/lb lint)	1.80	2.90	-61.11

Table 2. Summary of revenue and expenses per acre in the 2021 Agricenter International fields.

	Field	
Revenue/Expenses	**Agricenter No-till Cover**	**Agricenter Farmer Standard**
Revenue		
Yield (lb)	777	593
Price ($/lb)	0.62	0.62
Tot. Crop Rev.	**481.74**	**367.66**
Cottonseed Value	**128.52**	**98.08**
Expenses		
Seed	94.14	125.00
Fertilizer & Nutrients	51.75	68.37
Herbicide	70.12	53.58
Insecticide	4.88	14.66
Other Chemicals	26.78	26.78
Custom Applications	14.00	14.00
Other Inputs	11.23	8.57
Diesel Fuel	7.03	8.90
Irrigation Energy Costs	0.00	0.00
Input Costs	**279.93**	**319.86**
Fees	21.50	21.50
Repairs and Maintenance[a]	22.31	22.31
Labor, Field Act.	3.68	5.04
Production Exp.	**327.42**	**368.71**
Interest	7.28	7.62
Post Harvest Exp.	128.52	98.08
Operating Exp.	**334.70**	**376.33**
Returns to Op. Exp.	**147.06**	**-8.67**
Cap. Recovery of Fixed Costs	120.24	131.73
Total Specified Exp.[b]	**454.92**	**508.06**
Returns to Spec. Exp.	**26.82**	**-140.40**
Operating Exp./lb	0.43	0.63
Total Expenses/lb	0.59	0.86

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

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

Arkansas Cotton Variety Test 2021

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Abstract

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

Introduction

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

Procedures

Small Plot Tests

Cotton varieties and advanced strains were evaluated in small plots at Arkansas research sites (Manila, Keiser, Judd Hill, and Marianna) in the 2021 Arkansas Cotton Variety Test. Transgenic and conventional entries were evaluated in separate tests. The 2021 tests at Rohwer were abandoned due to excessive rain and flooding occurring on 8-9 June. Entries in the 2021 Arkansas Cotton Variety Test were evaluated into two groups – transgenic and conventional varieties. The 44 entries in the transgenic test included 3 B2XF, 30 B3XF, 10 W3FE, and 1 GLTP lines, which were evaluated at all five locations. The conventional test included 16 entries and was evaluated at all locations except Manila. Reported data include lint yield, lint percentage, plant height, percent open bolls, yield component variables, fiber properties, leaf pubescence, stem pubescence, and bract trichome density. All entries in the experiments were evaluated for response to tarnished plant bug and bacterial blight in separate tests at Keiser.

Originators of seed supplied seed of their entries treated with their standard fungicides. Prior to planting, all seeds were uniformly treated with imidacloprid (Gaucho®) at a rate of 6 oz/100 lb seed. Plots were planted with a constant number of seeds (about 3.6 seed/row ft). All varieties were planted in two-row plots on 38-inch centers and ranging from 40 to 50 feet in length. Experiments were arranged in a randomized complete block. Although exact inputs varied across locations, cultural inputs at each location were generally based on University of Arkansas System Division of Agriculture's Cooperative Extension Service recommendations for cotton production. Cereal rye was planted in the test plot area at Marianna as a cover crop. Conventional tillage was employed at all other locations. All plots were machine-harvested with 2-row or 4-row cotton pickers modified with load cells for harvesting small plots.

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Large Plot Tests

A group of 10 transgenic XtendFlexvarieties (DG 3456 B3XF, DG 3644 B3XF, DP 1646 B2XF, DP 2020 B3XF, DP 2038 B3XF, DP 2127 B3XF, NG 3195 B3XF, NG 4936 B3XF, ST 4993 B3XF, and ST 5091 B3XF were evaluated at nine locations from Ashley County to Mississippi County. Two Enlist varieties (PHY 400 W3FE and PHY 411 W3FE) were included in seven of the nine locations. 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. The studies were harvested with the producer's equipment. Grab samples were collected and ginned on a laboratory gin for lint fraction and fiber quality.

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.uada.edu/variety-testing/ (Bourland et al., 2022).

Small Plot Tests

The greatest deviation in the 2021 weather data was the excessive rainfall event (19 in. in 30 hr) that occurred on 8-9 June at Rohwer. Heat units were close to historical averages at each Arkansas location. Temperatures exceeding 95 °F were rare—4 days at Judd Hill (99 °F on 31 July; 96 °F on 30 July, 12 August, and 24 August); 2 days at Marianna (101 °F on 31 July and 97 °F on 1 August); and 1 day at Rohwer (24 August). The absence of extremely high temperatures and the occurrence of relatively high rainfall provided excellent growing conditions throughout the season. Rainfall in 2021 was near the historical average rainfall at Keiser/Judd Hill but greatly exceeded historical averages at Marianna and Rohwer.

Variety by location interactions in the transgenic test were significant for lint yield, lint fraction, plant height, percent open bolls, seed index, seed-score, number of seeds per acre, and micronaire. In the conventional test, interactions occurred for lint yield, number of seed per acre, and fiber density. Despite the interactions, several of the top-yielding varieties were similar at each site. Parameters measured at only one location included leaf pubescence, bract trichome density, tarnished plant bug damage, and bacterial blight response. Significant variety effects for each of these parameters were found in both tests.

The transgenic varieties included 17 that were evaluated in both 2020 and 2021. The five transgenic varieties producing the highest two-year yield means over all locations were DP 2127 B3XF, NG 3195 B3XF, ST 5091 B3XF, DP 2115 B3XF, and DG 3535 B3XF. Eight conventional lines were evaluated in both 2020 and 2021. Out of these eight, three new germplasm lines from the UA Cotton Breeding Program produced the highest two-year yield means over all locations.

Large Plot Tests

On-farm plots were established with a wide range of planting and harvest dates. Acceptable plant stands were achieved at each location. Nodes above white flower (NAWF) data were recorded for all varieties to calculate days to cutout. Lint yield was summarized across locations.

Practical Applications

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

Acknowledgments

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

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Evaluation of Cotton in Large-Plot On-Farm Variety Testing in Arkansas for 2021

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Abstract

When selecting 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 relevant 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 objective of this study is to evaluate the 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 also collected for lint fractions. Lint yield was summarized across locations. The relative ranking among varieties was fairly consistent across locations.

Introduction

Yield is often the primary selection criteria used for variety selection. When selecting varieties for planting, a producer should not simply choose the top-yielding variety at any single testing location but look at the averages of several relevant 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 fiber quality parameters should be determined by unbiased testing programs to learn more about new varieties. Plantings of new varieties should be limited to no more than 10 percent of the farm. Acreage of a variety may be expanded slightly if it performs well in the first year. Consider planting the bulk of the farm to four or five proven varieties of different maturity to reduce the risk of weather interactions and to spread harvest timings.

Procedures

Replicated strips that extended the length of the field were planted with the producer's planter. Tests were located across the state. The sizes of the plots averaged approximately 1.1 acres with 4 replications. The Lonoke County trial was not replicated. The study was managed according to the remainder of the field in which the study was located. Two varieties chosen by the seed company were entered for this study: Bayer, Americot, BASF, Phytogen, and Nutrien. Bayer was allowed an extra selection based on its market share. The check variety consisted of DP 1646 B2XF as it was the most widely planted variety in Arkansas in 2020. The study was harvested with the producer's picker and weighed with platform scales. Grab samples were ginned on a tabletop gin to determine lint fraction.

Results and Discussion

On-farm plots were established at 7 locations (Table 1). These trials were stretched over the eastern Arkansas Delta Region from Portland (Ashley County) up to Manila (Mississippi County). The tests represented a wide set of different soil types, as well as weather events that happened through the course of the growing season. Each trial was managed by the producer to fit their management practices for the variety that the remainder of the field was planted with. Only one county trial was planted within the optimum planting window (1 May – 10 May), with the rest being planted after that. Harvest dates ranged from the start of October into the middle of November.

Yields were summarized across all locations (Table 2). Varieties are ranked from highest to lowest yields for each county trial and organized on the table by their average ranking across all locations. Planting dates may have led to some variability among varieties. However, the top four varieties ranked in the top half greater than 70% of the time, with the top variety being in the top half 100% of the time. The yield averages across all locations for all the varieties in the test were higher than the 2021 state average yield of 1,263 pounds (USDA-NASS, 2022). It is important to note that these are all good, well-established varieties that have gone through much testing before being entered into this trial. Although a variety may have been at the bottom of the rankings in these tests, this does not mean it does not have a place within Arkansas cotton production.

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Practical Applications

There were some differences between varieties across the state trials. Some varieties that performed very well at several locations also had locations where they were outperformed by lower-ranking varieties. It is important to select four or five varieties to plant across the farm as one variety may not work for every field. Producers should look for varieties that will do well in their soil type and with their cultural farming practices to aid in maximizing yield potential.

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Table 1. Planting, harvest dates, final plant population, soil type and irrigation type for the 2021 Arkansas large-plot variety testing program.

	Ashley County	Desha County	Jefferson County	Lonoke County	Mississippi County	Poinsett County	St. Francis County
Planting Date	5/22/2021	5/7/2021	5/19/2021	5/16/2021	5/19/2021	5/20/2021	5/23/2021
Harvest Date	10/19/2021	11/4/2021	10/27/2021	10/5/2021	11/6/2021	11/1/2021	11/15/2021
Plant Population	35599	32689	34899	33752	36618	29594	41922
Soil Type	Hebert Silt Loam	Sharkey and Desha Clays	Coushatta Silt Loam	Caspiana Silt Loam	Keo Silt Loam	Dundee Silt Loam	Loring Silt Loam
Irrigation type	Furrow	Furrow	Furrow	Furrow	Center Pivot	Furrow	Furrow

Table 2. Lint yield and ranking (R) of varieties in the 2021 Arkansas large-plot variety testing program.

	Ashley County		Desha County		Jefferson County		Lonoke County		Mississippi County		Poinsett County		St. Francis County		Average Rank	
Variety Name	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
NG 3195 B3XF	1469	2	1357	6	1390	3	1126	5	1854	4	1639	2	1905	1	1534	3.5
PHY 411 W3FE	1562	1	1671	1	1460	1	1120	6	1631	11	1659	1	1716	4	1546	3.6
DP 2127 B3XF	1460	3	1320	9	1291	9	1190	3	1915	2	1601	3	1807	2	1512	4.7
DP 2038 B3XF	1425	4	1314	10	1407	2	1281	1	1946	1	1532	5	1627	10	1505	4.7
ST 5091 B3XF	1384	6	1386	4	1377	4	1180	4	1734	6	1517	6	1642	7	1460	5.2
ST 4993 B3XF	1323	8	1437	3	1335	6	1099	7	1600	12	1569	4	1651	6	1431	6.6
DP 1646 B2XF	1353	7	1362	5	1356	5	1004	10	1858	3	1495	7	1494	11	1417	6.8
DG 3456 B3XF	1242	12	1329	7	1325	8	1247	2	1804	5	1399	8	1464	12	1401	7.7
PHY 400 W3FE	1389	5	1258	12	1331	7	1068	9	1647	8	1370	10	1716	3	1397	7.7
DP 2020 B3XF	1316	9	1457	2	1199	12	935	12	1674	7	1389	9	1636	9	1372	8.5
DG 3644 B3XF	1304	10	1324	8	1234	11	1092	8	1642	9	1280	12	1641	8	1360	9.4
NG 4936 B3XF	1302	11	1307	11	1274	10	971	11	1637	10	1302	11	1666	5	1351	9.9
LSD *P* = 0.05	75.6		165.7		79.5		Not replicated		84.5		153.2		121.2			

BREEDING AND PHYSIOLOGY

University of Arkansas System Division of Agriculture's Cotton Breeding Program: 2021 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 over 100 germplasm lines and varieties. A strong breeding program relies upon continued research to develop techniques that can be used to identify genotypes with favorable genes. Improved lines that possess these favorable genes are subsequently selected and evaluated.

Introduction

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

Procedures

Conventional breeding lines and strains are annually evaluated at multiple locations in the University of Arkansas System Division of Agriculture's Cotton Breeding Program. Development and testing of strains generally progress in the following manner: Year 1 (summer)–Initial cross of selected parents at Keiser; Year 1 (winter)–Advance of F_1 generation; Year 2–F_2 segregating populations—modified single-seed descent at Keiser; Year 3–F_3 segregating populations—modified single-seed descent at Keiser; Year 4–F_4 segregating populations - individual plant selections at Keiser; Year 5–F—first year progeny rows at Keiser, Marianna, and Rohwer; Year 6–F_6—Advanced Progenies at Keiser, Marianna, and Rohwer; Year 7–10–Evaluation of strains in replicated Arkansas tests over four Arkansas locations; Year 9–Evaluation of selected strains in regional, multiple state tests and Year 11, If needed, additional testing in Arkansas Conventional Variety Test.

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

Arkansas testing locations include the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center at Keiser (the base of breeding program and testing of all generations), the Judd Hill Cooperative Research Station at Judd Hill (replicated tests of all strains), the Lon Mann Cotton Research Station at Marianna (observation of progenies and replicated tests of all strains), the Rohwer Research Station at Rohwer (observation of progenies and replicated tests of all strains). The Rohwer location was planted in 2021 but lost due to flooding in June.

Results and Discussion

Breeding Lines

Breeding lines evaluated in 2021 were derived from crosses made in 2016 (F_6 generation) through 2021 (F_1 generation). The primary objectives of these crosses included the development of enhanced nectariless lines (with the goal of improving resistance to tarnished plant bug), improvement of yield components (how lines achieve yield), and improvement of fiber quality (with specific use of Q-score fiber quality index). Particular attention has been given to combining the fiber quality of UA48 into higher-yielding lines.

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In addition to the 24 crosses, the 2021 breeding effort also included field evaluation of 24 F_2 populations, 24 F_3 populations, 23 F_4 populations, 960 first year progenies, and 216 advanced progenies. Bolls were harvested from superior plants in F_2 and F_3 populations and bulked by population. Individual plants (1150) were selected from the F_4 populations. After discarding individual plants for fiber traits, ~920 progenies from the individual plant selections will be evaluated in 2022. From the 1st year progenies in 2021, 272 were selected based on field performance. Ones having low fiber quality will be discarded prior to being advanced to 2022 testing. Out of the 2021 Advanced Progeny, 72 F_6 advanced progenies were promoted to strain status. Many of these selected 72 F_6 advanced progenies have either UA48 or UA222 (Bourland and Jones, 2012b) in their pedigrees.

Strain Evaluation

In 2021, a total of 119 strains (72 Preliminary Strains, 18 New Strains, and 29 Advanced Strains) were evaluated in replicated tests at three experiment stations in Arkansas. UA222 and UA48 were included as checks in each test. Over locations, numerical lint yields of 48 and 90 of the 119 strains produced lint yields and quality scores, respectively, that were numerically greater than UA222. Screening for host-plant resistance included evaluation for resistance to seed deterioration, bacterial blight, Verticillium wilt, and tarnished plant bug. Work to improve yield stability by focusing on yield components and improving fiber quality by reducing bract trichomes continues.

Genetic Releases

Genetic releases are a major function of public breeding programs. A total of 101 germplasm lines and eight varieties have been released from this program. These lines represent unique genetic materials that have demonstrated improved yield, yield components, host-plant resistance, and/or fiber quality. Seven conventional varieties released since 2010 include: UA48 (Bourland and Jones, 2012a); UA222 (Bourland and Jones, 2012b), UA103 (Bourland and Jones, 2013), UA107 (Bourland and Jones, 2018a), UA114 (Bourland and Jones, 2018b), UA212ne (Bourland and Jones, 2020) and UA248 (Bourland and Jones, 2021). All of these varieties have produced high yields, expressed excellent fiber quality, are early maturing, and are resistant to bacterial blight.

One variety (UA248) and six improved cotton germplasm lines were released/registered in 2021. All seven lines are resistant to bacterial blight. The variety UA248 possesses fiber quality equal to UA48 but has consistently produced higher yields in most environments. Arkot 0822 is a sister line to UA248 but differs in some traits. The three Arkot 0908 and the two Arkot 0912 lines have generally performed better than any other UA-released variety. They were released as germplasm lines due to a lack of interest in conventional varieties, but one company has expressed interest in releasing Arkot 0908-52 to replace conventional UA48. There is also interest in developing and releasing transgenic forms of these lines.

Practical Applications

The University of Arkansas 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 yields. Released germplasm lines should be valuable as breeding material to commercial and other public cotton breeders or released as varieties. In either case, Arkansas cotton producers should benefit from having genetic lines that are specifically adapted to their growing conditions.

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Characterizing Seed and Lint Indices Using Seed-Score

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Abstract

Cotton varieties differ greatly in seed size, which is expressed as seed index (SI) and amount of lint per seed which is expressed as lint index (LI). Moderate SI and high LI are optimum. Our objective was to develop an index to characterize both SI and LI. Seed-score (S-score) is a computer application that attempts to normalize SI and LI into a single index with penalties for both high and low SI values and for low LI values. Location × variety means (6453 lines of data) for SI and LI, extracted from the 1999 through 2020 Arkansas Cotton Variety Tests, produced mean SI of 10.17 ± 1.07 g and mean LI of 7.01 ± 0.90 g. These data were used to develop the normalization and weighting of factors for S-score. S-score was then calculated for transgenic varieties evaluated in the 2015 through 2020 Arkansas Cotton Variety Tests. Within each year, variety was the major source of variation, and varieties differed for SI, LI, and S-score. S-score among varieties varied by more than 25 points in each data set and was relatively consistent over the years. S-score will most likely be used as a secondary selection criterion in cotton variety development programs as lint yield and fiber quality will remain primary selection criteria. Among high-performing varieties, S-score can differentiate those that have favorable SI and LI values.

Introduction

Seed index (SI) is the gram weight of 100-cottonseed, while lint index (LI) is the gram weight of lint derived from 100 cottonseed. Both SI and LI vary greatly among cotton varieties and are intrinsically associated with field performance. Increased lint yields of cotton varieties over recent years have been accompanied by increased lint percentages (high gin turnouts) and decreased seed size (low SI). Small seed size may be associated with low seed and seedling vigor and can contribute to ginning problems. In contrast, large seed size may be associated with thin seed coats and lower lint yields. Medium-sized seed with increased weight of lint per seed should be favored. Our objective was to develop an index that would characterize both seed size and lint weight per seed. Seed-score (S-score) is a computer application that attempts to normalize SI and LI into a single index with penalties for both high and low SI values and for low LI values. The logic of the S-score is patterned after the logic of the Q-score (Bourland et al., 2010). Seed index in the S-score is handled like micronaire in the Q-score (penalties for both high and low values) and LI is handled like fiber length, length uniformity, and strength in the Q-score (no penalty for high values).

Procedures

Location × variety means (6453 lines of data) for SI and LI were extracted from data associated with the 1999 through 2020 Arkansas Cotton Variety Tests. These data produced mean SI of 10.17 ± 1.07 g and mean LI of 7.01 ± 0.90 g and were used to develop the normalization and weighting of factors for S-score. S-score was then calculated for transgenic varieties evaluated in the 2015 through 2020 Arkansas Cotton Variety Tests.

Results and Discussion

Within each year, variety was the major source of variation, and varieties differed for SI, LI, and S-score. The 2015–2017 data set and the 2018–2020 data set produced 12 and 15 common varieties, respectively. When both data sets were analyzed over years and locations, the greatest source of variation for S-score, SI, and LI was varieties. S-score among varieties varied by more than 25 points in each data set and was relatively consistent over locations and years.

Practical Applications

Selection based on increased lint percentages results in smaller seed size (lower SI). In contrast, selection based on increased lint per seed (LI) results in larger seed size (larger SI). S-score provides a quantitative method of identifying varieties and lines that possess both high LI and moderate SI. S-score will most likely be used as a secondary selection criterion in cotton variety development programs. Primary selection should continue to be placed on lint yield and fiber quality parameters. Without attention to SI, selection for high lint yield tends to be accompanied by increased lint percentage and lower SI. S-score brings attention to seed size by identifying those high performing varieties that have favorable combinations of SI and LI values. Like the Q-score, the accuracy of the S-score increases with the number of samples.

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Thus, Q-score and S-score values averaged over locations should be given more credence than single location values.

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Field Performance of Eleven Runner-Type Peanut Cultivars in 2021 in Mississippi County, Arkansas

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Abstract

The field performance of eleven runner-type peanut (*Arachis hypogea* L.) cultivars was evaluated in an on-farm trial in 2021 near Leachville, Arkansas, in a loamy sand soil previously cropped (2019 and 2020) in cotton (*Gossypium hirsutum* L.). The cultivars, TUFRunner 511 and one of two entries of Georgia 16HO, had greater pod yield compared to Georgia 20VHO. Pod yield average 5,673 lb/ac across all cultivars. No yield-limiting disease was observed. A low population density, 518 individuals/100 cm^3 soil, of the reniform nematode (*Rotylenchulus reniformis*) was detected at plating. Because peanut is a non-host, the reniform density (4 individuals/100 cm^3 soil) drops 99.2% by the end of the season. Newly released runner-type cultivars should be tested to see if they are adapted to the area and have excellent yield potential for northeast Arkansas.

Introduction

The southern root-knot nematode [*Meloidogyne incognita* (Kofold and White) Chitwood] and reniform nematode [*Rotylenchulus reniformis* (Linford and Oliveira)] are the most important, yield-limiting pests of cotton across the U.S. Cotton Belt (Lawrence et al., 2018). Of the two species, the reniform nematode is most problematic in the South-Central U.S., including Arkansas (Khanal et al., 2018). During the 2019 cropping season, it was estimated that approximately 1% (equivalent to 189,000 bales) of the U.S. cotton crop was lost due to R. *reniformis* (Lawrence et al., 2020). In Arkansas, lint yield losses were slightly higher and estimated at 2% (equivalent to 28,000 bales) (Lawrence et al., 2020). Crop rotation, nematicides, and host-plant resistance are all useful management tools to manage the reniform nematode. Crop rotation can be an effective option when non-host or resistant crops are grown in sequence with cotton. Corn (*Zea mays* L.), grain sorghum [*Sorghum bicolor* (L.) Moench], and peanuts (*A. hypogaea* L.) are non-host, while some soybean cultivars [*Glycine max*) (L.) Merr.] are resistant to the reinform nematode. Cotton farmers in Arkansas have incorporated peanut as a rotational crop for both M. *incognita* and R. *reniformis*; however, there is limited information on the suppression of R. *reniformis* densities after one season of peanut. Furthermore, there is limited information on the field performance of peanut cultivars in Arkansas. Currently, the most common type of peanut grown in the state is the runner-type peanut (*A. hypogea* L. subsp. *hypogaea* var. *hypogeae*) because of its high yield potential. However, with cultivars being developed in Florida, Alabama, and Georgia, there is a need to evaluate the field performance of these cultivars in Arkansas. Unlike other row crops currently grown in Arkansas, there is no official variety testing program for peanuts in Arkansas. With the renewed interest in peanuts production in Arkansas, a variety trial was established with an overall objective to evaluate eleven peanut cultivars for disease resistance, yield potential, and profitability in northeast Arkansas.

Procedures

Eleven peanut cultivars were planted in a field trial near Leachville, Arkansas. Seed for one cultivar, Georgia 16HO, was provided by two seed sources. The cultivars, both standard and high oleic (High O/L) (Table 1), were planted on 14 May approximately 1-inch deep in a randomized complete block design with four replications. High oleic acid/linoleic acid (O/L) ratios ≥ 9, whereas most traditional or standard cultivars have O/L ratios near 1.5 to 2.0. The high O/L cultivars have a longer shelf life when compared to standard cultivars. Cultivars were planted at a seeding rate of 6 seed/ft of row in a Routon-Dundee-Crevasse complex, loamy sand soil (79% sand, 18% silt, 3% clay) previously cropped in cotton (2019 and 2020). Weeds and diseases were controlled based on recommendations by the University of Arkansas System Division of Agriculture's Cooperative Extension Service. This study was watered by a center-pivot irrigation system. Plots consisted of two 20-ft-long rows spaced 38-in. apart separated by an 8-ft fallow alley. Imidacloprid (Admire Pro®, Bayer CropScience, Research Triangle Park, NC, at 7.0 fl oz/ac) and peanut inoculant (Primo Power CL® traditional liquid for peanut, Verdesian Life Sciences, Cary, N.C., at 7.0 fl oz/ac) were applied in-furrow at planting through a 0.22-in.-diam. (0.55-mm-ID) line meter and a 0.07-in.-diam. (1.8-mm-ID and 4.0-mm-OD) poly tubing using a pressurized sprayer to deliver 9.4 gal/ac.

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Plant stand was assessed on 28 May and 9 June and reported as seedlings per row ft. Plots were dug on 28 October (156 DAP) and thrashed on 20 October with a KMC 3020 two-row thrasher (Kelley Manufacturing Co., Tifton, Ga.) equipment with a bagging system for small plots. Peanut maturity was evaluated on 27 September (136 DAP) based on the percentage of harvestable brown and black pods using the hull scrape method (Williams and Drexler, 1981). Pod yields are reported at 6% moisture. A subsample (approximately 3-lb) of each cultivar was graded by USDA personnel at the Birdsong Peanut facility in Portia, Arkansas. Data were subjected to ANOVA using ARM Software (Version 2021.2) and mean separation by Tukey's honestly significant difference at $P = 0.05$.

Soil samples were collected within three blocks at planting and at harvest to assess the benefit of peanut in rotation with cotton in managing the reniform nematode. Soil samples were a composite of a minimum of 10 soil cores taken 8 to 10 in. deep with a 0.75-in.-diam soil probe. Nematodes were collected with a modified Baermann pan system and enumerated using a stereoscope. Nematode counts were reported as numbers of mixed-life stages per 100 cm^3 of soil.

Results and Discussion

Peanut plant stands at 26 days after planting (DAP) varied among cultivars, but all had an acceptable stand that was close to 4 plants per row feet (Table 2). The greatest ($P \leq 0.05$) number of plants per row feet plant was observed with Georgia 16HO, Georgia 06G, and Georgia 12Y. FloRun 331 and Georgia 07W produced the lowest stands.

Most cultivars grown in Arkansas are in a medium maturity range of approximately 135–145 days. Based on the hull scrape method, Georgia 20VHO had the numerically fewest harvestable pods at 136 DAP (27 September), while Georgia 09B and Georgia 07W had the most.

A greater ($P = 0.05$) pod yield was observed with TUFRunner 511 and Georgia 16HO (GSD) compared to Georgia 20VHO (Table 3). All cultivars, except Georgia 20VHO, had a pod yield above 5,000 lb/ac. All grades were above loan price (73) and ranged from 73 to 79. Although Georgia 20VHO had the lowest yield, it had the highest grade at 79, which was unexpected given the low percentage of mature/harvestable pods at 135 DAP. The immature pods may have passed through the harvester leaving fewer but more mature pods that contributed to a higher grade. Because of the high-grade value, Georgia 20VHO had the highest crop value per ton. In general, high O/L cultivars with a similar yield to a standard peanut had a greater value per acre. For example, Georgia 09B produced 471 lb/ac less than Georgia 18RU, but with the addition of $35/ac for high O/L cultivars, the total value per acre was $51 over that of Georgia 18RU. The cultivars with the greatest total value per acre were TUFRunner 511 and Georgia 16HO (GSD). In 2021, the average cost of peanut production in Arkansas was approximately $430 to $450/ac. At the highest average cost, these cultivars would have ranged from $503 to $772 in profit. These values in profit do not account for premiums in contract prices which in 2021 was an additional $120/ac.

The field was previously cropped for two years in cotton, and the initial reniform nematode population density at planting ranged from 120–733 individuals/100 cm^3 of soil with an average of 518. This population density of reniform nematode is low to moderate for a spring sample for cotton production in Arkansas. The reniform nematode population density at harvest ranged from 3 to 7 individuals/100 cm^3 of soil with an average of 4. Based on the average densities of reniform nematode at planting to harvest, peanuts contributed to a 99.23% decrease in the reniform population. These data support the rotation of peanuts with cotton to help manage reniform nematode populations.

Practical Applications

Reniform nematode and root-knot nematode are both important yield-limiting pathogens that affect cotton production in Arkansas. Peanut is an excellent rotation crop that could help manage these soilborne diseases, and its profitability makes it a good rotational crop for Arkansas cotton producers. These data provide yield information on a few runner-type peanut cultivars that farmers may consider adding in a peanut and cotton rotation.

Acknowledgments

The authors would like to thank the Arkansas peanut producers, Arkansas Peanut Growers Association, University of Arkansas System Division of Agriculture, and National Peanut Board for supporting this research. Furthermore, Wildy Farms for providing space and Mr. Dale Wells for communicating the logistics of planting and harvest. Finally, the gift of seed from Georgia Seed Development and Alabama Crop Improvement Association.

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Table 1. Runner-type peanut cultivars, type, and source used in 2021 in an on-farm cultivar trial in Mississippi County.

Cultivars	Peanut Type	Seed Source
Georgia 06G	Standard	Georgia Seed Development, Plains, Ga.
Georgia 18RU	Standard	Georgia Seed Development, Plains, Ga.
Georgia 12Y	Standard	Alabama Crop Improvement Association
Georgia 07W	Standard	Alabama Crop Improvement Association
Georgia 09B	High O/L	Alabama Crop Improvement Association
Georgia 16HO	High O/L	Alabama Crop Improvement Association
TUFRunner 297	High O/L	Florida Foundation Seed Producers, Inc., Marianna, Fla.
TUFRunner 511	High O/L	Florida Foundation Seed Producers Inc.
FloRun 331	High O/L	Florida Foundation Seed Producers Inc.
AU-NPL 17	High O/L	Alabama Crop Improvement Association
Georgia 20VHO	High O/L	Georgia Seed Development, Plains, Ga.
Georgia 16HO	High O/L	Georgia Seed Development, Plains, Ga.

Table 2. Plant stand counts on eleven runner-type peanut cultivars in a 2021 on-farm trial in Mississippi County.

Cultivars[†]	14 DAP Stand[‡] (28 May)	26 DAP Stand[‡] (9 June)	% Maturity[§] (27 September)
TUFRunner 511	3.5 bc[§]	3.8 ab	50
Georgia 16HO (GSD)	4.3 a	4.0 a	50
AU-NPL 17	4.0 ab	3.9 ab	40
Georgia 06G	4.7 ab	4.0 a	60
FloRun 331	3.3 c	3.2 b	65
TUFRunner 297	4.1 a	3.9 ab	45
Georgia 18RU	3.8 abc	3.8 ab	60
Georgia 16HO (ACIA)	4.3 a	3.9 ab	45
Georgia 09B	4.3 a	3.9 ab	75
Georgia 07W	4.0 ab	3.4 b	80
Georgia 12Y	4.3 a	4.0 a	70
Georgia 20VHO	3.8 abc	3.9 ab	30
P > F	0.0001	0.0009	…

[†] All cultivars are runner-type peanut. GSD = Georgia Seed Development and ACIA = Alabama Crop Improvement Association

[‡] Stand count is the total number of plants per row ft.

[§] Maturity is the percentage of brown and black pods based on harvestable peanuts using the hull scrape method.

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

Table 3. Grade, value, and yield of eleven runner-type peanut cultivars in a 2021 on-farm trial in Mississippi County.

Cultivars[†]	Grade[‡]	% Sound Splits	Value/T[§]	Yield	Value/ac
				lb/ac	
TUFRunner 511	74	5	$395.71	6,178 a	$1,222.35
Georgia 16HO (GSD)	75	4	$399.95	6,133 a	$1,226.45
AU-NPL 17	73	3	$391.73	5,905 ab	$1,156.58
Georgia 06G	77	5	$372.37	5,774 ab	$1,075.03
FloRun 331	73	7	$389.33	5,768 ab	$1,122.83
TUFRunner 297	74	5	$395.74	5,766 ab	$1,140.92
Georgia 18RU	77	11	$368.97	5,733 ab	$1,057.65
Georgia 16HO (ACIA)	73	7	$389.33	5,681 ab	$1,105.89
Georgia 09B	75	4	$399.95	5,544 ab	$1,108.66
Georgia 07W	76	5	$367.56	5,383 ab	$989.29
Georgia 12Y	73	3	$356.73	5,345 ab	$953.36
Georgia 20VHO	79	7	$415.39	4,871 b	$1,011.68
P > F	--	--	--	0.03	--

[†] All cultivars are runner-type peanut. GSD = Georgia Seed Development and ACIA = Alabama Crop Improvement Association.

[‡] Grade (total SMK) was based on USDA standard for peanuts and conducted at Birdsong Peanut in Portia, Ark.

[§] USDA Price Table for 2016 (each SS% >4% docked $0.80/%). Prices also include in addition $35.00 per ton for High O/L.

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

Seed Treatment Efficacy and Cotton Seedling Disease Prevalence in 2021 at Two Arkansas Locations

Q. Fan,[1] R. Guyer,[2] H.M. Kelly,[2] and J.A. Rojas[1]

Abstract

As part of the National Cottonseed Treatment Program, seed treatment trials were established in two locations in Arkansas, Judd Hill (Poinsett County) and Marianna (Lee County). A total of fifteen treatments were evaluated on cultivar DP 1646 B2XF targeting fungal and oomycete soilborne pathogens affecting cotton seedling health. Of the 15 treatments, four treatments were control or standard practices, and the remaining eleven treatments were nominated by industry. Plots were evaluated for plant stand at 30 days post-planting and yield at the end of the season. All treatments had plant stands higher than 81%, mefenoxam alone had the lowest yield, while combinations of three or more active ingredients provided better germination. The average seed cotton yields were 3,545 lb/ac and 3,714 lb/ac for Judd Hill and Marianna, respectively.

Introduction

Seedling diseases of cotton (*Gossypium hirsutum* L.) affect germination and plant stand in fields and can account for losses up to 23% of the lint yield (Rothrock et al., 2012). Seed root, seedling root rot, and damping-off are often the symptoms observed in the field, reducing plant population and also delaying crop development (Kirkpatrick and Rothrock, 2001). The most important pathogens commonly associated with seed and seedling diseases are *Rhizoctonia solani*, *Pythium* spp., *Fusarium* spp. and black root rot caused by *Thielaviopsis basicola* (Toksoz et al., 2009). This complex of pathogens can act alone or in synergy to complicate diagnosis of disease, resulting in lesions on the hypocotyl and root rot that reduce growth and delay development. *Rhizoctonia* may cause seed rot and postemergence damping off. The lesions are reddish-brown at the base of the hypocotyl, and these can progressively thin the stem and cause the girdling of plants (Rothrock, 1996). *Pythium* species are widespread and common in cotton fields, and the effects of the disease are greater at 16–20 ºC (61–68 ºF) and moist conditions, causing devastating effects that result in seed root and root rot, especially in pre-emergence (Kirkpatrick and Rothrock, 2001). *Fusarium* spp. is a common pathogen in cotton seedlings and often acts as a secondary pathogen that colonizes wounded tissue that was first attacked by nematodes or other soilborne pathogens (Kirkpatrick and Rothrock, 2001). *Fusarium*, similar to *Pythium,* can result in preemergence damping off, and if seedlings survive, plants will exhibit necrotic lesions in roots and hypocotyl. Seedlings can also become girdled and wilt (Kirkpatrick and Rothrock, 2001).

Cotton should be planted in soil where temperature favors rapid seed germination and seedling development and with high-quality seed on beds with proper water infiltration and drainage. Growers often plant early to increase the growing season and avoid other pests, such as weeds that could outcompete plants for water or harbor insect pests. However, early planting often exposes seed to moist and cool soils that favor most of the pathogens mentioned earlier. The National Cottonseed Program annually evaluates different fungicide seed treatment's performance on cotton. As part of the participation in the program, we conducted research at two locations in Arkansas to represent distinct environmental conditions and disease pressure. Standard treatments include Allegiance (mefenoxam) that controls *Pythium*, EverGol Prime (penflufen) against *Rhizoctonia solani,* and a combination of Proline and Spera (prothioconazole and myclobutanil) in combination with mefenoxam and penflufen. Single chemistries will help to identify the importance of specific groups of pathogens. Seed treatments are expected to increase plant stand, reducing seed rot and seedling disease.

Procedures

A fungicide seed treatment trial including fifteen treatments was planted at Marianna and Judd Hill on 14 May and 24 May, respectively. Seed from cultivar DP 1646 B2XF was selected, and base treatments containing Gaucho 600 (insecticide - 12.8 oz/cwt) were applied to the seed; the fungicide treatments are identified in Tables 1 and 2. A total of fifteen treatments were planted in a complete randomized

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block design using two-row plots 30 feet long on 38 in. centers, with a planting rate of 4 seeds per foot. Of the 15 treatments included in the study, treatments one through four are standard and/or control treatments. Including insecticide alone, insecticide + mefenoxam (oomyceticide), insecticide + fungicide and insecticide + four fungicides. The other remaining eleven treatments were selected based on recommendations done to the National Cottonseed Treatment Program. Percent germination prior to planting was established for all the different treatments using a moist towel paper using 50 seeds per treatment. Paper was rolled and moistened using sterile distilled water and incubated at 25 ºC (77 ºF) for seven days. The number of seeds with radicles longer than 2 cm were recorded as germinated and percent germination was established.

Stand counts at Marianna were done on 16 June and at Judd Hill were done on 28 June. Data were analyzed with JMP 15 Pro (SAS Institute Inc., Cary N.C.), values with the same letter within a column are not significantly different, where percent stand was analyzed across locations using Mixed Model – Tukey's honestly significant difference means separation with $\alpha = 0.05$ and by location using the Fit Model – Standard Least Squares procedure – Tukey's honestly significant difference means separation with $\alpha = 0.1$.

Plants from the untreated control were collected to establish inoculum pressure and disease severity. Plants collected were assessed for root discoloration and disease index for hypocotyl damage (Pate, 2020). The scale for hypocotyl damage was 1 = no symptoms, 2 = a few pinpoint lesions and diffuse color areas, 3 = distinct necrotic lesions, 4 = girdling lesion, and 5 = dead seedling. The scale for root region was 1 = no symptoms, 2 = 1-10% of root system discolored, 3 = 11-25% of root system discolored, 4 = 26-50% of root system discolored, 5 = 51-75% of root system discolored, and 6 = >75% of root system discolored. Seedlings collected were split into groups of 25, washed in sterile water, and blotted dry in a sterile paper towel. Pathogen isolation was done on semi-selective media: *Pythium* was isolated on CMA-PARPB (Jeffers 1986) and *Rhizoctonia solani* in TSM media (Spurlock et al. 2011). Other groups of seedlings were sterilized in 1% bleach (NaClO), and selective media including MGA was used for Fusarium (Castellá et al., 1997), and TB-CEN (Specht and Griffin 2009) for Thielaviopsis.

Plots were harvested using a plot picker on October 23rd at Judd Hill and November 4 for Marianna. Yield from each row was averaged and converted to seed cotton pounds per acre. Data were analyzed with JMP 15 Pro (SAS Institute Inc., Cary N.C.), where seed cotton yield (lb/ac) was analyzed across locations using Mixed Model.

Results and Discussion

The germination on rolled paper towels resulted in a 64% germination for the base treatment (Gaucho), while treatment 10 had the highest germination with 80%. Base treatment had the lowest, but there is no indication of phytotoxicity. However, field emergence was established as stand counts, these were higher in comparison with a pre-germination test done on rolled paper towel. At the Marianna site, stands counts ranged from 84% for treatment 2 to 98% for treatment 14 (Table 1). Most of the standard treatments (Treatments 1, 2, and 3) were significantly different from the other seed treatments. Of those standard treatments, only treatment four was higher and similar to other proposed treatments that included at least four different chemistries (Myclobutanil, Prothioconazole, Penflufen, Mefenoxam) targeting *Thielaviopsis*, *Rhizoctonia,* and *Pythium*.

At Judd Hill, germination rates ranged from 81% for treatment 9 to 99% for treatment 15 (Table 1). Treatment 15 included five chemistries (Mefenoxam, Ipconazole, Difenaconazole, Azoxystrobin, and Myclobutanil).

Root discoloration was about 50-75% for both locations and disease index in the hypocotyl averaged 2.5 and 2.7 for Marianna and Judd Hill, respectively. Black root rot (*T. basicola*) was in 1 out 25 seedlings at Judd Hill but in none at Marianna. *Fusarium* spp. was found in 24 of 25 and 22 of 25 samples at Marianna and Judd Hill, respectively. *Rhizoctonia solani* isolated was directly from soil at Marianna but not from soil at Judd Hill. From seedlings, 22 and 14 of 25 samples were positive for *Rhizoctonia* at Marianna and Judd Hill, respectively (even though no recovery had occurred in the Judd Hill soil).

Seed cotton yields at Marianna were higher than yields at Judd Hill. Treatment 5 (Mefanoxam, Fludioxinil, myclobutanil, Azoxystrobin, Sedaxane) had the highest yield ($\alpha = 0.1$); however, most treatments were similar or not different from the control treatment (Table 2).

Practical Applications

Management of seedling diseases relies mostly on the use of seed treatments for the control of fungal and oomycete soilborne pathogens. The continuous monitoring of chemistries to effectively control pathogens will aid the decision-making process for the coming season. In addition, the development of tolerance against chemistries by soilborne pathogens is a major risk, and it is necessary to monitor for pathogen resistance. This paper reports the results of research only. The mention of a pesticide in this paper does not constitute a recommendation.

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Table 1. Effects of seed treatments on cotton seedling stands at Marianna and Judd Hill, Arkansas, locations of the 2021 National Cottonseed Treatment Program. Emergence is expressed as percentages of plant emerged of the total plants per row. Values per plot were averaged for each replicate.

Product and Rate	Treatment	Marianna Emergence		Judd Hill Emergence	
(oz/cwt)		(%)		(%)	
NTC - Gaucho Only 12.8	1	84.9	CD[†]	82.3	D
Allegiance Fl 1.5 Gaucho 12.8	2	84.2	D	87.5	BCD
Evergol Prime 0.64 Gaucho 12.8	3	89.9	BCD	94.4	ABC
Spera 1.85 + Proline 480 Sc 0.16 + Allegiance Fl 0.75 + Evergol Prime 0.32 + Gaucho 12.8	4	93.2	AB	92.3	ABC
Apron Xl Ls 0.32 + Maxim 4FS 0.08 + Vibrance Cst 4.08 + Gaucho 12.8	5	94.2	AB	92.3	ABC
Apron Xl Ls 0.32 + Maxim 4fs 0.08 + Vibrance Cst 4.08 + A20597b 0.195 + Gaucho 12.8	6	94.8	AB	92.0	ABC
Apron Xl Ls 0.32 + Maxim 4FS 0.08 + Rally 0.84 + Vibrance Cst 4.08 + Saltro 10.6 + Gaucho 12.8	7	95.6	AB	88.2	BCD
Spera 1.25 + Stamina 1.7 + Systiva 0.94 + Allegiance Fl 0.75 + Gaucho 12.8	8	94.5	AB	91.0	ABCD
Spera 1.25 + Proline 480 Sc 0.16 + Fluoxastrobin FS480 0.32 + Evergol Prime 0.32 + Allegiance Fl 0.75 + Gaucho 12.8	9	92.1	ABC	86.9	CD
Spera 1.25 + Proline 480 Sc 0.16 + Fluoxastrobin FS480 0.32 + Evergol Prime 0.32 + Allegiance Fl 0.75 + Evergol Xtend	10	92.7	AB	97.0	AB
Spera 1.25 + Proline 480 Sc 0.16 + Fluoxastrobin Fs480 0.32 + Evergol Prime 0.64 + Evergol Xtend	11	90.5	BCD	92.9	ABC
Kabina St 0.69 + Rally 0.84 + Allegiance-Fl 1.5 + Maxim 4fs 0.16 + Gaucho 12.8	12	91.0	ABCD	93.6	ABC
Kabina ST 0.35 + Vibrance CST 3.06 + Maxim 4 FS 0.16 + Allegiance (Mefenoxam) 0.75 + Rally 0.84 + Gaucho 12.8	13	91.6	ABCD	89.8	ABCD
Kabina ST 0.35 + Evergol Xtend	14	98.0	A	94.3	ABC
Mefenoxam 0.64 + Ipconazole 0.085 + Difenaconazole 0.25 + Azoxystrobin 3.5 + Myclobutanil 2.25 + Biost VPH 7.75 + Gaucho 12.8	15	94.9	AB	99.1	A

[†] Data were analyzed with JMP 15 Pro (SAS Institute Inc., Cary N.C.). Values with the same letter within a column are not significantly different, where percent emergence was analyzed by location using the Fit Model–Standard Least Squares procedure–Tukey's honestly significant difference means separation with alpha = 0.05.

Table 2. Effects of of cotton seed treatments on seedcotton yield in the Marianna and Judd Hill locations part of the 2021 National Cottonseed Treatment Program.

		Seedcotton Yield			
Product and Rate	Treatment	Judd Hill	Marianna	Average by Treatment†	
(oz/cwt)		---------------------(lb/ac)---------------------			
NTC - Gaucho Only 12.8	1	3204.1	3348.9	3276.5	B
Allegiance Fl 1.5 Gaucho 12.8	2	3809.1	3602.2	3705.6	AB
Evergol Prime 0.64 Gaucho 12.8	3	3542.9	3722.0	3632.4	AB
Spera 1.85 + Proline 480 Sc 0.16 + Allegiance Fl 0.75 + Evergol Prime 0.32 + Gaucho 12.8	4	3751.0	3427.9	3589.5	AB
Apron Xl Ls 0.32 + Maxim 4FS 0.08 + Vibrance Cst 4.08 + Gaucho 12.8	5	3717.1	4273.7	3995.4	A
Apron Xl Ls 0.32 + Maxim 4fs 0.08 + Vibrance Cst 4.08 + A20597b 0.195 + Gaucho 12.8	6	3596.1	3815.1	3705.6	AB
Apron Xl Ls 0.32 + Maxim 4FS 0.08 + Rally 0.84 + Vibrance Cst 4.08 + Saltro 10.6 + Gaucho 12.8	7	3325.1	3937.3	3631.2	AB
Spera 1.25 + Stamina 1.7 + Systiva 0.94 + Allegiance Fl 0.75 + Gaucho 12.8	8	3552.6	3704.2	3628.4	AB
Spera 1.25 + Proline 480 Sc 0.16 + Fluoxastrobin FS480 0.32 + Evergol Prime 0.32 + Allegiance Fl 0.75 + Gaucho 12.8	9	3325.1	3452.1	3388.6	B
Spera 1.25 + Proline 480 Sc 0.16 + Fluoxastrobin FS480 0.32 + Evergol Prime 0.32 + Allegiance Fl 0.75 + Evergol Xtend	10	3601.0	3868.4	3734.7	AB
Spera 1.25 + Proline 480 Sc 0.16 + Fluoxastrobin Fs480 0.32 + Evergol Prime 0.64 + Evergol Xtend	11	3286.4	3667.5	3476.9	AB
Kabina St 0.69 + Rally 0.84 + Allegiance-Fl 1.5 + Maxim 4fs 0.16 + Gaucho 12.8	12	3634.8	3636.9	3635.8	AB
Kabina ST 0.35 + Vibrance CST 3.06 + Maxim 4 FS 0.16 + Allegiance (Mefenoxam) 0.75 + Rally 0.84 + Gaucho 12.8	13	3412.2	3598.5	3505.4	AB
KABINA ST 0.35 + Evergol Xtend	14	3789.7	3909.5	3849.6	AB
Mefenoxam 0.64 + Ipconazole 0.085 + Difenaconazole 0.25 + Azoxystrobin 3.5 + Myclobutanil 2.25 + Biost VPH 7.75 + Gaucho 12.8	15	3634.8	3752.2	3693.5	AB
	Average	3545.5	3714.4		

† Data were analyzed with JMP 15 Pro (SAS Institute Inc., Cary N.C.). Values with the same letter within a column are not significantly different, where seedcotton yield was analyzed by location using the Fit Model–Standard Least Squares procedure–Tukey's honestly significant difference means separation with alpha = 0.05.

Bacterial Blight Susceptibility in Cotton Varieties

M. Emerson,[1] J. Black,[1] and T.R. Faske[1]

Abstract

Bacterial blight is caused by *Xanthomonas citri* subsp. *malvacearum* (Smith 1901) Constantin 2016, and can cause defoliation and yield loss in susceptible cotton varieties. Cotton varieties are typically screened for bacterial blight through artificial inoculation because the only means of disease management is varietal resistance. The objective of this experiment was to evaluate twenty-six commercially available cotton varieties' susceptibility to bacterial blight. The trial was conducted in 2020 when a natural outbreak of bacterial blight occurred in a cotton variety trial and was rated for disease severity using a 0–9 index scale (0 = no disease and 9 = total defoliation). Of the 26 varieties sampled, 16 varieties were resistant, 3 were partially resistant, and 7 were susceptible. There was a correlation between disease severity and a decrease in yield (r = -0.435; $P < 0.001$). Of the 12 varieties with the highest yield, 10 were resistant and 2 were partially resistant to bacterial blight. These data support the use of bacterial blight-resistant cotton varieties for cotton production in Arkansas.

Introduction

Bacterial blight is caused by *Xanthomonas citri* subsp. *malvacearum* (Smith, 1901) Constantin 2016. Historically, bacterial blight was a major cotton disease across the U. S. Cotton Belt, causing significant yield losses (Mishra and Ashok, 2001). Currently, bacterial blight is an infrequent disease in Arkansas, with the last widespread outbreak occurring in 2011 due to severe thunderstorms creating a suitable environment for bacterium present on or within the seed coat of susceptible cotton varieties. Bacterial blight, prior to 2011, hadn't been reported in Arkansas since 1983 (Rothrock et al., 2012). This reduction in disease prevalence is mainly due to the development and implementation of cotton cultivars resistant to bacterial blight.

Bacterial blight symptoms on leaves begin as small water-soaked spots that develop into angular-shaped lesions due to movement restrictions imposed by leaf veins. Lesions first appear on the abaxial side of the leaf, turn dark in color as they expand, and can result in defoliation. Sometimes extensive defoliation can occur. Although leaf lesions are commonly observed, the bacterium can infect most of the vegetative portions of the cotton plant and can also cause lesions on fruiting bodies. Historically, yield losses due to bacterial blight were as high as 60%; however, due to development of resistant varieties and acid-delinting techniques, yield losses are estimated to be around 0.1% annually, but with some fields seeing yield losses as high as 20% (Kemerait et al., 2017).

Once a field is infected with bacterial blight, there are no in-season management practices to eliminate the disease. Therefore, to reduce yield losses due to bacterial blight, it is important to identify resistant cotton varieties. Typically, cotton breeders and plant pathologists screen cotton germplasm and varieties for bacterial blight in artificially inoculated field trials. This is a very useful technique to identify susceptible entries but does not provide information on yield loss due to a natural field infestation. These events are often limited, but one such isolated event occurred recently (2020) in an insecticide seed treatment study near Marianna. The objective of this study was to evaluate the susceptibility of 26 transgenic cotton varieties to bacterial blight and assess the impact on seed cotton yield.

Procedures

Twenty-six transgenic cotton varieties were treated with a basic fungicide plus Gaucho insecticide seed treatment (0.375 mg a.i./seed) and planted on 20 May at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Lee County, Arkansas. The varieties planted included 8 BollGard II Xtend Flex (B2XF) lines, 8 BollGard III Xtend Flex (B3XF) lines, 9 WideStrike 3 Enlist (W3FE) lines, and 1 Glyphosate Tolerant Liberty-Link (GLTP) line. Plots consisted of 2 rows, 30-ft long, spaced 38-in. apart, separated by a 5-ft fallow alley. Varieties were planted in a randomized complete block design with four replications per variety. Seeds were planted using a small plot cone planter at a seeding rate of 55,000 seeds/ac. Fertility, irrigation, and weed management followed recommendations by the University of Arkansas System Division of Agriculture's Cooperative Extension Service.

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All plots were rated on 16 July for bacterial blight disease severity using a 0-9 rating scale first described by Allen et al. (2011) (0 – no disease or defoliation from bacterial blight, 1–bacterial blight present [single lesion], 2–infected material present in lower canopy, 3–mid-canopy infection and some defoliation, 4–heavy mid-canopy infection and some defoliation, 5–mid to upper-canopy infection and some defoliation, 6–upper canopy infection and defoliation, 7–heavy upper canopy infection and defoliation, 8–majority of upper canopy infected with excessive defoliation, 9–total defoliation of plant). Each plot was harvested on 20 Oct. using a 2 row Case 1822 small plot picker equipped with a Harvest Master weigh system to record lb seed cotton/plot.

Data were subjected to analysis of variance using ARM 2021.2 (Gylling Data Management, Inc., Brookings, S.D.). When appropriate, mean separations were performed using Tukey's honestly significant difference test at $P = 0.05$.

Results and Discussion

These cotton varieties varied in susceptibility to bacterial blight (Table 1). Of the varieties evaluated, the Phytogen varieties had the lowest severity rating, which ranged from 0 - 0.3. Other varieties that had a similar bacterial blight rating to the Phytogen varieties included: DP 1518 B2XF, DG 3520 B3XF, DP 2012 B2XF, CP 9210 B3XF, DP 2038 B2XF, NG 4098 B3XF, and NG 3930 B3XF. Seven of the varieties were categorized as susceptible with a bacterial blight rating of greater than three (Table 1). Our findings were similar to the susceptibility ratings used by various seed companies to market their varieties and to the cotton variety test conducted by the University of Arkansas (Bourland et al., 2020). The varieties that were categorized as susceptible in this experiment account for 14.58% of the cotton grown in Arkansas in 2020 (USDA 2020).

Seed cotton yield was greater for PHY 360 W3FE, PHY 400 W3FE, PHY 332 W3FE, and PHY 443 W3FE than DP 2038 B2XF, DG 3317 B3XF, DG 3520 B3XF, and ST 455 GLTP (Table 1). Though some bacterial blight susceptible cultivars had a similar seed cotton yield as the resistant Phytogen varieties, there was a significant correlation between yield and disease severity, with a single unit increase in disease severity resulting in a loss of 96 lb seed cotton/ac ($r = -0.435$; $P < 0.001$). The regression equation ($y = 2{,}180.2 - 95.6x$) explained 10.7% of the variability observed in these data. Overall, this study indicates that bacterial blight can be problematic in fields with no history of the disease when susceptible varieties are grown, inoculum is present, and conditions favor disease development. Given the availability of bacterial-blight-resistant varieties with good yield potential, selecting such a variety would be the best approach to bacterial blight management.

Practical Applications

Bacterial blight has the ability to reduce cotton yield potential on susceptible varieties. Therefore, selecting a bacterial-blight-resistant variety that has a high yield potential is an important management tactic to maximize cotton yield in Arkansas.

Acknowledgments

The authors would like to thank the University of Arkansas System Division of Agriculture, Dr. Bourland for providing seed, Dr. Lorenz and his crew for planting and scouting for insect pests, and the National Cotton Council and Cotton Incorporated.

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Table 1. Yield values and bacterial blight disease severity for each variety tested.

Variety	Yield	Bacterial Blight Severity	Field Response[†]	Marketed Response[‡]
	(lb seed cotton/ac)	(0-9)[§]		
PHY 360 W3FE	2822 a[¶]	0.0 a	R	R
PHY 400 W3FE	2704 ab	0.1 a	R	R
PHY 332 W3FE	2575 abc	0.0 a	R	R
PHY 443 W3FE	2515 abc	0.0 a	R	R
NG 4936 B3XF	2438 a–d	2.4 cd	MS	PR
NG 3729 B2XF	2399 a–d	2.3 cd	MS	PR
PHY 480 W3FE	2394 a–d	0.1 a	R	R
DP 2012 B2XF	2386 a–d	0.1 a	R	R
PHY 350 W3FE	2285 a–e	0.0 a	R	R
PX5C45 W3FE	2149 a–f	0.3 a	R	n/a
PX5E28 W3FE	2022 a–g	0.0 a	R	n/a
DP 1646 B2XF	1956 a–g	1.8 bc	MR	PR
CP 9608 B2XF	1939 b–g	3.6 de	S	n/a
PX5E34 W3FE	1934 b–g	0.0 a	R	n/a
NG 4098 B3XF	1930 b–g	0.4 ab	R	R
DG 3385 B2XF	1879 b–g	4.0 e	S	n/a
NG 3522 B2XF	1851 b–g	4.3 ef	S	S
DP 1518 B2XF	1821 c–g	0.0 a	R	R
CP 9210 B3XF	1809 c–g	0.1 a	R	R
DP 1725 B2XF	1787 c–g	4.1 ef	S	S
DG 3427 B3XF	1735 c–g	5.5 f	S	PR
NG 3930 B3XF	1726 c–g	0.6 ab	R	R
DP 2038 B2XF	1621 d–g	0.3 a	R	R
DG 3317 B3XF	1619 d–g	4.9 ef	S	PR
DG 3520 B3XF	1387 fg	0.0 a	R	PR
ST 4550 GLTP	1238 g	4.6 ef	S	S

[†] Resistance response determined by: (S) susceptible ≥ 3, (MS) moderately susceptible = 2, (MR) moderately resistant = 1, (R) resistant < 1.

[‡] Information found on individual seed company’s website, not based on this experiment. (R) resistant, (PR) = partially resistant, (S) susceptible.

[§] 0 = no bacterial blight, 9 = total defoliation due to bacterial blight.

[¶] Means followed by the same letter are not significantly different at *P* = 0.05.

Effects of Water Hardness on Insecticide Performance for the Control of Tarnished Plant Bug, *Lygus lineolaris*, in Cotton

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Abstract

Insecticide efficacy often varies from location to location and year to year. Many factors can influence an insecticide's efficacy, but an often-overlooked factor is the quality of water in an insecticide solution. Experiments were conducted to evaluate the impact of water hardness on insecticide efficacy. In these experiments, Transform 1.5 oz/ac, Acephate 0.75 lb/ac, Bidrin 8 oz/ac, and Centric 2 oz/ac, were each mixed in waters with hardnesses of 10.9, 178, and 430 ppm and applied to cotton, then evaluated for control of tarnished plant bug. No differences in control were present between tested waters for any insecticide.

Introduction

Most insecticides used in agriculture are required to be dissolved or suspended in water. A spray solution is often 95% or more water. Water is commonly seen as a clean input, and its quality is commonly overlooked. One important measurement of water quality is hardness. Water hardness is the amount of dissolved calcium, magnesium, and other minerals in water. Spray solutions containing hard water have the potential to cause antagonism, which may reduce the degree or speed of the activity of pesticide or reduce active ingredient uptake. Water hardness in the Mid-south can vary from soft (0–60 ppm) to very hard (>181 ppm). Previous research has shown that excessively hard water has been shown to negatively impact herbicides (Devkota and Johnson, 2020). The objective of this study is to evaluate the impact of water hardness on tarnished plant bug insecticide efficacy in cotton.

Procedures

An experiment was repeated in two field trials in Marianna, Arkansas, at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station. In this experiment, Transform 1.5 oz/ac, Acephate 0.75 lb/ac, Bidrin 8 oz/ac, and Centric 2 oz/ac were each mixed in three containers of water with hardnesses of 10.9, 178, and 430 ppm, and were then sprayed on cotton for the control of tarnished plant bugs. Plot size was 12.5 ft. (4 rows) by 40 ft. Both trials were arranged as a randomized complete block with 4 replications. Applications were made using a Bowman Mudmaster at a pressure of 40 psi and a rate of 10 gal/ac. Samples were conducted at 3 and 7 days after application using a 2.5ft shake sheet with two samples per plot for a total of 10 row ft. Tarnished plant bug nymphs and adults were counted. Data were combined from both trials and analyzed using PROC GLIMMIX with SAS v 9.4 at an alpha level of 0.05.

Results and Discussion

No differences in tarnished plant bug control were observed among treatments at 3 days after application (Fig. 1). No differences in tarnished plant bug control among water hardness levels occurred at 7 days after application (Fig. 2). Although no differences were found in this experiment, testing will be expanded in 2020 to confirm these results. More extensive research will also be conducted to determine if water hardness, pH, and combinations of the two impact the efficacy of these and other additional insecticides.

Practical Applications

The results of this study indicated that there are no differences in tarnished plant bug control on Transform, Acephate, Bidrin, and Centric when mixed with water hardness ranging from 10.9 ppm to 430 ppm. The results from this and future studies will be used to help make recommendations to farmers for the use of water conditioners in a spray solution to improve insect control in cotton.

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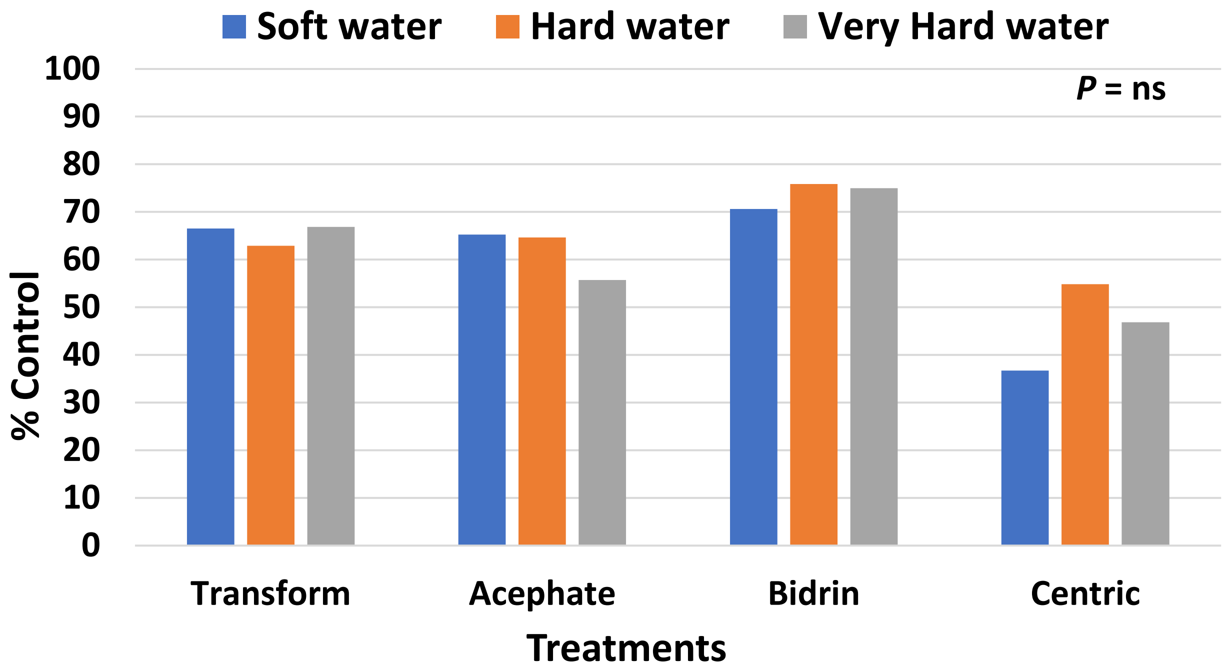

Fig. 1. Percent control of tarnished plant bugs in cotton for multiple insecticides in different water hardnesses, Marianna, Arkansas, 2021, 3 days after application.

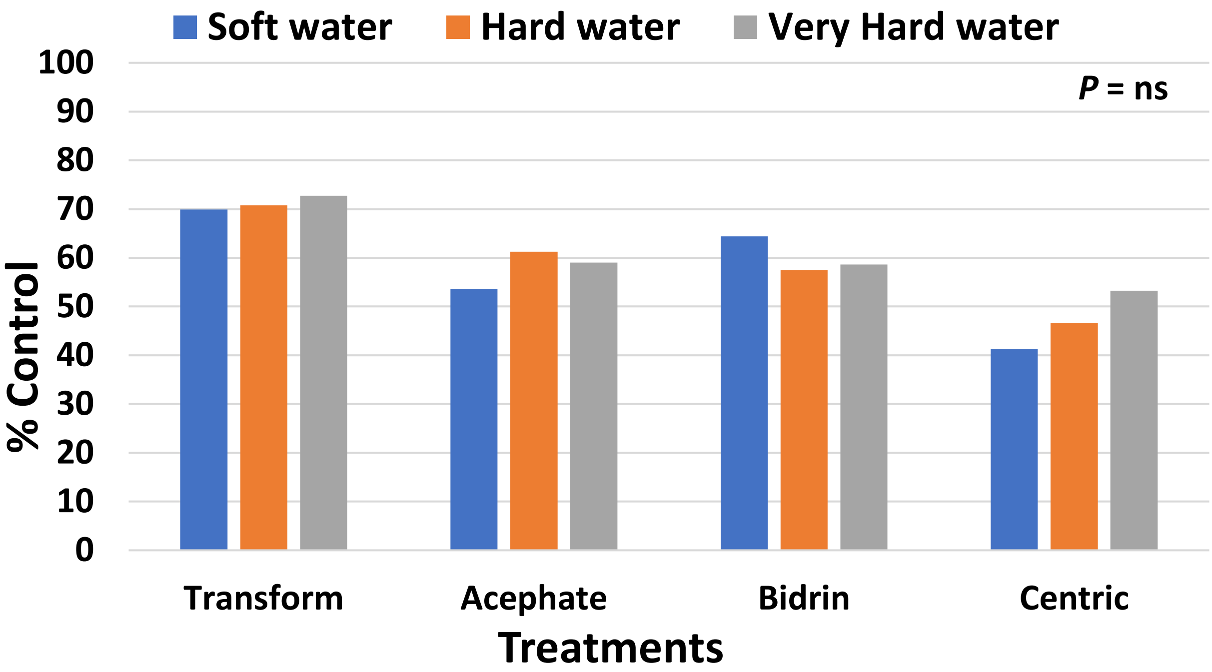

Fig. 2. Percent control of tarnished plant bugs in cotton for multiple insecticides in different water hardnesses, Marianna, Arkansas, 2021 7 days after application.

Cotton Tolerance to Potassium Tetraborate Tetrahydrate: A Nutritional and Dicamba Volatility Reducing Agent

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

Abstract

Volatility reducing agents (VRAs) are now required for all in-crop dicamba applications. The University of Arkansas System Division of Agriculture has continued to evaluate potassium tetraborate tetrahydrate (potassium borate) as a VRA and boron (B) nutritional. A greenhouse and field experiment were conducted in Fayetteville, Ark., in 2021, to ensure the crop safety of postemergence mixtures containing dicamba and potassium borate. For each experiment, potassium borate was applied at six rates (0, 0.1, 0.2, 0.3, 0.4, and 0.5 lb B/ac) alone or in combination with the XtendiMax formulation of dicamba at 0.5 lb ae/ac. Additionally, a mixture of XtendiMax, Roundup PowerMax, and Dual II Magnum, as well as Liberty, Roundup PowerMax, and Dual II Magnum at labeled field use rates, were used as a comparison for cotton injury. Treatments were applied in the greenhouse on 1- to 2-leaf cotton and at the pinhead square growth stage in the field. At 3 days after treatment (DAT) for the greenhouse experiment, only three-way mixtures caused injury, showing that potassium borate is not injurious to cotton when applied alone or with dicamba. Biomass collected 28 DAT also reflected that treatments containing potassium borate were comparable to those that were not mixed with the additive. In the field, injury to cotton was not observed for any treatment, possibly due to a later growth stage at application. Based on these findings, it is unlikely that potassium borate would cause unacceptable levels of injury to cotton if utilized in the Xtend system.

Introduction

The introduction of the XtendFlex® technology allows cotton and soybean producers to utilize the XtendiMax® (diglycolamine salt of dicamba (DGA)) with VaporGrip® Technology and Engenia® (N,N-bis(3-aminopropyl)methylamine (BAPMA)) formulations of dicamba for postemergence (POST) control of problematic broadleaf weeds. However, continuous usage of these relatively new, low-volatile formulations of dicamba has caused a record number of complaints from off-target movement via a combination of volatility and spray drift of the herbicide, specifically in areas with a geography similar to the mid-South (Oseland et al., 2020). To mitigate dicamba volatility, the University of Arkansas System Division of Agriculture has been evaluating potassium tetraborate tetrahydrate (potassium borate) as an alternative boron (B)-derived volatility reducing agent (VRA) and nutritional for dicamba-based production systems. Previous research has determined that potassium borate is an effective VRA for POST dicamba applications (unpublished data, 2020), and that to move forward in the commercialization process, crop safety must be established.

Procedures

An initial greenhouse experiment followed by a late-season field experiment were conducted at the University of Arkansas System Division of Agriculture's Milo J. Shult Agricultural Research and Extension Center in Fayetteville, Arkansas, in 2021 to evaluate crop safety from POST applications of dicamba and potassium borate mixtures. Both greenhouse and field experiments were arranged as a single-factor completely randomized design and a randomized complete block design, respectively, with each experiment consisting of four replications and the same treatment structure. Potassium borate at 0, 0.1, 0.2, 0.3, 0.4, and 0.5 lb B/ac were applied with or without the XtendiMax formulation of dicamba at 0.5 lb ae/ac. Additionally, commonly-applied POST mixtures in cotton, such as XtendiMax, Roundup PowerMax® (glyphosate), and Dual II Magnum® (S-metolachlor), as well as Liberty® (glufosinate), Roundup PowerMax, and Dual II Magnum, were applied at field use rates as a standard of comparison for visual injury.

For the greenhouse experiment, each treatment was applied to two 1- to 2-leaf dicamba-resistant cotton plants (DP 1518 B2XF) in a 4-in. wide pot filled with standard potting mix on 1 April 2021. All applications made to potted cotton plants were delivered using a spray chamber operated by compressed air at a spray volume of 20 gal/ac. For the field experiment, the same cotton variety was planted on 36-inch rows, with each plot measuring 12 by 20 ft. Treatments were applied with a CO_2-pressurized backpack sprayer with an output of 15 gal/ac at the pinhead square growth stage on 14

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June 2021. Injury to cotton was visually rated on a scale of 0 to 100% (no injury and crop death, respectively) at 3, 7, and 14 days after treatment (DAT) for both experiments to capture any rapid symptomology that is common with contact herbicides. Additionally, above-ground biomass was collected at 28 DAT and oven-dried for the greenhouse experiment.

All injury data collected from each experiment were subjected to analysis of variance (ANOVA) in JMP Pro 16 using Fisher's protected LSD ($\alpha = 0.05$), with an additional contrast analysis of greenhouse biomass data.

Results and Discussion

Visual injury at 3 DAT for the greenhouse experiment was negligible for all rates of potassium borate as a standalone treatment or when mixed with XtendiMax (Fig. 1). The only treatments that were identified to elicit some degree of phytotoxicity to cotton plants (ranging from 5 to 18%) were three-way mixtures with Liberty, Roundup PowerMax, and Dual II Magnum being the greatest. It is not surprising for mixtures containing a greater amount of labeled herbicides, that generally cause little-to-no injury, to show increased injury to younger cotton plants (Cahoon et al. 2015). In addition to results from ANOVA, a contrast with treatments grouped into two categories: containing potassium borate or not containing potassium borate, determined that potassium borate did not influence cotton biomass (1.43 and 1.47 g, respectively) (Fig 2). For the field experiment, no injury was recorded for each of the assessment dates, which is potentially due to the later growth stage at the time of application. Additional early-season and sequential application field evaluations are needed to fully understand cotton tolerance to potassium borate.

Practical Applications

The record-high number of off-target movement complaints in Arkansas surrounding the launch of the Xtend technology in 2017 has challenged both industry and university researchers to reach a solution to the problem. Repurposing potassium borate as an effective VRA and B nutritional additive could potentially mitigate the risk associated with POST dicamba applications in either cotton or soybean, as well as alleviate B deficiencies that are common to several regions in the state. The optimal rates of potassium borate needed to reduce dicamba volatility are sufficient to satisfy a foliar B recommendation in cotton (up to 0.5 lb B/ac) (Howard et al., 1998), potentially eliminating the need for applying additional B.

Acknowledgments

The authors would like to thank the University of Arkansas System Division of Agriculture and the Milo J. Shult Agricultural Research and Extension Center for funding and support in conducting this research.

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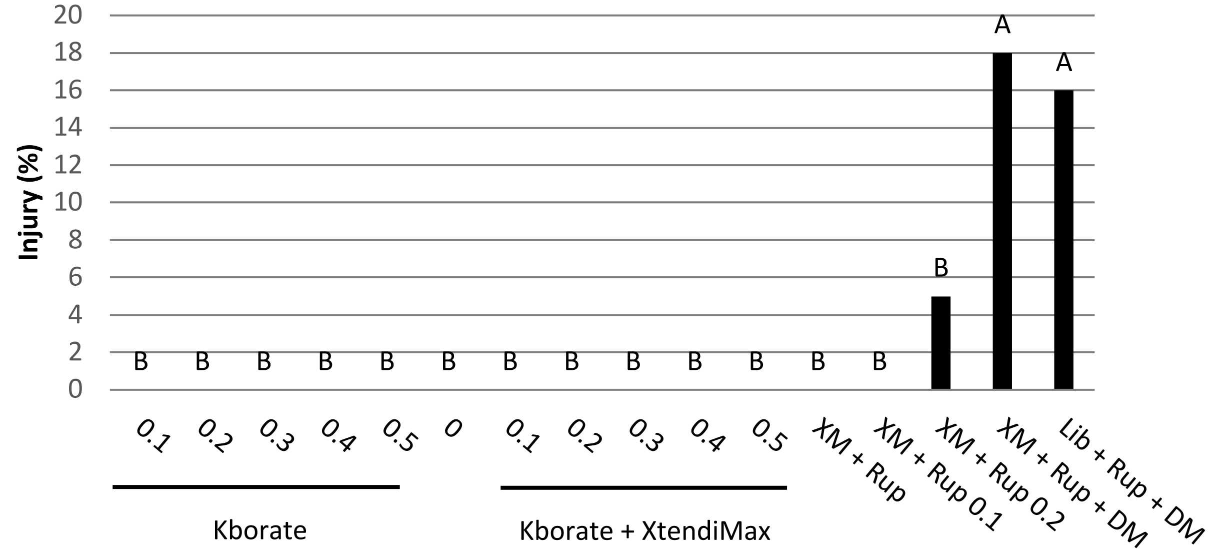
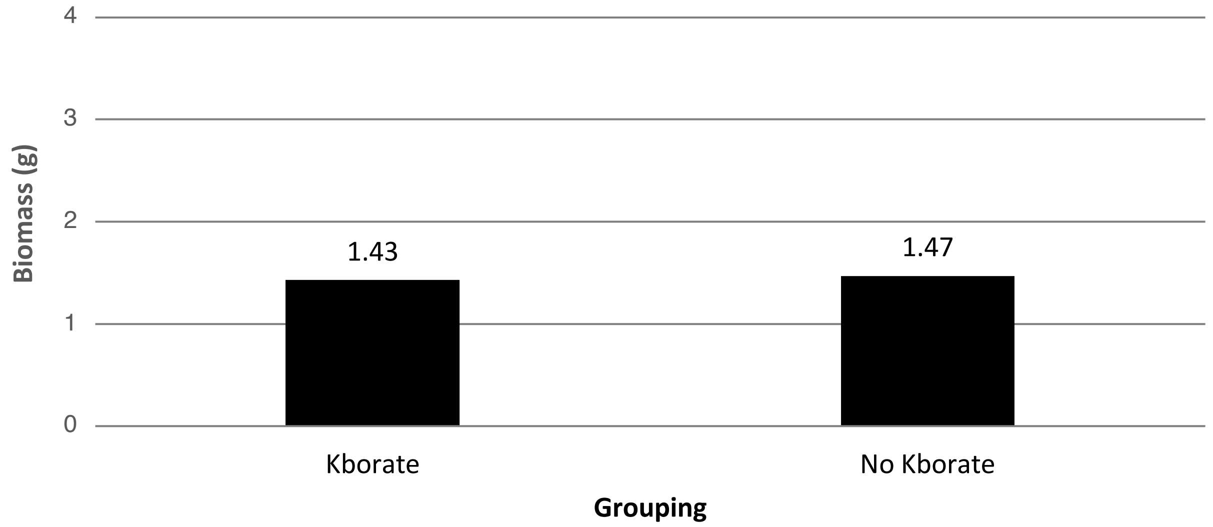


Fig. 1. Visual injury to cotton at 3 days after treatment in Fayetteville, Arkansas, in 2021. Means followed by the same letter are not significantly different ($\alpha = 0.05$). Abbreviations: Kborate, potassium tetraborate tetrahydrate; Lib, Liberty; Rup, Roundup PowerMax; XM, XtendiMax with VaporGrip.



P-value = 0.7857

Fig. 2. Cotton biomass of two plants per pot grouped by treatments that contain or do not contain potassium tetraborate tetrahydrate at 28 DAT in greenhouse study at Fayetteville, Arkansas, in 2021. Means denoted by an asterisk are different. Abbreviations: Kborate, potassium tetraborate tetrahydrate.

Longevity of Residual Palmer Amaranth Control with Preemergence-Applied Cotton Herbicides

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Abstract

Cotton growers in the mid-Southern U.S. region must successfully control Palmer amaranth populations to produce high-yielding crops. For effective control of this weed, growers must implement a strategy that incorporates residual herbicides containing multiple modes of action (MOA) for effective control of this weed. The objective of this research was to evaluate the longevity of Palmer amaranth control using multiple MOA herbicides applied prior to cotton emergence. Experiments were conducted in 2021 at a farm in Tillar, Arkansas and at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Arkansas, to evaluate the longevity of residual Palmer amaranth control with preemergence-applied cotton herbicides. A total of 11 treatments containing one to three different modes of action were applied at planting. Herbicides and rates included Brake (fluridone) (alone/tank mix) at 24/16 fl oz/ac, Caporal (prometryn) at 16 fl oz/ac, Cotoran (fluometuron) at 24 fl oz/ac, Warrant (acetochlor) at 32 fl oz/ac, and Xtendimax (dicamba) at 22 fl oz/ac. Visual Palmer amaranth control ratings were taken 4 and 6 weeks after treatment (WAT). Data were analyzed using JMP Pro 16.1 and subjected to analysis of variance. Means were separated using Fisher's protected least significant difference (LSD) to determine if single and MOA herbicides differed in longevity of residual Palmer amaranth control ($\alpha = 0.05$). Results indicate that treatments containing 2 or 3 MOA provided the greatest control of Palmer amaranth 4 and 6 WAT. Treatment combinations containing fluridone herbicide provided the best control at 6 WAT. Therefore, Palmer amaranth can successfully be controlled up to 6 WAT using multiple MOA herbicides. Additionally, multiple MOA herbicides with residual activity will provide lengthy Palmer amaranth control while reducing the risk of yield loss in cotton production systems.

Introduction

Palmer amaranth (*Amaranthus palmeri* (S.) Watson) has been ranked the number one most troublesome weed in Arkansas cotton production systems (Wychen, 2019). The unique characteristics associated with Palmer amaranth include its vigorous growth habit in extremely hot and dry conditions, ability to develop herbicide resistance (Duke and Powles, 2009), ability to compete for essential nutrients (Norsworthy et al., 2014), large amount of seed production (up to 1 million seeds/female plant) (Keely et al., 1987), and easy seed dispersal (Norsworthy et al., 2014). For example, one Palmer amaranth plant per 9.1 m of row can reduce cotton lint yield by 13% (Morgan et al., 2001). In Arkansas, Palmer amaranth has developed resistance to more than five herbicide sites of action (Heap, 2022). Therefore, control of Palmer amaranth is imperative to protect yield potential and decrease the spread of herbicide resistance. As a result, residual herbicides containing multiple modes of action need to be utilized as an effective tool to control Palmer amaranth while decreasing the spread of resistance (Norsworthy et al., 2012).

Procedures

A field trial was conducted in 2021, on-farm in Tillar, Arkansas (Herbert silt loam) and at the University of Arkansas System Division of Agriculture's Lonn Mann Cotton Research Station in Marianna, Arkansas (Loring silt loam) to evaluate the longevity of residual Palmer amaranth control with preemergence-applied cotton herbicides. The trial was planted with DP 1646 B2XF cotton cultivar at 44,000 seeds/ac. Each plot consisted of 4 rows, 12.6 ft wide by 30 ft long. Herbicide treatments were applied PRE at planting on 17 May 2021 at Tillar and 14 May 2021 at Marianna with a CO_2–pressurized tractor-mounted sprayer calibrated to 15 gal/ac at 3 mph. TeeJet® TTI 110015 nozzles were used for dicamba applications, and TeeJet® AIXR 110015 nozzles were used for non-dicamba applications. A total of 11 treatments containing one to three different modes of action were applied at planting. Herbicides and rates included Brake (fluridone) (alone/tank mix) at 24/16 fl oz/ac, Caporal (prometryn) at 16 fl oz/ac, Cotoran (fluometuron) at 24 fl oz/ac, Warrant (acetochlor) at 32 fl oz/ac, and Xtendimax

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(dicamba) at 22 fl oz/ac (Table 1). Data collection included visual control ratings (0–100% where 0 = no control and 100 = total control) taken 4- and 6-weeks after treatment (WAT).

The experimental design of the trial was a randomized complete block design with four replications. Also, contrasts were used to compare means from treatments containing 1, 2, and 3 MOA. Data were analyzed using JMP Pro 16.1 and subjected to analysis of variance. Means were separated using Fisher's protected least significant difference to determine if single and MOA herbicides differed in longevity of residual Palmer amaranth control ($\alpha = 0.05$).

Results and Discussion

The data collected in 2021, across two locations in the Arkansas Delta, were combined and analyzed to determine the longevity of residual Palmer amaranth control. Treatments containing a single MOA exhibited 84–88% control 4 WAT (Fig. 1). However, at 6 WAT, applications containing a single MOA only provided 61–83% control. Overall, results indicate that treatments containing 2 or 3 MOA provided the greatest control of Palmer amaranth 4 and 6 WAT with up to 96% and 86% control, respectively. Furthermore, 2 and 3 MOA treatments increased control by 12% and 17%, respectively, compared to 1 MOA 4 WAT (Table 2). Additionally, 2 MOA treatments increased control by 8% when compared to 1 MOA 6 WAT. Lastly, treatment and treatment combinations containing Brake herbicide provided the best control at 6 WAT (Fig. 1). Therefore, Brake alone provided approximately 83% control at 6 WAT while Cotoran and Warrant only provided 61% and 67%, respectively. In conclusion, Palmer amaranth can successfully be controlled in cotton for up to 6 weeks with preemergence applied residual herbicides containing multiple MOA.

Practical Applications

Palmer amaranth can successfully be controlled for up to 6 WAT with herbicide treatments containing multiple MOA herbicides. Including multiple MOA herbicides with residual activity will provide lengthy Palmer amaranth control and reduce the risk of yield loss in cotton production systems. Herbicide combinations, including Brake, should be implemented on cotton fields heavily infested with Palmer amaranth. Future research is needed to evaluate best management practices associated with herbicides containing multiple modes of action in order to control Palmer amaranth and other weeds.

Acknowledgments

The authors would like to thank Cotton Incorporated, the University of Arkansas System Division of Agriculture, and the Lon Mann Cotton Research Center for funding and support in conducting this research.

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Table 1. Preemergence-applied residual herbicide treatments at Marianna and Tillar, Arkansas 2021.

Treatment	Trade Name	Rate
		(fl oz/ac)
1	Warrant	32
2	Brake	24
3	Cotoran	24
4	Brake + Cotoran	16 + 24
5	Brake + Warrant	16 + 32
6	Cotoran + Warrant	24 + 32
7	Cotoran + Caparol	16 + 16
8	Brake + Xtendimax	16 + 22
9	Brake + Cotoran + Xtendimax	16 + 24 + 22
10	Xtendimax + Warrant	22 + 32
11	Xtendimax + Cotoran + Caparol	22 + 16 + 16

Table 2. Contrast of Palmer amaranth control (%) means and 1, 2, and 3 modes of action (MOA) herbicides 4 and 6 weeks after treatment (WAT) (α = 0.05).

4 WAT[a]		***P*-value: 0.0009**	
	1 MOA[b]	vs.	**2 MOA**
	75%		87%
		***P*-value: 0.0033**	
	1 MOA	vs.	**3 MOA**
	75%		92%
		***P*-value: 0.2906 (NS)[c]**	
	2 MOA	vs.	**3 MOA**
	91%		95%
6 WAT		***P*-value: 0.0078**	
	1 MOA	vs.	**2 MOA**
	70%		78%
		***P*-value: 0.9542 (NS)**	
	1 MOA	vs.	**3 MOA**
	70%		71%
		***P*-value: 0.1155 (NS)**	
	2 MOA	vs.	**3 MOA**
	78%		71%

[a] WAT = weeks after treatment.

[b] MOA = modes of action.

[c] *P*-value is not a statistically significant value (NS) (> 0.05).

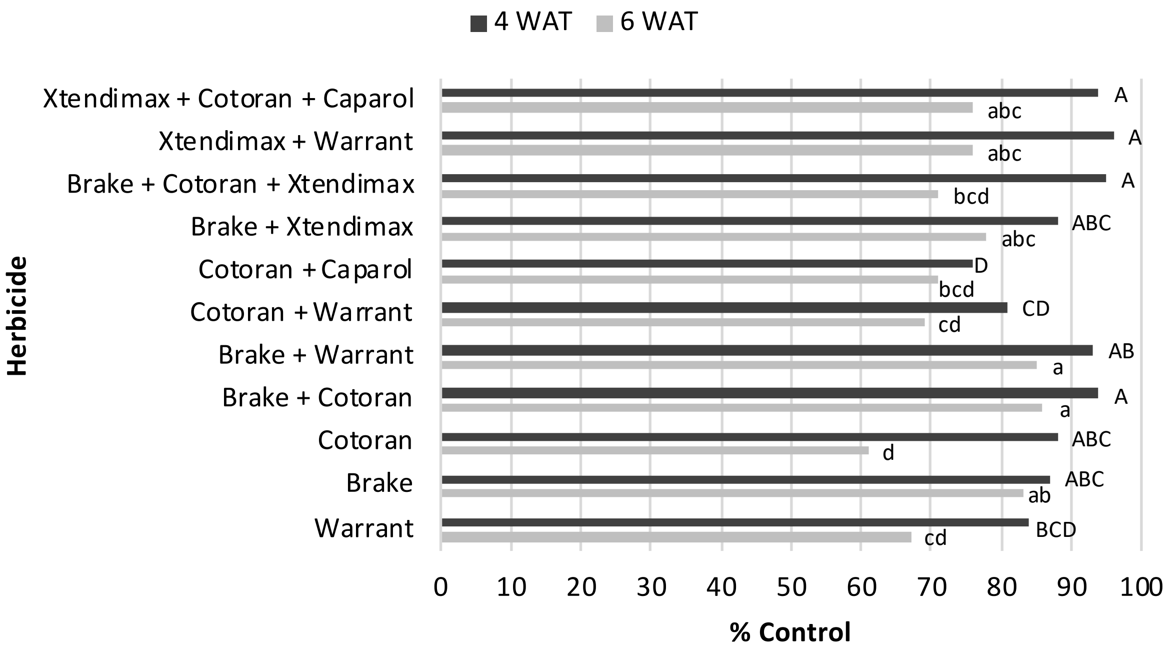

Fig. 1. Visual Palmer amaranth control ratings 4 and 6 weeks after treatment (WAT). Means followed by the same letter are not significantly different within species (α = 0.05).

Impact of Cotton Weed Management Practices on Palmer Amaranth Populations in Year Three of a Long-Term Study

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Abstract

In United States' cropping systems, Palmer amaranth has become one of the most troublesome weeds, particularly in slow canopying crops such as cotton. A long-term field trial was initiated at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research and Extension Center, Marianna, Arkansas, to assess the impact of cultural and mechanical weed management strategies on Palmer amaranth over a three-year period. Non-chemical approaches such as tillage, cover cropping with cereal rye, and zero-tolerance were evaluated in combination with two standard weed control systems, one with dicamba used preemergence (PRE) and early postemergence (POST) compared to a program with no dicamba herbicide. The experiment was organized in a randomized complete block design with 16 treatments and four replications. Results showed that adopting a cover crop reduced weed emergence by 82%. The use of the zero-tolerance approach plus dicamba and non-dicamba herbicides showed comparative results, both causing a 63% reduction in Palmer amaranth emergence. A 37% reduction was observed in treatments that included tillage, but statistically, no difference was observed compared to treatments lacking tillage. The adoption of zero-tolerance with dicamba and non-dicamba herbicides plus the use of a cover crop (cereal rye) had a high impact on reducing the number of Palmer amaranth seedlings emerging throughout the trial. In the battle against herbicide resistance, the combination of multiple weed control practices (chemical, cultural, mechanical, and others) is essential to manage resistant weed populations and maintain sustainable cotton production.

Introduction

Palmer amaranth [*Amaranthus palmeri* (S.) Watson] has been ranked as the most troublesome weed in cotton in the United States (Wychen, 2019). Likewise, this weed has also been ranked the number one weed in cotton systems in Arkansas. One factor that makes this weed hard to manage is the number of seeds it can produce. For instance, a single female plant can produce up to 600,000 seeds in a single growing season (Keely et al., 1987). Palmer amaranth seeds are small and easily dispersed by wind, water, animal waste, tillage, and farm equipment (Norsworthy et al., 2014). The continued use of herbicide-resistant crops has led to selective pressure and faster evolution of herbicide-resistant weed populations (Duke and Powles, 2009). The practice of alternating or combining different weed management practices has been used to reduce weed populations and selective pressure for resistance caused by the repetitive use of herbicides. DeVore et al. (2012) showed that cultural practices such as cover crops have reduced Palmer amaranth emergence by 91% due to the high level of biomass ground coverage. They also found that the use of tillage (mechanical method) reduced Palmer amaranth emergence by 69%, while weed zero-tolerance reduced emergence by 65%. Zero-tolerance is a method that includes the removal of weeds that survive by other means of control before they are able to produce seed. The objective of this study is to evaluate the long-term effects of integrated weed management practices on Palmer amaranth in a cotton cropping system.

Procedures

A field trial was initiated in 2018 at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station in Marianna, Arkansas, to evaluate the effect of integrated weed management strategies in a cotton system. Even though this trial has been repeated since 2018, this report will focus on the data obtained in 2021. Each plot was 25 ft wide by 120 ft long with 36-in. row spacing. A one-time treatment procedure of deep tillage (moldboard plow) at a depth of 25–30 cm was completed in the fall of 2018 for plots including this treatment. Wrens Abruzzi cereal rye was seeded as a cover crop in the fall of 2020 at 75 lb/ac. The trial was arranged in a split, split, split, split-plot design

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consisting of 16 treatments and 4 replications. The whole-plot factor was zero-tolerance (with and without), with a sub-plot factor of tillage (moldboard plow once in 2018 vs. no moldboard plow), a sub-sub-plot factor of cover crop (cereal rye vs. no cover crop), and a sub-sub-sub-plot factor of herbicide program (dicamba containing vs. non-dicamba). Dicamba and non-dicamba herbicide programs are listed in Table 1. Herbicide treatments were applied: pre-emergence, first post-emergence at 21 days after planting (DAP), second post-emergence application at 42 DAP, and layby application at 63 DAP. Herbicide applications were sprayed at 15 gal/ac using a Bowman Mudmaster and tractor-mounted hooded sprayer. TeeJet® TTI 110015 nozzles were used for dicamba applications and TeeJet® AIXR 110015 nozzles for non-dicamba applications. In 2021 the trial was planted with DP 1518 B2XF cotton at a rate of 44,000 seed/ac.

Four square meter quadrants were randomly placed and flagged in each plot; weed counts were taken at 21, 42, 63, and 74 DAP in each of the four quadrants. Weed counts were totaled, and data were subjected to analysis of variance using JMP Pro 16.1, and means were separated using Fisher's protected least significance difference ($\alpha = 0.05$).

Results and Discussion

The reduction of Palmer amaranth emergence was greatest in treatments that included the adoption of cereal rye cover crop with an 82% reduction (Fig. 1). This result is similar to previous research conducted in Arkansas, where an 83% reduction in weed emergence was obtained with the use of cover crops (Palhano et al., 2017). Treatments that contained a dicamba herbicide system or those that included zero-tolerance had comparable results, reducing emergence by 63% (Fig. 2). Using a dicamba system over a non-dicamba system has been determined to reduce Palmer amaranth in the soil seed bank by 30–60%, and zero-tolerance adoption has shown a reduction in emergence by 65% (Barber et al., 2017; Johnson et al., 2010). Deep tillage treatment showed a numerical reduction of 37% in 2021 when compared to treatments with no tillage (Fig. 3), which is lower than previously observed, where the use of deep tillage decreased Palmer amaranth emergence by 69% one year after the tillage event (DeVore et al., 2012). No interactions were observed among factors. Treatments with a cover crop, dicamba, zero-tolerance, and a deep tillage event resulted in the best control of Palmer amaranth throughout the growing season.

Practical Applications

The continuous use of herbicides has contributed to the resistance development of Palmer amaranth to eight herbicide modes of action, making it hard for producers to manage this weed (Heap, 2022). The use of a single weed management practice can reduce weed emergence, but the combined use of these practices can further improve weed control while reducing selective pressure for herbicide resistance. Palmer amaranth control can be maximized over time by utilizing a cover crop such as cereal rye, an effective herbicide program, and removing any escapes that could replenish the soil seedbank.

Acknowledgments

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Table 1. Herbicide programs with common names, application rate, and timing for a cotton system at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Arkansas, in 2021.

	Dicamba program		Standard program	
Timing	Common name	Rate	Common name	Rate
		(lb ai/ae/ac)		(lb ai/ae/ac)
Burndown	glyphosate[b]	1.1	glyphosate[b]	0.6
	dicamba[b]	0.5	dicamba[b]	0.5
PRE[a]	dicamba[b]	0.5	paraquat	0.6
	fluometuron	1.0	fluometuron	1.0
21 DAP	dicamba[b]	0.5	glufosinate	0.6
	S-metolachlor	1.0	*S*-metolachlor	1.0
	glyphosate[b]	1.0	glyphosate[b]	1.0
42 DAP	glufosinate	0.6	glufosinate	0.6
	glyphosate[b]	1.1	glyphosate[b]	1.1
	acetochlor	1.1	acetochlor	1.1
Layby	flumioxazin	0.06	flumioxazin	0.06
	MSMA	2.0	MSMA	2.0

[a] Abbreviations: DAP = days after preemergence; PRE = preemergence.

[b] lb/ae acre; ae = acid equivalent. All other rates are in lb/ai acre; ai = active ingredient.

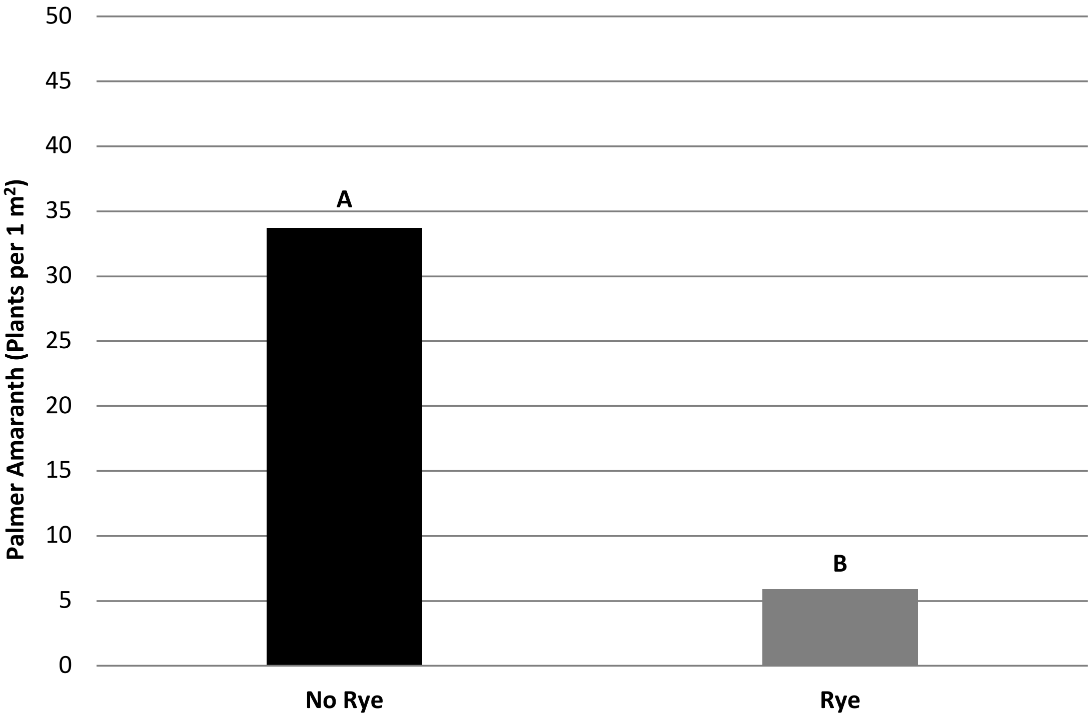

Fig. 1. Pre-harvest densities of Palmer amaranth in cover crop treatments, at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Arkansas, in 2021. Means were averaged over other factors, and means followed by the same letter are not significantly different (α = 0.05).

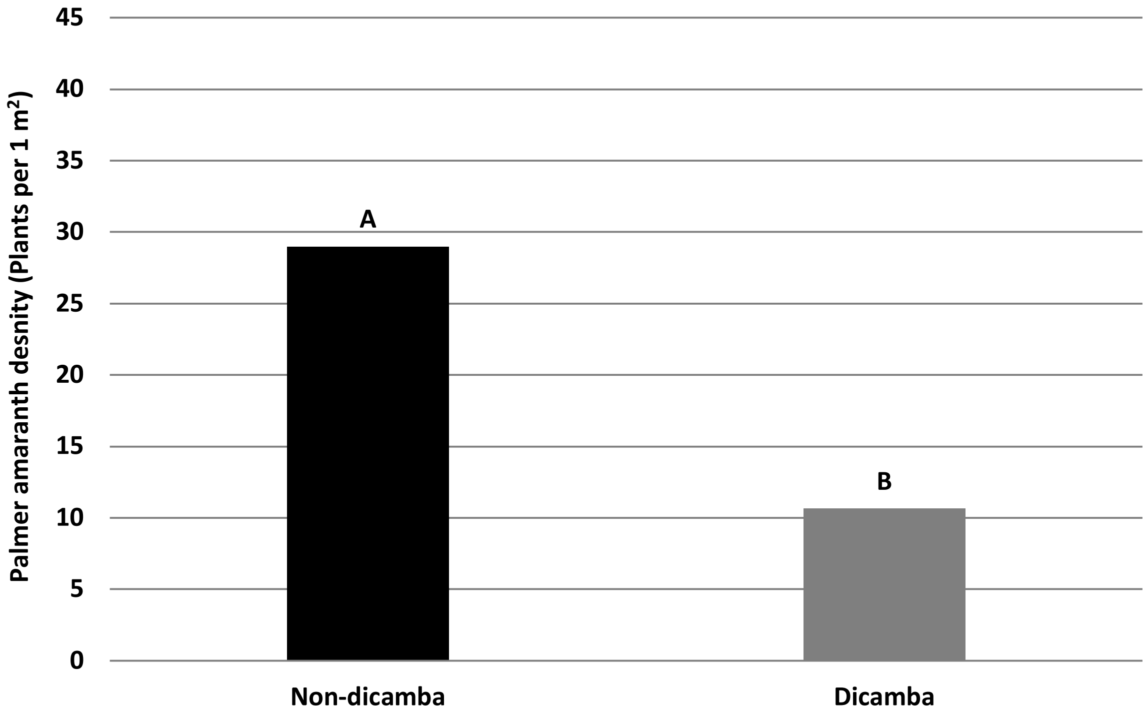

Fig. 2. Pre-harvest densities of Palmer amaranth in dicamba and non-dicamba-containing herbicide systems at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Arkansas, in 2021. Means were averaged over other factors, and means followed by the same letter are not significantly different (α = 0.05).

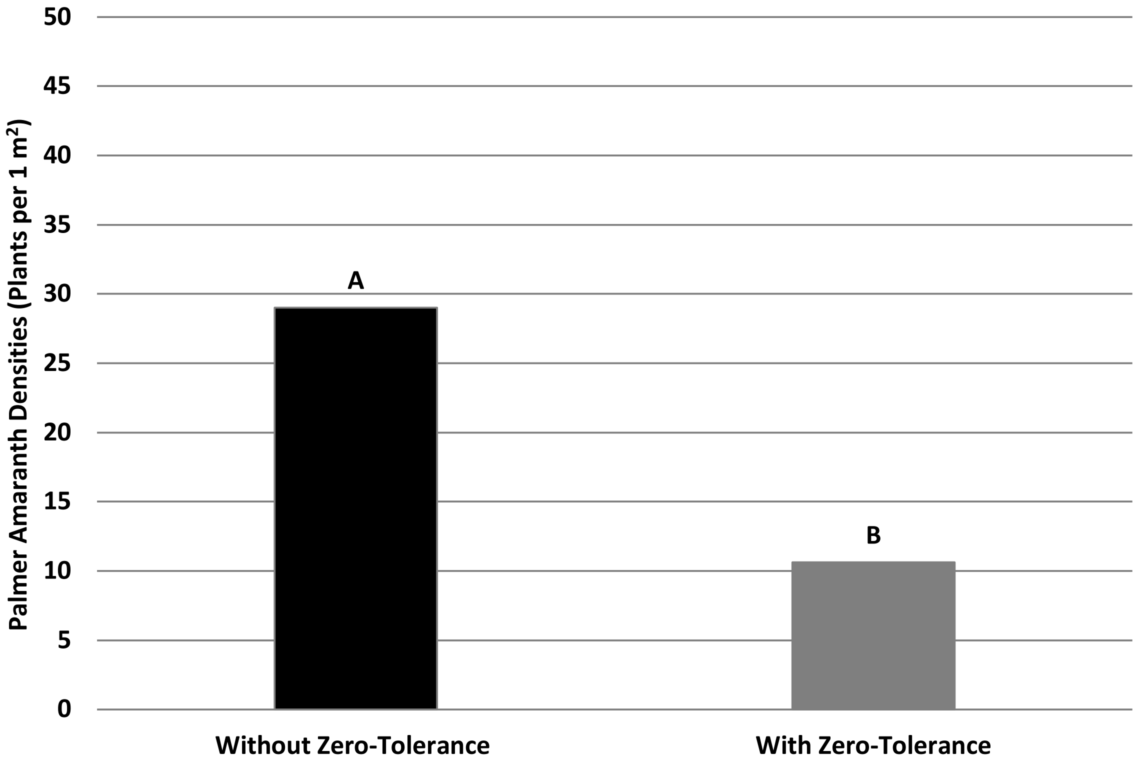

Fig. 3. Pre-harvest densities of Palmer amaranth in zero-tolerance and without zero-tolerance treatments at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station, Marianna, Arkansas, in 2021. Means were averaged over other factors, and means followed by the same letter are not significantly different (α = 0.05).

Johnsongrass Resistance to Glyphosate and Aryloxyphenoxypropionate Herbicides: Implications for Management in Cotton

J.A. Fleming,[1] J.K. Norsworthy,[1] L.T. Barber,[2] and T.R. Butts[2]

Abstract

In recent years, johnsongrass (*Sorghum halepense*) escapes and infestations have been a growing issue for cotton (*Gossypium hirsutum*) producers across the mid-South. This could be due to reliance on specific herbicides such as glyphosate and acetyl CoA carboxylase inhibitors. A greenhouse study was conducted in Fayetteville, Arkansas, in 2020 and 2021 to determine the extent of johnsongrass in Arkansas with resistance to aryloxyphenoxypropionate herbicides and glyphosate. Johnsongrass seeds were collected from 63 locations within six counties in eastern Arkansas. These accessions were then seeded in the greenhouse and treated with fluazifop at 0.9 lb ai/ac, quizalofop at 0.04 lb ai/ac, and glyphosate at 0.77 lb ae/ac. Quizalofop was the only herbicide that provided 100% mortality of all accessions. Some plants escaped fluazifop, but all accessions had greater than 90% mortality, except one accession from Crittenden County. Glyphosate resulted in variable levels of mortality, ranging from 10% to 100%. Overall, Arkansas johnsongrass accessions showed high levels of variability in control when treated with glyphosate, while fluazifop and quizalofop applications appeared effective on almost all of the accessions tested.

Introduction

Herbicide resistance has been one of the leading concerns for producers throughout Arkansas in recent years, specifically with Palmer amaranth [*Amaranthus palmeri* (S.) Watson] in soybean (*Glycine max* L.) and cotton (*Gossypium hirsutum* L.). Recent studies have found Palmer amaranth populations resistant to multiple modes of action (Norsworthy et al., 2014). Additionally, johnsongrass (*Sorghum halepense*) has shown the potential for resistance but has not been heavily researched in Arkansas since discovering the first glyphosate-resistant population in 2007 (Riar et al., 2011). Johnsongrass is a perennial grass weed that reproduces through both seed and rhizomes. One johnsongrass plant can produce more than 10,000 seeds and 5,000 rhizomes per plant, causing up to 90% yield loss in cotton, making it one of the most prolific weeds in Arkansas and the United States (McWhorter 1971; Klein and Smith 2020). In the most recent study of herbicide resistance in johnsongrass, populations from roadsides in Arkansas were found to have a 36-fold resistance to fluazifop and 2.8-fold resistance to glyphosate (Bagavathiannan and Norsworthy, 2014). Therefore, heavy reliance on both glyphosate and acetyl CoA carboxylase (ACCase) inhibitors for johnsongrass control could potentially have led to an increase in the number of herbicide-resistant populations in Arkansas.

Procedures

A greenhouse study was conducted in 2020 and 2021 at the University of Arkansas System Division of Agriculture's Milo J. Shult Agricultural Research and Extension Center in Fayetteville, Arkansas, to evaluate johnsongrass' resistance to glyphosate and aryloxyphenoxypropionate (AOP) herbicides. This experiment was a single factor completely randomized design. Seedheads from 63 different johnsongrass populations were collected throughout six counties (Crittenden, Greene, Poinsett, Cross, Mississippi, and Craighead) in 2020. The seed was hand-harvested from seedheads and placed into cold storage for two weeks before planting to break seed dormancy. Trays were filled with standard potting mix, and johnsongrass seed was sown at 100 seeds per tray. Four trays were planted per accession, one for each of the three herbicides and one nontreated for comparison (Table 1). Trays of seedlings were sprayed when johnsongrass reached the 2- to 3-leaf stage. Applications were made at 1 mph and 20 GPA in a spray chamber using flat fan 1100067 nozzles at 40 psi. Both AOP herbicides received 1% v/v of crop oil concentrate as recommended by the label. Before application, the total number of plants in each pot was recorded. The final number of living plants was recorded again 28 days after application (DAA) and used to calculate percent mortality. Visual johnsongrass control was evaluated every 7 days until 28 DAA

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on a scale of 0 to 100, where 0 represents no johnsongrass injury, and 100 represents no living johnsongrass tissue. Data were analyzed using JMP Pro 16.1, and means were separated using Fisher's Protected least significant difference ($\alpha = 0.05$), and boxplots were assembled.

Results and Discussion

Overall, 100% johnsongrass control was achieved on most accessions evaluated. Quizalofop resulted in 100% visual control and percent mortality on all evaluated johnsongrass accessions from eastern Arkansas, while fluazifop reached 99% johnsongrass visual control and 98% mortality. Glyphosate resulted in lower johnsongrass visual control and mortality at 94% and 93%, respectively (Table 1). While average values are important, the accessions most concerning are the outliers, which essentially do not fit the majority of the data due to a lower level of control. Fluazifop had four accessions that were considered outliers, meaning the control levels of these particular accessions do not fall within the 90% of the data. While three of these accessions had visual control and mortality levels greater than 90%, one accession from Crittenden County resulted in only 73% mortality (Figs. 1 and 2). No outliers were observed with quizalofop since 100% mortality and visual control were achieved across all accessions. Glyphosate resulted in the largest variation and the most outliers, with mortality ranging from 10% to 100%, with 5 outliers present (Fig. 2). Johnsongrass accessions observed as outliers following applications of glyphosate were all located in Crittenden County. Bagavthiannan and Norsworthy (2014) observed a similar trend with johnsongrass collected from roadsides throughout Arkansas when treated with fluazifop and glyphosate with accessions exhibiting 36-fold resistance to fluazifop and 2.8-fold resistance to glyphosate. This study agrees with their assumption that if resistance is present on roadsides near the production field, then similar results could be observed within the field itself.

Practical Applications

Johnsongrass accessions resistant to fluazifop and glyphosate are of the most concern in this study. Most cotton producers across Arkansas utilize glyphosate-resistant cotton varieties and rely on glyphosate for johnsongrass control. In these instances, other control options will be vital to mitigate the spread of these resistant populations. In most fields, an ACCase-inhibitor would be the best substitute for glyphosate for johnsongrass control, but fluazifop was ineffective on some accessions. Therefore, producers must be cautious not to overutilize fluazifop and further increase the number of resistant populations in the absence of glyphosate. From the herbicides evaluated, quizalofop would be an effective alternative for producers with known or suspected glyphosate or fluazifop resistance since no resistance was observed in the johnsongrass accessions evaluated. Integrated weed management strategies that utilize cultural, mechanical, and biological control methods along with chemical control methods are needed to better control resistant johnsongrass populations and preserve herbicides that are currently effective.

Acknowledgments

The authors would like to thank the University of Arkansas Systems Division of Agriculture for their support with this study and the Crittenden, Mississippi, Poinsett, Greene, Cross, and Craighead County agents for their assistance in collecting these johnsongrass samples.

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Table 1. Control and mortality of johnsongrass accessions collected in eastern Arkansas in 2020 by herbicide averaged over accession.

Herbicide	lb ai/ac	Visual control	Mortality
		--------------------%--------------------	
Fluazifop	0.90	99 a[†]	98 a
Quizalofop	0.04	100 a	100 a
Glyphosate	0.77	94 b	93 b

[†] Values in each column with different letters are different based on Fisher's protected least significant difference (α = 0.05).

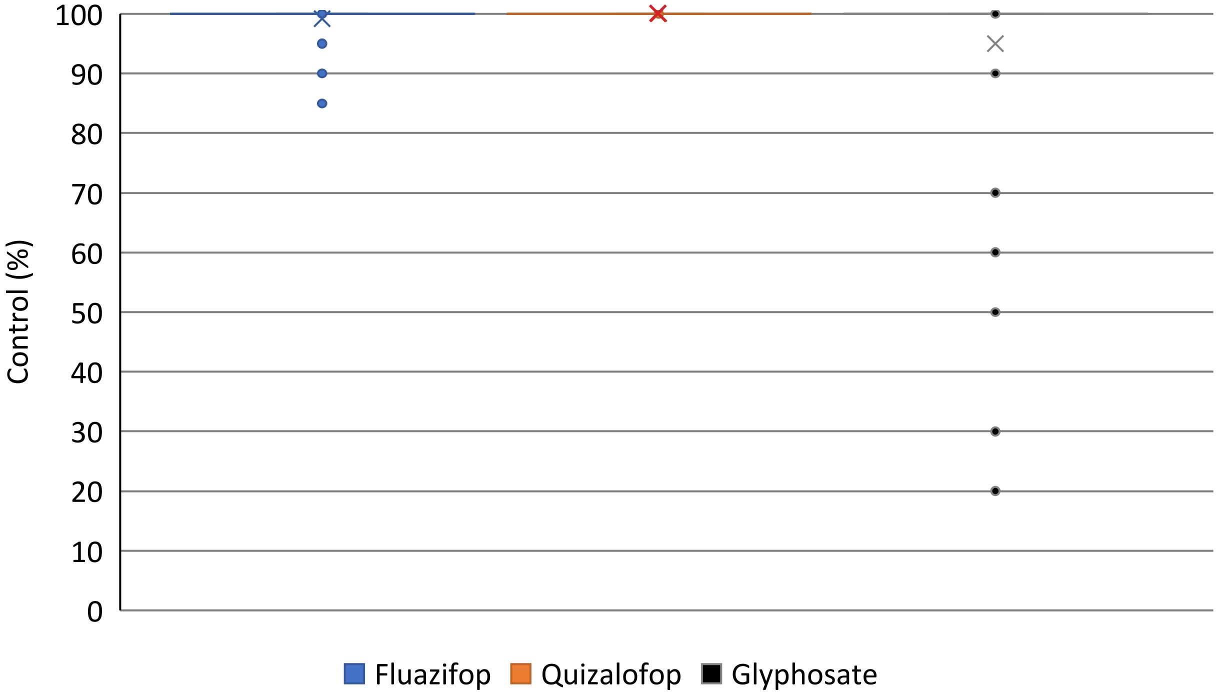

Fig. 1. Box and whisker plots representing visual control of johnsongrass accessions collected in eastern Arkansas in 2020 by herbicide 21 days after treatment. Lines represent median control level, Xs represent the mean control, and dots represent outlier accessions, which do not fall within 90% of the data.

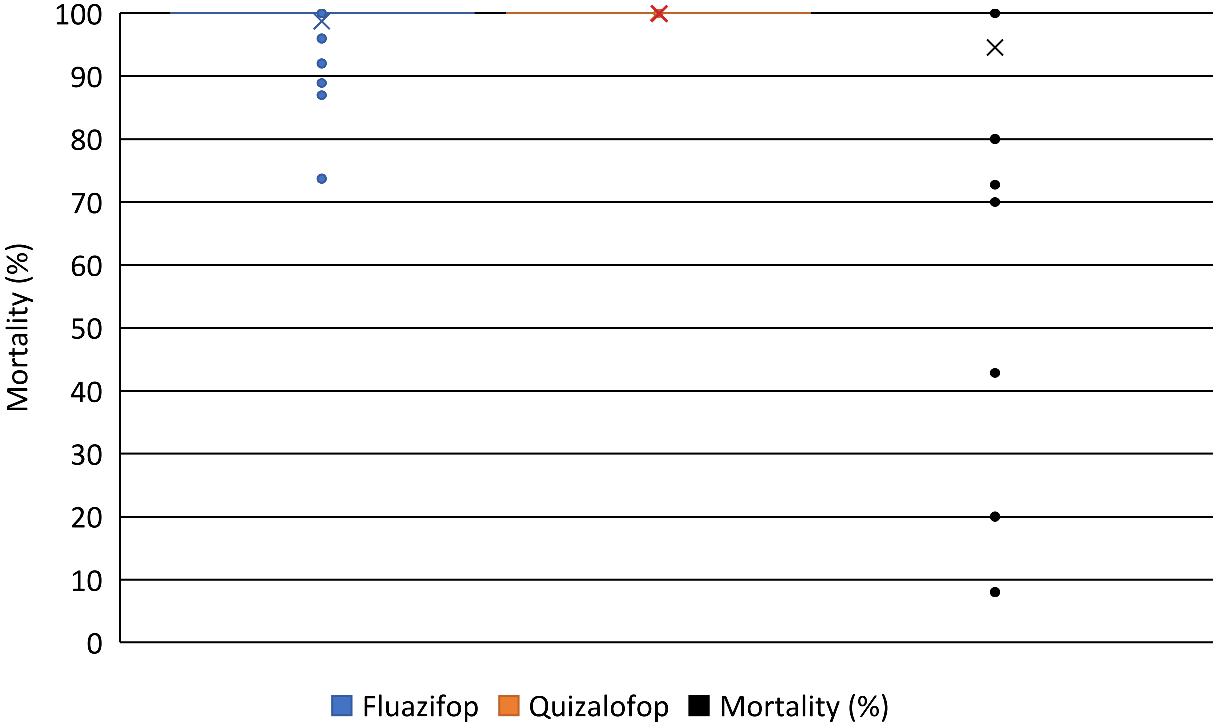

Fig. 2. Box and whisker plots representing percent mortality of johnsongrass accessions collected in eastern Arkansas in 2020 by herbicide 21 days after treatment. Lines represent median percent mortality, Xs represent the mean percent mortality, and dots represent outlier accessions, which do not fall within 90% of the data.

Evaluation of Thryvon Technology for Control of Tobacco Thrips in Cotton

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Abstract

Tobacco thrips are one of the most important pests in mid-South cotton production. Thrips are a pest of seedling cotton feeding on the leaf tissue of plants which can result in stunted growth, delayed fruiting, loss of apical dominance, and possible stand loss. Field studies were conducted in 2021 to evaluate Thryvon, a new transgenic trait in cotton that produces the *Bt* toxin Cry51Aa, for control of tobacco thrips. Thryvon cotton was tested at two locations, Marianna, Arkansas, and Tillar, Arkansas. The trials evaluated thrips control on Thryvon vs. non-Thryvon cotton and the effect of in-furrow insecticides and insecticide seed treatments on Thryvon cotton. Thryvon cotton had 75% fewer thrips and less injury than non-Thryvon cotton. Both the Gaucho insecticide seed treatment and AgLogic in-furrow improved yields in non-Thryvon cotton; however, no treatment improved Thryvon cotton yields. Results from this study indicate that Thryvon has the potential to be a valuable tool for controlling thrips.

Introduction

Tobacco thrips, *Frankliniella fusca*, are the most important pest of seedling cotton in Arkansas. One hundred percent of cotton acres in Arkansas are infested with Thrips (Cook, 2019). Feeding injury on cotton seedlings causes ragged and crinkled leaves, a silver or whitish appearance, and the size of the first true leaf can be greatly reduced. Thrips feeding injury can result in stunted growth, delayed fruiting, loss of apical dominance, and possible stand loss. In Arkansas, cotton producers will typically use an insecticide seed treatment or an insecticide applied in-furrow at planting. On top of this, growers are commonly required to apply a foliar insecticide to successfully manage tobacco thrips. Because of this, mid-South cotton producers are seeking alternative methods of control that offer season-long protection. Thryvon technology is the first cotton biotech trait that will provide season-long protection against tarnished plant bugs and thrips species and will reduce the need for some insecticide applications. Currently, researchers have established an action threshold of 2-5 thrips per plant with damage present for thrips management. The objective of this study was to evaluate Thryvon technology for the control of tobacco thrips.

Procedures

In the first test, plots were planted at two locations, on 20 May at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station and on 2 June on a grower's field in Tillar, Arkansas. Treatments were Thryvon (DP 2131 B3TXF) and non-Thryvon (DP 2055 B3XF) cotton. Both cultivars were treated with Acceleron Elite insecticide seed treatment. At each location, a non-replicated strip trial was conducted with plot size being 37.5 ft. (12 rows) by 600 ft. Thrips samples were collected at 2 to 3 true leaf in a mason jar containing a 70% alcohol solution with 4 samples randomly taken per plot on the same day, and 5 plants per sample. Samples were washed and filtered, and thrips were counted using a dissection microscope.

The second test was conducted at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station. Plots, which were planted on 7 July to accommodate a county extension meeting, generated a high number of thrips. Plot sizes were 25 ft. (8 rows) by 300 ft. Treatments were Thryvon (DP 2131 B3TXF) and non-Thryvon (DP 2055 B3XF) cotton in combination with a fungicide only untreated check or a fungicide + Gaucho insecticide seed treatment for a total of four treatments. On 28 July, thrips samples were collected in a jar with 70% alcohol solution, and 4 samples were taken per plot (5 plants per sample). Samples were washed and filtered, and thrips were counted using a dissection microscope.

In the third test, plots were planted on 27 May at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station. Thryvon cotton was

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compared with and without AgLogic (aldicarb). Plot sizes were 12.5 ft (4 rows) by 50 ft. with 4 replications per treatment. Treatments included a Thryvon (DP2131 B3TXF) and non-Thryvon (DP2055 B3XF) cotton cultivar with each containing an untreated check, 3.5 lb/ac AgLogic in-furrow, 5 lb/ac AgLogic in-furrow and Gaucho insecticide in combination with cotton for a total of eight treatments. All treatments had a base fungicide seed treatment. On 15 June, thrips samples were collected in a jar with 70% alcohol solution, and 4 samples were taken per plot (5 plants per sample) at 2 to 3 true leaf. Samples were washed and filtered, and thrips were counted using a dissection microscope. A damage rating was also collected with a damage rating ranging from 0 (good) to 5 (bad). Once cotton reached desirable moisture, plots were mechanically harvested using a two-row research cotton picker Seed cotton was then weighed to determine yields (Fig. 6). All data were processed using Agriculture Research Manager Version 10, AOV, and Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

Results and Discussion

In the first test, non-Thryvon cotton seedlings had a greater number of total thrips when compared to Thryvon cotton seedlings at both locations. At Tillar, treated and untreated non-Thryvon cotton had over 200 thrips/5 plants, while the Thryvon had fewer than 50 total thrips/5 plants (Fig. 1). Thrip density was lower at the Marianna location, with the total number of thrips on non-Thryvon at 34 and the total number of thrips on non-Thryvon at 15 (Fig. 2). Thrips density was higher at the Tillar location due to a later planting date.

In the second test, there was no difference between the number of thrips on the Gaucho treated cotton when compared to the untreated on both Thryvon and non-Thryvon cotton cultivars (Fig. 3). However, both Thryvon treatments contained fewer thrips than both non-Thryvon treatments.

In the third test, all products reduced damage in the non-Thryvon cultivar, but AgLogic 5 lb/ac was the only treatment to have a lower damage rating than the untreated in the Thryvon cultivars (Fig. 4). All Thryvon treatments had lower damage ratings than the untreated and Gaucho treated non-Thryvon cotton. The AgLogic 5 lb/ac in the non-Thryvon had the least amount of damage of all treatments. Adult thrips numbers were greater in the Gaucho treated non-Thryvon plots than in all other treatments (Fig. 5). Similar to the first and second tests, thrips nymph densities were lower in the untreated and Gaucho treated Thryvon cotton than in their respective treatments in the non-Thryvon cotton. Both rates of AgLogic were the only treatments to reduce nymphal thrip densities in both Thryvon and non-Thryvon cotton. Both Gaucho and both rates of AgLogic improved yields in non-Thryvon cotton; however, no treatment improved Thryvon cotton yields (Fig. 6).

In summary, thrips densities and injury were generally reduced in Thryvon cotton when compared to non-Thryvon cotton. No treatment increased yield in the Thryvon cultivar, but all treatments were associated with increased yields in the non-Thryvon. This would indicate that Thryvon does not benefit from a thrips treatment. These observations are similar to those of other extension and research entomologists throughout the U.S. (pers. comm.). Based on these data, Arkansas should not recommend treatment of tobacco thrips in Thryvon cotton. Because of widespread resistance in tobacco thrips to neonicotinoids and acephate, Thryvon technology has the potential to be a valuable tool in controlling this early season pest.

Practical Applications

Tobacco thrips have consistently been an important pest in cotton. Growers have been looking for alternative methods of control that could reduce insecticide applications as well as increase yield. The information provided from this study shows that Thryvon cotton has the potential, depending on technology cost, to be a valuable tool in thrips management.

Acknowledgments

The authors would like to thank Cotton Incorporated and Bayer Crop Science for their support of this work. We would like to thank all the staff at the Lonoke Extension office for their cooperation and collaboration with this trial. We would also like to thank the staff at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station for their support.

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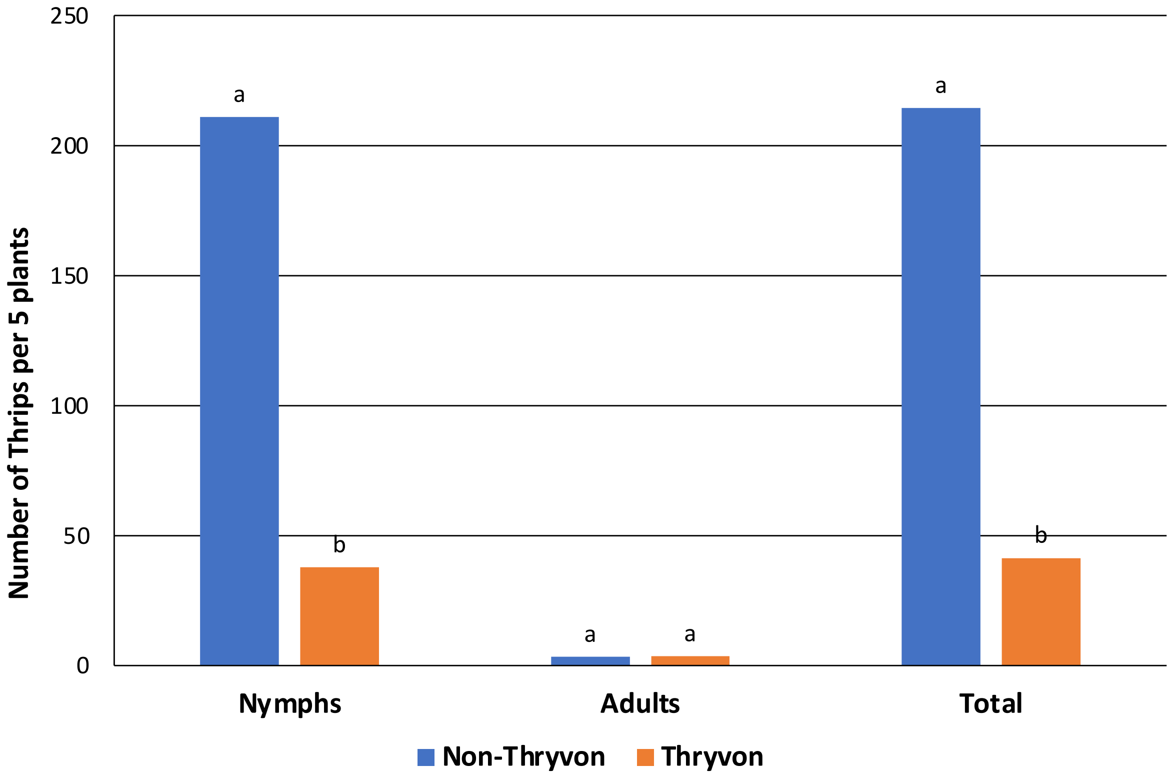

Fig 1. The number of thrips on Thryvon seedlings and non-Thryvon seedlings at Tillar, Arkansas, in 2021 (Test 1). Treatments with the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

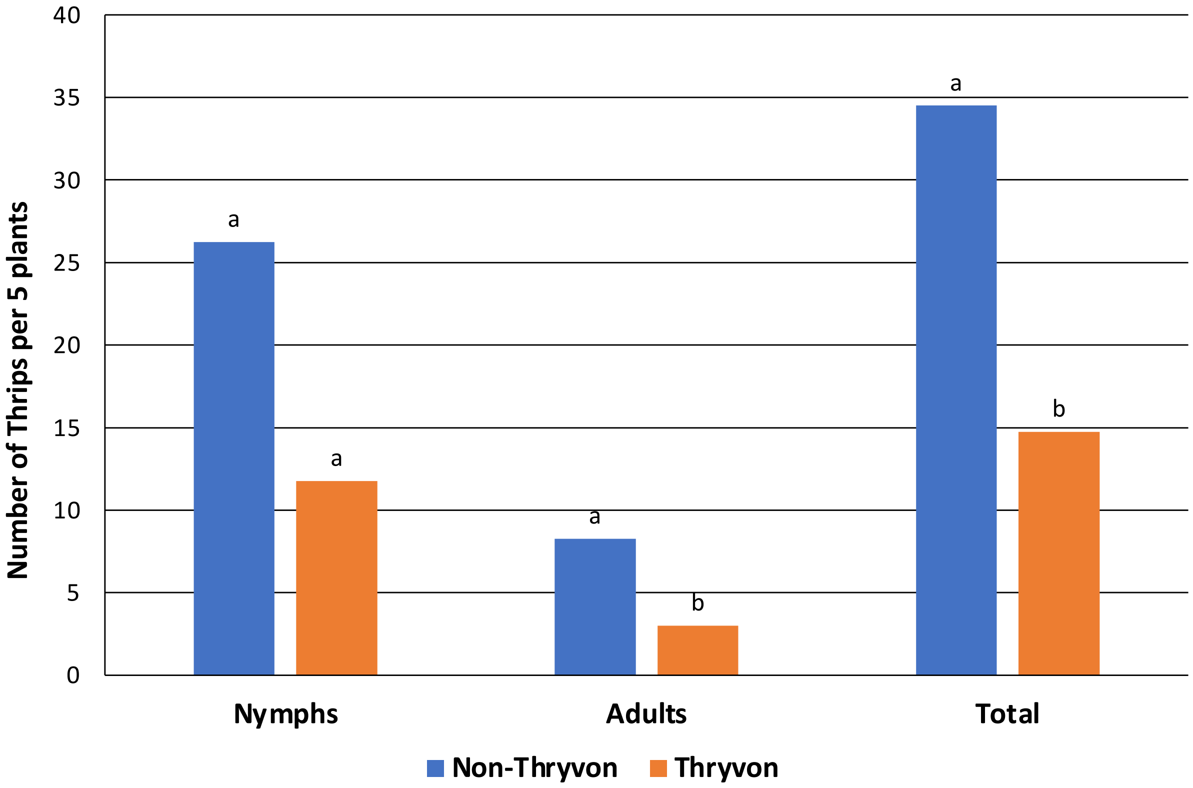

Fig 2. The number of thrips on Thryvon seedlings and non-Thryvon seedlings at Marianna, Arkansas, in 2021 (Test 1). Treatments with the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

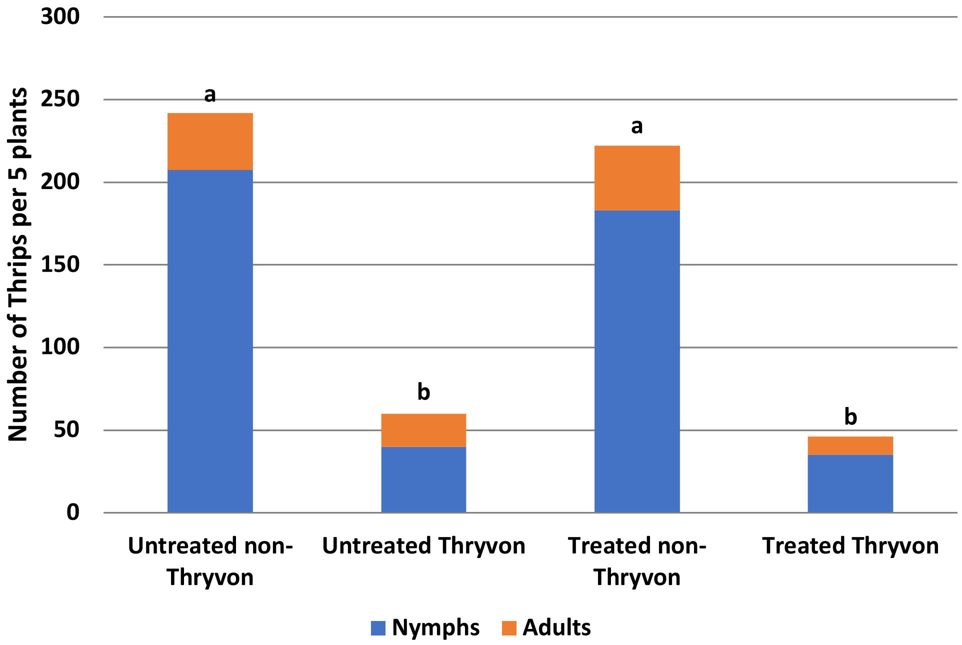

Fig 3. Effects of Gaucho seed treatment on Thryvon and non-Thryvon cotton at Marianna, Arkansas, in 2021 (Test 2). Treatments with the same lowercase latter are not significantly different according to Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

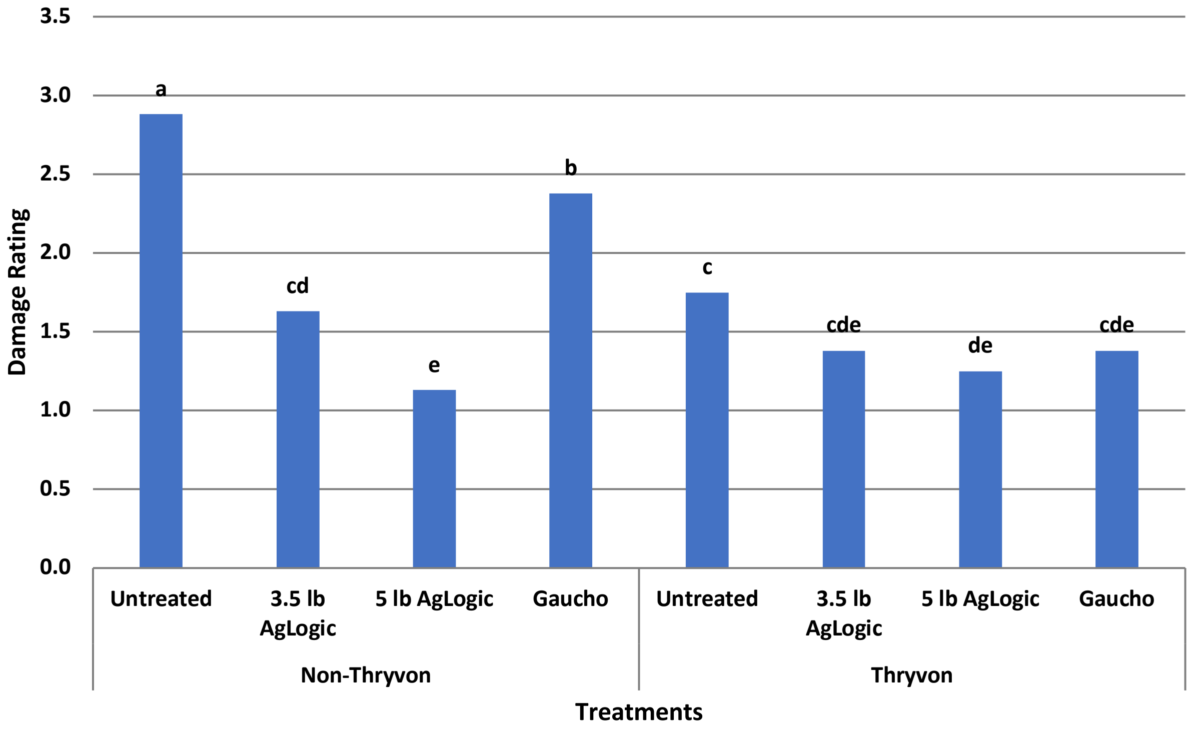

Fig 4. Damage ratings associated with Gaucho seed treatment and AgLogic (3.5 lb/ac and 5 lb/ac) on Thryvon and non-Thryvon cotton at Marianna, Arkansas, in 2021 (Test 3). Treatments with the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

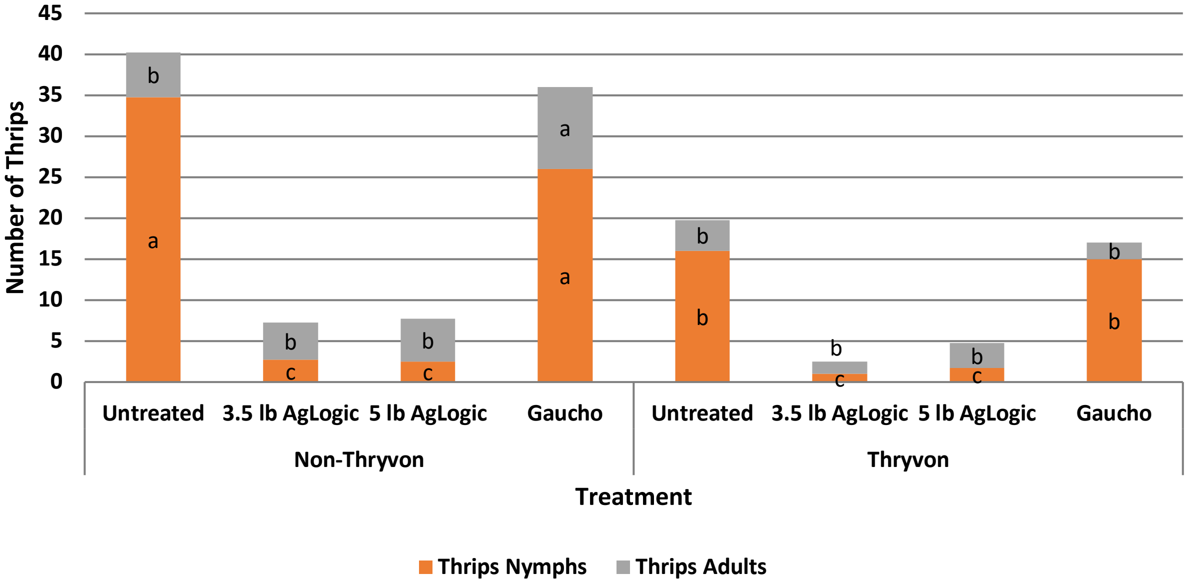

Fig 5. The number of thrips associated with Gaucho seed treatment and AgLogic (3.5 lb/ac and 5 lb/ac) on Thryvon and non-Thryvon cotton at Marianna, Arkansas, in 2021 (Test 3). Treatments with the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

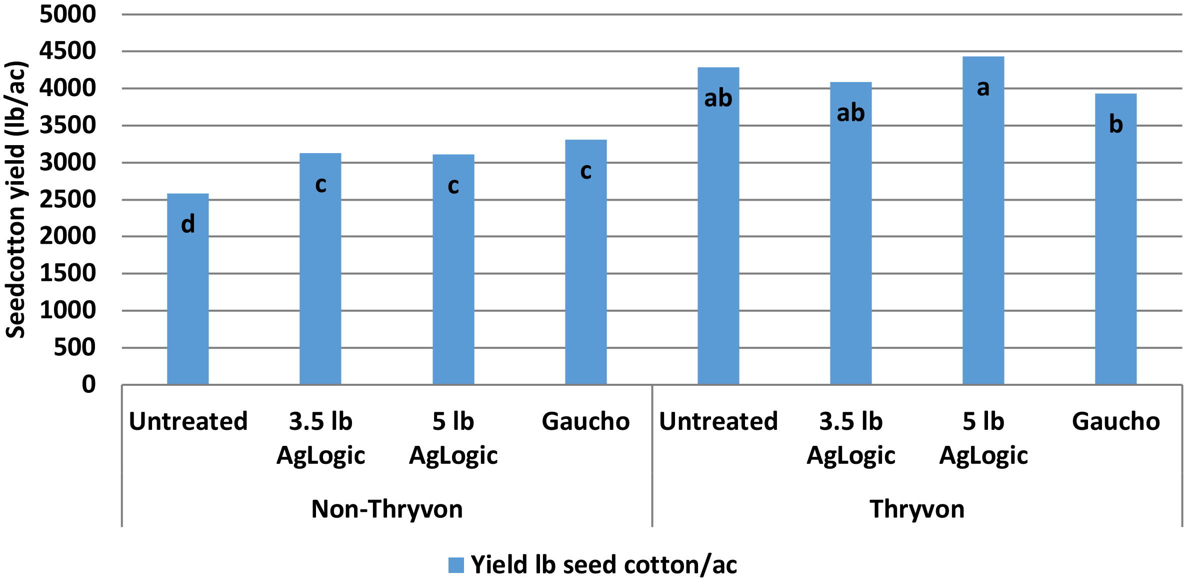

Fig 6. Seed cotton yield (lb/ac) associated with Gaucho seed treatment and AgLogic (3.5 lb/ac and 5 lb/ac) on Thryvon and non-Thryvon cotton at Marianna, Arkansas, in 2021 (Test 3). Treatments with the same lowercase letter are not significantly different according to Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

Evaluation of Thryvon Technology for Control of Tarnished Plant Bug in Cotton

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Abstract

Tarnished plant bug (TPB) is the most important pest in mid-South cotton production, causing square loss, deformed flowers, and damaged bolls, ultimately reducing yield. Tarnished plant bug is difficult to control, with growers averaging 4–6 insecticide applications per year. A field study was conducted in Marianna, Arkansas in 2021 to evaluate Thryvon, a new transgenic trait in cotton that produces the *Bt* protein Cry51Aa, for TPB control. The trial consisted of Thryvon and non-Thryvon cotton that were either left untreated or sprayed at 1x, 2x, or 3x the currently recommended University of Arkansas System Division of Agriculture threshold. Based on our standard threshold, Thryvon required 2 applications for TPB compared to 5 in non-Thryvon at Marianna. Yields in unsprayed Thryvon were no different than any of the sprayed Thryvon treatments. Results from this study indicate that Thryvon may be a valuable tool in TPB management.

Introduction

Tarnished plant bug (TPB), *Lygus lineolaris,* is the number one insect pest of cotton in Arkansas. Tarnished plant bug typically feeds on cotton terminals, squares, flowers, and bolls, causing a reduction in lint yield as well as lint quality. Arkansas cotton producers typically make 4–6 insecticide applications to control TPB (Cook, 2019). Multiple insecticide applications are very expensive for producers; they are continually seeking alternative methods of control. It is currently recommended that growers budget approximately $100 per acre to allow for proper control of TPB throughout the season (CES, 2019). Thryvon technology is the first cotton biotech trait that may provide season-long protection against tarnished plant bugs and may reduce the need for some insecticide applications. Thryvon cultivars are also stacked with Bollgard 3 XtendFlex technology, offering protection against bollworm, tobacco budworm, and other common worm pests and are tolerant to glyphosate, glufosinate, and dicamba. The current action threshold is 3 plant bugs per 5 row feet in non-Thryvon cotton and maintaining a square set greater than 80% is recommended, but this threshold may need to be modified for use in Thryvon cultivars. The objectives of this study were to evaluate Thryvon technology for control of TPB and determine if thresholds for tarnished plant bugs will need to be changed.

Procedures

A study was conducted in 2021 at the University of Arkansas System Division of Agriculture's Lon Mann Cotton Research Station located in Marianna, Arkansas. Plots were planted on 20 May, and plot sizes were 12.5 ft. (4 rows) by 50 ft with 4 replications per treatment. Treatments included treating TPB on Thryvon (DP 2131 B3TXF) and non-Thryvon (DP2055 B3XF) cotton when 1x, 2x, and 3x threshold levels were attained. Samples were taken with a 2.5 ft drop cloth, and 2 samples were taken per plot for a total of 10 row ft. Square retention was also recorded by checking 25 plants per plot. Plots were scouted twice per week, and an application was made when the threshold was met (Table 1). Treatment thresholds included untreated check, 6 nymphs per 10 row ft. (1x threshold), 12 nymphs per 10 row ft. (2x threshold), and 18 per 10 row ft. of any size (3x threshold). When the target threshold was met, plots were sprayed with 1.75 oz of Transform using a Mud-Master sprayer fitted with 80-02 dual flat fan nozzles with 19.5-in. spacing. Spray volume was 10 gal/ac at 40 psi. Once cotton reached desirable moisture, plots were mechanically harvested using a two-row research cotton picker Seed cotton was then weighed to determine yields (Fig. 3). Data were processed using JMP 12 and Tukey's honestly significant difference ($P = 0.10$) to separate means.

Results and Discussion

At the 1x, 2x, and 3x threshold levels, Thryvon cotton required 3, 1, and 0 fewer insecticide applications than the non-Thryvon cotton plot, respectively (Table 1). Season total mean TPB nymph density was reduced by 34.9% in the untreated Thryvon plots when compared to untreated non-Thryvon plots (Fig. 1). Season total mean square retention

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did not differ between Thryvon and non-Thryvon plots in their respective 1x and 2x threshold treatments (Fig. 2). However, Thryvon cotton did have higher square retention than the respective non-Thryvon treatment in the 3x threshold and untreated plots. Square retention did not differ across all Thryvon treatments but in non-Thryvon cotton, square retention was lower in the 3x threshold and untreated plots than the 1x and 2x threshold treatments. The trends were similar for yield where 1x and 2x threshold treatments in the non-Thryvon did not differ from the respective Thryvon treatments but were lower in the 3x threshold and untreated plots (Fig. 3). Across the Thryvon treatments, yields did not differ from the untreated check. Across the non-Thryvon treatments the 3x and untreated plots yielded lower than the 1x threshold treatment.

Thryvon cotton reduced the number of TPB nymphs found in the field and had improved square retention over the comparable non-Thryvon plots. These data indicate that Thryvon cotton has the ability to reduce TPB applications while continuing to maintain yield when compared to non-Thryvon treatments. Thryvon cotton has the potential to be another valuable tool in TPB management.

Practical Applications

Tarnished plant bug has been the most important pest within cotton for over a decade now. Growers need alternative methods of control that reduce the number of insecticide applications and increase yield. These data suggest that Thryvon has the potential to be a valuable tool in controlling TPB.

Acknowledgments

The authors would like to thank Cotton Incorporated and Bayer Crop Science for their support of this work. We would like to thank all the staff at the Lonoke Extension office for their cooperation and collaboration with this trial. The authors would like to thank the staff at the Lon Mann Cotton Research Station for their support. We would also like to thank A.J. Hood at Tillar and Company for allowing us to conduct research on their land.

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

Table 1. Number and dates of insecticide applications in Thryvon and non-Thryvon cotton at 1x, 2x, and 3x threshold at Marianna, Arkansas, in 2021.

Threshold Level	Thryvon	Non-Thryvon
1x Threshold	2 (7/20, 8/9)	5 (7/9, 7/12, 7/20, 7/27, 8/11)
2x Threshold	2 (7/12, 7/27)	3 (7/9, 7/12, 7/30)
3x Threshold	1 (7/30)	1 (7/23)

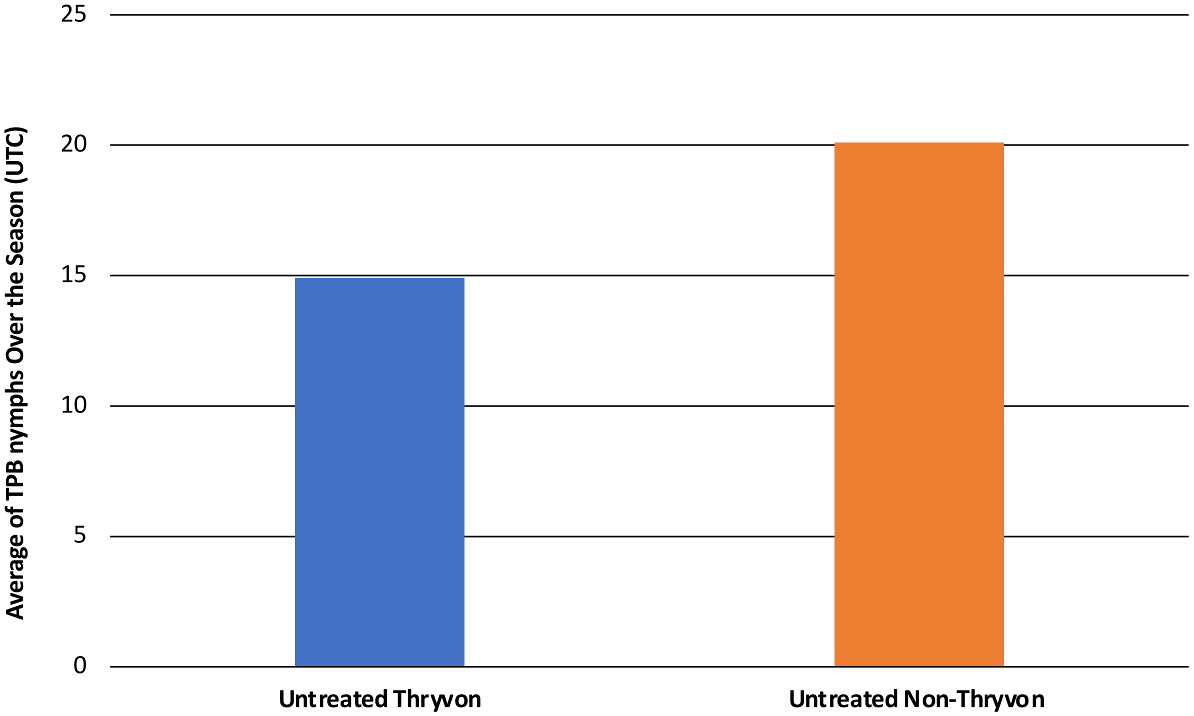

Fig. 1. Average of tarnished plant bug (TPB) nymphs over the season in untreated Thryvon and non-Thryvon cotton at Marianna, Arkansas, in 2021. UTC = untreated check.

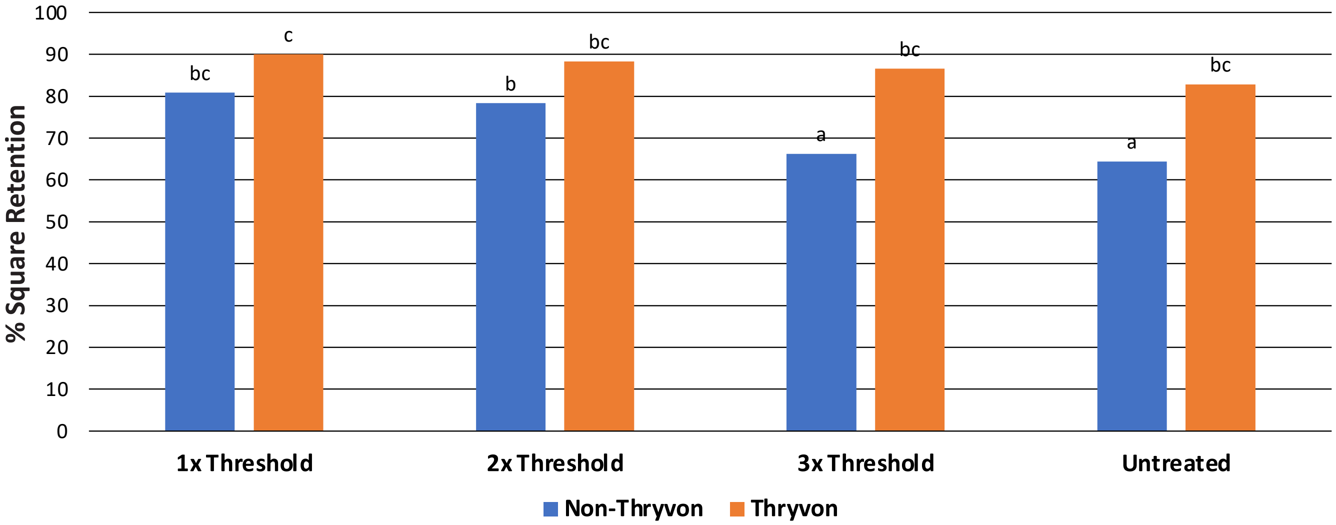

Fig. 2. Square retention in Thryvon and non-Thryvon cotton receiving treatment at three tarnished plant bug treatment thresholds at Marianna, Arkansas, in 2021. Treatments with the same lowercase latter are not significantly different according to Duncan's New Multiple Range Test (*P* = 0.10) to separate means.

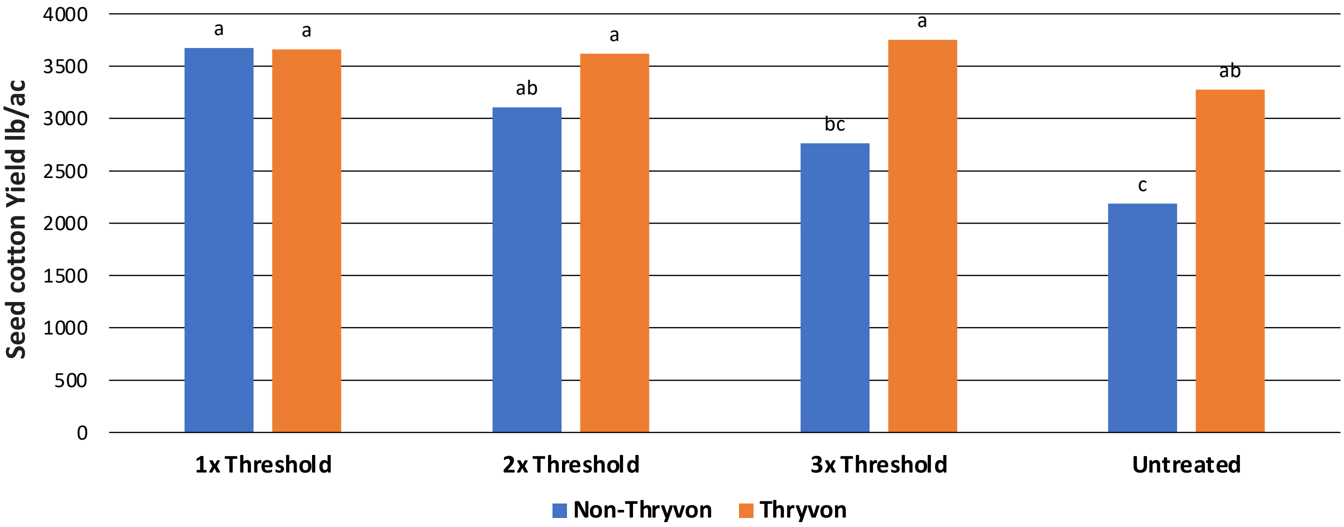

Fig. 3. Seed cotton yields for Thryvon and non-Thryvon cotton receiving treatment for tarnished plant bugs at three treatment thresholds at Marianna, Arkansas, in 2021.

Large Plot Evaluation of Cotton Cultivars for Resistance to Tarnished Plant Bug

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

Abstract

Tarnished plant bug (TPB) (*Lygus lineolaris*) is one of the most damaging pests of cotton (*Gossypium hirsutum* L.) in Arkansas. Tarnished plant bug has been ranked as the number one pest of cotton, causing the highest crop losses in recent years. The objective of this research was to evaluate TPB populations and yield associated with cotton cultivars that purportedly vary in their resistance to TPB. Performance was evaluated in large plots (16 rows by 100 feet) in which TPB was controlled or not controlled. Four cultivars (PHY 360 W3FE, PHY 350 W3FE, DP 1725 B2XF, and Armor 9608 B3XF) had significantly lower TPB populations throughout the season when compared to a susceptible cultivar (DG 3317 B3XF). The same cultivars reached the treatment threshold of 3 TPB/5 row feet 2 times compared to 4 times for the susceptible cultivar. Two cultivars (PHY 390 W3FE and PHY 350 W3FE) exhibited low yield loss under high TPB populations. One cultivar, Armor 9608 B3XF, showed no significant yield loss under high TPB populations, indicating potential useful resistance to TPB. The 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) is a key pest of cotton in the mid-South (Williams, 2016). Increasing levels of insecticide resistance as well as loss of key insecticides have limited growers' options to control this pest. Overuse of insecticides can also have adverse effects on predatory insects and pollinators. Host-plant resistance is an important component of IPM and should not be overlooked. Utilizing varietal resistance as a tool for TPB management in cotton should reduce the number of insecticide applications made annually for this pest, help delay the further development of insecticide resistance and reduce long-term effects on non-target organisms. As new cultivars become available, it is important that their level of resistance or susceptibility to TPB should be evaluated.

Procedures

A field trial was planted on 20 May 2021 at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center, Keiser, Arkansas, to validate TPB resistance in large field plots. Plots were 16 rows by 100 feet long arranged in a randomized complete block design with four replications. Seven cultivars showing resistance from the small plot data from previous years (NG 3195 B3XF, DP 1646 B2XF, DP 1725 B2XF, PHY 360 W3FE, PHY 390 W3FE, PHY 350 W3FE, and Armor 9608 B3XF) were evaluated. DG 3317 B3XF was also evaluated as a susceptible check 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 3 plant bugs per 5 row feet. 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 (NAWF = 5) plus 250 accumulated heat units. Heat units were determined on a DD60 heat unit scale. Plots were taken to yield by harvesting the eight center rows in each plot with a small plot cotton picker. All data were analyzed using Agriculture Research Manager (ARM) version 2020 software. Means were separated using least significant difference at the $P = 0.05$ level.

Results and Discussion

Tarnished plant bug populations were high, reaching a peak of 21 per 10 row feet in DG 3317 B3XF (susceptible) as well as DP 1646 B2XF on week 3 (Fig. 1). Tarnished plant bug numbers are reported in levels per 10 row-ft; therefore, the economic threshold in the figure would be six. Cultivars could be divided into three separate groups based on TPB numbers in untreated plots. DG 3317 B3XF, DP 1646 B2XF, and NG 3195 B3XF had overall high populations; PHY 350 W3FE, PHY 360 W3FE, and PHY 390 W3FE had moderate populations, while TPB numbers remained low in DP 1725 B2XF and Armor 9608 B3XF throughout the season (Fig. 2). Cultivars reached the economic threshold ranging from 2 to 4 times throughout the season, with all eight cultivars reaching threshold at least twice (Fig. 3). Yield loss was de-

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termined by subtracting yields from the untreated plots from those that were treated at threshold and is reported in Figure 4. Armor 9608 B3XF was the only cultivar that did not experience significant yield loss due to TPB (Fig. 4, $P = 0.05$). The lack of significant yield loss indicates there is a good level of resistance or tolerance in Armor 9608 B3XF. Both Armor 9608 B3XF and DP 1725 B2XF experienced similar TPB populations throughout the season, both reaching economic threshold twice. However, DP 1725 B2XF experienced yield loss similar to the susceptible check DG 3317 B3XF and both had approximately 1000 lb/ac more loss in yield than Armor 9608 B3XF. While DP 1725 B2XF exhibited decent resistance in ultra-small plots in previous years, this did not translate in the large plot study.

Practical Applications

Knowledge of the susceptibility of cotton cultivars to tarnished plant bug will aid growers in cultivar selection. Timely insecticide applications are required to properly manage tarnished plant bug. Utilizing more tolerant/resistant cultivars can give growers more wiggle room on timing insecticide applications and should minimize yield loss.

Acknowledgments

The authors would like to thank the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center for providing a location, as well as Cotton Incorporated for providing funding for this project.

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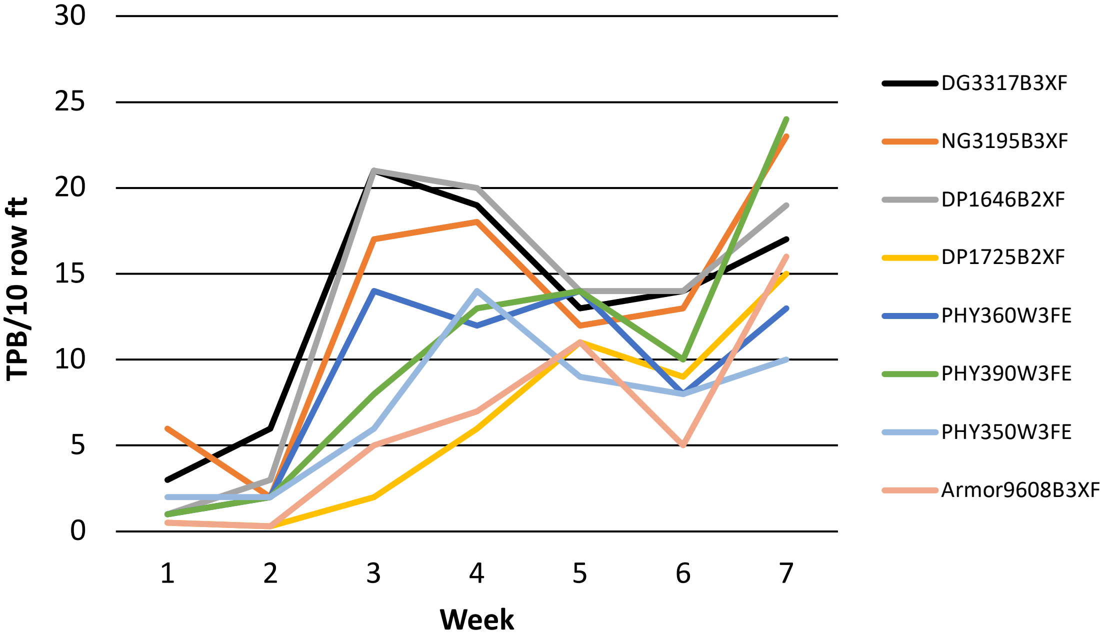

Fig. 1. Tarnished plant bugs per 10 row feet per week in untreated plots, 2021.

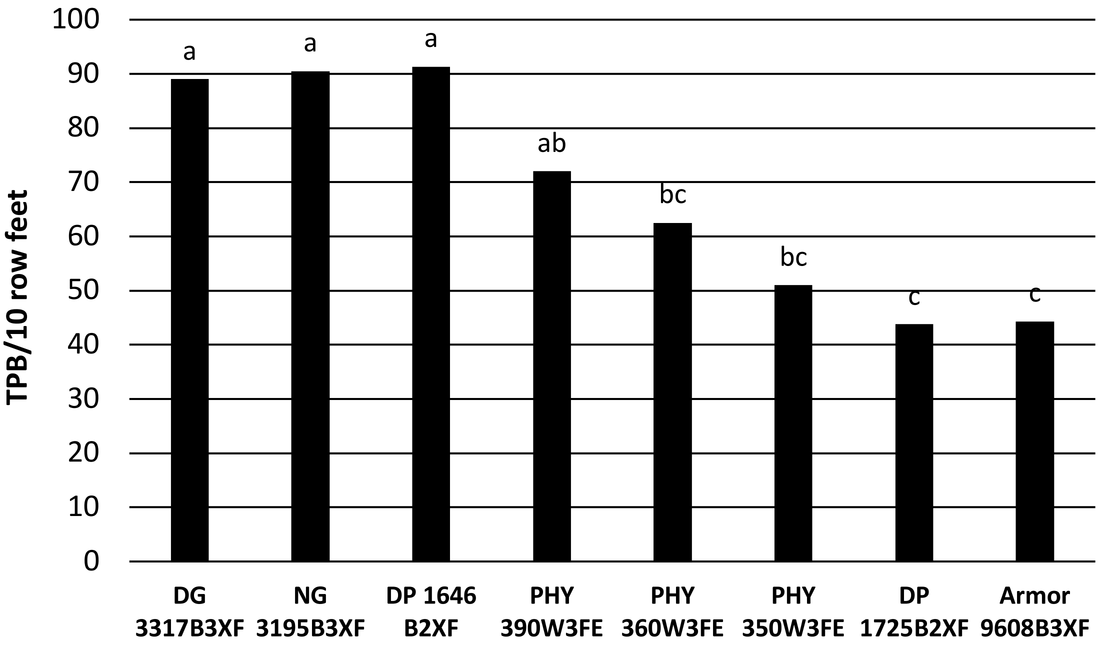

Fig. 2. Season-long total of tarnished plant bugs in untreated plots, 2021. Columns with different letters are significantly different (*P* = 0.05).

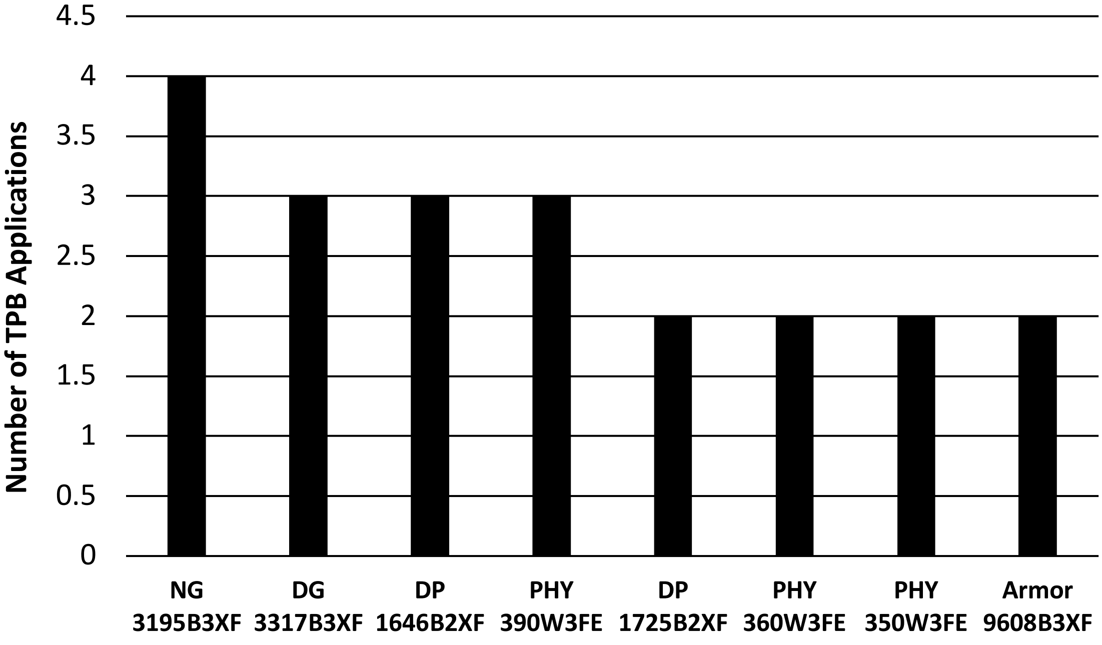

Fig. 3. The number of tarnished plant bug insecticide applications by cultivar throughout the 2021 season.

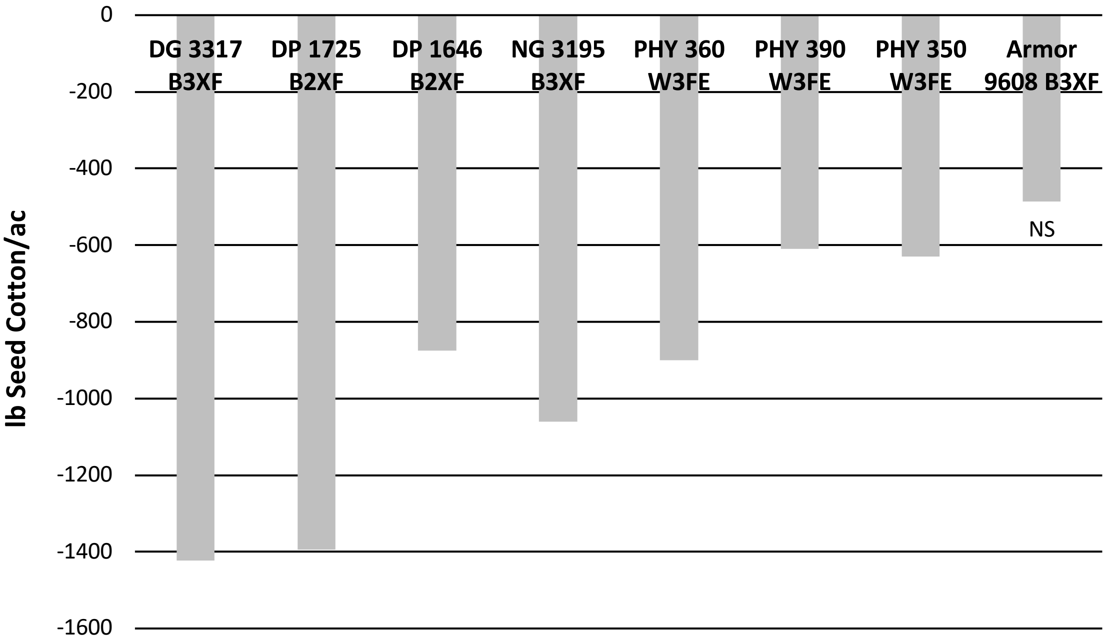

Fig. 4. Seed cotton yield loss attributed to tarnished plant bugs (TPB) in 2021. Loss was determined by subtracting yield from TPB unmanaged plots from plots where TPB were managed. NS indicates yields were not significantly different (*P* = 0.05).

Assessment of Foliar Insecticide Applications in Arkansas Cotton Systems for Control of Cotton Bollworm, *Helicoverpa zea*

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S.G. Felts,[3] C.A. Floyd,[1] C. Rice,[1] T. Newkirk,[1] A. Whitfield,[1] and T. Harris[1]

Abstract

Transgenic *Bacillus thuringiensis (Bt)* technologies are one of the widely used methods of controlling cotton bollworm (*Helicoverpa zea*). Due to high technology fees and documented cotton bollworm resistance to transgenic *Bt* technologies, supplemental foliar applications may be required to manage high populations of bollworm. Despite additional input costs, growers could achieve greater profits with an insecticide application when bollworm threshold is exceeded. Research was conducted in 2021 in Drew County, Arkansas, to evaluate several insecticides, including Prevathon, acephate, and bifenthrin, for efficacy and residual control of cotton bollworm on multiple *Bt* cotton technologies. Results suggest that sprayed Bollgard II had similar levels of damage to all Bollgard 3 treatments. All Bollgard 3 treatments, sprayed Bollgard II, and non-*Bt* plots receiving a second insecticide application had similar yields, which were greater than unsprayed non-*Bt* and non-*Bt* sprayed with Prevathon or Acephate plus Bifenthrin.

Introduction

Cotton is a high input crop, and many growers are struggling to make profits due to the increasing costs of insecticide applications, weed control, field maintenance, and technology fees. This makes finding ways to save growers money imperative. Each year cotton bollworm (*Helicoverpa zea*, Bodie) infests 100% of all cotton planted in Arkansas (Cook, 2020). Despite widespread use of transgenic *Bacillus thuringiensis (Bt)* cotton cultivars, cotton bollworm remains a major pest of flowering cotton, and foliar insecticides are often needed for supplemental control. Fleming et al. (2018) conducted studies in 2017 that indicated widespread resistance to Cry1Ac, a major protein used in *Bt* cotton. Recent research has established a new bollworm threshold based on damaged fruit, with the new threshold being set at 6% fruit damage with larvae present or 20% egg-lay (Studebaker, 2019). Because of the high technology fees associated with these traits and the growing concern of *Bt* resistance, it is imperative that growers know the best tools to protect yield potential. Of particular interest are comparisons of *Bt* cultivars using insecticides with three different modes of action. The objective of this study was to determine the cost-effectiveness of cheaper short residual insecticides versus more expensive long residual insecticides on non-*Bt*, dual gene, and three gene cotton against cotton bollworm.

Procedures

A study was conducted in Tillar, Arkansas, in 2021 to determine the efficacy and residual control of multiple insecticides on cotton bollworm on multiple *Bt* technologies. A non-*Bt* (DP 1822 XF), a two-gene (DP 1646 B2XF), and a three-gene cultivar (DP 1845 B3XF) were planted on 16 May. Plot size was 12.5 ft. (4 rows) by 40 ft.

Treatments within each cultivar included: Untreated Check (UTC); Prevathon (20 oz/ac); Prevathon (20 oz/ac) followed by Prevathon (20 oz/ac); Prevathon (20 oz/ac) followed by Acephate (0.75 lb/ac) plus Bifenthrin (6.4 oz/ac); and Acephate (0.75 lb/ac) plus Bifenthrin (6.4 oz/ac).

Each insecticide application was initiated when the 6% fruit damage threshold was exceeded in the non-*Bt* plots. The first applications of Prevathon and Acephate plus Bifenthrin were applied on 22 July. Data collection occurred at 4,7, 12, 15,19, and 22 days after application (DAA1) for the first series of sprays. For the plots receiving a second application of Prevathon or Acephate plus Bifenthrin, it was applied on 9 August. For the two plots within each technology, one received an a additional application of Prevathon and the other received Acephate plus Bifenthrin. Data collection occurred at 3, 8, 12, and 20 days after application (DAA2). Each application was made using a Mudmaster high clearance sprayer fitted with TXVS-6 flat fan nozzles at 19.5-in.

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spacing with a spray volume of 10 gal/ac at 40 psi. In each plot, 25 squares, 25 flowers, and 25 bolls were sampled, and the number damaged for each was recorded. The two center rows of each plot were harvested on 1 Nov. Yield was reported as lb/ac of seed cotton. Data were processed using Agriculture Research Manager 2019 (Gylling Data Management, Inc., Brookings, S.D.). Analysis of variance was conducted with Duncan's New Multiple Range Test ($P = 0.10$) to separate means.

Results and Discussion

At 4 DAA1, the unsprayed non-*Bt* plots had the greatest amount of damaged fruit at 9 percent (Fig. 1). Both the sprayed Bollgard II and Bollgard 3 plots had similar amounts of damage and had less than unsprayed non-*Bt* and unsprayed Bollgard II. At 7 DAA1, the percent damaged fruit was greatest in unsprayed non-*Bt* (Fig. 2). Insecticides across each technology, except Acephate plus Bifenthrin in the non-*Bt*, adequately reduced fruit damage. Similar trends were observed for the 12 DAA1 sampling time (Fig. 3). Decreased damage was noticed across all plots at 15 DAA1, except the unsprayed non-*Bt*, due to bollworm larvae reaching pupation (data not shown). At 19 DAA1, increased fruit damage was observed in the non-*Bt* plots sprayed with Acephate plus Bifenthrin and the plot receiving two applications of Prevathon (Prev FB Prev). Increased fruit damage was also observed in the unsprayed Bollgard II. Bollgard 3 and sprayed Bollgard II plots contained the least amount of damage (Fig. 4). During data collection at 22 DAA1, all non-*Bt* plots and unsprayed Bollgard II were above the 6% fruit damage threshold, which initiated the second insecticide application (data not shown).

At 3 DAA2, Bollgard II and Bollgard 3 plots received a second application of insecticide, denoted by red boxes to indicate which plots were below the fruit damage threshold (Fig. 5). Decreased damage was noticed across all plots that received two applications of insecticide at 8 DAA2 and 12 DAA2, except the non-*Bt* plots receiving the second application (data not shown). At 20 DAA2, all plots that received a second application of insecticide had similar levels of damage and had less damage than plots that did not receive a second application, except all Bollgard 3 plots (Fig. 6). Non-*Bt* plots sprayed with two applications of Prevathon and Prevathon along with Acephate plus Bifenthrin had yields similar to the Bollgard II and Bollgard 3 plots (Fig. 7). Acephate plus Bifenthrin may not provide the protection needed and additional applications of insecticide may be required. Due to recently documented resistance in bollworm to multiple cry proteins, growers should budget at least one diamide insecticide application when planting anything other than a three-gene variety to prevent yield loss.

Practical Applications

Supplemental foliar applications may be needed in order to protect yield from cotton bollworm in non-*Bt* and Bollgard II technologies. These results imply that growers applying Prevathon at 20 oz/ac will achieve adequate control across non-*Bt* and two gene cultivars. Acephate plus Bifenthrin may not provide sufficient control of high populations of bollworm. Growers should consider pest pressure and fruit damage loss when selecting insecticide, as well as technology.

Acknowledgments

Appreciation is expressed to A.J. Hood for providing the land where this research was conducted. Support was also provided by the University of Arkansas System Division of Agriculture.

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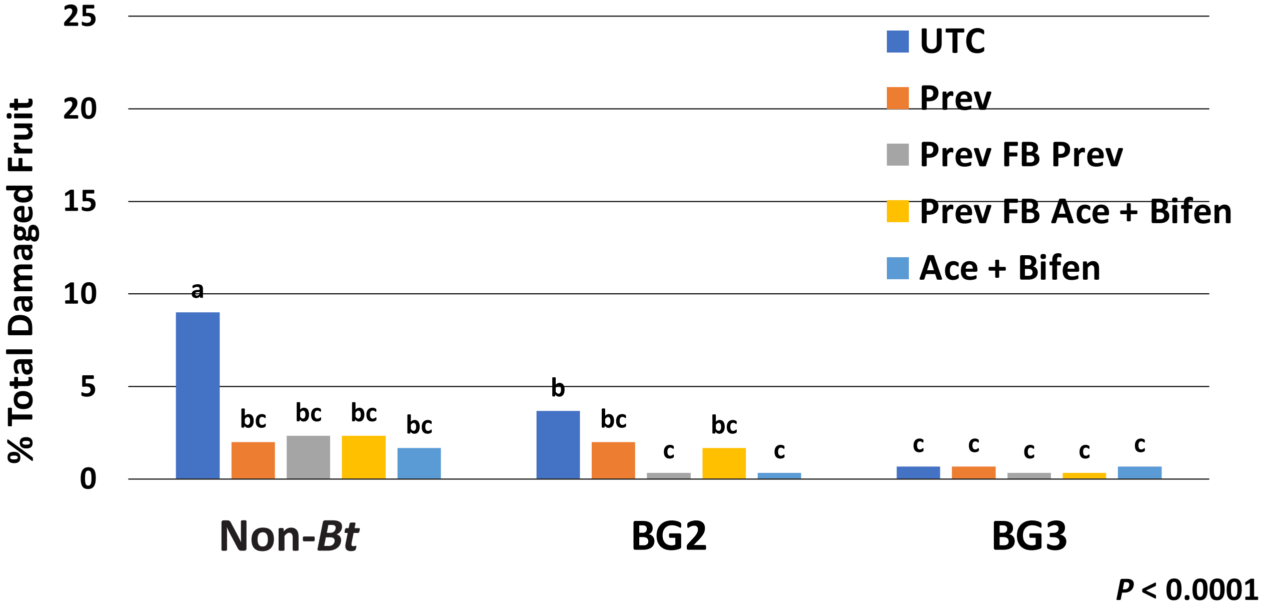

Fig. 1. Combined damage of 25 squares, 25 flowers, and 25 bolls on 26 July 2021, 4 days after the application of three classes of chemistry in Drew County, Arkansas.

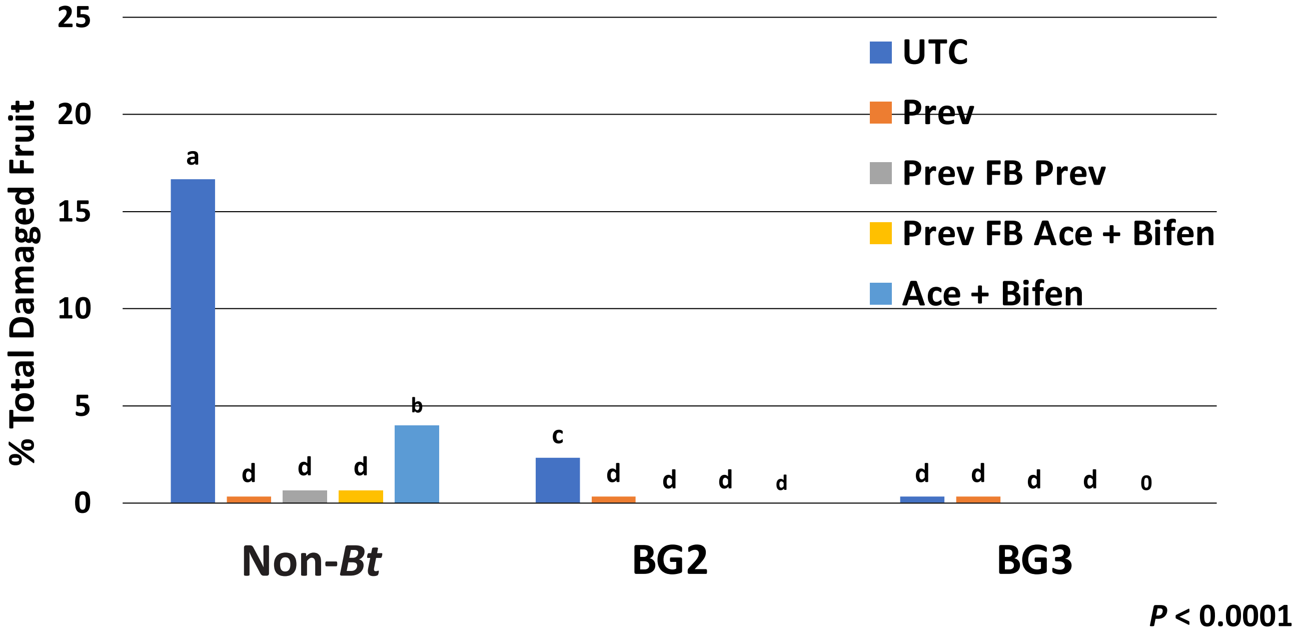

Fig. 2. Combined damage of 25 squares, 25 flowers, and 25 bolls on 29 July 2021, 7 days after the application of three classes of chemistry in Drew County, Arkansas.

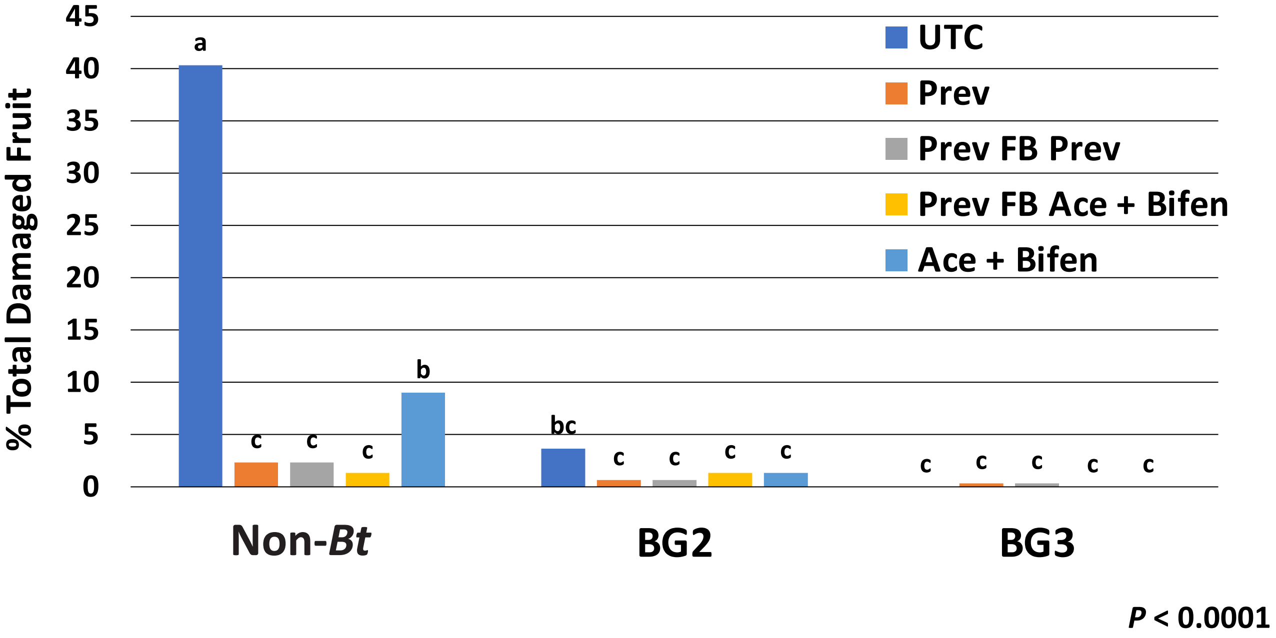

Fig. 3. Combined damage of 25 squares, 25 flowers, and 25 bolls on 3 August 2021, 12 days after the application of three classes of chemistry in Drew County, Arkansas.

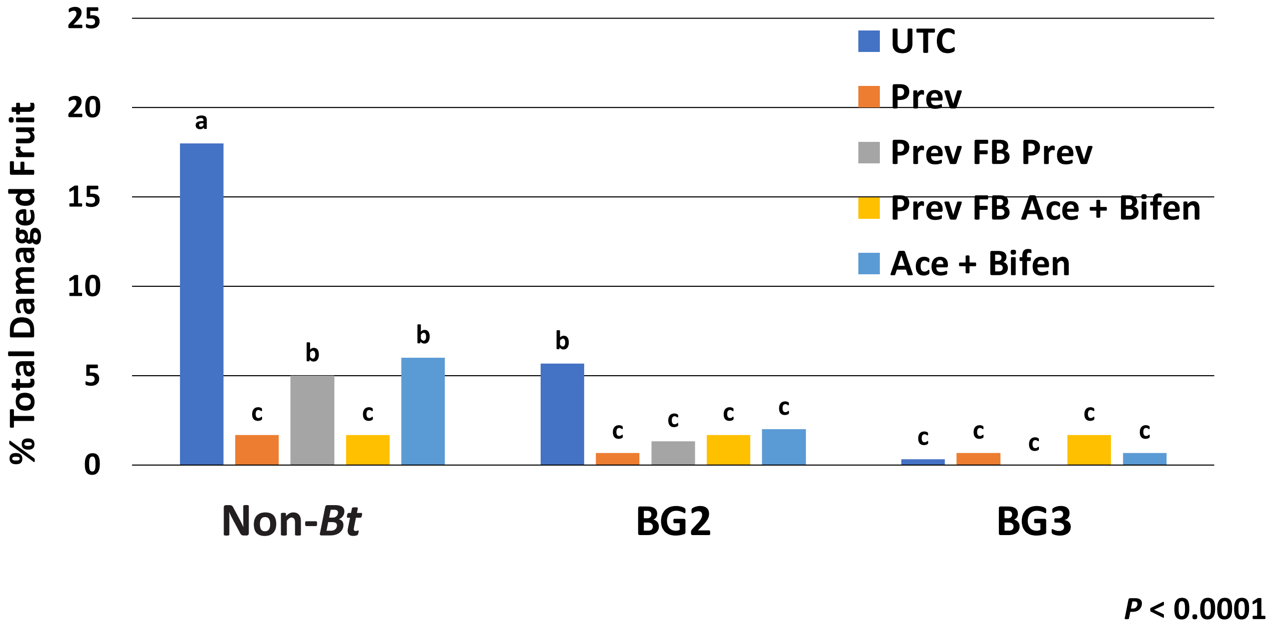

Fig. 4. Combined damage of 25 squares, 25 flowers, and 25 bolls on 10 August 2021, 19 days after the application of three classes of chemistry in Drew County, Arkansas.

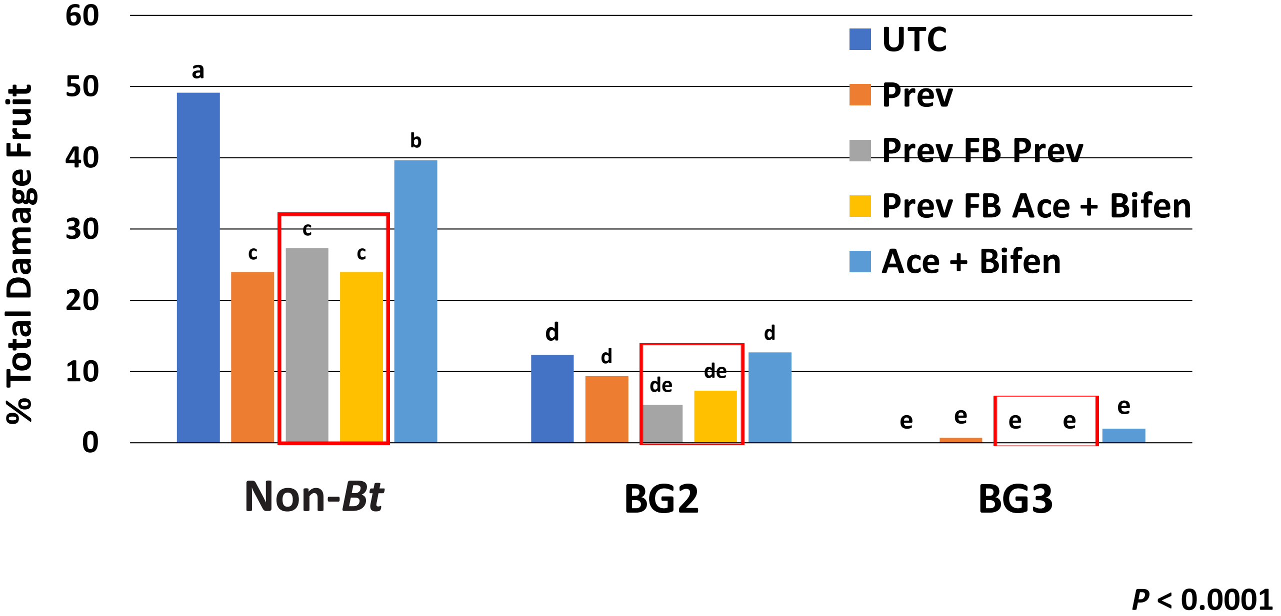

Fig. 5. Combined damage of 25 squares, 25 flowers, and 25 bolls on 12 August 2021, 3 days after the second application of three classes of chemistry in Drew County, Arkansas. Red boxes were placed around the plots that received the second application.

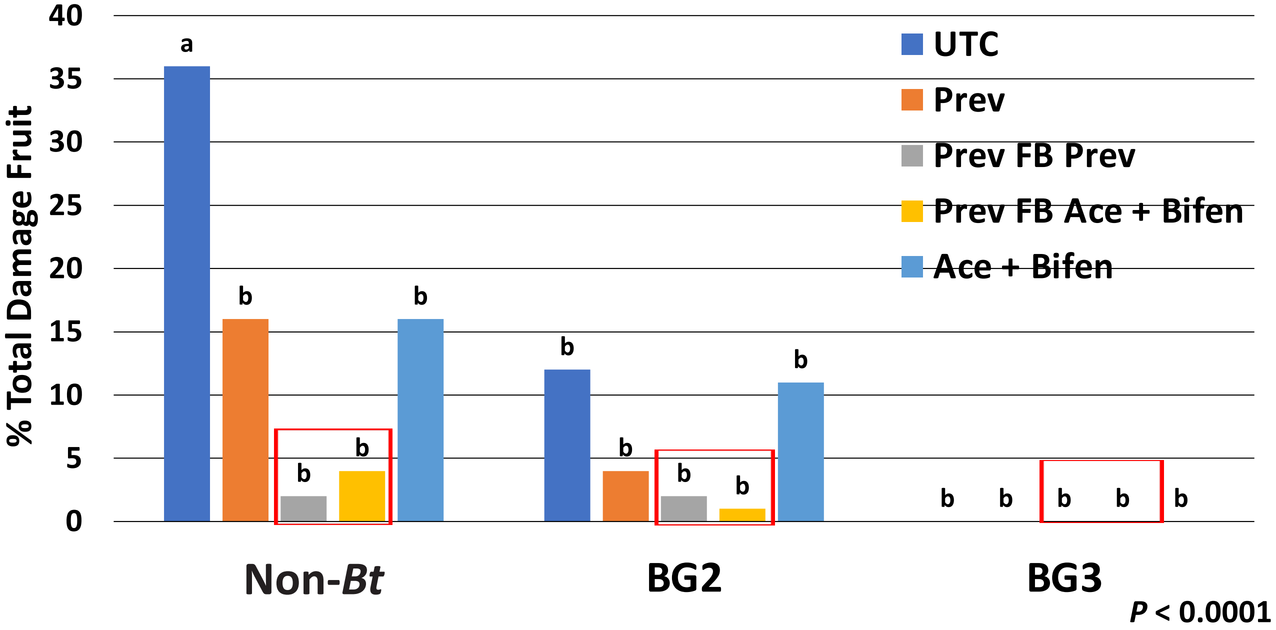

Fig. 6. Combined damage of 25 squares, 25 flowers, and 25 bolls on 29 August 2021, 20 days after the second application of three classes of chemistry in Drew County, Arkansas. Red boxes were placed around the plots that received the second application.

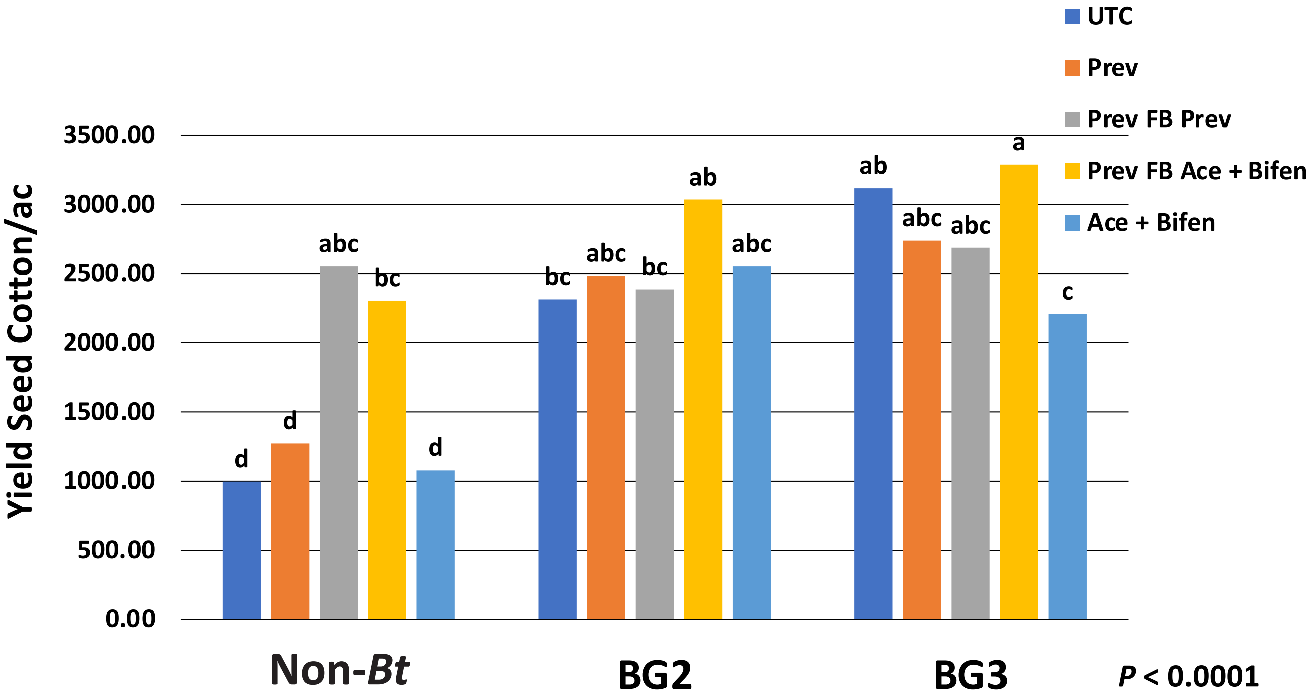

Fig. 7. Yield of non-*Bt*, two-gene, and three-gene cotton cultivars, with and without an application of insecticide in Drew County, Arkansas, in 2021.

Comparison of Transgenic *Bacillus thuringiensis* Technologies in Arkansas Cotton Systems for Control of Cotton Bollworm, *Helicoverpa zea*

Z. Murray,[1] G.M. Lorenz,[2] B.C. Thrash,[2] N.R. Bateman,[3] W.A. Plummer,[2] J.P. Schafer,[2]
S.G. Felts,[3] C.A. Floyd,[1] C. Rice,[1] T. Newkirk,[1] A. Whitfield,[1] and T. Harris[1]

Abstract

A widely used method of controlling cotton bollworm (*Helicoverpa zea*) in cotton is the use of transgenic *Bacillus thuringiensis (Bt)* technologies. Resistance has recently been documented in cotton bollworm to dual gene cotton cultivars, and results indicate that dual gene cultivars may require supplemental foliar applications to manage high populations. There is some evidence that, while more efficacious against bollworm, three-gene cotton cultivars yield less than dual-gene cultivars. Despite this yield gap, growers could have greater profits using three-gene cultivars due to lower input and production cost. Research was conducted in 2021 in Drew County, Arkansas, to evaluate the efficacy of several *Bt* technologies and the economic value of Bollgard II and Bollgard 3 technologies. Results suggest sprayed dual-gene cultivars had similar levels of damage to unsprayed three-gene cultivars. All three-gene treatments, sprayed non-*Bt* and sprayed Bollgard II, had similar yields, which were greater than unsprayed non-*Bt* and unsprayed Bollgard II.

Introduction

Cotton is a high input crop and many growers are struggling to make profits due to the increasing costs of insecticide applications, weed control, field maintenance, and technology fees. This makes finding ways to save growers money imperative. Each year cotton bollworm (*Helicoverpa zea*, Bodie) infests 100% of all cotton planted in Arkansas (Cook, 2020). Despite widespread use of dual-gene transgenic *Bacillus thuringiensis (Bt)* cotton cultivars, cotton bollworm remains a major pest of flowering cotton, and foliar insecticides are often needed to supplement control. Fleming et al. (2018) conducted studies in 2017 that indicated widespread resistance to Cry1Ac, a major protein used in *Bt* cotton. Recent research has established a new bollworm threshold based on damaged fruit, with the new threshold being set at 6% fruit damage with larvae present or 20% egg-lay (Studebaker, 2019). Because of the high technology fees associated with these traits and the growing concern of *Bt* resistance, it is important to monitor efficacy of these traits. Of particular interest are comparisons of cultivars having dual genes with the newer three-gene cultivars. The objective of this study was to determine if dual- or three-gene cotton is more cost-effective for growers to plant, with the understanding that the dual-gene cotton may need supplemental foliar applications to control bollworm.

Procedures

A study was conducted in Tillar, Arkansas, in 2021. Plots were planted on 16 May using a non-*Bt* (DP 1822 XF), a dual gene (DP 1518 B2XF), and multiple three gene cultivars (DP 1845 B3XF), (PHY 400 W3FE), (ST 5471 GLTP). Plot size was 12.5 ft. (4 rows) by 40 ft. Each cultivar had a plot that either remained unsprayed or was sprayed with 20 oz/ac Prevathon for a total of 10 treatments. The Prevathon application was made on 22 July using a Mudmaster high clearance sprayer fitted with TXVS-6 flat fan nozzles at 19.5-in. spacing with a spray volume of 10 gal/ac, at 40 psi. Data collection occurred at 4,7, 12, 15, and 19 days after application (DAA). In each plot, 25 squares, 25 flowers, and 25 bolls were sampled, and the number damaged for each was recorded. The two center rows of each plot were harvested on 1 Nov. Yield was reported as lb/ac of seed cotton. Data were processed using Agriculture Research Manager 2019 (Gylling Data Management, Inc., Brookings, S.D.). Analysis of variance was conducted with Duncan's New Multiple Range Test ($P = 0.10$) to separate means

Results and Discussion

At 4 DAA, the unsprayed non-*Bt* plots had the greatest amount of damaged fruit at 23% (Fig.1). The sprayed non-

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Bt, sprayed Bollgard II, and all three-gene plots had the least amount of damage. At 7 DAA, the percent damaged fruit was greatest in unsprayed non-*Bt* and unsprayed Bollgard II (Fig. 2). Three-gene, sprayed non-*Bt* and sprayed Bollgard II plots had lesser amounts of damage than the previously mentioned plots. Data for 12 DAA and 15 DAA are not shown due to damage levels being analogous to those found in 7 DAA. At 19 DAA, the total damaged fruit levels decreased due to bollworm larvae cycling out. All three- gene plots, sprayed Bollgard II, and sprayed non-*Bt* plots contained a lesser amount of damage than unsprayed non-*Bt* and unsprayed Bollgard II plots (Fig. 3). Sprayed non-*Bt*, sprayed Bollgard II, and all three-gene treatments had similar yields and were greater than unsprayed non-*Bt* and unsprayed Bollgard II (Fig. 4). The Prevathon application only improved yield in non-*Bt* and Bollgard II treatments

In Arkansas, dual-gene cotton may not provide the protection needed to manage cotton bollworm and foliar applications may be required. Growers planting dual-gene cultivars should budget at least one application of a diamide insecticide to prevent yield loss. Based on information collected from the Arkansas Field Crops Enterprise Budget, Bollgard II has higher input and production cost than Bollgard 3 (Table 1) (Crop Enterprise Budget 2022). Compared to Bollgard II cotton, three-gene cotton reduces insecticide use, lessens the amount of diesel used, decreases time spent in the field, and has a higher seed cost per acre (Table 2). Yields were compared between the dual and three gene cultivars from data generated by the On-Farm Variety Trials (OVT) conducted in Arkansas (Bourland et al., 2020). A dual-gene cultivar yielded the highest, followed closely by three-gene cultivars. However, three-gene cultivars ($715) provided a $115 per acre advantage compared to dual-gene cotton ($600). Depending on seed cost and yield, the reduction in operating expenses and higher average income could provide the grower with a greater profit margin when planting a three-gene cultivar. Growers should consider yield potential first and technology second when choosing which cultivar to plant.

Practical Applications

Resistance has recently been recorded in cotton bollworm to dual-gene cotton cultivars. These results imply that growers planting dual-gene cultivars should budget at least one application of a diamide to prevent yield loss. Three-gene cultivars appear to provide sufficient control of bollworm but should still be monitored to prevent unexpected yield loss. Growers should consider yield potential first and then technology when selecting cultivars, but be aware that dual-gene cultivars may need a supplemental foliar application for worm control.

Acknowledgments

Appreciation is expressed to A.J. Hood for providing the land where this research was conducted. Support was also provided by the University of Arkansas System Division of Agriculture.

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Table 1. The four main operating expenses for growers planting Bollgard II cotton taken from the Arkansas Field Crops Enterprise Budget 2020.

Operating Expenses	Unit	Quantity	Price/Unit	Cost
Insecticide	Acre	1	$92.76	$92.76
Diesel (Pre/Post Harvest)	Gallon	5.423	$1.60	$8.68
Labor, Field Activities	Hours	0.929	$11.33	$10.53
Seed, Per Acre	Thousands	47.5	$2.50	$118.75

Table 2. The four main operating expenses for growers planting Bollgard 3 cotton taken from the Arkansas Field Crops Enterprise Budget 2020.

Operating Expenses	Unit	Quantity	Price/Unit	Cost
Insecticide	Acre	1	$70.36	$70.36
Diesel (Pre/Post Harvest)	Gallon	5.294	$1.60	$8.47
Labor, Field Activities	Hours	0.915	$11.33	$10.36
Seed, Per Acre	Thousands	47.5	$2.80	$133.00

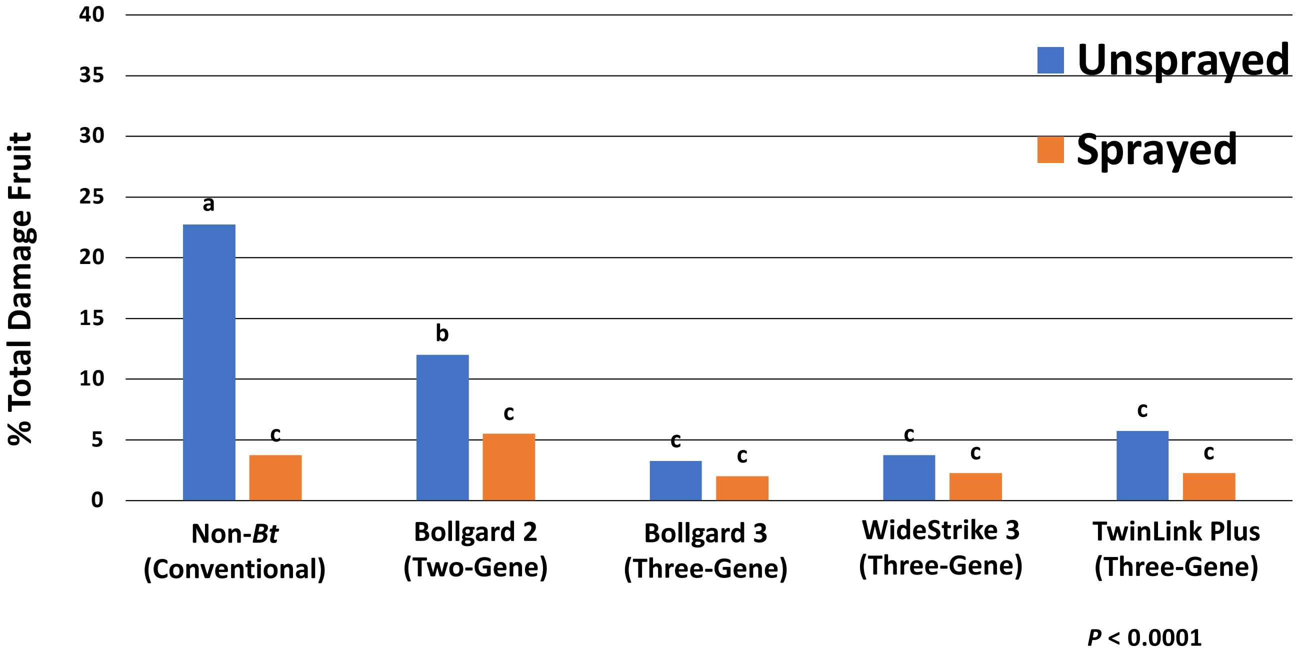

Fig. 1. Combined damage of 25 squares, 25 flowers, and 25 bolls 4 days after application of Prevathon 20 oz/ac in Drew County, Arkansas, in 2021.

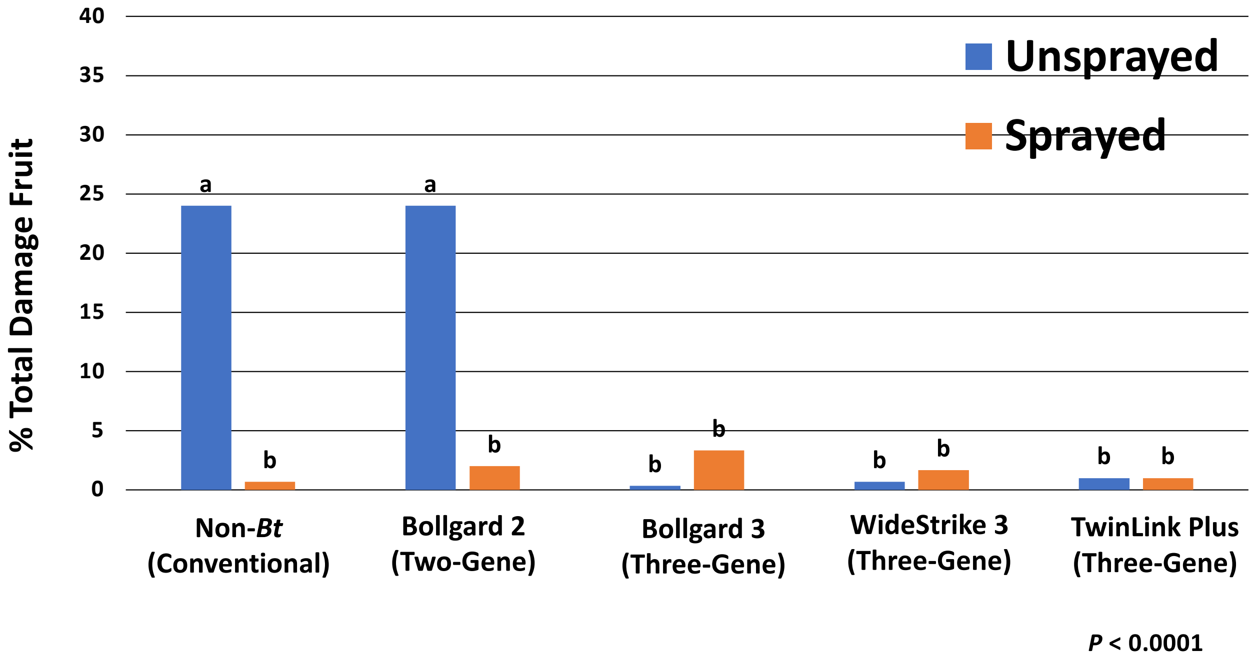

Fig. 2. Combined damage of 25 squares, 25 flowers, and 25 bolls 7 days after application of Prevathon 20 oz/a in Drew County, Arkansas, in 2021.

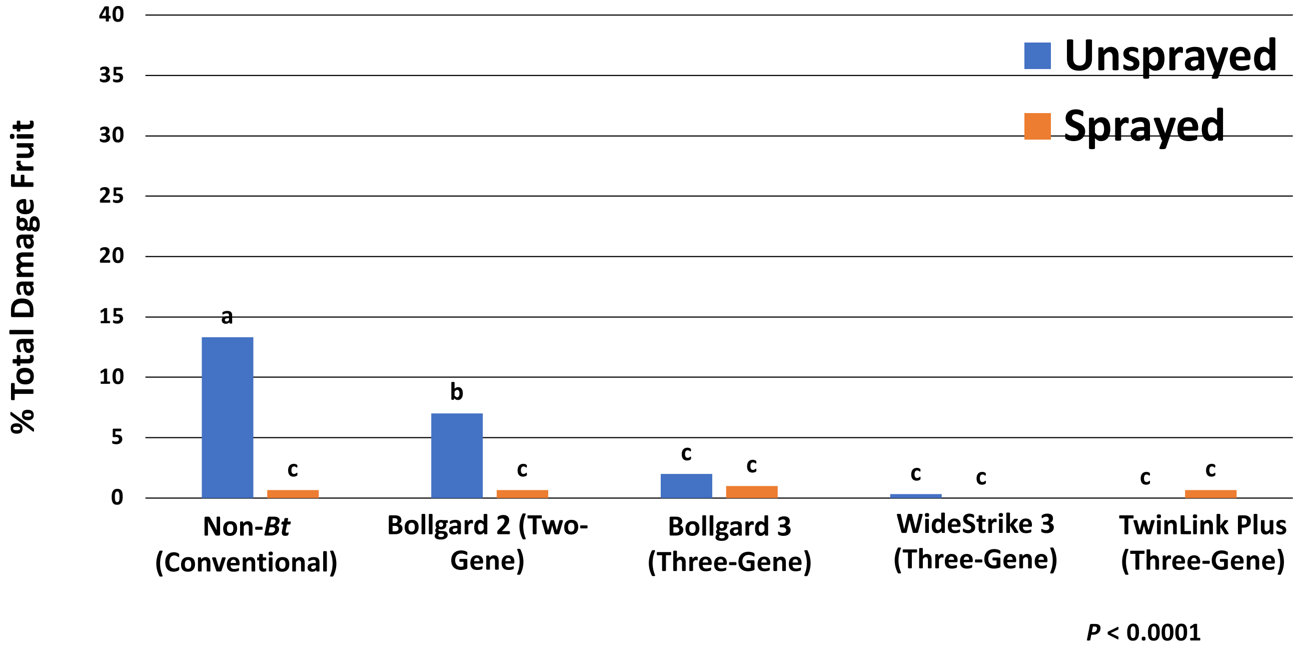

Fig. 3. Combined damage of 25 squares, 25 flowers, and 25 bolls 19 days after application of Prevathon 20 oz/a in Drew County, Arkansas, in 2021.

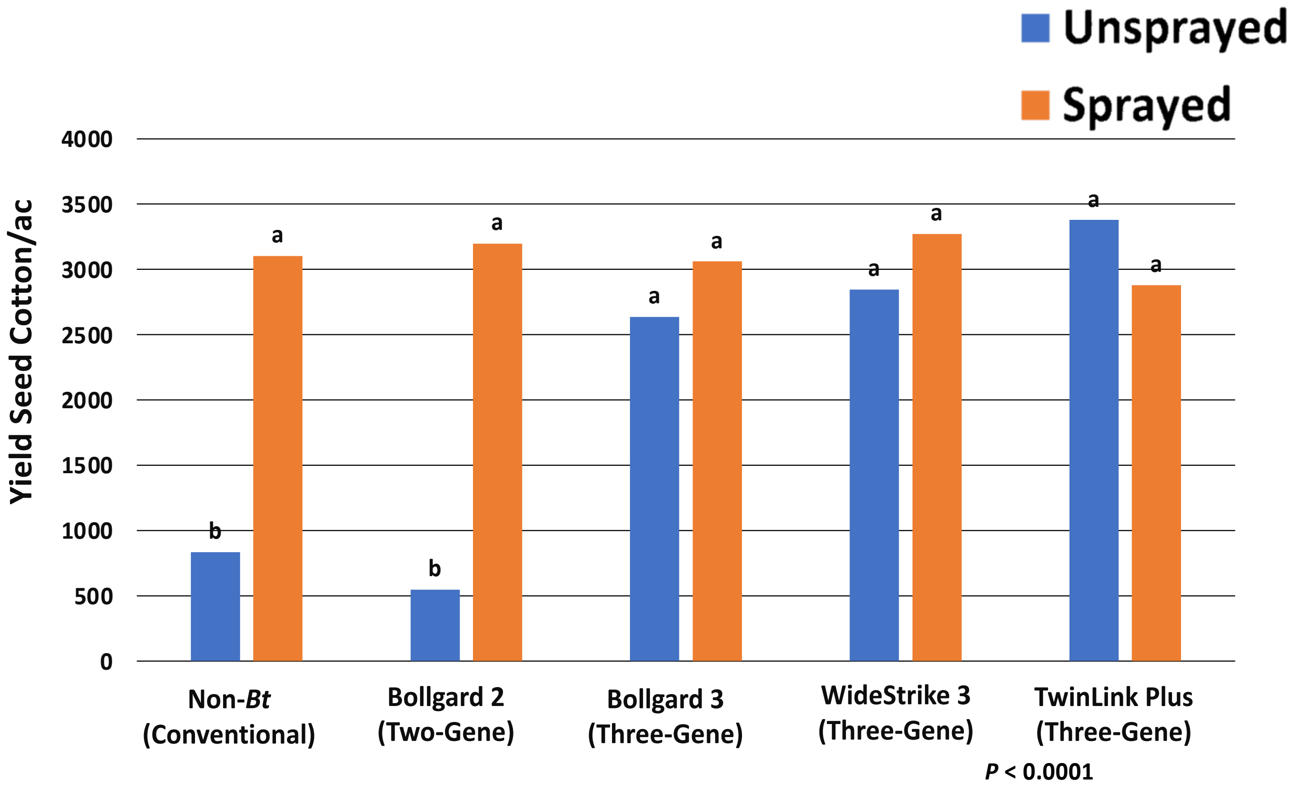

Fig. 4. Seed cotton yield (lb/ac) of non-*Bt*, two-gene, and three-gene cotton cultivars, with and without an application of Prevathon 20 oz/ac in Drew County, Arkansas, in 2021.

Control of Twospotted Spider Mite with Selected Miticides

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

Abstract

Twospotted spider mites (*Tetranchus urticae*) are an important pest of cotton in Arkansas, causing potentially significant yield loss and being a season-long pest. Foliar miticides are a crucial pest management tool in cotton fields infested with spider mites. The field efficacy of nine miticides against twospotted spider mite populations was evaluated in comparison to non-treated plots at 4, 7, and 15 days after application (DAT). With the exception of the plots treated with Liberty, all of the miticide applications were effective at lowering twospotted spider mite numbers 4 DAT and 15 DAT. 7 DAT, three treatments had statistically fewer twospotted spider mites compared to the non-treated control plots. These data are an important tool useful in the decision-making process when managing cotton fields infested with spider mites.

Introduction

Twospotted spider mites (*Tetranchus urticae*) are often considered a secondary pest of cotton (Catchot et al., 2014). During periods of drought, they can become more important and can be damaging throughout the growing season. Spider mites are most damaging early in the vegetative growth stages of the cotton plant. Heavy infestations on seedling cotton can often cause plant death resulting in stand loss. Later in the season on larger plants, mite feeding reduces photosynthesis and can cause leaf drop, resulting in reduced yield. Historically, twospotted spider mites have not been as problematic as other pests of cotton. However, repeated usage of organophosphates, neonicotinoids, and pyrethroids are often required for the management of tarnished plant bug and other pests of cotton to mitigate yield loss. These applications often reduce predatory insect populations. Removal of these natural enemies has a negative side-effect of increasing populations of twospotted spider mites. Determining effective miticides to manage spider mite populations is imperative to protect cotton yield.

Procedures

The impact of selected miticides on twospotted spider mite infesting cotton was evaluated at the University of Arkansas System Division of Agriculture's Northeast Research and Extension Center (Mississippi County). Cotton seed (DG 3327 B3XF) were planted on 25 May 2021. Plot size was four rows (38-in. centers) by 30 feet. Treatments were replicated four times in a randomized complete block design. Foliar miticide treatments (listed in Table 1) were applied with a high clearance sprayer with a compressed air spray system calibrated to deliver 15 gal/ac through TX-6 hollow cone nozzles (2/row) on 2 August 2021. Treatment efficacy was determined by counting the number of mites on 2-square inches of each of 10 leaves (20-square inches total) from the center two rows of each plot using a 10x magnifier at 4, 7, and 15 days after treatment (DAT). All data were analyzed using Agriculture Research Manager (ARM) version 2020 software. Means were separated using LSD at the $P = 0.05$ level.

Results and Discussion

The average number of twospotted spider mites per 10 leaves (20-square inches of leaf surface area) is reported in Table 1. All treatments except Liberty significantly reduced numbers of twospotted spider mites below the untreated check at 4 DAT. Agri-Mek + Zeal significantly reduced populations below Agri-Mek alone, Oberon, and Liberty at 4 DAT. At 7 DAT, plots treated with Portal, Portal + Brigade, and Agri-Mek + Zeal resulted in significantly lower densities of twospotted spider mites than the untreated check. Zeal alone and Agri-Mek + Zeal significantly reduce populations compared to Oberon, Liberty, and Denim. At 15 DAT, all of the insecticide treatments, except Liberty, resulted in significantly lower densities of twospotted spider mites than the untreated check. Tank mixing Portal and Brigade and Agri-Mek and Zeal did not appear to increase activity of the miticides evaluated. The addition of Agri-Mek to Zeal did not reduce numbers compared to Zeal alone.

Practical Applications

These data can be used to make more informed decisions regarding twospotted spider mite management in cotton. Growers do not need to apply more costly tank mixes in order to manage twospotted spider mites.

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Acknowledgments

The authors would like to thank the University of Arkansas System Division of Agriculture Northeast Research and Extension Center for providing a location, as well as Cotton Incorporated, Syngenta, and Nichino America for providing funding for this project.

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Table 1. Mite counts at 4, 7, and 15 days after miticide application at Keiser, Arkansas, in 2021.

		Number of Mites[†]		
Treatment	**oz product/ac**	**4 DAT[‡]**	**7 DAT[§]**	**15 DAT[¶]**
Agri-Mek 0.7SC	2.5	96.5 b[#]	47.3 bcd	1.5 bc
Portal 0.4EC	16.0	51.3 bc	78.5 a-d	0.8 c
Zeal 2.88SC	2.0	57.5 bc	13.0 d	0.0 c
Oberon 4SC	4.0	94.8 b	126.5 ab	2.5 bc
Athena 0.87SC	10.0	64.8 bc	83.8 a-d	0.5 c
Liberty 2.34SL	32.0	174.8 a	132.3 a	15.0 ab
Denim 0.16EC	8.0	89.0 bc	108.8 abc	0.0 c
Portal 0.4EC + Brigade 2EC	10.0 + 6.4	43.3 bc	32.8 cd	0.0 c
Agri-Mek 0.7SC + Zeal 2.88SC	1.75 + 1.0	27.5 c	9.8 d	0.0 c
Untreated Check	–	177.8 a	117.5 ab	18.8 a
$P > F$		<0.01	0.02	<0.01

[†] Number of mites found per 20 square inches.

[‡] Number of mites found per 20 square inches 4 days after treatment was applied.

[§] Number of mites found per 20 square inches 7 days after treatment was applied.

[¶] Number of mites found per 20 square inches 15 days after treatment was applied.

[#] Means within columns followed by a common letter are not significantly different ($P \leq 0.05$, least significant difference).

Interactions of Cotton Seeding Rates and Insect Pest Control in Arkansas Cotton Grown in Different Cover Crop Systems

T.G. Teague[1] and N.R. Benson[1]

Abstract

Mid-South cotton producers question whether adjustments in cotton seeding rates or arthropod pest management programs are needed as they expand their use of soil conservation practices, including reduced tillage operations and use of cover crops. A multifactor field experiment was conducted in northeast Arkansas in 2020 to evaluate cotton management options in two prevalent cover crop system approaches: fall-seeded cereal rye (*Secale cereale*) or spring-seeded black oats (*Avena strigose*). Also included in each system was thrips control (*Thrips tabaci*, *Frankliniella occidentalis*) control (foliar insecticide application or unsprayed). Additional factors in the 4×3×2 split-plot study were 3 seeding rates (equivalent to 61,901, 41,267, or 20,634 seeds per acre in 38-inch row spacing) and different timing for late-season insecticide termination for tarnished plant bug (*Lygus lineolaris*) at either early (cutout (NAWF = 5)) or recommended termination timing (cutout + 250 DD60s). Cotton emergence was delayed in the black oats system, likely related to diminished soil moisture at planting in the "green" cover crop. Higher thrips numbers also were associated with the black oats cover crop system compared to terminated cereal rye. Late-season *Lygus* numbers were greater in the highest seeding rate treatments. Yields were measured with a yield monitor, and because of the spatially variable soil textures in the field, soil electrical conductivity (EC_a) was included in statistical evaluations. There were significant interactions among treatments. Lint yields were lower in coarse sand compared to loamy sand areas and with the highest seeding rate. When thrips were controlled with foliar insecticide, yields from the cereal rye cover crop system typically were higher compared to the black oats system. The highest *Lygus* numbers were associated with the highest seeding rate, and there was a yield penalty for early *Lygus* insecticide termination timing. The COTMAN® plant monitoring system was beneficial in identifying the date of cutout and for timing late-season termination.

Introduction

Mid-South cotton producers who manage farms with sandy soils often use cover crops and reduced tillage to lessen the damaging effects of wind erosion on seedling cotton. General Extension recommendations in Arkansas suggest that cover crops be terminated at least 3 weeks prior to planting cotton to avoid risks from arthropod pests, allelopathy, and to preserve soil moisture; however, producers may opt to delay termination if additional spring growth and increased cover crop residue are needed to protect delicate cotton seedlings from damaging wind and blowing sand.

In this 2020 on-farm research project, we compared two cover crop systems commonly used in northeast Arkansas and SE Missouri cotton—cereal rye (*Secale cereale*) seeded in standing cotton in fall (no-till) and black oats (*Avena strigose*) seeded in early spring into newly reformed beds (lo-till). One research objective was to compare relative pest risk and the effect of cover crops on thrips (*Thrips tabaci, Frankliniella occidentalis*) populations in cotton seedlings and to assess how thrips injury might influence cotton growth, maturity, and yield. Crop maturity delays in season-limited production areas of the northern mid-South often result in cotton yield and fiber quality penalties. The study also included consideration of cotton seeding rates. Treated, traited (GM) seed is one of the costliest inputs in U.S. cotton production, and there are grower questions about the need to modify cotton seeding rates when planting into cover crops. The insecticide termination component of the study was included to gauge how maturity delays associated with cover crop system, seeding rate, or thrips control might impact late-season crop susceptibility to insect pest damage.

Procedures

The 2020 study was conducted in northeast Arkansas at the Manila Airport Complex Cooperative Research Farm (35.903006, -90.151197). The field site lies in the New Madrid seismic zone, where large sandy deposits, associated with sand blows, are common. The alluvial soils were classified as Routon-Dundee-Crevasse complex (Typic Endoqualfs). The cover crop system ×seeding rate×insecticide termination study was designed as a 4×3×2 factorial experiment arranged as a split-plot design with cover crop systems as main plots and seeding rate and late-season *Lygus* control (insecticide termination) as sub-plots. Plots were 12

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rows wide and 100 ft long with 10 ft alleys. There were 3 replications.

Cover crop systems were fall-planted (broadcast) cereal rye, no-till, or spring-planted black oats (banded), low-till. For each system, thrips control treatments were foliar insecticide spray for thrips control (thrips spray) or no foliar insecticide spray (thrips check). Details for timing, rates, and other production details and irrigation are listed in Table 1. The three cotton seeding rates were 4.5, 3, or 1.5 seeds per ft of row, which, with 38-in. row spacing, were equivalent to 61,901, 41,267, or 20,634 seeds per acre, respectively. Insecticide termination treatments were either Extension recommended timing (physiological cutout + 250 DD60s) or early insecticide termination timing (physiological cutout), ca. 2 weeks earlier than recommended (Studebaker et al., 2021). Termination timing was based on plant monitoring using the COTMAN® system (Oosterhuis and Bourland, 2008) to identify the timing of physiological cutout and the flowering date of the last effective boll population.

Cereal rye (var. *Elbon*) was broadcast seeded at 1 bu./ac in standing cotton on 8 September 2019 prior to defoliation of the 2019 cotton crop. The cereal rye winter cover crop was terminated by the cooperating producers with herbicides on 20 March 2020. For the black oats system, plots were fallowed through winter, and on 8 April 2020, rows were re-bedded and black oats seeded at 30 lb/ac in row middles. There was no further tillage. A burn-down herbicide application was applied across all plots following cotton planting. Cotton cultivar Deltapine 1646 B2XF was planted on 25 May using a 12-row variable rate planter (Fig. 1). Cotton seed had standard seed treatments with the insecticides imidacloprid + acephate. All production activities were performed by the cooperating producers with their equipment and following their standard management practices. The only exceptions were selective foliar insecticide applications for thrips and *Lygus* (Table 1).

Cotton stand counts were made using line-transect sampling to assess the success of meeting seeding rate targets. Samplers counted plants per 3 ft in two transects across each 12-row sub-plot. Seedling growth assessments were made with 10-plant collections per plot made at 14, 21, and 29 days after planting (DAP) and included measurements of shoot length (height), counts of mainstem monopodial nodes (no. of true leaves), leaf area (LI-3100C Area Meter, LI-COR, Lincoln, NE, US), and dry weight (biomass) (oven-dried, shoots only). COTMAN plant monitoring activities were initiated in the second week of squaring and included evaluations of plant main-stem nodal development and first position square and boll retention (Oosterhuis and Bourland, 2008). Additional assessments were made during the first week of flowering to gauge treatment effects on earliness. Plants were inspected over 3 days (58, 59, and 60 DAP) to estimate % plants with white flowers. To determine % of plants flowering, scouts inspected consecutive plants in rows 5 and 6 of the 100-ft plot and made counts of the total number of plants required to find 10 flowers. When a flower was observed, scouts counted nodes above white flower (NAWF) to estimate the mean number of main-stem sympodia at first flower.

Arthropod pests were monitored weekly from seedling emergence through physiological cutout (mean NAWF = 5). Sampling was restricted to rows 3 and 4 of the 12-row plot. Thrips assessments were made using whole plant alcohol washes of 10- plant samples collected per sub-plot. Tarnished plant bug numbers were monitored weekly with sweep net sampling during early squaring, followed by drop cloth sampling starting at first flower and continuing through physiological cutout.

Final, end-of-season plant mapping was performed on a selection of 10 plants in each plot to evaluate treatment effects on plant structure, boll counts, and distribution. Plant mapping was initiated after crop defoliation, and mappers followed the COTMAP procedures described by Bourland and Watson (1990).

Yield assessments were based on data collected from the cooperating producer's 6-row cotton picker equipped with a calibrated yield monitor with GPS receiver to attain site-specific lint yield. Data were post-calibrated using final module weights retrieved from the gin. Because of within-field spatial variability of soils (sand blows associated with historic seismic events), we included soil texture as a covariant in yield analysis. Delineation of soil texture was established from indirect measurements using a Veris 3150 EC Surveyor instrument® (Veris Technologies, Inc., Salina, KS) to generate a soil EC_a map. Soil EC_a classifications were grouped to produce two soil textural zones: 1) loamy-sand category, which represented the highest EC classifications [soil EC_a values from shallow layer (0–24 in) with values ≥9 mS/m], and 2) coarse sand, which represented the lowest soil EC_a classifications [soil EC_a values from shallow layer (0–24 in) with values <9 mS/m]. The coarse-sand areas, associated with sand blows, encompassed ca. 40% of the field. The soil EC_a maps were also used to guide scouts during plant and pest monitoring activities, allowing them to avoid sand blow areas to focus on sampling in loamy sand field areas.

A four-way factorial structure was used for analysis of the yield monitor measured yield with cover crop system, seeding rate, and termination timing and block effect. Soil EC_a classifications were included as a covariate. Georeferenced data layers from the yield monitor and soil EC_a (5 m perimeter -shallow) were joined using ArcGis 10.2 (ESRI; Redlands, CA). Soil texture was not included for analysis of plant and pest monitoring data. Analysis of variance was conducted using mixed model procedures (Proc Mixed & Proc GLIMMIX). Mean comparisons were made using the LSMEANS procedure with the Tukey adjustment ($P \leq 0.05$; SAS Institute; Cary, N.C.).

Fiber quality was evaluated using hand-harvested 40-boll samples, which were ginned using a laboratory gin. Samples were sent to the Texas Tech Fiber and Biopolymer Research Institute for HVI (high volume instrument) evaluations.

Results and Discussion

Stand count results (Fig. 2) show that emergence rate and stand density were lower ($P < 0.05$) in the lo-till, black oats system compared to the no-till, cereal rye. Target plant stand densities for all seeding rate treatments were above 80% by 28 DAP. Soil moisture at planting was limited and was further reduced by the growing black oats compared to the terminated cereal rye. With reduced soil moisture, cotton seed germination and seedling emergence in the black oats system were delayed.

Thrips numbers were low and comparable among treatments in early assessments; however, by 20 DAP numbers had risen above Arkansas Extension action thresholds (Studebaker et al., 2021). Whole plant wash samples at 21 DAP showed higher numbers ($P = 0.01$) associated with black oats compared to cereal rye cover crop treatments (Fig. 3). Thrips numbers were similar among seeding rate treatments ($P > 0.25$). The foliar application of dicrotophos made at 22 DAP was effective in reducing thrips numbers to sub-threshold levels compared to plants in the unsprayed (check) treatments to ($P > 0.001$). Seedling leaf area and plant biomass measurements made 8 days after the thrips insecticide spray did not show clear indications of negative impacts related to thrips-induced injury/damage in the check compared to protected plants (Table 2).

The COTMAN growth curve provides a composite plant response to direct and indirect influences affecting plant development. The COTMAN growth curves for the cover crop system*seeding rate effects show slight variation in the pace of nodal development among plants for seeding rate treatments in comparison to the target development curve (=standard curve) (Fig. 4). The COTMAN growth curve apogee indicates the number of main-stem nodes differentiated by the plant during the time required for the first square to develop into a white flower. For seeding rate effects, the mean values for NAWF at first flower were lower for plants at the highest compared to lowest seeding rate ($P < 0.01$) (Table 3). A higher proportion of plants with flowers were observed in the low compared to the high-density planting. There were no differences in % flowering associated with cover crop and thrips control.

One gauge of treatment effect on crop maturity using COTMAN monitoring data is the calculation of days from planting to physiological cutout (NAWF = 5). Results from this 2020 trial showed no clear association between thrips control and cover crop on mean days to cutout. For seeding rates, mean days to cutout for the 1.5, 3, and 4.5 seeding rates were calculated to be 86.6, 85.2, and 84.4 days, respectively ($P = 0.07$); there were no significant interactions among treatment combinations (Table 4).

Insecticide applications by the cooperating producer maintained low *Lygus* numbers during squaring and through the first week of flowering. Square shed results from COTMAN monitoring showed 1st position square retention was greater than 90% in all treatment plots through the first week of flowering, indicating low infestation levels of *Lygus* (data not shown). By 71 DAP, numbers increased, and a positive response to seeding rate (plant stand density) became apparent. The lowest *Lygus* numbers were observed in treatment plots with the lowest plant population densities (Fig. 5). By 78 DAP, *Lygus* numbers across the experiment exceeded Arkansas Extension's pre-cutout action threshold of an average of 3 bugs per drop cloth sample. On 79 DAP (~date of NAWF = 5), the entire field was sprayed with insecticide, and *Lygus* numbers were reduced. Over the following 2 weeks, *Lygus* numbers once again increased, exceeding the post-cutout action level of 6 bugs per drop cloth sample. The final termination spray was applied at 91 DAP in selected treatment plots (Table 2), and *Lygus* numbers were reduced to sub-threshold levels. In untreated plots, *Lygus* numbers remained above the post-cutout action threshold (Fig. 5). Arkansas Extension recommendations suggest insecticidal control of *Lygus* through cutout +250 DD60s. Heat unit totals at the time for insecticide termination for each treatment combination are shown in Table 4.

End-of-season plant mapping results using COTMAP showed seeding rate resulted in significant differences in plant structure, boll distribution, and boll retention (Table 5). Plants growing at lower stand densities were larger, produced more monopodial bolls, outside bolls, and total bolls, as well as more total nodes, compared to plants in high stand density. For insecticide termination timing sub-plot effects, there was a higher mean number of effective sympodia (defined as highest main-stem sympodium with a boll in the first position) for plants that received the recommended insecticide termination application (cutout + 250 DD60s) compared to plants receiving the final insecticide application at cutout (9.5 compared to 8.7 nodes, respectively) ($P = 0.01$). These results likely indicate that upper canopy bolls were vulnerable to *Lygus* feeding damage that occurred between cutout and cutout + 250 DD60s. With early termination timing, there also were fewer main-stem sympodia with 2nd position bolls compared to recommended termination timing (1.1 compared to 1.3 bolls, respectively) ($P = 0.06$). No significant differences were associated with cover crop and thrips control main effects.

Yields

Growing conditions in 2020, particularly during effective flowering and boll filling periods, were conducive for high yields in the region. Even with the relatively late date of planting for this study, yields ranged from 1313 to 1635 lb lint/ac. There were significant interactions among all factors evaluated (Table 6). Soil texture had a major influence on yield, with lower yields associated with plants in coarse sand soils compared to plants in loamy sand (Table 7). Generally, the lowest yields were associated with the highest seeding rate with early *Lygus* termination timing. Higher *Lygus* pest risks are typically associated with high plant stand density (Leigh et al., 1974), and we have noted a similar response in our previous work at the Manila site (Teague et al., 2018). A positive yield response to thrips control was most apparent for plants in coarse sand, particularly in the black oats system. These results suggest reduced tolerance to pest-induced injury and lower plant compensation capacity for lower-yielding plants in the coarse sand soils (Fig. 6). The highest overall yields were associated with the seeding rate of 3 seeds per ft of row, although there were treatment combinations with high yields in each of the seeding rates.

Fiber quality assessments showed significant effects of seeding rate on boll weight, micronaire, and fiber elongation (Table 8). There were no fiber quality differences observed with cover crop system or termination timing.

Interactions often are difficult to untangle in a large multifactor study, but if yield results are considered in context with production input costs (and net revenue), then practical interpretations can inform future management decisions. Seed costs for treated, traited cotton seed were substantial, and there was approximately a $100/acre difference between lowest and highest seeding rates used in the study. Our previous work with seeding rates has shown that selection of reduced seeding rates has generally produced comparable yields and has overall resulted in increased profits (Benson et al., 2015, 2016, 2017, Teague et al., 2018, 2019, 2020, 2022).

Practical Applications

Several practical applications are suggested based on these 2020 findings and previous seeding rate and cover crop work. When planning for cotton seeding rates, producers should choose the least expensive option that results in an acceptable stand of at least 1 plant per ft of row. Cover crop termination is recommended at least 2 weeks prior to planting to reduce risks of allelopathic effects on cotton seedlings and to conserve soil moisture for planting. Delayed emergence was observed in 2020, when the Black oats cover crop was not terminated until after cotton planting. Thrips infestation levels and effects on yield were reduced with a terminated cereal rye cover crop compared to black oats cover crop. Using the COTMAN system for plant monitoring of NAWF provides information on the flowering date of the last effective boll population and timing for insecticide termination for *Lygus*.

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Table 1. Dates of planting, irrigation, sampling, foliar insecticide application, and harvest for the 2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

Operation	Date	Days after planting
Cover crops – seeded / terminated	Cereal rye – 11 Sep. 2019 / 20 March Black oats – 8 April 2020 / 25 May	-187, -66 -47, 0
Date of cotton planting	25 May	0
Stand counts	1, 8, 15, 23 June	7, 14, 21, 29
Thrips assessments	8, 15, 19, 23 June	14, 21, 25, 29
Lygus sampling	21, 28 July, 4, 11, 17, 24, 27 Aug., 3 Sep.	57, 64, 71, 78, 84, 91, 94, 101
COTMAN Sampling	1, 8, 14, 21, 28 July, 4, 11, 17, & 24 Aug.	37, 44, 50, 57, 64, 71, 78, 84, 91
Foliar insecticides	16[†], 30 June, 10 July, 12, 25[†] Aug.	22[†], 36, 46, 79, 92[†]
Furrow irrigation	14, 21 July, 6, 13, 19, 26 Aug.	50, 57, 73, 80, 86, 93
Harvest aids	29 Sep., 13 Oct.	127, 142
Machine harvest	9 Nov.	168

[†] Only treatment-specific plots received insecticides on 16 June (dicrotophos-thrips) and 25 Aug. (acephate + lamba cyhalothrin- *Lygus*).

Table 2. Seedling cotton assessments showing mean leaf area, shoot length, plant dry weight, and number of true leaves for 10-plant samples collected 23 June, at 29 days after planting (7 days after thrips spray) – 2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

Seeding rate	Cover crop system	True leaves[†]	Dry weight[†]	Shoot length[†]	Leaf area[†]
(seeds/ft of row)	(species - thrips treatment)	(no)	(g)	(cm)	(cm^2)
1.5	Cereal rye - check	5.6 a	7.5 a	12.8 ab	667 a
	Cereal rye - thrips spray	4.9 ab	7.0 a	12.6 ab	694 a
	Black oats - check	5.5 ab	7.1 a	13.3 ab	756 a
	Black oats - thrips spray	5.4 ab	6.7 a	13.2 ab	618 a
3	Cereal rye - check	5.7 a	7.5 a	13.5 ab	677 a
	Cereal rye - thrips spray	5.0 ab	6.6 a	13.2 ab	699 a
	Black oats - check	5.4 ab	7.2 a	13.7 ab	763 a
	Black oats - thrips spray	5.6 ab	7.5 a	14.0 ab	684 a
4.5	Cereal rye - check	5.4 ab	6.3 a	13.7 ab	612 a
	Cereal rye - thrips spray	4.3 b	5.1 a	12.2 b	532 a
	Black oats - check	5.0 ab	5.6 a	12.8 ab	520 a
	Black oats - thrips spray	5.5 ab	7.1 a	15.2 a	642 a

[†] Means within each column followed by the same letter are not significantly different (α = 0.05).

Table 3. Mean number of nodes above white flower (NAWF) and % flowering plants determined in the first week of flowers for 2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

Seeding rate	Cover crop system	Nodes above white flower[†]	Plants with 1st position white flowers[†‡]
(seeds/ft of row)	(species – thrips treatment)	(no.)	(%)
1.5	Cereal rye - check	9.2 a	40.0 ab
	Cereal rye - thrips spray	9.0 ab	42.4 a
	Black oats - check	9.0 ab	37.7 abc
	Black oats - thrips spray	8.9 abc	39.6 ab
3	Cereal rye - check	8.6 abcd	23.7 def
	Cereal rye - thrips spray	8.5 bcd	32.7 abcd
	Black oats - check	8.2 def	29.8 bcde
	Black oats - thrips spray	8.3 cde	27.9 def
4.5	Cereal rye - check	8.1 def	17.2 f
	Cereal rye - thrips spray	8.3 cdef	17.2 f
	Black oats - check	7.9 ef	20.2 f
	Black oats - thrips spray	7.7 f	24.5 def

[†] Means within each column followed by the same letter are not significantly different (α = 0.05).

[‡] Observations were made daily 58 through 60 days after planting with percentages calculated based on number of plants inspected to find 10 flowering plants each sample day.

Table 4. Mean number of days from planting to physiological cutout (NAWF = 5) for cover crop system and seeding rate effects; includes heat unit accumulation from NAWF = 5 to insecticide termination sprays for the recommended timing (92 days after planting (DAP)) and 1st defoliant application 127 DAP – Manila, Arkansas, 2020.

				Heat units from NAWF = 5	
Seeding rate	Cover crop system	Days from planting to NAWF = 5	Date of NAWF = 5	Termination insecticide[†]	Defoliation[‡]
(seeds/ft of row)	(species – thrips treatment)	(days)		------(DD60s)------	
1.5	Cereal rye - check	82	15-Aug.	193	640
	Cereal rye - thrips spray	86	19-Aug.	120	567
	Black oats - check	83	16-Aug.	173	620
	Black oats - thrips spray	81	14-Aug.	212	659
3	Cereal rye - check	80	13-Aug.	230	677
	Cereal rye - thrips spray	82	15-Aug.	193	640
	Black oats - check	82	15-Aug.	193	640
	Black oats - thrips spray	80	13-Aug.	230	677
4.5	Cereal rye - check	79	12-Aug.	249	696
	Cereal rye - thrips spray	81	14-Aug.	212	659
	Black oats - check	79	12-Aug.	249	696
	Black oats - thrips spray	79	12-Aug.	249	696

[†] Insecticide sprays for the early *Lygus* termination were made 79 DAP (~week of physiological cutout).

[‡] Using the COTMAN-derived seasonal cutout date rather than physiological cutout (NAWF = 5), heat unit accumulation from the latest possible cutout date of 11 Aug. or 30 July to defoliation was 730 or 850 DD60s, respectively. Based on historical weather, these dates have either a 50% or 85% probability of accumulating the desired heat unit accumulations of 850 DD60s for defoliation.

Table 5. Seeding rate main effects on findings from final, end-of-season plant mapping results using COTMAP procedures in loamy sand sample sites for 2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

	Seeding Rate (seeds/ft of row)			
Category	**1.5**	**3**	**4.5**	***P > F***
	(mean per plant)			
Plant height (in.)	41.4	41.2	37.4	<0.01
First fruiting node	6.8	7.0	7.1	0.02
Total monopodia	2.3	1.5	0.8	<0.01
Sympodia on main-stem axis	16.2	14.6	13.2	<0.01
Highest effective sympodia [†]	10.6	8.9	7.7	<0.01
Highest sympodia with 2 positions	12.6	10.7	9.2	<0.01
Internode length (in.)	1.9	2.0	1.9	0.20
Total bolls	20.9	12.6	8.2	<0.01
% Bolls from 1st sympodial position	39.5	52.7	67.5	<0.01
% Bolls from 2nd sympodial position	28.4	28.0	25.0	<0.01
% Bolls from outer sympodial positions	11.4	6.5	2.9	<0.01
% Bolls from monopodial positions	20.6	12.7	4.6	<0.01
% Boll retention, 1st sympodial positions	50.8	44.3	41.7	<0.01
% Boll retention, 2nd sympodial positions	47.0	33.1	23.0	<0.01
% Early Boll retention [‡]	71.6	58.7	50.3	<0.01

[†] Highest main-stem sympodium with a boll in the first position.

[‡] Bolls retained on lowest 5 main-stem nodes on 1st and 2nd sympodial positions.

Table 6. Results from lint yield analysis using PROC MIXED (4*3*2 factorial arranged in a split-plot design with cover crop system as the main effect) showing fixed effects for cover crop system (CCS) (includes thrips spray), cotton seeding rate (SR), insecticide termination timing for *Lygus* (TPB), and soil texture (TEX).

Effect	**No. degrees of freedom of model**	***F* Value**	***P > F***
CCS	3	16.08	<0.0001
SR	2	45.63	<0.0001
CCS*SR	6	17.17	<0.0001
TPB	1	58.23	<0.0001
CCS*TPB	3	0.61	0.60
SR*TPB	2	4.11	0.02
CCS*SR*TPB	6	7.46	<0.0001
TEX	1	35.26	<0.0001
CCS*TEX	3	2.45	0.06
SR*TEX	2	0.34	0.71
CCS*SR*TEX	6	3.94	0.001
TPB*TEX	1	0.70	0.40
CCS*TPB*TEX	3	5.32	0.001
SR*TPB*TEX	2	7.02	0.001
CCS*SR*TPB*TEX	6	2.05	0.05

Table 7. Mean lint yield (lb/ac) for cover crop system with thrips control, seeding rate, and *Lygus* insecticide termination timing from yield monitor measurements in either loamy sand or coarse sand soil textural zones – Manila, Arkansas, 2020.

Soil texture [†]	Cover Crop	Thrips [‡]	*Lygus* termination[§]	Seeding Rate[¶] (seeds/ft of row) 1.5	3	4.5
				--------------------lb lint/ac--------------------		
Loamy sand	Cereal rye	Check	Early	1341 c	1420 bc	1365 c
		Spray	Early	1591 ab	1508 abc	1355 c
		Check	Recommended	1516 abc	1518 abc	1500 abc
		Spray	Recommended	1505 abc	1598 a	1459 abc
	Black oats	Check	Early	1430 bc	1389 bc	1275 c
		Spray	Early	1558 ab	1433 abc	1366 c
		Check	Recommended	1415 bc	1423 bc	1327 c
		Spray	Recommended	1492 abc	1526 abc	1526 abc
Coarse sand	Cereal rye	Check	Early	1427 bc	1503 abc	1479 abc
		Spray	Early	1391 bc	1505 abc	1422 bc
		Check	Recommended	1451 abc	1560 ab	1504 abc
		Spray	Recommended	1550 ab	1632 a	1341 c
	Black oats	Check	Early	1313 c	1447 abc	1351 c
		Spray	Early	1386 bc	1510 abc	1338 c
		Check	Recommended	1372 c	1451 abc	1544 ab
		Spray	Recommended	1373 bc	1635 a	1376 bc

[†] Soil texture categories were grouped in two soil EC_a classifications with loamy sand values ≥9 mS/m coarse sand soil EC_a values <9 mS/m (~sand blow regions of the field).

[‡] Foliar insecticide application (spray) for thrips control made 22 days after planting (DAP) or untreated control (check).

[§] Termination insecticide application for *Lygus* control made at either 79 DAP (early) or 92 DAP (recommended).

[¶] Means followed by the same letter are not significantly different (α = 0.05).

Table 8. Mean boll size and results from fiber quality assessments (HVI[†]) for 40-boll collections for seeding rate sub-plot effects – 2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

Seeding rate	Boll weight	Micronaire	Length	Uniformity	Strength	Elongation
seeds/ft of row	g	unit	in.	%	g/tex	%
1.5	4.15	4.22	1.26	84.68	29.38	7.43
3	4.03	4.12	1.27	84.55	29.61	7.63
4.5	3.88	4.18	1.26	84.30	29.37	7.45
P > F	*0.01*	*0.05*	*0.77*	*0.17*	*0.65*	*0.01*

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

Fig. 1. Field conditions at planting with terminated cereal rye winter cover crop and spring-planted black oats, "burn-down" herbicides were applied across the field 1 day after planting—2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

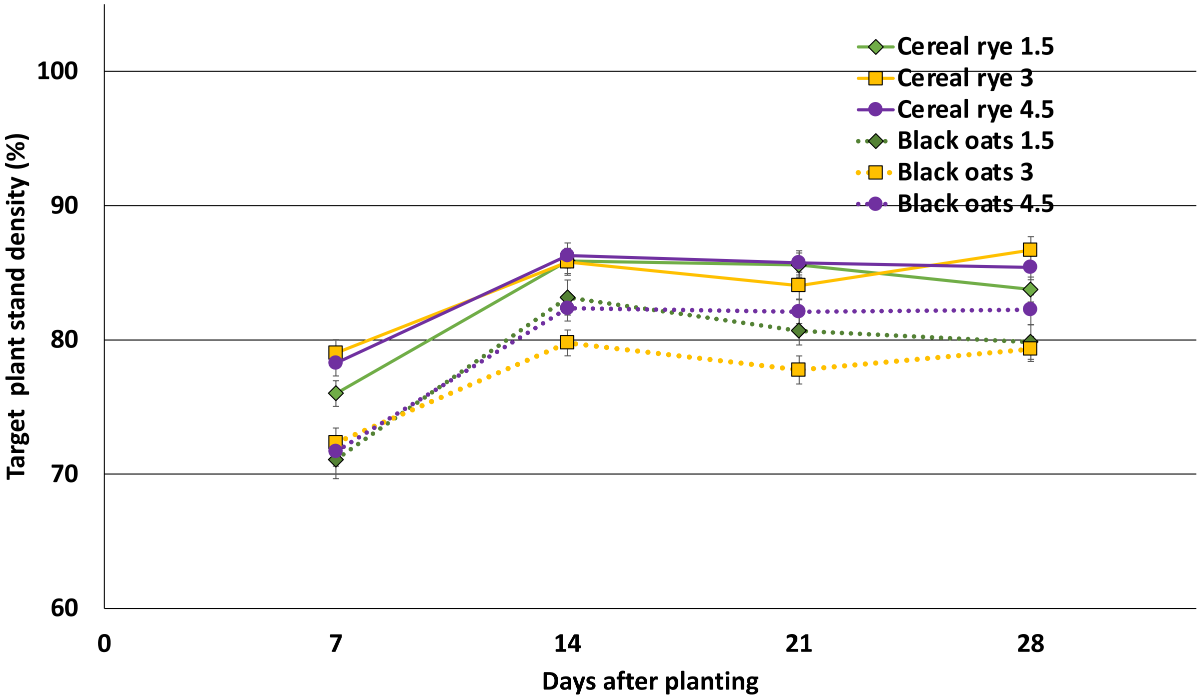

Fig. 2. Stand density expressed as % of target stand observed in the 2020 seeding rate trial in no-till, terminated cereal rye cover crop and low-till, spring-planted black oats at 3 seeding rates, 1.5, 3, and 4.5 seeds per ft of row–2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

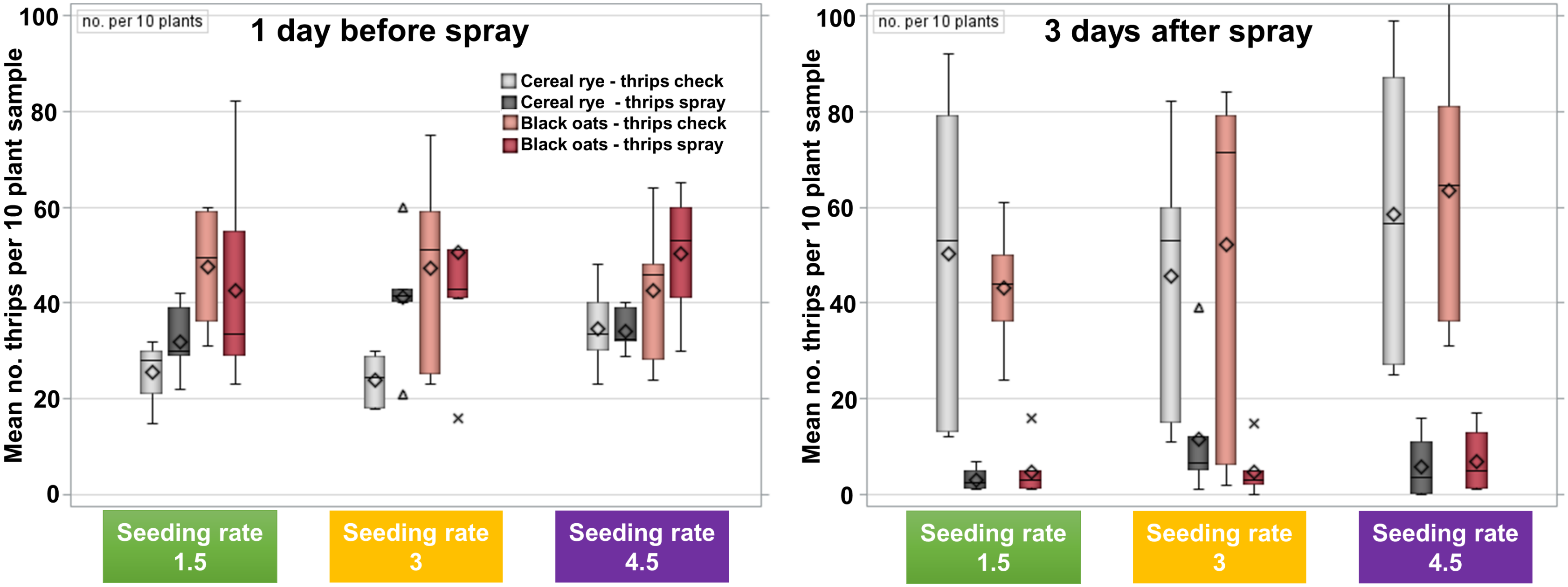

Fig. 3. Thrips counts per 10 plants observed in whole plant washes from collections made 1 day prior to and 3 days after application of dicrotophos in selected treatment plots made 21 days after planting in 2020 (labeled thrips spray)—2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

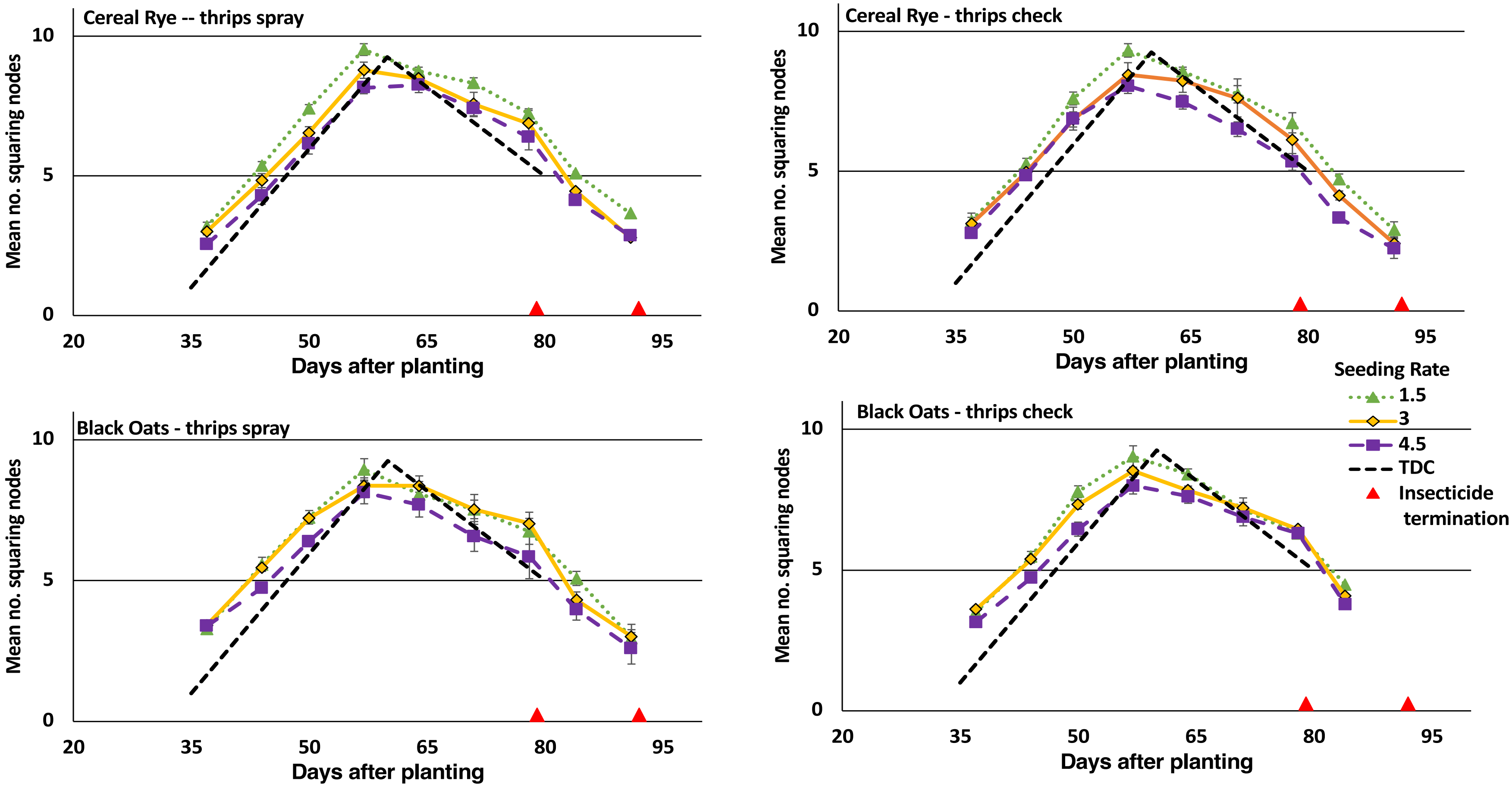

Fig. 4. COTMAN growth curves for cover crop systems of cereal rye or black oats with (thrips spray) and without (thrips check) early-season thrips spray in comparison with the COTMAN target development curve (TDC). The timings for the late-season *Lygus* insecticide termination sprays are also shown.

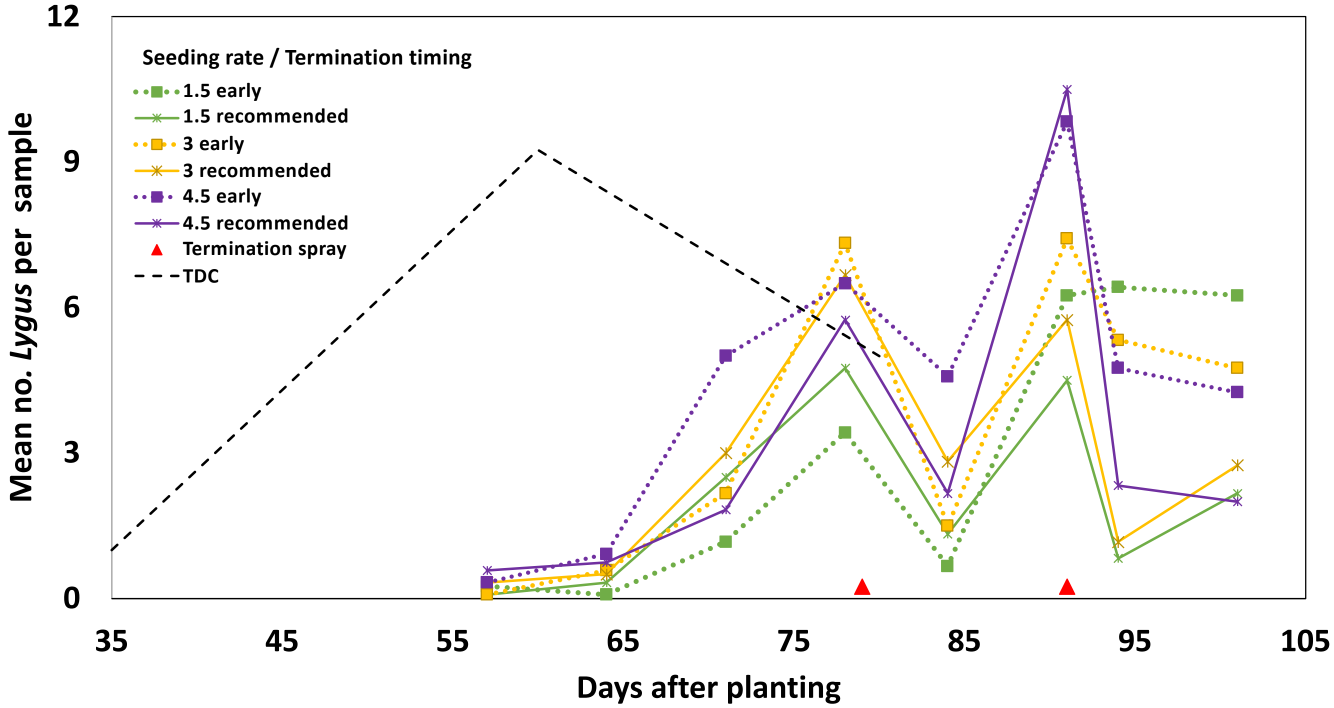

Fig. 5. Mean no. *Lygus lineolaris* (tarnished plant bug) for seeding rate effects with the early- and late-season termination sprays indicated. Also shown is the COTMAN Target Development Curve (TDC) to provide a reference line to aid examination of pest abundance in relation to plant maturity. The action threshold for Arkansas is an average of 3 *Lygus* per sample before cutout, and after cutout is 6 *Lygus* per sample. A blanket spray across the entire field was made at 79 days after planting (DAP), and the final (recommended timing) termination spray was made in selected plots at 91 DAP.

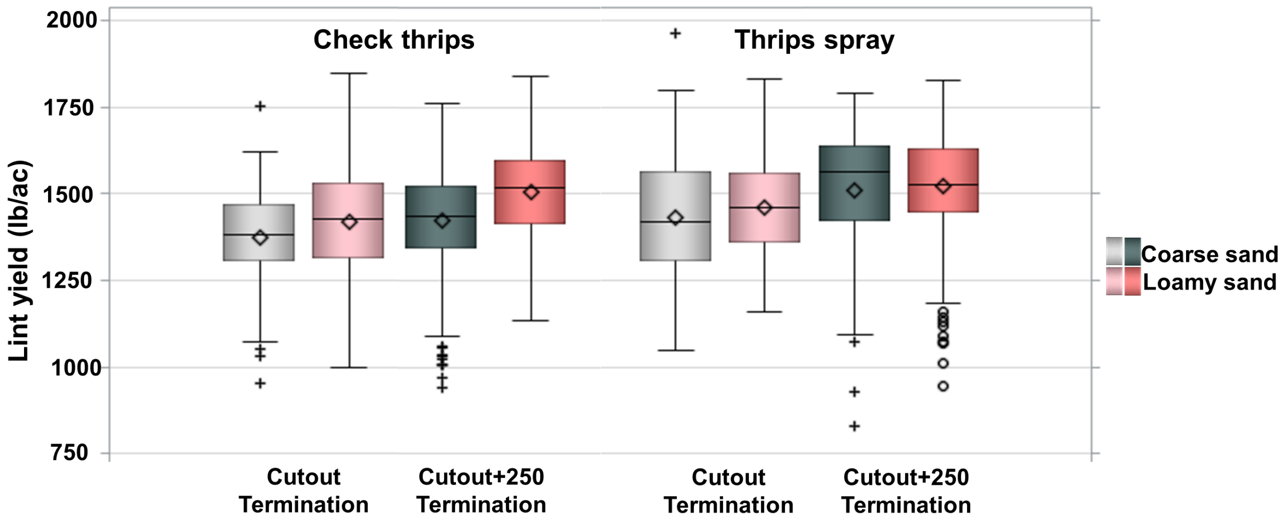

Fig. 6. Yield monitor-measured lint yield (lb/ac) associated with early-season insecticide applications for thrips and late-season *Lygus* termination timing effects (cutout (NAWF = 5) compared to cutout +250 DD60s) for plants in different soil textural zones in the 2020 cover crop system *seeding rate* termination timing trial at Manila, Arkansas.

Conservation Practices for Reducing Yield Losses and Global Warming Potentials in Cotton Production

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Abstract

Conservation practices have been developed for cotton cultivation, but their efficacies vary by crop and environment; hence, integrated management practices are realized. Multiple conservation practices can be a more effective strategy to reduce greenhouse gas (GHG) emissions. This study investigated the many conservation practices that aim to reduce GHG emission footprint in cotton. The experiment was a factorial design with Irrigated, IR vs. Rainfed, RA and Conventional, Conv vs. Conservation, Cons, cropping in triplicates. Lint yields, CH_4, N_2O, and CO_2 fluxes were measured using a static flux chamber technique. Lint yields were 13% higher in the conservation systems relative to conventional systems, but yields decreased by 10-20% between irrigated and rainfed irrigation practices. Annual N_2O emissions ranged from 0.01 to 0.02 oz N_2O-N 1000/ac/yr (0.8 to 1.5 mg N_2O-N/ha/yr) with emissions not affected by tillage and cropping practices. Annual CO_2 emissions (3390 to 5621 lb CO_2-C/ac/yr or 3.8 to 6.3 mg CO_2-C/ha/yr) were significantly different between tillage and irrigation systems ($P = 0.02-0.001$), with 35% larger emissions measured in the conservation irrigated systems relative to conventional irrigated systems. The increased CO_2 emissions in conservation practices were related to vegetative cover and/or the amount of crop residues in the field. This study highlights the direct influence of some conservation practices on GHG emissions in cotton production.

Introduction

The agriculture sector contributes about 9% of the total global greenhouse gas (GHG) emissions in the U.S. (USEPA, 2020). Methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) are the major GHG that are emitted from cultivated land, which is highly impacted by the improvement of crop and water management systems to maintain or increase the crop yield. Improvements in soil quality along with reductions in water pollution are linked with expanded adoption of conservation practices like reduced tillage and use of cover crops in U.S. cotton. However, there is little information about how these evolving systems impact greenhouse (GHG) emissions. In fact, there are large uncertainties about the total GHG budgets from cotton production due to limited flux measurements conducted under the cotton cropping system.

This study is being conducted to evaluate the agronomic and environmental benefits of conservation practices such as vegetated buffer strips, reduced till, conservation furrow tillage, and cover cropping in cotton production. The overarching goal of this study is to explore the long-term environmental and agronomic impacts of conservation practices in irrigated and non-irrigated cotton production. The specific objectives of this study are to 1) compare greenhouse gas (methane, carbon dioxide, nitrous oxide) emissions and yield-scaled global warming potential from conventional and conservation cropping systems; and 2) assess the impacts of conservation practices on lint yield under irrigated and non-irrigated cropping.

Procedures

Field Description and Cropping System Treatments

A long-term field experiment was established at the Judd Hill Foundation Research Farm, Trumann, Arkansas (33.60 N; 90.53 W; elevation 65 m above mean sea level [amsl]). In its third year of implementation, a 2 × 2 factorial field experiment with 3 replicates with irrigation and tillage as main treatments was maintained. Irrigation treatments were Irrigated (IR) and Rainfed (RA), while Tillage treatments were Conservation and Conventional systems.

- Conservation-Irrigated (Cons-IR): Furrow irrigated; cereal rye winter cover crop; low tillage; vegetated turn-row buffer strip.
- Conservation-Rainfed (Cons-RA): Rainfed; cereal rye winter cover crop; no tillage; vegetated turn-row buffer strip.

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- Conventional-Irrigated (Conv-IR): Re-bedding in spring; furrow irrigated; low tillage; cultivated turn-row and field border.
- Conventional-Rainfed (Conv-RA): Re-bedding in spring; rainfed, no tillage; cultivated turn-row and field border.

Treatment plots were extended the length of the field, which was 12 rows and 520 ft long. PHY 360 W3FE was planted on 16 May 2021 at a seeding rate of three seeds per foot. Round up and pre-emergence chemicals were applied on 31 May 2021. Across cropping system treatments, the field plots were fertilized at a rate of 100 lb of N/ac (101 kg N/ha) on 15 June 2021; no fertilizers P and K were applied this year. Irrigation water was applied on 8 events starting on 23 June 2021 to Conv-IR and Cons-IR treatments using the furrow irrigation method (polypipe tubing) (Table 1).

In the conservation system treatments plots, winter rye (*Secale cereal* L) was seeded on 9 September 2020 at a 1 lb/ac (1.12 kg/ha) rate, and the cover crop was terminated using glyphosate on 1 April 2021 to prepare the field for cotton planting.

Lint Yield Measurements

The cotton was treated with harvest aids on 24 September and 2 October 2021 and harvested using a cotton picker on 13 October 2021. For this year, the treatment replicate plot was divided into 3 tiers and each tier was sampled for lint yield. Two inner cotton rows were chosen to capture differences in crop response on various cropping management systems. Yield data were converted to kg/ha and lb/ac.

Greenhouse Gas Emissions Measurements

Measurements of soil trace gases such as methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2), also known as greenhouse gases (GHG), were conducted in all tillage and irrigation treatment plots. Greenhouse gas fluxes from the soil surface were measured at least weekly and during emission-related events such as N fertilization, tillage, irrigation, maximum crop N uptake, and heavy rainfall. The method used in the gas flux measurements was similar to the configuration used in maize and other upland crops. The gas flux chamber consisted of a base and chamber lid all made of PVC. Treatment plot edges were avoided in the installation of collars and were randomly placed in a representative portion of the treatment plot. The collars were pushed into the soil at about 4 in. so that a 6 in. headspace remained above the soil surface. After cotton had emerged, collars were randomly and permanently placed in between crop rows (Fig. 1). One collar was inserted between crop rows and another collar was placed within cotton rows in each plot to assess differences in surface emissions associated with rows.

During gas sampling, a vented chamber lid was placed on a chamber collar and sealed. Four gas samples (25 mL) were drawn from the chamber headspace and one from outside of the chamber at equal time intervals within 1 hour of chamber closure. Also, ambient gas samples were collected from each plot at 0 min. The gas samples were transferred in pre-evacuated 12.5 mL vials. The glass vials were sealed with rubber septa and silicon to avoid gas leakage. Currently, gas fluxes were measured on 10 occasions (growing dates) and samples were generally collected from 9:00 to 13:00. Gas concentrations of CH_4, CO_2, and N_2O were determined on a GC-2014 gas chromatograph (Shimadzu Scientific, Inst., Columbia, MD) connected with an autosampler (XYZTEK, Sacramento, CA) configured and calibrated as described by Adviento-Borbe et al., (2013). Other ancillary soil variables such as soil temperature, soil water content, and crop growth stages were determined during gas collection.

Environmental Variables

Air temperature and precipitation data were obtained from a weather station installed at the study site. Also, air temperature during chamber closure was recorded using a thermocouple wire attached to each chamber. Soil temperatures at 2 and 4-in. soil depths were recorded using a digital thermometer (Fisher Scientific, U.S.) during gas measurement campaigns.

Data Analysis

Cumulative seasonal fluxes were calculated by linear interpolation between sampling dates. Cumulative fluxes were calculated for each collar and then averaged for each treatment. Global warming potential (GWP) of N_2O was calculated in mass of CO_2 equivalent (lb CO_2eq/ac and kg CO_2eq/ha) over 100-year time horizon. A radiative forcing potential relative to CO_2 of 265 was used for N_2O (Myhre et al., 2013). Yield-scaled global warming potential (GWPY) was calculated by taking the ratio of GWP and corresponding lint yield for each treatment.

The differences in mean cumulative N_2O, CO_2, GWP, and lint yield due to main effects such as irrigation and tillage were analyzed using R version 3.6.1 at *P*-level < 0.05 with package least squares means (R Core Team, 2019).

Results and Discussion

Ancillary Data and Lint Yield

The mean daily air temperature ranged from 52 to 99 °F (11 to 37 °C), and total precipitation was 10-in. (257 mm), with 25 rain events occurring throughout the growth of cotton (growing season) (Fig. 2). Relative to last year's weather, the growing season weather this year was warm with more or less the same amount of rain.

During the study period, the average soil temperature ranged between 68 to 95 °F (20 to 35 °C) at 0–2 in. (0–5 cm) depth and 68 to 91 °F (20 to 33 °C) at 0–4 in. (0–10 cm) (Fig. 3). There was no difference in soil temperature between the convention and conservation treatments. However, the soil temperature was higher in rainfed than irrigated treatments at both soil depths.

Lint Yields

There was no difference in lint yield between conservation and conventional systems (Fig. 4). Actually, there was 13% yield increase in the conservation systems relative to conventional systems. Between irrigated and rainfed irrigation practices, managing cotton under a rainfed system showed a 10–20% yield decrease. This shows that although more rain occurred during the growing season, an accurate time of irrigation application is needed to obtain better yield response. Our findings highlight the benefit of practicing irrigated conservation systems on the yield of cotton.

Daily CH_4 Fluxes

Almost 50% of measured CH_4 fluxes were below the detection limit of the gas chromatograph. CH_4 fluxes that were detected were also low and virtually negligible in all management treatments and ranged from -0.003 to 0.012 lb CH_4-C/ac/day (-3 to 13 g CH_4-C/ha/day) (Fig. 5).

Daily N_2O Fluxes

Daily fluxes of N_2O were also low and fluctuated around zero in all treatments except in July (Fig. 6). During this period, the highest N_2O peak of 0.179 lb N_2O-N/ac/day (201 g N_2O-N/ha/day) was observed on 9 July, a day after the third irrigation and three weeks after N fertilization from the conventional irrigated treatments. Nitrous oxide emissions also peaked at 0.401 lb N_2O-N/ac/day (45 g N_2O-N/ha) from the conservation irrigated system on the same day. The highest N_2O emissions from irrigated conventional and rainfed conservation systems were observed a week later, coinciding after the rainfall events. The N_2O emissions were higher from irrigated treatments than from rainfed under the conventional system. However, in the conservation system, the case was the opposite, i.e., the N_2O emissions were higher from rainfed treatments than irrigated treatment. Nitrous oxide emissions were greater in the conservation rainfed system compared to irrigated systems because of the wet and warm conditions caused by continuous rain and elevated ambient temperature at the 0–4 in. soil depth (Figs. 2, 3, and 6). The crop residue on the surface may contribute to warming of rooting depth during this period.

Daily CO_2 Fluxes

During the gas measurements period from May to September, CO_2 emissions ranged from 2.7 to 38 lb CO_2-C/ac/day (3 to 42 kg CO_2-C/ha/day) (Fig. 7). Carbon dioxide emissions were consistently higher from the conservation system than in the conventional system throughout the measurement period. The seasonal trend follows a similar pattern from conventional and conservation systems in the rainfed system. The highest CO_2 peak of 38 lb CO_2-C/ac/day (42 kg CO_2-C/ha/day) and 32 lb CO_2-C/ac/day (36 kg CO_2-C/ha/day) was observed on 9 July after herbicide application from conservation and conventional rainfed treatments, respectively. The highest emissions in both irrigated treatments were observed in late August with 33 and 24 lb CO_2-C/ac/day (37 and 27 kg CO_2-C/ha/day) from conservation and conventional irrigated treatments, respectively. Similar higher peak emission of 32 lb CO_2-C/ac/day (36 kg CO_2-C/ha/day) was observed in late July from the conservation irrigated treatment but no CO_2 emission peaks were observed in conventional irrigated treatments. Elevated CO_2 emissions conservation irrigated system treatment were measured during the early spring following the termination of winter rye.

Seasonal Emissions and Global Warming Potential

Cumulative seasonal CH_4 emissions ranged from -0.18 to 0.09 lb CH_4-C/ac/season (-0.2 to 0.1 kg CH_4-C/ha/season) (Table 2) with no significant difference between irrigation treatments ($P = 0.20$) and between conservation and conventional treatments ($P = 0.27$).

There was a considerable variation in cumulative seasonal N_2O emissions ranging from 0.71 to 3.8 lb N_2O-N/ac/season (0.8 to 4.3 kg N_2O-N/ha/season) (Table 2). However, there was neither significant difference between irrigation treatments ($P = 0.67$) nor between conservation and conventional treatments ($P = 0.14$). The range of seasonal N_2O emissions measured during the growing cotton season in this study is much higher than the growing season N_2O emission reported from furrow irrigated cotton production systems in Arizona (0.36 to 0.80 lb N_2O-N/ac or 0.4 to 0.9 kg N_2O-N/ha) (Bronson et al., 2018). The highest seasonal emission of 3.84 lb N_2O-N/ac/season (4.3 kg N_2O-N/ha/season) measured in the conventional irrigated system was higher than the average seasonal N_2O emissions reported for wheat and maize globally with the estimated values of 1.3 and 2.7 lb N_2O-N/ac (1.44 and 3.01 kg N_2O-N/ha), respectively (Linquist et al., 2012). However, it was close to seasonal emissions of 4.1 to 4.4 lb N_2O-N/ac (4.6 to 4.9 kg N_2O-N/ha) reported for irrigated maize in the U.S. (Adviento-Borbe et al., 2007).

Total seasonal CO_2 emissions (1,759 to 2,263 lb CO_2-C/ac/season or 1,947 to 2,504 kg CO_2-C/ha/season) were significantly different between conservation and convention treatments ($P = 0.01$) but not between the irrigation treatments (0.57) (Table 2). Higher CO_2 emissions from the conservation system were most likely driven by the decomposition of cover crop resulting in the addition of liable carbon to the soil. In addition, reduced tillage and inclusion of cover crops for four straight years might have increased the soil organic carbon input in the site (Abdalla et al., 2013). The average daily fluxes of CO_2 determined in this study were similar to those observed from cotton production under conservation and conventional tillage in Texas (McDonald et al., 2019).

As CH_4 emissions were low, there was a negligible contribution of CH_4 to total GWP in all treatments. Emissions of CO_2 were the main contributor to global warming potential (GWP) in all treatments contributing more than 90% of its total GWP except for convention irrigated treatment with 82% contribution to the total GWP. There was no significant difference in total GWP among the treatments. Relatively lower N_2O emissions counterbalanced the higher CO_2 emissions from the conservation system.

Practical Applications

The four cropping treatments had various influences on lint yield and greenhouse gas emissions. The lint yields increased by 13% in conservation practices as compared to conventional cropping. Nitrous oxide emissions were significantly large in conservation systems. CH_4 emissions were small and virtually negligible in all tillage and irrigation treatments. Nitrous oxide emissions were directly influenced by fertilizer N, water, and warm weather while CO_2 emissions were influenced greatly by crop growth, cover crop, and crop residues. CO_2 emissions constituted mainly the seasonal GHG emissions. Conservation practices such as reduced furrow tillage, adequate N fertilization, and time of irrigation may lead to lower N_2O emissions. Our results also show the apparent tradeoff between cover cropping and CO_2 emissions. This study provides field-based datasets of GHG emissions, which is important in the assessment of impacts of adoption of conservation production practices in cotton.

Acknowledgments

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Table 1. Summary of agronomic activities in the four cropping system treatments during the 2021 growing season.

Agronomic activities	Date	Days after planting
Cover crops seeded	9 Sep. 2020	
Cover crop termination	1 April 2021	
Date of cotton planting	16 May 2021	
Stand counts	27 May and 3 June 2021	11 and 18
N fertilizer application	15 June 2021	30
Furrow irrigation	23, 30 June; 6, 8 July; 2, 9, 17, 25 Aug.	38, 45, 53, 71, 78, 85, 93, 101
Harvest aids	24 Sep.; 2 Oct. 2021	131, 139
Machine Harvest	13 Oct. 2021	150

Table 2. Cumulative CH_4, N_2O, CO_2 emissions, and total global warming potential (GWP) from different management treatments during the cotton growing season in 2021 (May–September). Data shown are average ± standard error (*n* = 6). Different letters denote statistical difference (*P* < 0.05) among treatments.

Cropping system	CH_4 emissions (lb CH_4-C/ac/ season)	N_2O emissions (lb N_2O-N/ac/ season)	CO_2 emissions (lb CO_2-C/ac/ season)	Total GWP (lb CO_2 eq/ac/ season)
Conventional-Irrigated	-0.18 ± 0.1 a	3.8 ± 2.1 a	1759 ± 108 b	8093 ± 869 a
Conventional-Rainfed	-0.18 ± 0.1 a	2.0 ± 0.6 a	1899 ± 199 b	7773 ± 922 a
Conservation-Irrigated	0.09 ± 0.1 a	0.7 ± 0.2 a	2220 ± 159 a	8422 ± 657 a
Conservation-Rainfed	-0.18 ± 0.1 a	1.6 ± 0.5 a	2263 ± 190 a	8978 ± 670 a

Fig. 1. Chamber collars installation and location in the study field.

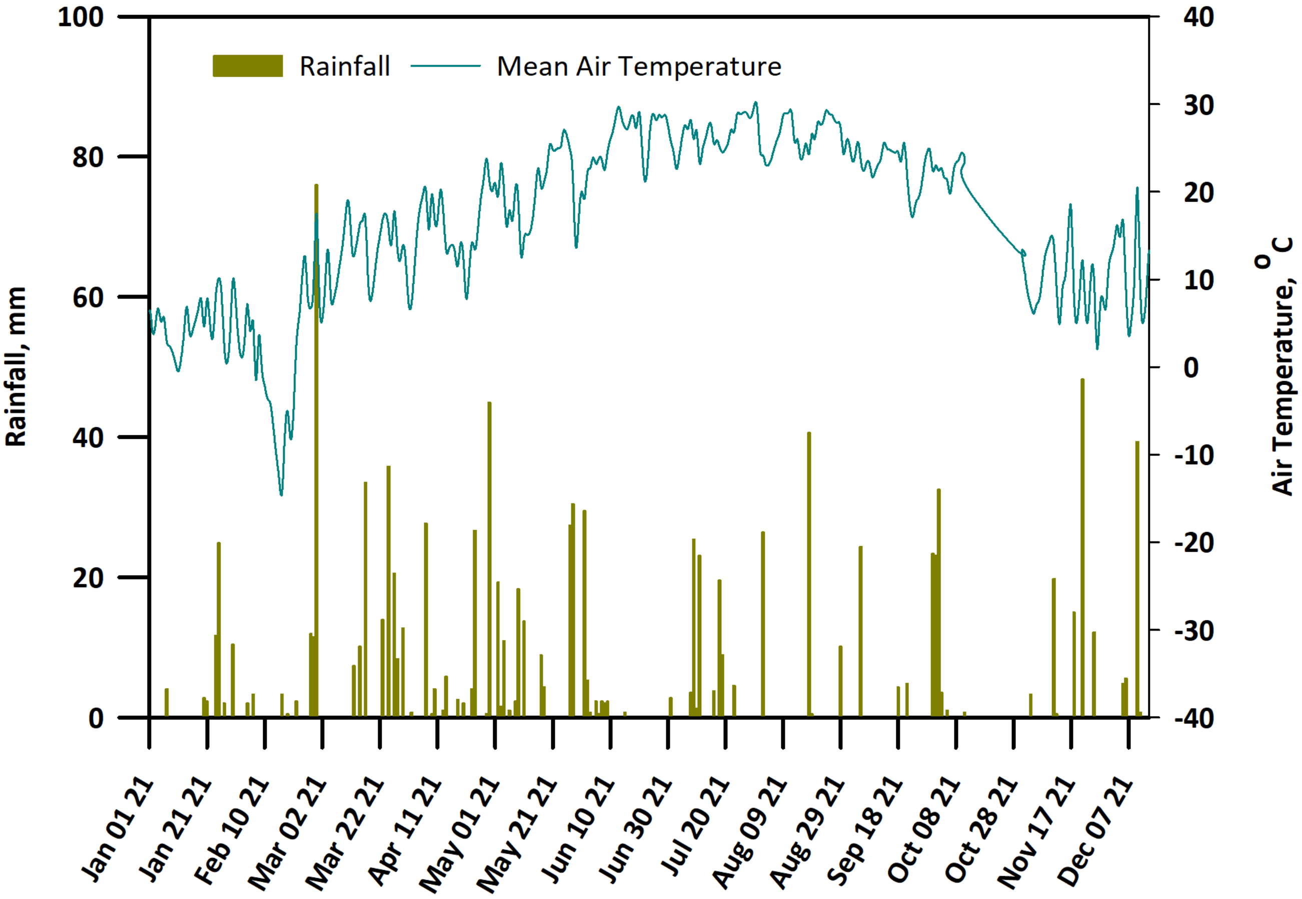

Fig. 2. Daily average air temperature and precipitation in the study site during the 2021 growing season.

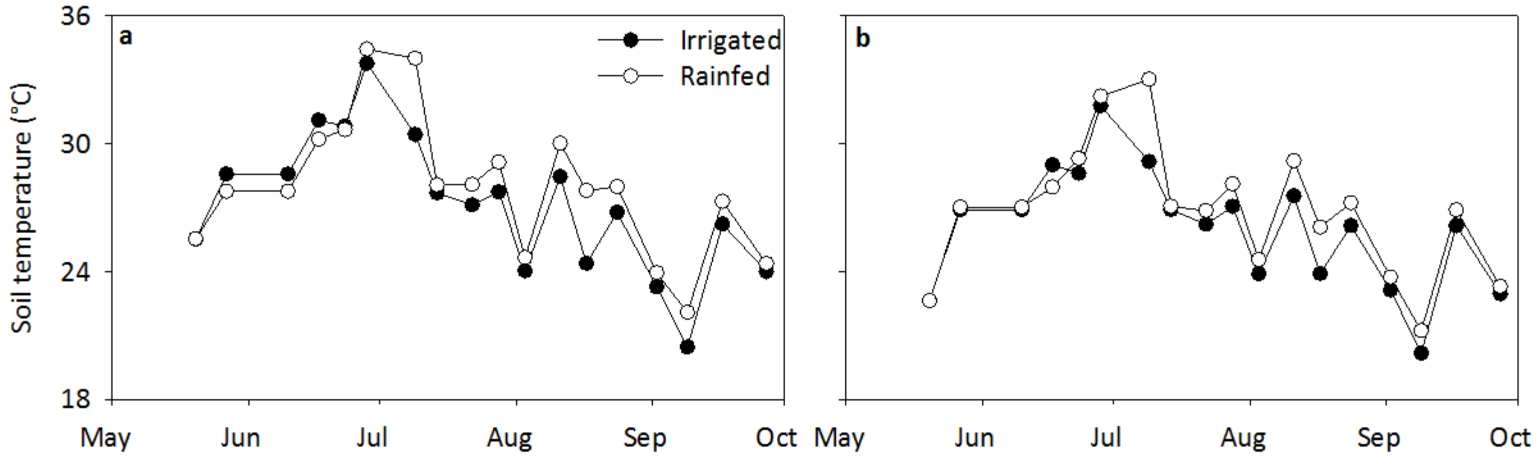

Fig. 3. Average soil temperature at (a) 0-5 cm and (b) 0-10 cm soil depth in the study site during the 2021 gas measurement period.

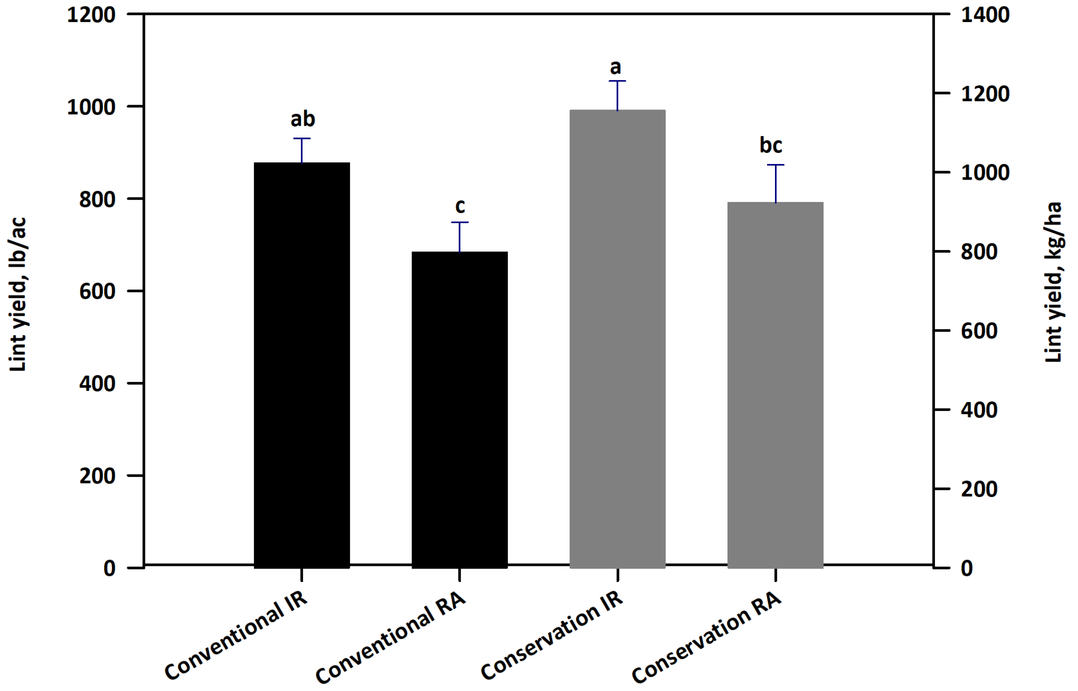

Fig. 4. Average lint yield in the four cropping systems during the 2021 growing season. Average lint yield values followed by the same letter are not significant at the *P* < 0.05 level, standard errors were computed from 3 replicates.

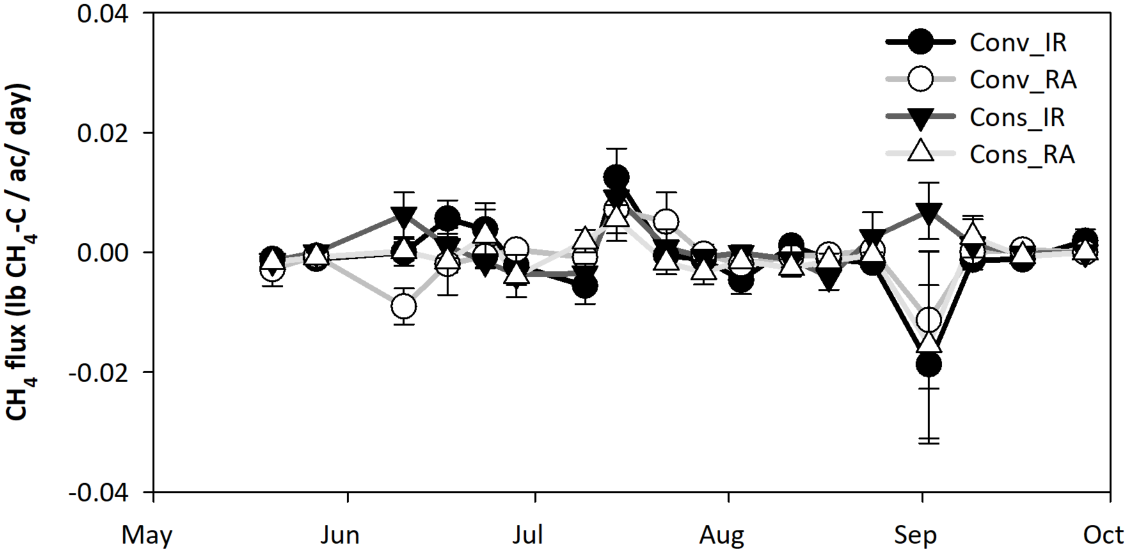

Fig. 5. Methane (CH_4) emissions from conventional (Conv) and conservation (Cons) management practices under irrigated (IR) and rainfed (RA) conditions during the 2021 gas measurement period.

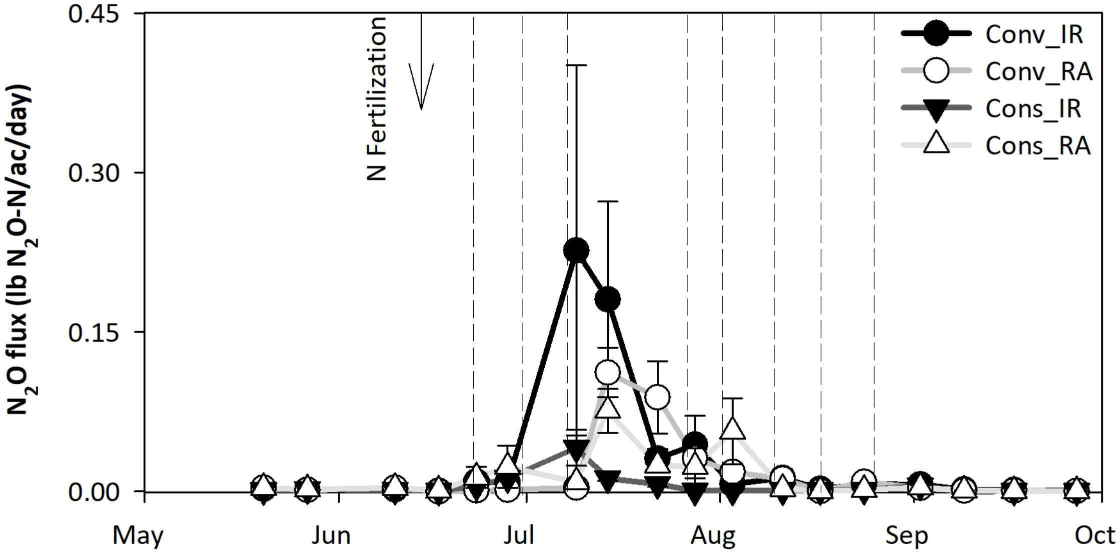

Fig. 6. Nitrous oxide (N_2O) emissions from conventional (Conv) and conservation (Cons) management practices under irrigated (IR) and rainfed (RA) conditions during the 2021 gas measurement period. Dotted lines represent irrigation events in irrigated treatment, and an arrow represents nitrogen fertilization.

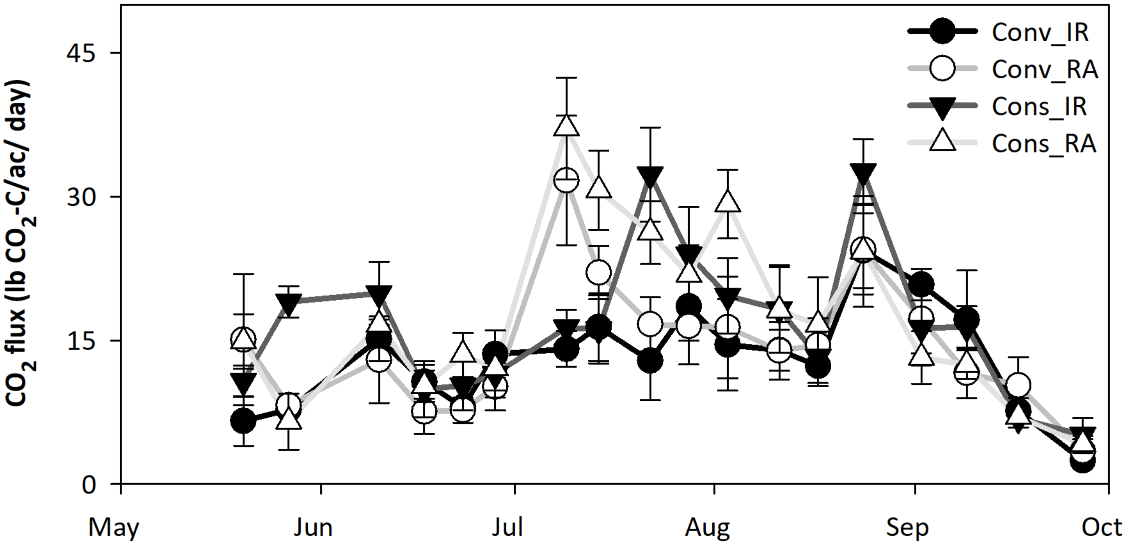

Fig. 7. Carbon dioxide (CO_2) emissions from conventional (Conv) and conservation (Cons) management practices under irrigated (IR) and rainfed (RA) conditions during the 2021 growing season.

Increasing Profitability by Reducing Input Costs Facilitated by Improving Soil Health

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Abstract

Improving soil health reduces the producer's environmental footprint, which is key to meeting the goals of the U.S. Cotton Industry to supply brands and retailers with the sustainably produced fiber they desire. Widespread adoption of practices to improve soil health will be more likely to occur when producers can utilize the improved relationship of their crop with soil microbes and a greatly improved effective rooting zone to reduce inputs without sacrificing yield. In the first year of this study, with cotton production following one cycle of a cover crop, improvements in soil health were observed in the fields where cover crops were planted. However, lint yields did not follow this trend. Yields were highest in conventional tillage without cover crops plots and lowest in the intensification with cover crops plots. The yield decrease of the crop intensification field highlights the complicated mechanisms involved in improving soil health and building soil microbe activity to a point that input reduction will not negatively impact lint yield. Expenses were reduced by $8.05/ac on the cover crop field and $92.49/ac on the crop intensification field compared to the producer standard field. However, loss of gross income because of the decline in yield compared to the farmer standard field in this study translated to a net loss of $218.44/ac and $308.96/ac for the cover crop and crop intensification field, respectively. It is believed by some that two to three years may be necessary to achieve the well-balanced ecosystem necessary to sustain this system. This study demonstrates that one cycle of diverse cover crops is not adequate to transition into this system.

Introduction

The Research Verification Sustainability Program has demonstrated the effectiveness of improving soil health on positively impacting various soil health parameters in Arkansas and how yield is impacted. In dry years economic benefits are great, with as much as a 10% increase in yield and a $0.09 reduction in cost per pound of production. In wet years, the yield improvements are greatly diminished.

Improving soil health in both wet and dry years consistently reduces the producer's environmental footprint, which is key to meeting the goals of the U.S. Cotton Industry to supply brands and retailers with the sustainably produced fiber they desire.

Widespread adoption of practices to improve soil health will not occur based solely on a yield response. For adoption to occur, producers must utilize the improved relationship of their crop with soil microbes, and a greatly improved effective rooting zone, to reduce inputs without sacrificing yield.

An educational and demonstration program to improve producer confidence in reducing or eliminating inputs without sacrificing yield is needed to reduce production costs and to achieve sustainable improvements in profitability, as we strive to provide the fiber brands and retailers have committed to source.

Procedures

Production strategies were evaluated employing differing input strategies to improve profitability by utilizing on-farm comparisons of three systems using 40 to 80 ac fields. Arkansas Soil Health Alliance, https://www.facebook.com/Arsoilhealth/, recommendation of crop intensification coupled with no-till and diverse cover crops to greatly reduce inputs was established in a 40 ac block and compared to the cooperating producer's standard practice in both a system using conventional tillage without a cover crop in an adjoining 40 ac block and a system utilizing reduced tillage/no-till with a single-species cereal rye cover crop in an 80 ac block. The Fieldprint Calculator, https://calculator.fieldtomarket.org/, was used to document differences in the three systems: 1) crop intensification with no-till and cover crops, 2) cooperating producer's standard practices in a system utilizing reduced tillage/no-till with a cereal rye cover crop, and 3) cooperating producer's standard practices in a system using conventional tillage without a cover crop. Lint yields were calculated from seed cotton weights from machine-picked plots. Turnout was calculated from grab samples and ginned on a tabletop gin. Operating expenses, profitability, and changes in environmental footprint are compared.

Results and Discussion

In the first year of cotton production following a cover crop, differences in soil health were observed (data not shown). Watermark soil moisture sensors detected water infiltration occurring at deeper depths on the fields with improved soil health. However, issues were encountered in

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both the cover crop field and the crop intensification fields. Herbicide injury greatly impacted the growth of the cover crops in the crop intensification field. Adequate growth was achieved just prior to planting but was not at the level expected. Initial plans to terminate the cereal rye cover crop field were altered due to persistent rainfall events, which prevented timely ground application of products to terminate the cover. The cereal rye cover termination was delayed until planting, which is largely responsible for the yield decrease in this production system (Table 1).

The producer standard field and cover crop field was seeded at 36K seed per acre and came up to a very nice stand and grew off well. The cover crop field did get lanky with excessive biomass that never really laid flat the entire season. The crop intensification field was seeded at half the seeding rate of the other fields. Stands were skippy from the onset of the season. Yields were excellent for the producer standard field, while the other two production systems experienced lower yields (Table 1). The significant yield decrease of the crop intensification field highlights the complicated mechanisms involved in improving soil health and building soil microbe activity to a point that input reduction will not negatively impact lint yield.

Expenses differed between production systems (Table 1). A summary of the budget analysis revealed that $8.05/ac less was spent on the cover crop field and $92.49/ac less on the crop intensification field compared to the producer standard field (Table 2). However, loss of gross income because of the decline in yield compared to the farmer standard field in this study translated to a net loss of $218.44/ac and $308.96/ac for the cover crop and crop intensification field, respectively.

Some that two to three years may be necessary to achieve the well-balanced ecosystem necessary to sustain this system. This study demonstrates that one cycle of diverse cover crops is not adequate to transition into this system.

Comparisons of the three systems using the Field to Market Fieldprint Platform indicate that the two cover crop production strategies have a positive impact on reducing energy and greenhouse gas emissions expressed on an acre basis (Table 3). These sustainability metrics expressed per unit of cotton lint production favor the producer standard production practice field because of the yield differences.

Practical Applications

Improving soil health reduces the producer's environmental footprint, which is key to meeting the goals of the U.S. Cotton Industry to supply brands and retailers the sustainably produced fiber they desire. Widespread adoption of practices to improve soil health will not occur based solely on a yield response. For adoption to occur, producers must utilize the improved relationship of their crop with soil microbes and a greatly improved effective rooting zone to reduce inputs without sacrificing yield. The timeframe necessary to achieve the well-balanced ecosystem necessary to sustain a crop intensification production system is not clearly understood. This study demonstrates that one cycle of diverse cover crops is not adequate to transition into this system.

Acknowledgments

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

Table 1. Expenses and revenue of production systems to improve soil health compared to the producer standard field and an enterprise budget at Judd Hill in 2021.

	Field			
Revenue/Expenses	Judd Hill Crop Intensification	Judd Hill Cover Crop	Judd Hill Producer Standard	U of A 2021 Enterprise Budget
Revenue				
Yield (lb)	1176	1458	1824	1200
Price ($/lb)	0.62	0.62	0.62	0.62
Total Crop Revenue	**729.31**	**904.27**	**1130.76**	**744.00**
Cottonseed Value	**194.56**	**241.24**	**301.66**	**198.48**
Expenses				
Seed	63.65	108.00	93.60	123.50
Fertilizer and Nutrients	58.35	84.23	84.23	73.37
Herbicide	65.42	65.42	65.42	94.87
Insecticide	52.43	58.21	81.10	70.36
Other Chemicals	29.05	29.05	30.65	24.38
Custom Applications	44.00	46.75	39.25	14.00
Other Inputs	20.89	24.97	30.25	21.23
Diesel Fuel	10.14	10.14	9.27	12.87
Irrigation Energy Costs	5.67	5.67	7.56	22.68
Input Costs	**349.60**	**432.44**	**441.33**	**457.26**
Fees	21.50	21.50	21.50	21.50
Repairs and Maintenance[a]	23.27	23.03	23.27	25.19
Labor, Field Act.	7.66	7.66	6.93	10.36
Production Expenses	**402.03**	**484.63**	**493.03**	**514.31**
Interest	8.94	10.78	10.43	11.44
Post Harvest Expenses	194.56	241.24	301.65	198.48
Operating Expenses	**410.97**	**495.41**	**503.46**	**525.75**
Returns to Op. Expenses	**318.59**	**408.88**	**651.72**	**218.26**
Cap. Recovery of Fixed Costs	139.52	139.52	135.82	160.16
Total Specified Expenses[b]	**550.24**	**634.90**	**614.86**	**685.90**
Returns to Spec. Expenses	**179.07**	**269.37**	**515.90**	**58.10**
Operating Expenses/lb	0.35	0.34	0.28	0.32
Total Expenses/lb	0.47	0.44	0.34	0.41

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

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

Table 2. Summary of expenses and income compared to the producer standard field as influenced by production systems at Judd Hill in 2021.

Production System	Lint Yield	Change in Expense	Change in Gross Income	Change in Net Income
	lb/ac	$/ac	$/ac	$/ac
Producer Standard	1824	--	--	--
Cover Crop	1459	-33	-328	-295
Crop Intensification	1176	-189	-582	-393

Table 3. Influence of production systems on sustainability metrics of energy (BTU) and greenhouse emissions (lb CO_2 eq) on an acre basis and per unit of production and cotton lint yield at Judd Hill in 2021.

Production System	Lint Yield	Energy Use		Greenhouse Gas Emissions	
	lb/ac	BTU/ac	BTU/lb lint	lb CO_2 eq/ac	lb CO_2 eq/lb lint
Producer Standard	1824	7.28 m	3993	2270	1.2
Cover Crop	1459	6.66 m	4568	2148	1.5
Crop Intensification	1176	4.83 m	4107	1610	1.4

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