



SOUTHEAST RESEARCH AND EXTENSION CENTER AGRICULTURAL RESEARCH 2019

K-STATE
Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service



JAYMELYNN K. FARNEY

Beef Systems Specialist, Associate Professor

B.S., Animal Science and Industry, Kansas State University

M.S., Animal Science and Industry - Ruminant Nutrition, Oklahoma State University

Ph.D., Animal Science and Industry - Ruminant Nutrition, Kansas State University

Jaymelynn joined the staff in 2012. Her research and extension efforts have focused on cow-calf and stocker management. Specific areas include forage utilization by livestock of annual forages within integrated production systems, mineral and feed supplementation for production, and fescue management for production and cattle utilization.



LYLE LOMAS

Animal Scientist, Professor

B.S., M.S., Animal Husbandry, University of Missouri

Ph.D., Animal Husbandry, Michigan State University

Lyle directs beef cattle research at the Kansas State University Research and Extension Center. He joined the staff in 1979 as Animal Scientist and served as Research Center Head from 1986 to 2018. His research interests are beef cattle nutrition and forage utilization by grazing beef cattle.



J.D. McNUTT

Professor and Southeast Research and Extension Center Department Head

B.S. Oklahoma State University, Agricultural Education

M. Ed. East Central University, Secondary Education/Natural Sciences

Ed.D. Oklahoma State University, Higher Education Administration

Dr. McNutt provides administrative and research leadership to the faculty and staff at the SEREC, as well as being the Director of Extension for the Southeast extension region. His research efforts were in the field of community/rural development.



GRETCHEN F. SASSENATH

Cropping Systems Agronomist, Professor

B.A., Oberlin College

M.S., Biophysics, University of Illinois

Ph.D., Plant Physiology, University of Illinois

Gretchen joined the staff in 2013. Her research focuses on crop production; physiological, edaphic, biotic, and abiotic stressors in cropping systems; and integrated production systems.



DAN SWEENEY

Soil and Water Management Agronomist, Professor

B.S., Chemistry, Kentucky Wesleyan College

M.S., Agronomy, Purdue University

Ph.D., Soil Science, University of Florida

Dan joined the staff in 1983. His research focuses on soil fertility, tillage and compaction, water quality, and irrigation.

SEREC

AGRICULTURAL RESEARCH

2019

Contents

1 *Beef Cattle Research*

- 1 Effects of Interseeding Ladino Clover into Tall Fescue Pastures of Varying Endophyte Status on Grazing and Subsequent Finishing Performance of Stocker Steers
- 9 Including Legumes in Wheat-Bermudagrass Pastures
- 11 Effects of Various Grazing Systems on Grazing and Subsequent Finishing Performance
- 25 Evaluation of Supplemental Energy Source for Grazing Stocker Cattle
- 33 Effects of Supplementation with Corn or Dried Distillers Grains on Gains of Heifer Calves Grazing Smooth Bromegrass Pastures
- 37 Cattle Preference for Annual Forages
- 42 Evaluating Single and Multi-Species Summer Cover Crops for Biomass Yield

49 *Soil and Water Management Research*

- 49 Nitrogen Fertilizer Timing and Phosphorus and Potassium Fertilization Rates for Established Endophyte-Free Tall Fescue
- 52 Tillage and Nitrogen Placement Effects on Yields in a Short-Season Corn/Wheat/Double-Crop Soybean Rotation
- 54 Pre-Plant Nitrogen Rate and Application Method and Side-Dress Nitrogen Rate Effects on Corn Grown No-Till on a Claypan Soil
- 56 Response of Soybean Grown on a Claypan Soil in Southeastern Kansas to the Residual of Different Plant Nutrient Sources and Tillage

58	Use of a Fungicide to Reduce Stomatal Conductance for Production of Sweet Corn Planted at Different Populations with Limited Irrigation
60	<i>Cropping Systems Research</i>
60	Southeast Kansas Crop Production Summary – 2018
70	Controlling Soil-Borne Disease in Soybean With a Mustard Cover Crop
75	Corn Planting Date and Depth – Impacts on Yield
81	Modeling Wheat Susceptibility to Disease
85	Using Cover Crops as an Effective Weed Control Method in Southeast Kansas
90	Biomass Production of Single Species Cover Crop
96	Characterization of Claypan Soils in Southeastern Kansas
105	Changes in Soil Microbiology Under Conventional and No-Till Production During Crop Rotation
111	Annual Summary of Weather Data for Parsons - 2018
113	Acknowledgments
115	Research and Extension Personnel

Kansas Agricultural Experiment Station Research Reports are available at
<http://newprairiepress.org/kaesrr/>

Effects of Interseeding Ladino Clover into Tall Fescue Pastures of Varying Endophyte Status on Grazing and Subsequent Finishing Performance of Stocker Steers

L.W. Lomas and J.L. Moyer

Summary

One hundred ninety-two yearling steers grazing tall fescue pastures were used to evaluate the effects of fescue cultivar and interseeding ladino clover on available forage, grazing gains, and subsequent finishing performance in 2016, 2017, and 2018. Fescue cultivars evaluated were high-endophyte 'Kentucky 31,' low-endophyte Kentucky 31, 'HM4,' and 'MaxQ.' In 2016 and 2018, steers that grazed pastures of low-endophyte Kentucky 31, HM4, or MaxQ gained significantly more ($P < 0.05$) and produced more ($P < 0.05$) gain/a than those that grazed high-endophyte Kentucky 31 pastures. Gains of cattle that grazed low-endophyte Kentucky 31, HM4, or MaxQ were similar ($P > 0.05$). In 2017, steer gains were similar ($P > 0.05$) among all cultivars. High-endophyte Kentucky 31 pastures had more ($P < 0.05$) available forage than low-endophyte Kentucky 31, HM4, or MaxQ pastures during both 2016 and 2017. Steer gains and gain/acre were similar ($P > 0.05$) between pastures fertilized with nitrogen (N) in the spring and those interseeded with ladino clover during all three years. Fescue cultivar or legume treatment had little effect on finishing performance or carcass characteristics of steers grazed in 2016 or 2017. Steers that grazed high-endophyte Kentucky 31 in 2016 had lower ($P < 0.05$) final finishing weight and lower ($P < 0.05$) carcass weight than those that grazed low-endophyte Kentucky 31, HM4, or MaxQ. In 2017, steers that grazed pastures interseeded with ladino clover had lower ($P < 0.05$) finishing gains and greater ($P < 0.05$) feed:gain than those that grazed pastures with no legume.

Introduction

Tall fescue, the most widely adapted cool-season perennial grass in the United States, is grown on approximately 66 million acres. Although tall fescue is well adapted in the eastern half of the country between the temperate north and mild south, presence of a fungal endophyte results in poor performance of grazing livestock, especially during the summer. Until recently, producers with high-endophyte tall fescue pastures had two primary options for improving grazing livestock performance. One option was to destroy existing stands and replace them with endophyte-free fescue or other forages. Although it supports greater animal performance than endophyte-infected fescue, endophyte-free fescue has been shown to be less persistent under grazing pressure and more susceptible to stand loss from drought stress. In locations where high-endophyte tall fescue must be grown, the other option was for producers to adopt management strategies that reduce the negative effects of the endophyte on grazing animals, such as diluting the effects of the endophyte by incorporating legumes into existing pastures or providing supplemental feed. In recent years, new tall fescue cultivars have been developed with a non-toxic endophyte that provides vigor to the fescue plant without negatively affecting performance of grazing livestock. Interseeding legumes into

endophyte-free tall fescue cultivars and those with the non-toxic endophyte should be an effective way of increasing gains of cattle grazing tall fescue. However, these cultivars lack the vigor of high-endophyte Kentucky 31 and their competitiveness with legumes could be a potential problem. Objectives of this study were to evaluate forage availability, stand persistence, and performance of stocker steers grazing tall fescue cultivars with non-toxic endophyte and high- and low-endophyte Kentucky 31 with and without ladino clover.

Experimental Procedures

Sixty-four mixed black yearling steers were weighed on two consecutive days and allotted to sixteen 5-acre established pastures of high-endophyte Kentucky 31 or low-endophyte Kentucky 31, HM4, or MaxQ tall fescue (4 replications per cultivar) on March 30, 2016 (535 lb), March 28, 2017 (597 lb), and April 3, 2018 (581 lb). The HM4 and MaxQ are cultivars with a non-toxic endophyte. Two pastures of each cultivar had been interseeded with 5 lb/a of 'Will' ladino clover on February 22, 2016. Four steers were assigned to each pasture. Pastures without clover were fertilized with 80 lb/a N on February 10, 2016, February 16, 2017, and January 31, 2018. All pastures were fertilized with 40 lb/a N and P₂O₅ and K₂O as required by soil test on September 13, 2016, September 11, 2017, and September 25, 2018.

Pasture was the experimental unit and weight gain was the primary measurement. No implants or feed additives were used. Cattle were weighed and forage availability was measured every 28 days in 2016 and 2017 with a disk meter calibrated for tall fescue. Cattle were treated for internal and external parasites before being turned out to pasture and later vaccinated for protection from pinkeye. Steers had free access to commercial mineral blocks that contained 12% calcium, 12% phosphorus, and 12% salt. Four steers were removed from the study in 2016 for reasons unrelated to experimental treatment and replaced with grazers to maintain equal stocking rates. Pastures were grazed continuously until November 29, 2016 (244 days), December 6, 2017 (253 days), and November 7, 2018 (218 days) when steers were weighed on two consecutive days and grazing was terminated.

After the grazing period, cattle were moved to a finishing facility, implanted with Synovex-S (Zoetis, Madison, NJ), and fed a diet of 80% whole-shelled corn, 15% corn silage, and 5% supplement (dry matter basis) to determine the effect of grazing treatment on subsequent finishing performance. Cattle that grazed in 2016 and 2017 were fed a finishing diet for 98 days and were slaughtered in a commercial facility, and carcass data were collected on each steer. Cattle that were grazed during 2018 were being finished for slaughter at the time that this report was written.

Results and Discussion

Grazing and finishing performance is pooled across legume treatment and presented by tall fescue cultivar for 2016 and 2017 in Table 1 and Table 3, respectively; and pooled across fescue cultivar and presented by legume treatment for 2016 and 2017 in Table 2 and Table 4, respectively. There were significant interactions ($P < 0.05$) between fescue cultivar and legume treatment for average available forage DM in 2016 and average daily dry matter intake during the finishing phase in 2017. In 2016 and 2018, steers that grazed low-endophyte Kentucky 31, HM4, or MaxQ were heavier ($P < 0.05$) at the

end of the grazing period, had greater ($P < 0.05$) grazing gain, greater ($P < 0.05$) daily gain, and produced greater ($P < 0.05$) gain/a than steers that grazed high-endophyte Kentucky 31. Average available forage DM of high-endophyte Kentucky 31 pasture was greater ($P < 0.05$) than that of low-endophyte Kentucky 31, HM4, or MaxQ. In 2016, MaxQ pasture had greater ($P < 0.05$) available forage DM than low-endophyte Kentucky 31. Average available forage DM of HM4 pasture was similar ($P > 0.05$) to that of low-endophyte Kentucky 31 and MaxQ pastures. In 2017, average available forage DM of low-endophyte Kentucky 31, HM4, or MaxQ pastures were similar ($P > 0.05$). Steer gains were similar ($P > 0.05$) between pastures fertilized with an additional 80 lb/a N and those interseeded with ladino clover in all three years. Pastures with clover had less ($P < 0.05$) available forage DM than those without clover for all cultivars except high-endophyte Kentucky 31 where available forage DM of pastures with and without clover were similar ($P > 0.05$).

In 2016, fescue cultivar had no effect ($P > 0.05$) on finishing gain, dry matter intake, or feed:gain ratio. However, steers that previously grazed high-endophyte Kentucky 31 had lower ($P < 0.05$) weight at the end of the finishing phase and lower ($P < 0.05$) hot carcass weight than those that previously grazed low-endophyte Kentucky 31, HM4, or MaxQ. The weight differential between cattle that grazed high-endophyte Kentucky 31 and those that grazed low-endophyte Kentucky 31, HM4, or MaxQ was similar at the end of the grazing phase (156 lb) and the end of the finishing phase (155 lb). Therefore, the weight advantage of cattle that grazed low-endophyte Kentucky 31, HM4, or MaxQ occurred during the grazing phase and was maintained during the finishing phase. Cattle that grazed high-endophyte Kentucky 31 did not exhibit any compensatory gain during the finishing phase. Backfat thickness of steers that grazed high-endophyte Kentucky 31 or HM4 were similar ($P > 0.05$) and lower ($P < 0.05$) than that of steers that grazed low-endophyte Kentucky 31 or MaxQ. Yield grade of steers that grazed high-endophyte Kentucky 31 was numerically lower ($P < 0.05$) than that of steers that grazed low-endophyte Kentucky 31 or MaxQ and similar ($P > 0.05$) to that of steers that grazed HM4. Fescue cultivar had no effect ($P > 0.05$) on ribeye area, marbling score, or percent of carcasses that graded USDA Choice. Overall gain of steers that grazed high-endophyte Kentucky 31 was lower ($P < 0.05$) than that of steers that grazed low-endophyte Kentucky 31, HM4, or MaxQ and overall gain of steers that grazed low-endophyte Kentucky 31, HM4, or MaxQ were similar ($P > 0.05$). Legume treatment had no effect ($P > 0.05$) on finishing performance or carcass traits.

In 2017, fescue cultivar had no effect ($P > 0.05$) on finishing performance or overall performance. Steers that grazed pastures interseeded with ladino clover had lower ($P < 0.05$) finishing gains and greater ($P < 0.05$) feed:gain than those that grazed pastures with no legume.

Grazing performance for 2018 is pooled across legume treatment and presented by tall fescue cultivar in Table 5, and pooled across fescue cultivar and presented by legume treatment in Table 6. Steers that grazed low-endophyte Kentucky 31, HM4, or MaxQ were heavier ($P < 0.05$) at the end of the grazing period, had greater ($P < 0.05$) grazing gain, greater ($P < 0.05$) daily gain, and produced greater ($P < 0.05$) gain/a than steers that grazed high-endophyte Kentucky 31. Legume treatment had no effect ($P > 0.05$) on grazing performance.

BEEF CATTLE RESEARCH

Table 1. Effects of cultivar on grazing and subsequent finishing performance of steers grazing tall fescue pastures, Southeast Research and Extension Center, 2016

Item	Tall fescue cultivar			
	High-endophyte Kentucky 31	Low-endophyte Kentucky 31	HM4	MaxQ
Grazing phase (244 days)				
Number of head	13	16	16	15
Initial weight, lb	533	535	535	537
Ending weight, lb	770a	920b	931b	924b
Gain, lb	238a	385b	396b	387b
Daily gain, lb	0.97a	1.58b	1.62b	1.59b
Gain/a, lb	190a	308b	310b	310b
Average available forage dry matter, lb/a*	7,365a	5,944b	6,139bc	6,300c
Finishing phase (98 days)				
Beginning weight, lb	770a	920b	931b	924b
Ending weight, lb	1219a	1374b	1366b	1386b
Gain, lb	449	454	435	462
Daily gain, lb	4.58	4.63	4.44	4.71
Daily dry matter intake, lb	26.2	27.4	28.3	28.3
Feed:gain	5.74	5.91	6.41	6.05
Hot carcass weight, lb	756a	852b	847b	859b
Backfat, in.	0.47a	0.60b	0.55a	0.60b
Ribeye area, sq. in.	12.7	12.8	12.7	12.9
Yield grade	2.3a	3.0b	2.9ab	3.0b
Marbling score ¹	627	669	623	616
Percentage USDA grade Choice	100	100	100	100
Overall performance (grazing plus finishing; 342 days)				
Gain, lb	687a	839b	831b	849b
Daily gain, lb	2.01a	2.45b	2.43b	2.48b

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

*There was a significant ($P < 0.05$) fescue cultivar \times legume interaction.

BEEF CATTLE RESEARCH

Table 2. Effects of interseeding ladino clover on grazing and subsequent finishing performance of steers grazing tall fescue pastures, Southeast Research and Extension Center, 2016

Item	Legume treatment	
	No legume	Ladino clover
Grazing phase (244 days)		
Number of head	30	30
Initial weight, lb	534	536
Ending weight, lb	868	905
Gain, lb	334	369
Daily gain, lb	1.37	1.51
Gain/a, lb	267	295
Average available forage dry matter, lb/a*	6,888a	5,986b
Finishing phase (98 days)		
Beginning weight, lb	868	905
Ending weight, lb	1320	1353
Gain, lb	453	448
Daily gain, lb	4.62	4.57
Daily dry matter intake, lb	27.4	27.6
Feed:gain	5.97	6.09
Hot carcass weight, lb	819	839
Backfat, in.	0.55	0.56
Ribeye area, sq. in.	12.8	12.8
Yield grade	2.8	2.8
Marbling score ¹	619	649
Percentage USDA grade Choice	100	100
Overall performance (grazing plus finishing; 342 days)		
Gain, lb	786	817
Daily gain, lb	2.30	2.39

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

*There was a significant ($P < 0.05$) fescue cultivar \times legume interaction.

BEEF CATTLE RESEARCH

Table 3. Effects of cultivar on grazing and subsequent finishing performance of steers grazing tall fescue pastures, Southeast Research and Extension Center, 2017

Item	Tall fescue cultivar			
	High-endophyte Kentucky 31	Low-endophyte Kentucky 31	HM4	MaxQ
Grazing phase (253 days)				
Number of head	16	16	16	16
Initial weight, lb	597	597	597	597
Ending weight, lb	901	1029	986	1007
Gain, lb	304	432	389	411
Daily gain, lb	1.20	1.71	1.54	1.62
Gain/a, lb	244	346	311	328
Average available forage dry matter, lb/a	5,179a	4,728b	4,812b	4,808b
Finishing phase (98 days)				
Beginning weight, lb	901	1029	986	1007
Ending weight, lb	1311	1422	1374	1400
Gain, lb	410	393	389	393
Daily gain, lb	4.18	4.01	3.97	4.01
Daily dry matter intake, lb*	28.5	28.4	28.7	27.6
Feed:gain	6.82	7.13	7.25	7.01
Hot carcass weight, lb	813	882	852	868
Backfat, in.	0.46	0.58	0.58	0.52
Ribeye area, sq. in.	13.1	13.3	13.1	13.1
Yield grade	2.4	2.8	2.8	2.7
Marbling score ¹	659	694	754	701
Percentage USDA grade Choice	94	100	100	100
Overall performance (grazing plus finishing; 351 days)				
Gain, lb	715	826	778	803
Daily gain, lb	2.04	2.35	2.22	2.29

¹600 = modest, 700 = moderate, 800 = slightly abundant.

Means within a row followed by the same letter do not differ ($P < 0.05$).

*There was a significant ($P < 0.05$) fescue cultivar × legume interaction.

BEEF CATTLE RESEARCH

Table 4. Effects of interseeding ladino clover on grazing and subsequent finishing performance of steers grazing tall fescue pastures, Southeast Research and Extension Center, 2017

Item	Legume treatment	
	No legume	Ladino clover
Grazing phase (253 days)		
Number of head	32	32
Initial weight, lb	597	597
Ending weight, lb	951	1011
Gain, lb	354	414
Daily gain, lb	1.40	1.64
Gain/a, lb	283	331
Average available forage dry matter, lb/a	5,215a	4,548b
Finishing phase (98 days)		
Beginning weight, lb	951	1011
Ending weight, lb	1363	1391
Gain, lb	412a	380b
Daily gain, lb	4.20a	3.88b
Daily dry matter intake, lb*	28.0	28.6
Feed:gain	6.68a	7.42b
Hot carcass weight, lb	845	862
Backfat, in.	0.51	0.56
Ribeye area, sq. in.	13.0	13.3
Yield grade	2.7	2.7
Marbling score ¹	693	711
Percentage USDA grade Choice	97	100
Overall performance (grazing plus finishing; 351 days)		
Gain, lb	766	794
Daily gain, lb	2.18	2.26

¹600 = modest, 700 = moderate, 800 = slightly abundant.

Means within a row followed by the same letter do not differ ($P < 0.05$).

*There was a significant ($P < 0.05$) fescue cultivar \times legume interaction.

BEEF CATTLE RESEARCH

Table 5. Effects of cultivar on performance of steers grazing tall fescue pastures, Southeast Research and Extension Center, 2018

Item	Tall fescue cultivar			
	High-endophyte Kentucky 31	Low-endophyte Kentucky 31	HM4	MaxQ
Grazing phase (218 days)				
Number of head	16	16	16	16
Initial weight, lb	581	581	581	581
Ending weight, lb	815a	954b	940b	953b
Gain, lb	234a	372b	359b	372b
Daily gain, lb	1.08a	1.71b	1.65b	1.70b
Gain/a, lb	187a	298b	287b	297b

Means within a row followed by the same letter do not differ ($P < 0.05$).

Table 6. Effects of interseeding ladino clover on performance of steers grazing tall fescue pastures, Southeast Research and Extension Center, 2018

Item	Legume treatment	
	No legume	Ladino clover
Grazing phase (218 days)		
Number of head	32	32
Initial weight, lb	581	581
Ending weight, lb	914	917
Gain, lb	332	336
Daily gain, lb	1.52	1.54
Gain/a, lb	266	269

Means within a row followed by the same letter do not differ ($P < 0.05$).

Including Legumes in Wheat-Bermudagrass Pastures

L.W. Lomas and J.L. Moyer

Summary

Use of legumes in wheat-bermudagrass pastures did not affect cow gains in 2018.

Introduction

Bermudagrass is a productive forage species when intensively managed. However, it has periods of dormancy and requires proper management to maintain forage quality. Legumes in the bermudagrass sward could improve forage quality and reduce fertilizer usage; however, legumes are difficult to establish and maintain with the competitive grass. Clovers can maintain survival once established in bermudagrass sod, and may be productive enough to substitute for some N fertilization. This study was designed to compare dry cow performance on a bermudagrass pasture system that included ladino and crimson clovers (Legume) vs. bermudagrass alone (Nitrogen).

Experimental Procedures

Eight 5-acre 'Hardie' bermudagrass pastures at the Mound Valley Unit of the Southeast Research and Extension Center (Parsons silt-loam soil) were assigned to Legume or Nitrogen treatments in a completely randomized design with four replications. All pastures were interseeded with 90 lb/a of 'Everest' wheat on October 2, 2017. Legume pastures previously interseeded with 'Will' ladino clover were interseeded with 26 lb/a of crimson clover using a no-till drill at on October 3, 2017. Nitrogen pastures were fertilized with 50 lb/a N on January 31 and May 9, 2018, and all pastures received 50-30-30 of N-P₂O₅-K₂O on July 19, 2018.

Thirty-two pregnant fall-calving cows of predominantly Angus breeding were weighed on consecutive days and assigned randomly by weight to pastures on April 4, 2018. Final cow weights were taken on consecutive days before removal from the pastures on August 23 (141 days).

Results and Discussion

Cow performance data are presented in Table 1. Cow gains and gain/a for the Nitrogen and Legume treatments were similar ($P > 0.05$).

BEEF CATTLE RESEARCH

Table 1. Performance of cows grazing wheat-bermudagrass pastures interseeded with wheat and fertilized with nitrogen or interseeded with legumes, Mound Valley Unit, Southeast Research and Extension Center, 2018

Item	Management system	
	Nitrogen	Legumes
Number of cows	16	16
Number of days	141	141
Stocking rate, cows/a	0.8	0.8
Cow initial weight, lb	1356	1356
Cow final weight, lb	1682	1637
Cow gain, lb	325	281
Cow daily gain, lb	2.42	2.10
Cow gain, lb/a	260	225

Means within a row followed by the same letter do not differ ($P < 0.05$).

Effects of Various Grazing Systems on Grazing and Subsequent Finishing Performance

L.W. Lomas and J.L. Moyer

Summary

A total of 360 mixed black yearling steers were used to compare grazing and subsequent finishing performance from pastures with 'MaxQ' tall fescue, a wheat-bermudagrass double-crop system, or a wheat-crabgrass double-crop system in 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, and 2018. Daily gains of steers that grazed MaxQ fescue, wheat-bermudagrass, or wheat-crabgrass were similar ($P > 0.05$) in 2010, 2016, 2017, and 2018. Daily gains of steers that grazed wheat-bermudagrass or wheat-crabgrass were greater ($P > 0.05$) than those that grazed MaxQ fescue in 2011 and 2012. Daily gains of steers that grazed wheat-crabgrass were greater ($P > 0.05$) than those that grazed wheat-bermudagrass and similar ($P > 0.05$) to those that grazed MaxQ fescue in 2013. Daily gains of steers that grazed wheat-crabgrass were greater ($P > 0.05$) than those that grazed wheat-bermudagrass or MaxQ fescue in 2014. In 2015, daily gains of steers that grazed wheat-crabgrass were greater ($P < 0.05$) than those that grazed wheat-bermudagrass or MaxQ fescue and daily gain of steers grazing wheat-bermudagrass was greater ($P < 0.05$) than that of those that grazed MaxQ fescue. Finishing gains were similar ($P > 0.05$) among forage systems in 2010, 2012, 2013, 2014, and 2016. Finishing gains of steers that grazed MaxQ fescue were greater ($P < 0.05$) than those that grazed wheat-bermudagrass in 2011 and greater ($P < 0.05$) than those that grazed wheat-bermudagrass or wheat-crabgrass in 2015. In 2017, finishing gains of steers that grazed wheat-crabgrass were greater ($P < 0.05$) than those that grazed MaxQ fescue.

Introduction

MaxQ tall fescue, a wheat-bermudagrass double-crop system, and a wheat-crabgrass double-crop system have been three of the most promising grazing systems evaluated at the Southeast Research and Extension Center in the past 30 years, but these systems have never been compared directly in the same study. The objective of this study was to compare grazing and subsequent finishing performance of stocker steers that grazed these three systems.

Experimental Procedures

From 2010-2018, 40 mixed black yearling steers were weighed on two consecutive days and allotted on April 6, 2010 (633 lb); March 23, 2011 (607 lb); March 22, 2012 (632 lb); April 4, 2013 (678 lb); April 1, 2014 (636 lb); March 31, 2015 (644 lb); March 30, 2016 (600 lb); March 28, 2017 (669 lb); and April 3, 2018 (655 lb) to three 4-acre pastures of 'Midland 99' bermudagrass, three 4-acre pastures of 'Red River' crabgrass, and four 4-acre established pastures of MaxQ tall fescue (4 steers/pasture).

- Bermudagrass and crabgrass pastures had previously been no-till seeded with approximately 120 lb/a of 'Fuller' hard red winter wheat on September 30, 2009, and September 22, 2010; and 130 lb/a, 95 lb/a, 85 lb/a, 180 lb/a, 100 lb/a,

BEEF CATTLE RESEARCH

100 lb/a, and 88 lb/a of ‘Everest’ hard red winter wheat on September 27, 2011, September 25, 2012, September 23, 2013, September 29, 2014, September 22, 2015, October 4, 2016, and September 29, 2017, respectively.

- All pastures were fertilized with 80-40-40 lb/a of N-P₂O₅-K₂O on March 3, 2010; January 27, 2011; January 25, 2012; February 19, 2013; January 28, 2014; February 10, 2015; February 11, 2016; February 13, 2017; and January 31, 2018.
- Bermudagrass and crabgrass pastures received an additional 46 lb/a of nitrogen (N) on May 28, 2010; June 10, 2011; May 18, 2012; July 3, 2013; June 2, 2014; June 8, 2015; May 23, 2016; June 13, 2017; and June 8, 2018.
- Fescue pastures received an additional 46 lb/a of N on August 31, 2010; September 15, 2011; September 18, 2013; September 4, 2014; October 7, 2015; September 7, 2016; September 22, 2017; and August 29, 2018.
- An additional 5 lb/a, 4 lb/a, 4 lb/a, 4 lb/a, 4 lb/a, 4 lb/a, 4 lb/a, and 4 lb/a of crabgrass seed was broadcast on crabgrass pastures on April 8, 2011, April 4, 2012, May 7, 2013, April 18, 2014, June 4, 2015, April 12, 2016, February 21, 2017, and April 24, 2018, respectively.

Pasture was the experimental unit. No implants or feed additives were used. Weight gain was the primary measurement. Cattle were weighed every 28 days, and forage availability was measured approximately every 28 days in 2010-2017 with a disk meter calibrated for wheat, bermudagrass, crabgrass, or tall fescue. Cattle were treated for internal and external parasites before being turned out to pasture and later were vaccinated for protection from pinkeye. Steers had free access to commercial mineral blocks that contained 12% calcium, 12% phosphorus, and 12% salt.

- Wheat-bermudagrass and wheat-crabgrass pastures were grazed continuously until: September 14, 2010 (161 days); September 7, 2011 (168 days); September 10, 2013 (159 days); September 3, 2014 (155 days); September 15, 2015 (168 days); September 15, 2016 (169 days); September 12, 2017 (168 days); and September 11, 2018 (161 days).
- Fescue pastures were grazed continuously until: November 9, 2010 (217 days); October 21, 2011 (212 days); October 29, 2013 (208 days); October 14, 2014 (196 days); November 10, 2015 (224 days); November 15, 2016 (230 days); November 14, 2017 (231 days); and November 6, 2018 (217 days).
- In 2012, all pastures were grazed continuously until August 23 (144 days), when grazing on all pastures was terminated due to limited forage availability because of below-average precipitation. Steers were weighed on two consecutive days at the end of the grazing phase.

After the grazing period, cattle were moved to a finishing facility, implanted with Synovex-S (Zoetis, Madison, NJ), and fed a diet of 80% whole-shelled corn, 15% corn silage, and 5% supplement (dry matter basis). Finishing diets were fed for:

- 2010: 94 days (wheat-bermudagrass and wheat-crabgrass) or 100 days (fescue);
- 2011: 98 days (wheat-bermudagrass and wheat-crabgrass) or 96 days (fescue);
- 2012: 105 days;
- 2013: 105 days (wheat-bermudagrass and wheat-crabgrass) or 91 days (fescue);
- 2014: 119 days (wheat-bermudagrass and wheat-crabgrass) or 106 days (fescue);
- 2015: 99 days (wheat-bermudagrass and wheat-crabgrass) or 97 days (fescue);
- 2016: 99 days (wheat-bermudagrass and wheat-crabgrass) or 98 days (fescue); and
- 2017: 99 days (wheat-bermudagrass and wheat-crabgrass) or 91 days (fescue).

All steers were slaughtered in a commercial facility, and carcass data were collected. Cattle that grazed these pastures in 2018 were being finished for slaughter at the time that this report was written.

Results and Discussion

Grazing and subsequent finishing performance of steers that grazed MaxQ tall fescue, a wheat-bermudagrass double-crop system, or a wheat-crabgrass double-crop system are presented in Tables 1, 2, 3, 4, 5, 6, 7, and 8 for 2010, 2011, 2012, 2013, 2014, 2015, 2016, and 2017, respectively. Grazing performance only for 2018 is presented in Table 9. Daily gains of steers that grazed MaxQ tall fescue, wheat-bermudagrass, or wheat-crabgrass were similar ($P > 0.05$) in 2010, but total grazing gain and gain/a were greater ($P < 0.05$) for MaxQ tall fescue than wheat-bermudagrass or wheat-crabgrass because steers grazed MaxQ tall fescue for more days. Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 362, 286, and 258 lb/a, respectively. MaxQ tall fescue pastures had greater ($P < 0.05$) average available forage dry matter (DM) than wheat-bermudagrass or wheat-crabgrass. Grazing treatment in 2010 had no effect ($P > 0.05$) on subsequent finishing gains. Steers that grazed MaxQ were heavier ($P < 0.05$) at the end of the grazing phase, maintained their weight advantage through the finishing phase, and had greater ($P < 0.05$) hot carcass weight than those that grazed wheat-bermudagrass or wheat-crabgrass pastures. Steers that previously grazed wheat-bermudagrass or wheat-crabgrass had lower ($P < 0.05$) feed:gain than those that grazed MaxQ.

In 2011, daily gains, total gain, and gain/a of steers that grazed wheat-bermudagrass or wheat-crabgrass were greater ($P < 0.05$) than MaxQ fescue. Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 307, 347, and 376 lb/a, respectively. MaxQ tall fescue pastures had greater ($P < 0.05$) average available forage DM than wheat-bermudagrass or wheat-crabgrass. This was likely due to greater forage production by MaxQ and/or greater forage intake by steers grazing wheat-bermudagrass and wheat-crabgrass. Steers that grazed MaxQ had greater ($P < 0.05$) finishing gain than those that grazed wheat-bermudagrass and lower ($P < 0.05$) feed:gain than those that grazed wheat-bermudagrass or wheat-crabgrass. Carcass weight was similar ($P > 0.05$) among treatments.

In 2012, daily gains, total gain, and gain/a of steers that grazed wheat-bermudagrass or wheat-crabgrass were greater ($P < 0.05$) than MaxQ fescue. Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 226, 325, and 313 lb/a, respectively. MaxQ tall fescue pastures had greater ($P < 0.05$) average available forage DM than wheat-bermudagrass or wheat-crabgrass. Grazing treatment had no effect ($P > 0.05$) on subsequent finishing performance or carcass characteristics.

In 2013, daily gain was greater ($P < 0.05$) for steers that grazed wheat-crabgrass than for those that grazed wheat-bermudagrass, and daily gain from MaxQ fescue and wheat-bermudagrass were similar ($P > 0.05$). Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 338, 244, and 316 lb/a, respectively. Gain/a was greater ($P < 0.05$) for MaxQ fescue and wheat-crabgrass than for wheat-bermudagrass. Overall gain was not different between forage systems; however, steers grazed MaxQ fescue for 49 more days than wheat-bermudagrass or wheat-crabgrass. Overall daily gain was

greater ($P < 0.05$) for wheat-crabgrass than for MaxQ tall fescue. MaxQ tall fescue pastures had greater ($P < 0.05$) average available forage DM than wheat-bermudagrass or wheat-crabgrass and wheat-bermudagrass pastures had more ($P < 0.05$) available forage DM than wheat-crabgrass. Grazing treatment had no effect ($P > 0.05$) on subsequent finishing daily gain or carcass characteristics.

In 2014, daily gain was greater ($P < 0.05$) for steers that grazed wheat-crabgrass than for those that grazed wheat-bermudagrass or 'MaxQ' fescue, and daily gain from MaxQ fescue and wheat-bermudagrass were similar ($P > 0.05$). Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 370, 282, and 383 lb/a, respectively. Gain/a was greater ($P < 0.05$) for MaxQ fescue and wheat-crabgrass than for wheat-bermudagrass. Overall gain and overall daily gain for wheat-crabgrass were greater ($P < 0.05$) than for wheat-bermudagrass or MaxQ fescue, while overall gain and overall daily gain for MaxQ fescue and wheat-bermudagrass were similar ($P > 0.05$). MaxQ tall fescue pastures had greater ($P < 0.05$) average available forage DM than wheat-bermudagrass or wheat-crabgrass, and wheat-bermudagrass pastures had more ($P < 0.05$) available forage DM than wheat-crabgrass. Grazing treatment had no effect ($P > 0.05$) on subsequent finishing daily gain or carcass characteristics.

In 2015, daily gain was greater ($P < 0.05$) for steers that grazed wheat-crabgrass than for those that grazed wheat-bermudagrass or MaxQ fescue, and daily gain from wheat-bermudagrass was greater ($P < 0.05$) than for those that grazed MaxQ fescue. Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 291, 337, and 396 lb/a, respectively. Gain/a was greater ($P < 0.05$) for wheat-crabgrass than for wheat-bermudagrass or MaxQ fescue and greater ($P < 0.05$) for wheat-bermudagrass than MaxQ fescue. Overall gain for MaxQ fescue was greater ($P < 0.05$) than for wheat-bermudagrass or wheat-crabgrass, while overall gain for wheat-bermudagrass and wheat-crabgrass were similar ($P > 0.05$). Overall daily gains were similar ($P > 0.05$) among forage systems. MaxQ tall fescue pastures had greater ($P < 0.05$) average available forage DM than wheat-bermudagrass or wheat-crabgrass, and wheat-bermudagrass pastures had more ($P < 0.05$) available forage DM than wheat-crabgrass. Slaughter weight, finishing gains, hot carcass weight, and ribeye area of steers that grazed MaxQ fescue were greater ($P < 0.05$) and feed:gain was less ($P < 0.05$) than those that grazed wheat-bermudagrass or wheat-crabgrass. Much of this difference in finishing performance can be attributed to muddier feedlot conditions during the time that the wheat-bermudagrass and wheat-crabgrass steers were being finished for slaughter than for the MaxQ fescue cattle.

In 2016, daily gains were similar ($P > 0.05$) for steers that grazed MaxQ tall fescue, a wheat-bermudagrass double-crop system, or a wheat-crabgrass double-crop system. However, MaxQ tall fescue pastures were grazed 61 days longer and as a result produced greater ($P < 0.05$) steer grazing gain, heavier ($P < 0.05$) steer ending weight, and greater ($P < 0.05$) gain per acre than wheat-bermudagrass or wheat-crabgrass pastures. Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 368, 280, and 287 lb/a, respectively. Average available forage DM for MaxQ tall fescue was greater ($P < 0.05$) than for the wheat-bermudagrass double-crop system or wheat-crabgrass double-crop system and average available forage DM for the wheat-bermudagrass double-crop system was greater ($P < 0.05$) than for the wheat-crabgrass double-crop system. Grazing treatment had no effect ($P > 0.05$) on finishing gain or feed:gain;

however, final finishing weight and hot carcass weight of steers that grazed MaxQ fescue were greater ($P < 0.05$) than those that grazed wheat-bermudagrass or wheat-crabgrass. Overall gain of steers that grazed MaxQ tall fescue was greater ($P < 0.05$) and overall daily gain was lower ($P < 0.05$) than that of those that grazed wheat-bermudagrass or wheat-crabgrass. This was due to steers that grazed wheat-bermudagrass or wheat-crabgrass spending a greater percentage of time in the finishing phase than those that grazed MaxQ tall fescue.

In 2017, daily gains were similar ($P > 0.05$) for steers that grazed MaxQ tall fescue, a wheat-bermudagrass double-crop system, or a wheat-crabgrass double-crop system. However, MaxQ tall fescue pastures were grazed 63 days longer and as a result produced greater ($P < 0.05$) steer grazing gain, heavier ($P < 0.05$) steer ending weight, and greater ($P < 0.05$) gain per acre than wheat-bermudagrass or wheat-crabgrass pastures. Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 411, 312, and 332 lb/a, respectively. Average available forage DM for MaxQ tall fescue was greater ($P < 0.05$) than for the wheat-bermudagrass double-crop system or wheat-crabgrass double-crop system and average available forage DM for the wheat-bermudagrass double-crop system was greater ($P < 0.05$) than for the wheat-crabgrass double-crop system. Finishing gains of steers that grazed wheat-crabgrass were greater ($P < 0.05$) than those that grazed MaxQ tall fescue and similar ($P > 0.05$) to steers that grazed wheat-bermudagrass. Steers that grazed MaxQ tall fescue had higher ($P < 0.05$) feed:gain and higher ($P < 0.05$) marbling scores than those that grazed wheat-bermudagrass or wheat-crabgrass.

In 2018, daily gains were similar ($P > 0.05$) for steers that grazed MaxQ tall fescue, a wheat-bermudagrass double-crop system, or a wheat-crabgrass double-crop system. However, MaxQ tall fescue pastures were grazed 56 days longer and as a result produced greater ($P < 0.05$) steer grazing gain, heavier ($P < 0.05$) steer ending weight, and greater ($P < 0.05$) gain per acre than wheat-bermudagrass or wheat-crabgrass pastures. Gain/a for MaxQ fescue, wheat-bermudagrass, and wheat-crabgrass were 403, 305, and 302 lb/a, respectively.

Hotter and drier weather during the summer of 2011 and 2012 likely provided more favorable growing conditions for bermudagrass and crabgrass than for fescue, which was reflected in greater ($P < 0.05$) gains by cattle grazing those pastures. Lack of precipitation also reduced the length of the grazing season for MaxQ fescue pastures in 2012, which resulted in less fall grazing and lower gain/a than was observed for those pastures in other years.

BEEF CATTLE RESEARCH

Table 1. Effects of forage system on grazing and subsequent performance of stocker steers, Southeast Research and Extension Center, 2010

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	217	161	161
Number of head	16	12	12
Initial weight, lb	633	633	633
Ending weight, lb	995a	919b	891b
Gain, lb	362a	286b	258b
Daily gain, lb	1.67	1.78	1.60
Gain/a, lb	362a	286b	258b
Average available forage dry matter, lb/a	6214a	3497b	3174c
Finishing phase			
Number of days	100	94	94
Beginning weight, lb	995a	919b	891b
Ending weight, lb	1367a	1281b	1273b
Gain, lb	372	361	382
Daily gain, lb	3.72	3.84	4.07
Daily dry matter intake, lb	27.3a	24.6b	25.2b
Feed:gain	7.35a	6.42b	6.22b
Hot carcass weight, lb	847a	794b	790b
Backfat, in.	0.43	0.38	0.35
Ribeye area, sq. in.	12.5	12.5	12.2
Yield grade	2.8	2.5	2.5
Marbling score ¹	649	590	592
Percentage USDA Choice grade	100	92	83
Overall performance (grazing plus finishing)			
Number of days	317	255	255
Gain, lb	734a	648b	640b
Daily gain, lb	2.32a	2.54b	2.51ab

¹500 = small, 600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 2. Effects of forage system on grazing and subsequent performance of stocker steers, Southeast Research and Extension Center, 2011

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	212	168	168
Number of head	16	12	12
Initial weight, lb	607	607	607
Ending weight, lb	914a	954b	982b
Gain, lb	307a	347b	376b
Daily gain, lb	1.45a	2.07b	2.24b
Gain/a, lb	307a	347b	376b
Average available forage dry matter, lb/a	5983a	4172b	3904c
Finishing phase			
Number of days	96	98	98
Beginning weight, lb	914a	954b	982b
Ending weight, lb	1355	1344	1385
Gain, lb	442a	389b	403ab
Daily gain, lb	4.60a	3.97b	4.11ab
Daily dry matter intake, lb	27.9	28.0	29.3
Feed:gain	6.09a	7.07b	7.13b
Hot carcass weight, lb	841	833	859
Backfat, in.	0.41	0.41	0.44
Ribeye area, sq. in.	12.9	13.0	13.3
Yield grade	2.6	2.7	2.8
Marbling score ¹	619	640	612
Percentage USDA Choice grade	100	92	92
Overall performance (grazing plus finishing)			
Number of days	308	266	266
Gain, lb	749	737	779
Daily gain, lb	2.43a	2.77b	2.93b

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 3. Effects of forage system on grazing and subsequent performance of stocker steers, Southeast Research and Extension Center, 2012

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	144	144	144
Number of head	16	12	12
Initial weight, lb	632	632	632
Ending weight, lb	858a	957b	945b
Gain, lb	226a	325b	313b
Daily gain, lb	1.57a	2.26b	2.17b
Gain/a, lb	226a	325b	313b
Average available forage dry matter, lb/a	5983a	4172b	3904c
Finishing phase			
Number of days	105	105	105
Beginning weight, lb	858a	957b	945b
Ending weight, lb	1355	1409	1431
Gain, lb	497	451	486
Daily gain, lb	4.73	4.30	4.63
Daily dry matter intake, lb	30.7	28.3	29.1
Feed:gain	6.53	6.61	6.28
Hot carcass weight, lb	840	873	887
Backfat, in.	0.44	0.38	0.45
Ribeye area, sq. in.	12.6	12.8	13.3
Yield grade	2.8	2.7	2.8
Marbling score ¹	625	591	603
Percentage USDA Choice grade	100	83	92
Overall performance (grazing plus finishing)			
Number of days	249	249	249
Gain, lb	722	776	799
Daily gain, lb	2.90	3.12	3.21

¹500 = small, 600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 4. Effects of forage system on grazing and subsequent performance of stocker steers, Southeast Research and Extension Center, 2013

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	208	159	159
Number of head	16	12	12
Initial weight, lb	678	678	678
Ending weight, lb	1017a	923b	994a
Gain, lb	338a	244b	316a
Daily gain, lb	1.63ab	1.54a	1.99b
Gain/a, lb	338a	244b	316a
Average available forage dry matter, lb/a	6290a	3590b	2980c
Finishing phase			
Number of days	91	105	105
Beginning weight, lb	1017a	923b	994a
Ending weight, lb	1390	1387	1480
Gain, lb	374a	464b	486b
Daily gain, lb	4.11	4.42	4.63
Daily dry matter intake, lb	27.1	27.7	28.1
Feed:gain	6.64	6.29	6.09
Hot carcass weight, lb	862	860	918
Backfat, in.	0.40	0.38	0.46
Ribeye area, sq. in.	12.7	13.6	13.5
Yield grade	2.6	2.2	2.4
Marbling score ¹	594	599	612
Percentage USDA Choice grade	94	100	92
Overall performance (grazing plus finishing)			
Number of days	299	264	264
Gain, lb	712	708	802
Daily gain, lb	2.38ac	2.68bc	3.04b

¹500 = small, 600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 5. Effects of forage system on grazing and subsequent performance of stocker steers, Southeast Research and Extension Center, 2014

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	196	155	155
Number of head	16	12	12
Initial weight, lb	636	636	636
Ending weight, lb	1006a	918b	1019a
Gain, lb	370a	282b	383a
Daily gain, lb	1.89a	1.82a	2.47b
Gain/a, lb	370a	282b	383a
Average available forage dry matter, lb/a	5733a	3344b	2509c
Finishing phase			
Number of days	106	119	119
Beginning weight, lb	1006a	918b	1019a
Ending weight, lb	1461a	1405a	1548b
Gain, lb	455a	487ab	529b
Daily gain, lb	4.29	4.09	4.45
Daily dry matter intake, lb	28.9	29.0	29.2
Feed:gain	6.80	7.08	6.57
Hot carcass weight, lb	906a	871a	960b
Backfat, in.	0.48a	0.49a	0.61b
Ribeye area, sq. in.	13.3a	12.4b	12.7b
Yield grade	2.6	2.7	3.3
Marbling score ¹	648	639	648
Percentage USDA Choice grade	100	100	100
Overall performance (grazing plus finishing)			
Number of days	302	274	274
Gain, lb	825a	769a	912b
Daily gain, lb	2.73a	2.81a	3.33b

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 6. Effects of forage system on grazing and subsequent performance of stocker steers, Southeast Research and Extension Center, 2015

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	224	168	168
Number of head	16	12	12
Initial weight, lb	644	644	644
Ending weight, lb	934a	982b	1040c
Gain, lb	291a	337b	396c
Daily gain, lb	1.30a	2.01b	2.36c
Gain/a, lb	291a	337b	396c
Average available forage dry matter, lb/a	6911a	3507b	3154c
Finishing phase			
Number of days	97	99	99
Beginning weight, lb	934a	982b	1040c
Ending weight, lb	1359a	1230b	1264b
Gain, lb	425a	248b	224b
Daily gain, lb	4.38a	2.51b	2.26b
Daily dry matter intake, lb	26.9a	25.4a	29.5b
Feed:gain	6.19a	10.29b	13.26c
Hot carcass weight, lb	843a	762b	784b
Backfat, in.	0.44	0.45	0.41
Ribeye area, sq. in.	12.6a	11.1b	11.2b
Yield grade	2.7	2.7	2.7
Marbling score ¹	635	599	597
Percentage USDA Choice grade	94	100	100
Overall performance (grazing plus finishing)			
Number of days	321	267	267
Gain, lb	715a	586b	620b
Daily gain, lb	2.23	2.19	2.32

¹500 = small, 600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 7. Effects of forage system on grazing and subsequent finishing performance of stocker steers, Southeast Research and Extension Center, 2016

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	230	169	169
Number of head	16	12	12
Initial weight, lb	600	600	600
Ending weight, lb	968a	880b	887b
Gain, lb	368a	280b	287b
Daily gain, lb	1.60	1.66	1.70
Gain/a, lb	368a	280b	287b
Average available forage dry matter, lb/a	7613a	4008b	3750c
Finishing phase			
Number of days	98	99	99
Beginning weight, lb	968a	880b	887b
Ending weight, lb	1412a	1322b	1328b
Gain, lb	444	442	441
Daily gain, lb	4.53	4.47	4.46
Daily dry matter intake, lb	28.8	28.7	28.5
Feed:gain	6.38	6.43	6.39
Hot carcass weight, lb	875a	820b	823b
Backfat, in.	0.50	0.53	0.47
Ribeye area, sq. in.	13.2a	12.2b	12.5ab
Yield grade	2.7ab	2.9a	2.6b
Marbling score ¹	645	620	607
Percentage USDA Choice grade	100	100	100
Overall performance (grazing plus finishing)			
Number of days	328	268	268
Gain, lb	812a	723b	728b
Daily gain, lb	2.48a	2.70b	2.72b

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 8. Effects of forage system on grazing and subsequent finishing performance of stocker steers, Southeast Research and Extension Center, 2017

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	231	168	168
Number of head	16	12	12
Initial weight, lb	669	669	669
Ending weight, lb	1080a	981b	1002b
Gain, lb	411a	312b	332b
Daily gain, lb	1.78	1.86	1.98
Gain/a, lb	411a	312b	332b
Average available forage dry matter, lb/a	7183a	5191b	4719c
Finishing phase			
Number of days	91	99	99
Beginning weight, lb	1080a	981b	1002b
Ending weight, lb	1390	1371	1411
Gain, lb	310a	390b	410b
Daily gain, lb	3.41a	3.94ab	4.14b
Daily dry matter intake, lb	29.4	28.3	29.9
Feed:gain	8.65a	7.21b	7.22b
Hot carcass weight, lb	862	850	875
Backfat, in.	0.52	0.46	0.51
Ribeye area, sq. in.	13.4	13.4	13.1
Yield grade	2.6	2.4	2.6
Marbling score ¹	724a	597b	634b
Percentage USDA Choice grade	100	100	92
Overall performance (grazing plus finishing)			
Number of days	322	267	267
Gain, lb	721	702	742
Daily gain, lb	2.24a	2.63b	2.78b

¹500 = small, 600 = modest, 700 = moderate, 800 = slightly abundant.
Means within a row followed by the same letter do not differ ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 9. Effects of forage system on grazing performance of stocker steers, Southeast Research and Extension Center, 2018

Item	Forage system		
	MaxQ fescue	Wheat-bermudagrass	Wheat-crabgrass
Grazing phase			
Number of days	217	161	161
Number of head	16	12	12
Initial weight, lb	655	655	654
Ending weight, lb	1058a	959b	956b
Gain, lb	403a	305b	302b
Daily gain, lb	1.86	1.89	1.87
Gain/a, lb	403a	305b	302b

Means within a row followed by the same letter do not differ ($P < 0.05$).

Evaluation of Supplemental Energy Source for Grazing Stocker Cattle

L.W. Lomas, J.K. Farney, and J.L. Moyer

Summary

A total of 180 steers grazing smooth brome grass pastures were used to evaluate the effects of supplemental energy source on available forage, grazing gains, subsequent finishing gains, and carcass characteristics in 2014, 2015, 2016, 2017, and 2018. Supplementation treatments evaluated were: no supplement, a supplement with starch as the primary source of energy, and a supplement with fat as the primary source of energy. Supplements were formulated to provide the same quantity of protein and energy per head daily. Supplementation with the starch-based or fat-based supplement during the grazing phase resulted in higher ($P < 0.05$) grazing gains than feeding no supplement during all five years. In 2014, 2016, 2017, and 2018, grazing gains of steers supplemented with the starch-based or fat-based supplement were similar ($P > 0.05$). In 2015, steers supplemented with the fat-based supplement had greater ($P < 0.05$) grazing gains than those that received the starch-based supplement. In 2014, supplementation during the grazing phase had no effect ($P > 0.05$) on finishing gain, feed intake, and feed:gain. Steers supplemented with the starch-based supplement had greater ($P < 0.05$) final finishing live weight, and greater ($P < 0.05$) hot carcass weight than those that received no supplement. In 2015, steers fed the fat-based supplement had higher ($P < 0.05$) final finishing live weight, greater ($P < 0.05$) hot carcass weight, and lower ($P < 0.05$) finishing gain than those supplemented with the starch-based supplement or fed no supplement. In 2016, steers fed the starch-based or fat-based supplement had greater ($P < 0.05$) hot carcass weight and higher ($P < 0.05$) marbling scores than those fed no supplement. Supplementation had no effect ($P > 0.05$) on finishing gains. In 2017, steers fed the starch-based supplement had greater ($P < 0.05$) finishing gain and lower ($P < 0.05$) feed:gain than those fed no supplement, and steers that were supplemented while grazing had greater ($P < 0.05$) hot carcass weight than those that received no supplement.

Introduction

Supplementation of grazing cattle is most economically feasible when cattle prices are high relative to the price of grain. Energy supplementation of grazing ruminants may reduce forage intake and digestibility, but energy supplementation at low levels (less than 0.4% bodyweight) has been shown to have little effect on forage intake when crude protein was not limiting. Several studies have evaluated the effect of supplementation on stocker cattle gains and forage utilization during the grazing phase, but few have evaluated the effects of supplementation during the grazing phase on subsequent finishing performance and carcass traits. This research seeks to obtain a more thorough understanding of the interactions among grazing nutrition and management, finishing performance, and carcass traits to facilitate greater economic utilization of these relationships.

Experimental Procedures

Thirty-six steers of predominately Angus breeding were weighed on two consecutive days, stratified by weight, and randomly allotted to nine 5-acre smooth bromegrass pastures on April 9, 2014 (446 lb); April 7, 2015 (488 lb); April 6, 2016 (444 lb); March 21, 2017 (437 lb); and March 27, 2018 (443 lb). Three pastures of steers were randomly assigned to one of three supplementation treatments (3 replicates per treatment) and were grazed for 181, 224, 223, 238, and 224 days in 2014, 2015, 2016, 2017, and 2018, respectively. Supplementation treatments in 2014 and 2015 were: no supplement, 4.25 lb per head daily of a starch-based supplement, or 4.5 lb per head daily of a fat-based supplement. In 2016, 2017, and 2018, the starch-based supplement and fat-based supplement were both fed at 4.25 lb per head daily. Supplements were formulated to provide the same amount of protein (0.7 lb in 2014 and 2015 and 0.4 lb in 2016, 2017, and 2018) and energy (3.3 lb of TDN in 2014 and 2015 and 3.4 lb of TDN in 2016, 2017, and 2018) per head daily. Pastures were fertilized with 100 lb/a of nitrogen (N) on February 24, 2014; February 12, 2015; February 11, 2016; February 10, 2017; and February 13, 2018. Pastures were stocked with 0.8 steers/a and grazed continuously until October 7, 2014 (181 days); November 10, 2015 (224 days); November 15, 2016 (223 days); November 14, 2017 (238 days); and November 6, 2018 (224 days) when steers were weighed on two consecutive days and grazing was ended.

Cattle in each pasture were group-fed supplement in meal form on a daily basis in bunks, and pasture was the experimental unit. No implants or feed additives were used during the grazing phase. Weight gain was the primary measurement. Cattle were weighed every 28 days. Cattle were treated for internal and external parasites before being turned out to pasture and later were vaccinated for protection from pinkeye. Cattle had free access to commercial mineral blocks that contained 12% calcium, 12% phosphorus, and 12% salt. Forage availability was measured approximately every 28 days in 2014, 2015, 2016, and 2017 with a disk meter calibrated for smooth bromegrass.

After the grazing period, cattle were shipped to a finishing facility, implanted with Synovex S, and fed a diet of 80% whole-shelled corn, 15% corn silage, and 5% supplement (dry matter basis) for 125, 97, 98, and 91 days in 2014, 2015, 2016, and 2017 respectively. All cattle were slaughtered in a commercial facility at the end of the finishing period, and carcass data were collected. Cattle that grazed these pastures in 2018 were being finished for slaughter at the time that this report was written.

Results and Discussion

Average available forage for the smooth bromegrass pastures during the grazing phase, and grazing and subsequent finishing performance of grazing steers are presented by supplementation treatment for 2014, 2015, 2016, and 2017 in Tables 1, 2, 3, and 4, respectively. Grazing performance only is presented for 2018 in Table 5. Supplementation treatment had no effect ($P > 0.05$) on the quantity of forage available for grazing in any year. Pastures grazed by supplemented steers might be expected to have greater available forage dry matter as consumption of supplement by steers grazing these pastures would likely reduce forage intake thereby resulting in more residual forage. However, the levels of supplement fed in this study were likely small enough that they did not affect forage consumption.

Supplemented steers had greater ($P < 0.05$) weight gain, daily gain, and steer gain/a than those that received no supplement in all five years. In 2014, 2016, 2017, and 2018, grazing weight gain, daily gain, and gain/a were not different ($P > 0.05$) between steers that were supplemented with the starch-based or fat-based supplement. In 2014, steers fed the starch-based supplement had greater ($P < 0.05$) final finishing live weight, greater ($P < 0.05$) hot carcass weight, greater ($P < 0.05$) overall (grazing + finishing) gain, and greater ($P < 0.05$) overall daily gain than those that received no supplement. Supplementation during the grazing phase had no effect ($P > 0.05$) on finishing weight gain, feed intake, feed:gain, backfat, ribeye area, yield grade, or marbling score.

In 2015, steers supplemented with the fat-based supplement had greater ($P < 0.05$) grazing gains than those that received the starch-based supplement. Steers supplemented with the fat-based supplement had higher ($P < 0.05$) slaughter weight, higher hot ($P < 0.05$) carcass weight, and lower ($P < 0.05$) finishing gain than those fed no supplement or supplemented with the starch-based supplement.

In 2016, steers that were supplemented during the grazing phase maintained their weight advantage from grazing and were heavier ($P < 0.05$) at the end of the finishing phase, and had greater ($P < 0.05$) hot carcass weight than those that received no supplement. Final finishing weight and hot carcass weight were similar ($P > 0.05$) for steers supplemented with starch or fat during the grazing phase. Dry matter intake was lower ($P < 0.05$) for steers that received no supplement while grazing than for those supplemented with fat which may be due at least in part to the unsupplemented steers being lighter weight. Supplementation treatment during the grazing phase had no effect ($P > 0.05$) on backfat thickness, ribeye area, or percentage grading USDA Choice. Steers supplemented with starch during the grazing phase had lower ($P < 0.05$) numerical yield grades than those supplemented with fat. Steers supplemented with starch or fat during the grazing phase had higher ($P < 0.05$) marbling scores and greater ($P < 0.05$) overall gains than those that received no supplement. Marbling scores and overall gains were similar ($P > 0.05$) between those supplemented with starch or fat.

In 2017, steers that were supplemented during the grazing phase maintained their weight advantage from grazing and were heavier ($P < 0.05$) at the end of the finishing phase, and had greater ($P < 0.05$) hot carcass weight than those that received no supplement. Steers fed the starch-based supplement had greater ($P < 0.05$) finishing gain and lower ($P < 0.05$) feed:gain than those fed no supplement. Final finishing weight, hot carcass weight, and overall gain were similar ($P > 0.05$) for steers supplemented with starch or fat during the grazing phase. Supplementation treatment during the grazing phase had no effect ($P > 0.05$) on backfat thickness, ribeye area, yield grade, marbling score, or percentage grading USDA Choice. Steers that were supplemented during the grazing phase had greater ($P < 0.05$) overall gains than those that received no supplement.

Under the conditions of this study, supplementation of stocker cattle grazing smooth bromegrass pasture improved grazing performance and increased slaughter weight and carcass weight. Most of the increase in slaughter weight and carcass weight can be attributed to greater gains of supplemented cattle during the grazing phase. Supplemental energy source while grazing had little effect on carcass quality.

BEEF CATTLE RESEARCH

Table 1. Effect of supplemental energy source on grazing and subsequent finishing performance of steers grazing smooth brome grass pastures, Southeast Research and Extension Center, 2014

Item	Supplemental energy source		
	None	Starch	Fat
Grazing phase (181 days)			
Number of head	12	12	12
Initial weight, lb	446	446	446
Final weight, lb	706a	817b	810b
Gain, lb	260a	371b	364b
Daily gain, lb	1.43a	2.05b	2.01b
Gain/a, lb	208a	296b	291b
Supplement consumption, lb/head per day	0	4.25	4.5
Supplement, lb/additional gain, lb	---	6.9	7.8
Average available forage dry matter, lb/a	7,140	7,128	6,985
Finishing phase (125 days)			
Beginning weight, lb	706a	817b	810b
Ending weight, lb	1241a	1338b	1307ab
Gain, lb	535	522	497
Daily gain, lb	4.28	4.17	3.98
Daily dry matter intake, lb	26.1	27.0	24.7
Feed:gain	6.11	6.49	6.20
Hot carcass weight, lb	769a	830b	810ab
Backfat, in.	0.45	0.50	0.47
Ribeye area, sq. in.	11.2	12.1	12.1
Yield grade	2.8	3.0	2.8
Marbling score ¹	630	648	650
Percentage USDA grade choice	100	100	100
Overall performance (grazing plus finishing; 306 days)			
Gain, lb	795a	892b	861ab
Daily gain, lb	2.60a	2.92b	2.81ab

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter are not significantly different ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 2. Effect of supplemental energy source on grazing and subsequent finishing performance of steers grazing smooth brome grass pastures, Southeast Research and Extension Center, 2015

Item	Supplemental energy source		
	None	Starch	Fat
Grazing phase (224 days)			
Number of head	12	12	12
Initial weight, lb	489	488	488
Final weight, lb	753a	833b	886c
Gain, lb	264a	345b	398c
Daily gain, lb	1.18a	1.54b	1.78c
Gain/a, lb	211a	276b	318c
Supplement consumption, lb/head per day	0	4.25	4.5
Supplement, lb/additional gain, lb	---	11.8	7.5
Average available forage dry matter, lb/a	6,601	6,644	6,484
Finishing phase (97 days)			
Beginning weight, lb	753a	833b	886c
Ending weight, lb	1169a	1208a	1307b
Gain, lb	417a	374b	420a
Daily gain, lb	4.30a	3.86b	4.33a
Daily dry matter intake, lb	26.2	26.0	26.3
Feed:gain	6.09	6.74	6.08
Hot carcass weight, lb	725a	749a	810b
Backfat, in.	0.42	0.46	0.49
Ribeye area, sq. in.	11.7	11.7	12.2
Yield grade	2.3	2.8	2.8
Marbling score ¹	639	631	639
Percentage USDA grade choice	100	100	100
Overall performance (grazing plus finishing; 321 days)			
Gain, lb	681a	719a	818b
Daily gain, lb	2.12a	2.24a	2.55b

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter are not significantly different ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 3. Effect of supplemental energy source on grazing and subsequent finishing performance of steers grazing smooth brome grass pastures, Southeast Research and Extension Center, 2016

Item	Supplemental energy source		
	None	Starch	Fat
Grazing phase (223 days)			
Number of head	12	12	12
Initial weight, lb	445	444	444
Final weight, lb	754a	871b	856b
Gain, lb	309a	426b	412b
Daily gain, lb	1.39a	1.91b	1.85b
Gain/a, lb	247a	341b	329b
Supplement consumption, lb/head per day	0	4.25	4.25
Supplement, lb/additional gain, lb	---	8.2	9.2
Average available forage dry matter, lb/a	7,403	7,402	7,309
Finishing phase (98 days)			
Beginning weight, lb	754a	871b	856b
Ending weight, lb	1167a	1274b	1280b
Gain, lb	412	403	424
Daily gain, lb	4.21	4.11	4.33
Daily dry matter intake, lb	26.7a	27.7ab	28.5b
Feed:gain	6.36	6.75	6.58
Hot carcass weight, lb	723a	790b	794b
Backfat, in.	0.43	0.44	0.45
Ribeye area, sq. in.	11.9	12.4	12.1
Yield grade	2.4ab	2.3a	2.8b
Marbling score ¹	632a	684b	710b
Percentage USDA grade choice	100	100	100
Overall performance (grazing plus finishing; 321 days)			
Gain, lb	722a	829a	836b
Daily gain, lb	2.25a	2.58b	2.60b

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter are not significantly different ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 4. Effect of supplemental energy source on grazing and subsequent finishing performance of steers grazing smooth brome grass pastures, Southeast Research and Extension Center, 2017

Item	Supplemental energy source		
	None	Starch	Fat
Grazing phase (238 days)			
Number of head	12	12	12
Initial weight, lb	431	437	443
Final weight, lb	807a	912b	942b
Gain, lb	376a	475b	499b
Daily gain, lb	1.58a	2.00b	2.10b
Gain/a, lb	301a	380b	399b
Supplement consumption, lb/head per day	0	4.25	4.25
Supplement, lb/additional gain, lb	---	10.1	8.2
Average available forage dry matter, lb/a	6,371	6,369	6,293
Finishing phase (91 days)			
Beginning weight, lb	807a	912b	842b
Ending weight, lb	1104a	1304b	1301b
Gain, lb	297a	392b	359ab
Daily gain, lb	3.26a	4.31b	3.95ab
Daily dry matter intake, lb	26.4	28.0	27.0
Feed:gain	8.26a	6.49b	6.87ab
Hot carcass weight, lb	662a	783b	780b
Backfat, in.	0.39	0.45	0.50
Ribeye area, sq. in.	11.6	12.8	12.4
Yield grade	2.4	2.4	2.8
Marbling score ¹	650	646	692
Percentage USDA grade choice	92	92	100
Overall performance (grazing plus finishing; 329 days)			
Gain, lb	673a	868b	858b
Daily gain, lb	2.04a	2.64b	2.61b

¹600 = modest, 700 = moderate.

Means within a row followed by the same letter are not significantly different ($P < 0.05$).

BEEF CATTLE RESEARCH

Table 5. Effect of supplemental energy source on grazing performance of steers grazing smooth brome grass pastures, Southeast Research and Extension Center, 2018

Item	Supplemental energy source		
	None	Starch	Fat
Grazing phase (224 days)			
Number of head	12	12	12
Initial weight, lb	443	443	443
Final weight, lb	742a	864b	880b
Gain, lb	299a	421b	437b
Daily gain, lb	1.33a	1.88b	1.95b
Gain/a, lb	239a	336b	350b
Supplement consumption, lb/head per day	0	4.25	4.25
Supplement, lb/additional gain, lb	---	7.7	6.9

Means within a row followed by the same letter are not significantly different ($P < 0.05$).

Effects of Supplementation with Corn or Dried Distillers Grains on Gains of Heifer Calves Grazing Smooth Bromegrass Pastures

L.W. Lomas and J.L. Moyer

Summary

A total of 150 heifer calves grazing smooth bromegrass pastures were used to compare supplementation with 0.5% of body weight per head daily of corn or dried distillers grains (DDG) in 2014, 2015, 2016, 2017, and 2018. Daily gains of heifers supplemented with corn or DDG were similar ($P > 0.05$) in all years except 2018, when heifers supplemented with DDG had greater ($P < 0.05$) gains than those supplemented with corn.

Introduction

Distillers grains, a by-product of the ethanol industry, have tremendous potential as an economical and nutritious supplement for grazing cattle. Distillers grains contain a high concentration of protein (25 to 30%), with more than two-thirds escaping degradation in the rumen, which makes it an excellent supplement for younger cattle. Recent advancements in the ethanol manufacturing process have resulted in extraction of a greater amount of fat; therefore, creating distillers grains that may contain less energy than corn. This research was conducted to compare performance of stocker cattle supplemented with corn or DDG at 0.5% body weight per head daily while grazing smooth bromegrass pastures.

Experimental Procedures

Thirty heifer calves were weighed on two consecutive days, stratified by weight, and randomly allotted to six 5-acre smooth bromegrass pastures on April 8, 2014 (423 lb), April 7, 2015 (438 lb), April 6, 2016 (408 lb), March 17, 2017 (416 lb), and March 20, 2018 (394 lb). Three pastures of heifers were randomly assigned to one of two supplementation treatments (three replicates per treatment) and grazed for 142, 182, 197, 173, and 177 days in 2014, 2015, 2016, 2017, and 2018, respectively. Supplementation treatments were ground corn or DDG at 0.5% body weight per head daily. The DDG used in this study contained 25% protein and 6% fat. Corn was estimated to contain 10% protein and a similar level of energy as DDG. Pastures were fertilized with 100 lb/a nitrogen and P_2O_5 and K_2O as required by soil test on February 21, 2014, March 11, 2015, February 17, 2016, February 14, 2017, and February 13, 2018. Pastures were stocked with 1 heifer/a and grazed continuously until August 28, 2014, October 6, 2015, October 20, 2016, September 6, 2017, and September 13, 2018, when heifers were weighed on two consecutive days and grazing was terminated.

Cattle in each pasture were group-fed ground corn or DDG in meal form in bunks on a daily basis, and pasture was the experimental unit. No implants or feed additives were used. Weight gain was the primary measurement. Cattle were weighed every 28 days; quantity of supplement fed was adjusted at that time. Cattle were treated for

internal and external parasites before being turned out to pasture and later vaccinated for protection from pinkeye. Heifers had free access to commercial mineral blocks that contained 12% calcium, 12% phosphorus, and 12% salt.

Results and Discussion

Cattle gains and supplement intake are presented in Tables 1, 2, 3, 4, and 5, for 2014, 2015, 2016, 2017, and 2018, respectively. Grazing gains and supplement intake were 2.00 and 2.8 lb/head daily and 2.10 and 2.9 lb/head daily, 1.69 and 3.0 lb/head daily and 1.61 and 3.0 lb/head daily, 1.65 and 2.8 lb/head daily and 1.64 and 2.9 lb/head daily, 1.71 and 2.8 lb/head daily and 1.87 and 2.9 lb/head daily, and 1.49 and 2.7 lb/head daily and 1.67 and 2.7 lb/head daily for heifers supplemented with corn and DDG in 2014, 2015, 2016, 2017, and 2018, respectively. Gains and supplement intake of heifers supplemented with corn were similar ($P > 0.05$) to those of heifers that were supplemented with DDG in 2014, 2015, 2016, and 2017 which would suggest that protein was not limiting performance of heifers grazing these pastures, as heifers fed corn received a similar amount of supplemental energy but less supplemental protein than those fed DDG. However, in 2018, heifers supplemented with DDG had greater ($P < 0.05$) gains and resulted in more ($P < 0.05$) gain per acre than those supplemented with corn.

Table 1. Effects of supplementation with corn or dried distillers grains (DDG) on gains of heifer calves grazing smooth brome grass pastures, Southeast Research and Extension Center, 2014

Item	Supplement	
	Corn	DDG
Number of days	142	142
Number of head	15	15
Initial weight, lb	423	423
Final weight, lb	706	720
Gain, lb	284	298
Daily gain, lb	2.00	2.10
Gain/a, lb	284	298
Total supplement consumption, lb/head	397	409
Average supplement consumption, lb/head per day	2.8	2.9

BEEF CATTLE RESEARCH

Table 2. Effects of supplementation with corn or dried distillers grains (DDG) on gains of heifer calves grazing smooth bromegrass pastures, Southeast Research and Extension Center, 2015

Item	Supplement	
	Corn	DDG
Number of days	182	182
Number of head	15	15
Initial weight, lb	438	438
Final weight, lb	746	731
Gain, lb	308	293
Daily gain, lb	1.69	1.61
Gain/a, lb	308	293
Total supplement consumption, lb/head	539	537
Average supplement consumption, lb/head per day	3.0	3.0

Table 3. Effects of supplementation with corn or dried distillers grains (DDG) on gains of heifer calves grazing smooth bromegrass pastures, Southeast Research and Extension Center, 2016

Item	Supplement	
	Corn	DDG
Number of days	197	197
Number of head	15	15
Initial weight, lb	408	408
Final weight, lb	733	731
Gain, lb	324	323
Daily gain, lb	1.65	1.64
Gain/a, lb	324	323
Total supplement consumption, lb/head	558	562
Average supplement consumption, lb/head per day	2.8	2.9

BEEF CATTLE RESEARCH

Table 4. Effects of supplementation with corn or dried distillers grains (DDG) on gains of heifer calves grazing smooth bromegrass pastures, Southeast Research and Extension Center, 2017

Item	Supplement	
	Corn	DDG
Number of days	173	173
Number of head	15	15
Initial weight, lb	416	416
Final weight, lb	712	739
Gain, lb	295	323
Daily gain, lb	1.71	1.87
Gain/a, lb	295	323
Total supplement consumption, lb/head	493	497
Average supplement consumption, lb/head per day	2.8	2.9

Table 5. Effects of supplementation with corn or dried distillers grains (DDG) on gains of heifer calves grazing smooth bromegrass pastures, Southeast Research and Extension Center, 2018

Item	Supplement	
	Corn	DDG
Number of days	177	177
Number of head	15	15
Initial weight, lb	394	394
Final weight, lb	658a	688b
Gain, lb	264a	295b
Daily gain, lb	1.49a	1.67b
Gain/a, lb	264a	295b
Total supplement consumption, lb/head	480	486
Average supplement consumption, lb/head per day	2.7	2.7

Cattle Preference for Annual Forages

J.K. Farney

Summary

Many plant species that are available to use as cover crops also have potential as forage for cattle. With this array of options it can be daunting to decide which plants to establish to meet goals as either a cover crop, forage, or for both. Therefore, the purpose of this study was to identify the annual forages fed to cattle in the fall, winter, or summer that cattle preferred. To summarize, grasses were the most highly preferred forage for cattle regardless of grazing period. Low glucosinolate brassicas such as 'Graza' forage radish was the most highly preferred brassica that was offered. Selection by cattle of legume and broadleaf plant species was variable, and was primarily driven by other less-preferred plants that were offered.

Introduction

Integration of cattle grazing in cropping systems has been promoted as a management practice in certain areas of the country, including the southern Great Plains, western Corn Belt, and middle Plains states. However, adoption of these practices is still somewhat controversial, especially for producers who do not own cattle. Previous methods of integration include cattle grazing corn or sorghum residues or dual-purpose wheat. Cattle can graze wheat during its early growing period, and then the wheat grain is harvested at maturity. More producers have started to implement grazing of annual forages.

Land usage within the United States has been changing. Based on the most recent report from the USDA Economic Research Service (2011), of the nearly 2.3 billion acres of land in the US, 30% is forest-use land, 27% is grassland and range, 18% is used as cropland, 3% as urban land, and 23% for special usage and miscellaneous. Those numbers do not necessarily address the changes that are being seen with land usage. Urban land use, even though a small fraction of total land, has quadrupled from 1945 to 2007 and forest-use land has increased by 20 million acres from 2002 to 2007. The increases in urban and forest land usage has shown a trend for decreased land usage for crops and grasses. Overall, total land used for crops in the United States has not changed; however, regionally there have been large shifts in land usage. For example, nearly 12 million acres in the Corn Belt and northern Plains have been converted to cropland, while in other regions nearly 12 million acres have been removed from the cropland category. The human population is expanding, yet land mass is not, indicating a need to utilize a greater portion of the land to produce calories for human consumption. Integration of cattle in cropping systems is one method to accomplish the mission of producing more calories per acre, while also enhancing economic revenue to an operation in an implementable management practice.

There are two broad categories of cover crops: monocultures and multi-species cover crops. A monoculture is a single species of plant that is planted for a specific purpose. Multi-species cover crops include a diverse population of plants that have been selected to match producer's objectives. Even though limited data support enhanced cattle

performance with multi-species in annual forages that can function as a cover crop, because of theories of improved ecological systems from a soil perspective, producers are planting multi-species cover crops and grazing. Understanding the order and cattle selectivity to these cover crops can help producers make strategic decisions on what plant species to use in integrated systems. Therefore the purpose of this study is to determine cattle preference for fall, winter, and summer cover crops.

Experimental Procedures

Fall Annual Forages

On September 2, 2017, repurposed protein tubs (~452 in.² surface area) were filled with soil and planted with eight different cool season annual forages. The plant species evaluated consisted of Austrian winter pea, ‘Graza’ forage radish, mustard, winter barley, ‘Bayou’ kale, ‘Trophy’ rapeseed, ‘Impact’ collard, and purple top turnip. On October 11 three ruminally cannulated heifers were individually penned and allowed access to the 8 tubs for 24 hours. Heifers were observed during the first 30 minutes of exposure to the tubs by three staff members of the Southeast Research and Extension Center. These observers recorded behavior such as “sniffing plants and walking away” and “tasting (biting) and walking away”. Additionally, each pen had a trail camera that was set to capture video for 60 seconds with a 1 second lapse before recording again. This allowed for nearly a full 24 hours of observation for each heifer. These videos were then watched to determine the order that the plants were consumed. These were ranked as first, second, third, and so on, and then were used to determine cattle selectivity to plants. This was repeated again on October 12.

Summer Annual Forage

The same procedures were completed for the summer annual forages as that described for the fall annual forages. The date of planting was May 17, 2018, in the same repurposed protein tubs. During the summer study, the plants of interest included 3 grass species, 2 legume species, and 3 broadleaf species. The grass species were pearl millet, brown midrib (BMR) forage sorghum, and sorghum-sudan. The legume species were sunn hemp and mung bean. The broadleaf species were okra and black-oil sunflower. The grasses were allowed to grow to a minimum height of 2 feet before the preference test was initiated to minimize prussic acid issues. Therefore, on June 21 and 22, 2018, four ruminally cannulated Holstein heifers were placed on test for preference as previously described.

Winter Annual Forages

The same methods were used for the winter annual forage study, and several of the fall forages were used in this portion of the study. The difference is that we waited to start the preference study until three weeks after a killing freeze to see if brassica preferences were altered as compared to grazing prior to a freeze. The plant species used in the winter study included 2 grass species, 2 legume species, and 3 brassica species. The grass species were winter barley and winter oat; the legumes were Austrian winter pea and common vetch; and the brassicas were ‘Graza’ forage radish, ‘Trophy’ rapeseed, and purple top turnip. These were planted in the repurposed protein tubs on August 20, 2018, and were used in the preference study November 27 and 28, 2018.

Results and Discussion

Fall Annual Forages

Barley was the most highly preferred fall annual forage of the eight offered. There was a tie for the second favorite of this group: Austrian winter pea and 'Graza' forage radish. The heifers showed strong aversion to all the other brassicas offered: mustard, collard, turnip, rapeseed, and kale (Table 1). There did not seem to be much of a difference between these brassicas, with the exception of kale. Two of the three heifers refused to eat the kale on both days. These results were expected, except for the forage radish which was more highly preferred than anticipated. Brassicas in general are unpalatable because of nitrates and glucosinolates. Both of these compounds are fairly bitter, which is the predominant adverse flavor for cattle. Interestingly, the 'Graza' forage radish has been reported to have a fairly low level of glucosinolate, which led to its preference more than all the other brassicas. Even though the cattle preferred this more than the other brassica species, this plant had the greatest number of "bites and moving on" of any of the plants. Based on the method of determining preference, these cows consumed forage radish as second favorite, "one bite at a time." Interestingly, the spring forage pea was one of the top two that had the greatest number of "sniffs and move" indicating something was not desirable in that plant, but once the heifers took a bite of the Austrian winter pea, they stayed at the tub and consumed all the plants growing. This indicates that it is a palatable plant but cattle need to "learn" how to eat this legume.

Summer Annual Forages

Once again in the summer covers, the grass species were the most preferentially selected (Table 2). Even within the grass species, BMR forage sorghum and sorghum-sudan were preferentially selected more than pearl millet. The intermediate selected species consisted of sunflower and sunn hemp. The plants that were not preferred were okra, mung bean, and safflower. Of the broadleaves, sunflower was more preferentially selected as compared to okra and safflower. This could primarily be driven by the fact that the sunflower seeds did not do well in the protein tubs and were nearly 2 weeks younger in maturity than the other broadleaf species. Of the legumes, sunn hemp was more preferentially selected as compared to mung bean.

When trying to understand why pearl millet was less preferred than the other grasses, the first thought was nitrates were higher in pearl millet, as that is typically seen. However, in these samples nitrates were the lowest in pearl millet. When handling the pearl millet, the underside of the leaf was "hairy" in texture, which might have led to an unfavorable eating experience for the heifers. For this study, since okra and mung bean were not preferred, even though their nutritional composition indicates they should be a quality feed, one possible reason for adverse selection could be associated with plant morphology. Both of these plants have very large broad leaves. The sunn hemp used in this study was fairly immature which might have led to its preference.

Winter Annual Forages

Grass species were the most preferentially selected with no difference in oat or barley. The intermediate selected plants were 'Graza' forage radish, common vetch, and Austrian winter pea. The other two brassicas, rapeseed and purple top turnip, were not preferred (Table 3). Even after a hard killing freeze, the level of glucosinolate must have been high enough that it led to aversion to rapeseed and turnip, especially as compared

to forage radish. The legumes are reported to not have glucosinolates and the heifers did select them more than the high glucosinolate brassicas. Common vetch was selected as a possible option because other vetch species, such as hairy vetch and crown vetch, have been shown to grow well in Kansas but have toxicity issues for livestock species, cattle in particular.

Acknowledgments

This work is/was supported by the USDA National Institute of Food and Agriculture, Hatch project 1005401. Used protein tubs were donated by M-M Herefords. Seed was donated by Natural Ag Solutions, LLC. We also appreciate the work of Talana Erickson, Adam Harris, and Lonnie Mengerelli for care of the heifers, filling tubs with soil, and being the observers for the first 30 minutes of the study.

Table 1. Fall annual forages preference

Plant	Score ¹
Winter barley	6
Austrian winter pea	17
'Graza' forage radish	17
Mustard	34
'Impact' collard	35
Purple top turnip	37
'Trophy' rapeseed	39
'Bayou' kale	43

¹Numerical score: the lower number means more preferentially selected.

Table 2. Summer annual forage preference

Plant	Score ¹
'Silo Pro' brown midrib forage sorghum	13
'Sorgrow 80' sorghum-sudan	15
Pearl millet	25
Black oil sunflower	37
Sunn hemp	41
Okra	51
Mung bean	52
Safflower	55

¹Numerical score: the lower number means more preferentially selected.

Table 3. Winter annual forage preference

Plant	Score ¹
Winter oat	12
Winter barley	16
'Graza' forage radish	25
Common vetch	27
Austrian winter pea	29
'Trophy' rapeseed	36
Purple top turnip	44

¹Numerical score: the lower number means more preferentially selected.



Figure 1. One of the heifers during the fall preference study consuming forages in a repurposed protein tub.

Evaluating Single and Multi-Species Summer Cover Crops for Biomass Yield

J.K. Farney and G.F. Sassenrath

Summary

Cover crops have multiple benefits to integrated agricultural production systems. However, information is needed on best species and mixes to use. In this one-year study, the single species grass cover crops produced the most biomass. Spring forage peas did not perform well as a summer cover crop, yielding the same biomass as the fallow areas. Adding collards to the mixtures generally reduced total biomass production compared to single species of grasses alone. Total biomass production was affected by the number of plants in the mixture. Yields of grass-only plots were ~868 lb of dry matter (DM) per acre more than cover crop mixtures composed of two or three plant species. Plots with cover crop mixes yielded on average 1,348 lb DM/acre more than single species plots with legumes or collards. Grasses composed the greatest proportion of the total biomass (> 77% of total DM biomass was from grass species in mixtures).

Introduction

Maintaining productivity, improving quality, and providing an economic return are persistent challenges to agricultural production systems. Conservation agriculture and sustainable agriculture are ideologies and management practices in modern agriculture that are being highlighted as important by both producer and consumer groups. Sustainable agriculture has become increasingly important for agricultural commodity groups. Consumers, especially in developed countries, actively apply pressure to agricultural producers to confirm that they manage resources (land, livestock, water, etc.) to promote future commodity production and to minimize environmental contamination. Many agricultural producers rely on sustainable management practices. These practices are suitable for continued use, maintain and/or improve current natural resources, and are financially efficient.

Agricultural production systems in the United States are dictated by the productive capacity of the soil. Fields with better soils are used for crop production, while fields with poor soil quality (limited topsoil depth, rocky, or “worn out”) are commonly used for pasture. Most farming operations in central Great Plains include both crop and animal production to diversify the operation, capture return on investment in highly dynamic markets, and capitalize on the highly variable soil conditions. One method of conservation agriculture includes cover cropping. Cover crops offer multiple benefits to producers, including long-term improvements in soil quality, improved soil structure and water holding capacity, and reduced erosion. The quickest method to recover the cost associated with planting cover crops is to utilize the cover as a forage for livestock. Moreover, integrating livestock into crop production through grazing further diversifies the cropping system and can provide important improvements to the soil health, including additional nutrients.

There is an extensive list of cover crop plants available for producers. Understanding the purpose of the plant and the objective of the cover crop can help producers make decisions about plant selection. For many of the cover crops, maximizing biomass production provides the greatest benefits as a cover crop and for cattle grazing. Previous research has reported conflicting results about biomass production in multiple species mixtures versus single species. The objective of this study is to determine biomass production of summer cover crops based on the number and type of cover crops in the planting mixture.

Experimental Procedures

Sixteen cover crop treatments were planted on June 6, 2018, in 10- × 40-ft. replicated plots at the Southeast Research and Extension Center (SEREC) research station near Columbus, KS (Table 1). Treatments consisted of single species cover crops of brown midrib (BMR) sorghum, forage sorghum, pearl millet, sunn hemp, spring forage pea, and collards. The two-species mixtures consisted of each of the grass species with spring pea and each of the grass species with collards. The three-species mixtures included one of the grasses plus spring pea and collards. The cover crops were chosen for the safety and palatability for cattle grazing, as well as their potential contributions to soil health.

Total plant biomass from one 3- × 3-ft. area of each plot was clipped to a 2-inch stubble height using a sickle bar mower on July 17, 2018. The clipped biomass was immediately weighed for total wet biomass, then the samples were taken to the SEREC and separated by plant type. Each plant type (including weeds) was weighed separately and then completely dried to determine dry matter biomass of each species.

Results and Discussion

Total Biomass Production

Total biomass was different for each of the cover crops planted. Pearl millet, BMR sorghum, and forage sorghum yielded the most biomass, with mixtures of these grasses yielding intermediate levels. The lowest biomass was measured in the spring forage pea and fallow treatments (Figure 1). Grass was the predominant component of the biomass in the mixtures that included grasses. Overall, weeds were fairly low in the treatment mixtures (ranging from 1% to 23% of the mixtures), except for spring peas which contained 77% weed biomass. A lower weed amount in the cover crop mixture indicates a high biomass that out-competed the weed population at the sampling time.

To further illustrate the differences observed in biomass production based on the number of plant species in the mixture, we found that single grass species yielded the most biomass. This was followed by two- and three-species mixtures, which produced more biomass than the single species of legumes and collards (Figure 2). This is not an uncommon result as many other researchers have found that grass species yield the most biomass, with mixtures of grasses and non-grass species producing intermediate amounts of biomass, and legumes producing the least biomass. This is illustrated in Figure 3 where single species of grasses had the highest biomass and the collard (broad-leaf) and legumes were substantially lower in production. When adding the lower-producing species such as broadleaves and legumes to grass cover crop mixtures, the total grass biomass production is reduced, indicating a competitive effect of the other cover crop species.

Production Difference Between Two-Species and Three-Species Cover Crop Mixtures

The two-species mixtures showed no difference in biomass production when either pearl millet or BMR sorghum was the grass, regardless of whether a pea or collard was included. For the forage sorghum mixtures there was greater biomass with the spring pea in the mixture as compared to the collard (Figure 4).

In the three-species mixtures, there was no difference in biomass production regardless of grass type included (Figure 5). In this comparison all mixtures had spring forage pea and collards, the only difference was the type of grass.

Based on one year of data, if biomass is the driver for forage production and as the function for cover crop benefits, a single species cover crop of grass yields the greatest biomass production. We observed no difference in biomass production between the three grasses used: BMR sorghum, forage sorghum, or pearl millet. Spring forage pea was not a viable option for a summer cover crop. Single mixtures of sunn hemp and collards yielded similar total biomass, but had some of the lowest biomass production between all treatments. The plant species selected for this study were chosen as they have been promoted as high-quality grazing forages. Quantity and quality are the measurements needed to identify whether the forage is a wise choice for cattle feed. The quality components of these mixtures have not been analyzed at the time of the publication, but based on knowledge of previous research, the grasses utilized offer a quality feed for cattle. For the legumes, sunn hemp can be a good feed for cattle at specific times. To our knowledge, little information is available about spring forage peas in this area as a cattle feed. Collards have primarily been used in winter feeding mixtures and are a high protein, high energy feedstuff. To further determine if the species discussed in this publication are a feed that cattle will consume (Farney, 2019).

Acknowledgments

This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478, with partial funding from the Kansas Conservation Innovation Grant. We also appreciate the work of Lonnie Mengarelli and Dekon Stickland.

Reference

Farney, J.K. (2019) "Cattle Preference for Annual Forages," Kansas Agricultural Experiment Station Research Reports: Vol. 5: Iss. 2.

Table 1. Cover crop mixtures and seeding rates

Mixture	Grass, lb/a	Collard, lb/a	Legume, lb/a
BMR sorghum	20		
BRM sorghum + spring pea	10		25
BMR sorghum + collard	10	4	
BMR sorghum + spring pea + collard	7	2.7	17
Collard	8		
Forage sorghum	20		
Forage sorghum + spring pea	10		25
Forage sorghum + collard	10	4	
Forage sorghum + spring pea + collard	7	2.7	17
Pearl millet	20		
Pearl millet + spring pea	10		25
Pearl millet + collard	10	4	
Pearl millet + spring pea + collard	7	2.7	17
Spring forage pea	50		
Sunn hemp	15		

Variety names:

Brown midrib (BMR) sorghum: 400 brown mid-rib forage sorghum

Collard: Impact forage

Forage sorghum: Sorgrow 80

Pearl millet: pearl millet

Spring forage pea: 4010

Sunn hemp: sunn hemp

BEEF CATTLE RESEARCH

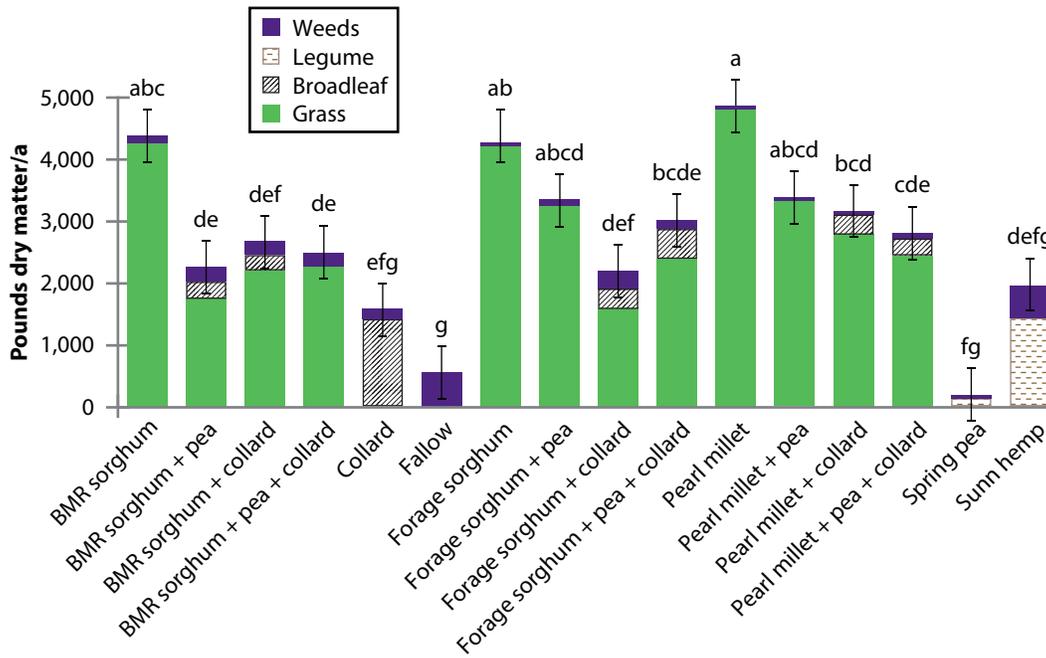


Figure 1. Total biomass production of each summer cover crop mixture including biomass of each component of the mixtures.

^{abcdefg}Different superscripts indicate differences in treatment at $P < 0.05$. Values are averages with standard error bars.

The grass component of the biomass production is represented by solid green and includes brown midrib (BMR) sorghum, forage sorghum, or pearl millet.

The broadleaf component of the biomass production is represented by black diagonal lines with check over-pattern lines and is the collard plant.

The legume component of biomass production is represented by white with purple dashes and is either spring forage pea or sunn hemp.

The biomass of the weeds in the mixtures is represented by the solid purple portion of the column.

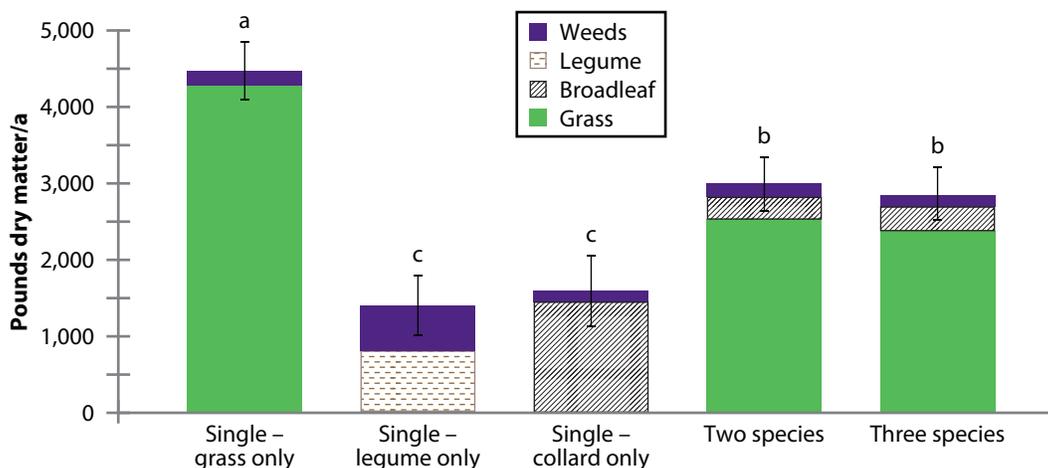


Figure 2. Biomass production based on the number of plant species in the cover crop mixture as well as the biomass type.

^{abc}Different superscripts indicate differences in treatment at $P < 0.05$. Values are averages with standard error bars.

Single – grass only is the average production from the brown midrib (BMR) sorghum, forage sorghum, and pearl millet treatment.

Single – legume only is the average of the sunn hemp and spring forage pea treatments.

Two-species are the averages of each grass type that was planted with either a collard or the spring forage pea.

Three-species are the average of each grass type that was planted with both the collard and the spring forage pea.

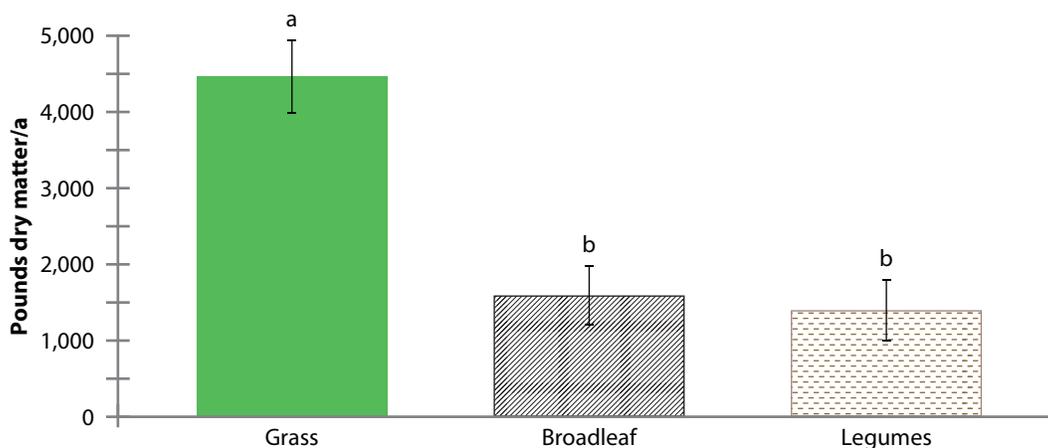


Figure 3. Biomass production of single species mixtures based on plant category (grass, broadleaf, and legume).

^{ab}Different superscripts indicate differences in treatment at $P < 0.05$. Values are averages with standard error bars.

Grass is the average production from the brown midrib (BMR) sorghum, forage sorghum, and pearl millet treatments.

Broadleaf is the collard treatment biomass production.

Legume is the average of the sunn hemp and spring forage pea treatments.

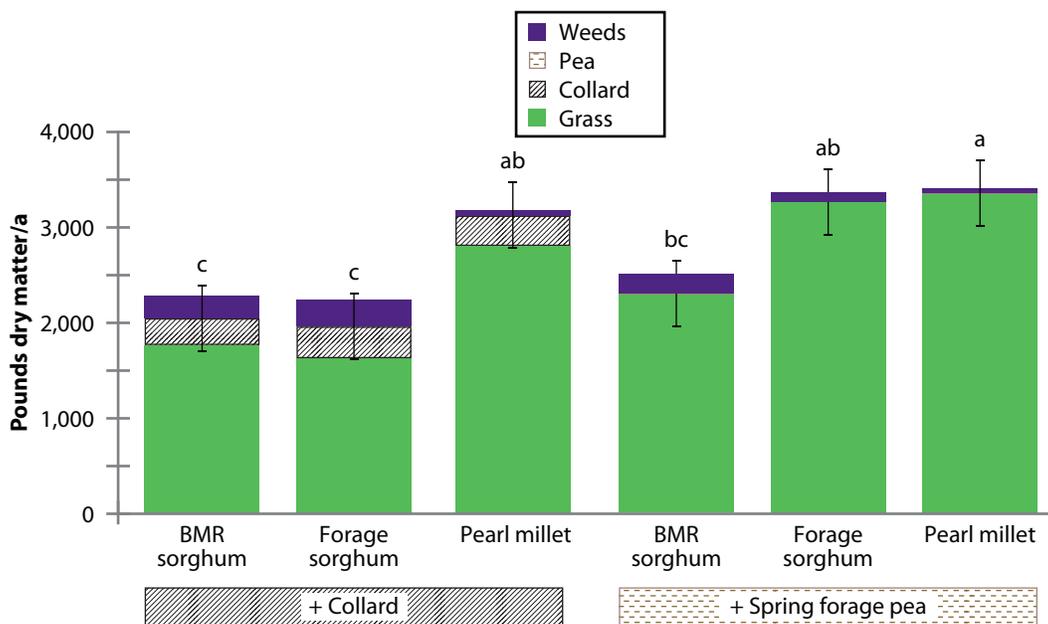


Figure 4. Biomass production of two-species mixtures including plant type biomass within treatment. The two-species include a grass species and spring forage pea, or a grass species and a collard.

^{ab}Different superscripts indicate differences in treatment at $P < 0.05$. Values are averages with standard error bars.

Treatments include brown midrib (BMR) sorghum + spring forage pea; forage sorghum + spring forage pea; pearl millet + spring forage pea; BMR sorghum + collard; forage sorghum + collard; and pearl millet + collard.

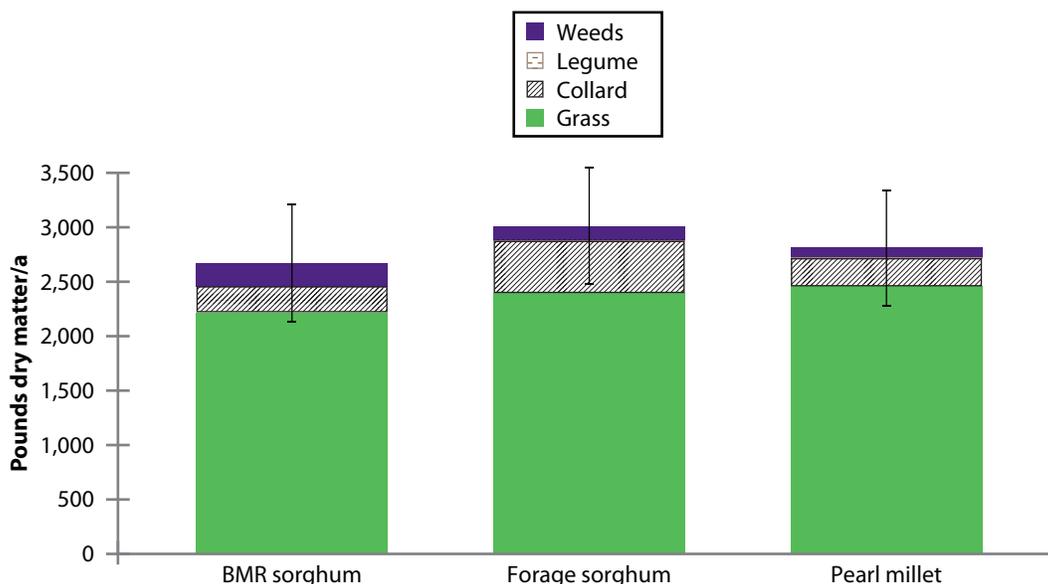


Figure 5. Biomass production of three-species mixtures including plant type biomass within treatment groups. The comparison is between grasses that are planted with both spring forage pea and collards.

Treatment comparisons are for brown midrib (BMR) sorghum + spring forage pea + collard; forage sorghum + spring forage pea + collard; and pearl millet + spring forage pea + collard. No differences were determined (non-significant).

Nitrogen Fertilizer Timing and Phosphorus and Potassium Fertilization Rates for Established Endophyte-Free Tall Fescue

D.W. Sweeney, J.K. Farney, and J.L. Moyer

Summary

A tall fescue production study was conducted at two locations, beginning in the fall of 2016 and the fall of 2017. At both sites, phosphorus (P) fertilization rate only affected the spring harvest, with few differences in yield. Applying nitrogen (N) in late fall or late winter resulted in greater spring yields than applying N in spring or not applying N. However, at Site 1 in 2017 fall harvest yields were greater from the spring N application, but this response was less at Site 2 in 2018. In both years, applying N increased tall fescue yield, but at Site 2 the yield differences from N timings were greater.

Introduction

Tall fescue is the major cool-season grass in southeastern Kansas. Perennial grass crops, as with annual row crops, rely on proper fertilization for optimum production; however, meadows and pastures are often under-fertilized and produce low quantities of low-quality forage. The objective of this study was to determine the effect of N fertilizer timing and P and potassium (K) fertilization rates on tall fescue yields.

Experimental Procedures

The experiment was conducted on two adjacent sites of established endophyte-free tall fescue in the fall of 2016 (Site 1) and 2017 (Site 2) at the Parsons Unit of the Kansas State University Southeast Research and Extension Center. The soil at both sites was a Parsons silt loam. The experimental design was a split-plot arrangement of a randomized complete block. The six whole plots received combinations of P_2O_5 and K_2O fertilizer rates allowing for two separate analyses: 1) four rates of P_2O_5 consisting of 0, 25, and 50 lb/a each year and a fourth treatment of 100 lb/a only applied at the beginning of the study; and 2) a 2×2 factorial combination of two rates of P_2O_5 (0 and 50 lb/a) and two levels of K_2O (0 and 40 lb/a). Subplots were four application timings of N fertilization consisting of none, late fall, late winter, and spring (E2 growth stage). Phosphorus and K fertilizers were broadcast applied in the fall as 0-46-0 (triple superphosphate) and 0-0-60 (potassium chloride). Nitrogen, as 46-0-0 (urea) solid at 120 lb N/a, was broadcast applied to appropriate plots on December 6, 2016, March 8, 2017, and April 19, 2017 at Site 1. Nitrogen was applied on December 1, 2017, March 2, 2018, and April 27, 2018 at Site 2. First-year harvest dates from each site were as follows: 1) spring yield was measured at R4 (half bloom) on May 15, 2017, at Site 1 and on May 17, 2018, at Site 2; 2) fall harvest was taken on September 13, 2017, at Site 1 and on September 12, 2018, at Site 2.

Results and Discussion

In the first year of the study at Site 1, spring harvest yield of tall fescue in 2017 was increased with 25 lb P_2O_5/a , but yield did not increase with greater P rates (Table 1). Fall harvest was unaffected by P rate so that the total annual production mirrored the response measured in the spring harvest. Spring harvest yield was greatest when N was applied either in late fall or late winter. Even though applying N fertilizer at the E2 growth stage in spring resulted in greater yield than with no N, delaying N application resulted in more than a 50% reduction in spring yield compared with the more traditional timings of either late fall or late winter. However, at the fall harvest tall fescue yield was greater from spring N applications compared with no N or N applied in either late fall or late winter. Thus, average annual total tall fescue yields were more than doubled by applying N. However, the differences in total yield from different N application timings were small with only late fall N application resulting in a 0.3 ton/a greater yield than applying N in the spring.

Dry conditions in 2018 resulted in low, first-year tall fescue yields at Site 2 (Table 2). Tall fescue yield was greater with 50 or 100 lb P_2O_5/a than with no P, but the average differences were less than 0.2 ton/a. Phosphorus fertilization rates had no effect on the fall or total harvest yields. Spring tall fescue yield was greatest with late fall fertilization. However, as for the first year at Site 1 (Table 1), both late fall and late winter N fertilization in the first year at Site 2 resulted in greater spring yield than with no N or N applied at the E2 growth stage in spring (Table 2). In contrast to results from Site 1 (Table 1), spring N application did not result in greater fall yield than with no N and only yielded 0.19 to 0.24 ton/a more than with late fall or late winter fertilization (Table 2). At Site 2, the first-year tall fescue yield rank as affected by N fertilizer timing was late fall>late winter>spring>no N.

Table 1. First-year yield of established tall fescue in the spring (R4-half bloom) and fall 2017 as affected by P₂O₅ fertilization rates and nitrogen (N) application timing at Site 1

Treatment	Spring harvest	Fall harvest	Total harvest (R4 + Fall)
P ₂ O ₅ (lb/a)	----- ton/a, 12% moisture -----		
0	0.69	1.32	2.01
25	1.11	1.41	2.53
50	1.08	1.35	2.43
100 ¹	1.19	1.23	2.42
LSD (0.10)	0.18	NS	0.34
N application timing			
None	0.20	1.03	1.23
Late fall	1.68	1.16	2.84
Late winter	1.57	1.22	2.78
Spring	0.63	1.91	2.54
LSD (0.05)	0.14	0.21	0.29

¹The 100 lb P₂O₅/a rate was only applied at the beginning of the study (Fall 2016).

Table 2. First-year yield of established tall fescue in the spring (R4-half bloom) and fall 2018 as affected by P₂O₅ fertilization rates and nitrogen (N) application timing at Site 2

Treatment	Spring harvest	Fall harvest	Total harvest (R4 + Fall)
P ₂ O ₅ (lb/a)	----- ton/a, 12% moisture -----		
0	0.80	0.72	1.53
25	0.87	0.76	1.64
50	0.90	0.72	1.62
100 ¹	0.97	0.84	1.81
LSD (0.10)	0.10	NS	NS
N application timing			
None	0.17	0.88	1.06
Late fall	1.31	0.67	2.17
Late winter	1.19	0.62	1.92
Spring	0.53	0.86	1.45
LSD (0.05)	0.09	0.13	0.13 ¹

¹The 100 lb P₂O₅/a rate was only applied at the beginning of the study (Fall 2017).

Tillage and Nitrogen Placement Effects on Yields in a Short-Season Corn/Wheat/Double-Crop Soybean Rotation

D.W. Sweeney and D. Ruiz-Diaz¹

Summary

In 2018, adding nitrogen (N) greatly improved average wheat yields with about a 10% increase with knife compared to broadcast application methods. Even though tillage did not affect wheat yields, soybean yield was about 10% greater with no-till.

Introduction

Many crop rotation systems are used in southeastern Kansas. This experiment is designed to determine the long-term effect of selected tillage and N fertilizer placement options on yields of short-season corn, wheat, and double-crop soybean in rotation.

Experimental Procedures

A split-plot design with four replications was initiated in 1983 with tillage system as the whole plot and N treatment as the subplot. In 2005, the rotation was changed to begin a short-season corn/wheat/double-crop soybean sequence. Use of three tillage systems (conventional, reduced, and no-till) continued in the same whole plots as the previous 22 years. The conventional system consisted of chiseling, disking, and field cultivation. Chiseling occurred in the fall preceding corn or wheat crops. The reduced-tillage system consisted of disking and field cultivation prior to planting. Glyphosate was applied to the no-till areas prior to planting. The four N treatments for the crop were: no-N (control) and N fertilizer placement as broadcast, dribble (surface band), and knife (subsurface band at 4 inches deep) UAN (28% N) solution. The N rate for the corn crop grown in odd-numbered years was 125 lb/a. The N rate of 120 lb/a for wheat was split as 60 lb/a applied pre-plant as broadcast, dribble, or knifed UAN. All plots except for the no-N controls were top-dressed in the spring with broadcast UAN at 60 lb/a N.

Results and Discussion

In 2018, tillage system did not affect wheat yield (Table 1). Overall, fertilizing with N quadrupled wheat yield. Preplant N application by knifing resulted in 10% greater wheat yield than with broadcast, with dribble application resulting in intermediate yields. The average yield of soybean planted doublecrop after wheat harvest was nearly 50 bu/a in 2018 and no-till was about 10% greater than with tillage. There was no residual effect on soybean yields from N applied by different pre-plant methods to the previous wheat crop.

¹ Department of Agronomy, Kansas State University, Manhattan, KS.

Table 1. Effect of tillage and fall nitrogen (N) fertilization on yield of wheat and following double-crop soybean in 2018

Treatment	Wheat yield	Double-crop soybean yield
	----- bu/a -----	
Tillage		
Conventional	31.2	46.5
Reduced	29.7	46.4
No-till	31.9	50.9
LSD (0.05)	NS	3.8
N Fertilization		
No-N control	9.0	48.0
Broadcast UAN†	38.2	48.5
Dribble UAN	40.4	48.9
Knife UAN	42.2	46.4
LSD (0.05)	3.0	NS

†UAN: urea-ammonium nitration solution, 28% N.

Pre-Plant Nitrogen Rate and Application Method and Side-Dress Nitrogen Rate Effects on Corn Grown No-Till on a Claypan Soil

D.W. Sweeney and D. Ruiz-Diaz¹

Summary

Corn yield in 2018 was increased by about 5 bu/a with knife application of pre-plant nitrogen (N) fertilizer compared with broadcast application. Fertilizing with increasing rates of N applied pre-plant, at side-dress, or both had little effect on yield or yield components of corn in 2018.

Introduction

Environmental conditions vary widely in the spring in southeastern Kansas. As a result, much of the N applied prior to corn planting may be lost before the time of maximum plant N uptake. Pre-plant N application method, pre-plant N rate, and side-dress N rate selection to provide N during rapid growth periods may improve N use efficiency while reducing potential losses to the environment. The objective of this study was to determine the effect of timing of pre-plant and side-dress N fertilization options on corn grown on a claypan soil.

Experimental Procedures

The experiment was established in spring 2018 on a Parsons silt loam soil at the Parsons Unit of the Kansas State University Southeast Research and Extension Center that had been in continuous no-till for more than 10 years. The experiment was a factorial arrangement of a randomized complete block design with four blocks (replications). The two factors were pre-plant N fertilizer placement of broadcast and knife (subsurface band at 4 inches deep) and pre-plant/side-dress N rates of 0-0, 0-150, 100-0, 100-50, 100-100, 150-0, 150-50, 150-100, and 200-0 lb/a. Side-dress applications were broadcast at the V10 growth stage using 7-stream pattern fertilizer nozzles. The N source for all treatments was liquid urea-ammonium nitrate (UAN; 28% N) fertilizer. Pre-plant N fertilizer was applied on March 12, 2018, and side-dress N was applied at V10 on June 4, 2018, to appropriate plots. Corn was planted on April 10 and harvested on August 28, 2018.

Results and Discussion

Even though individual yield components were not significantly affected by pre-plant N application method, general trends resulted in more than 5 bu/a greater corn yields when N was knife applied rather than broadcast prior to planting (Table 1). In general, applying N at any rate and time resulted in approximately 50% greater corn yield in 2018 than the 75.6 bu/a in the no-N control. However, there were few differences in yield among the eight treatments receiving N fertilizer. For example, general increases

¹ Department of Agronomy, Kansas State University, Manhattan, KS.

in total N applied, as well as applying no N until the V10 growth stage (0-150 lb/a pre-plant/side-dress N rate), had little effect on yield in 2018. Stand was not affected by pre-plant/side-dress N rates, but fertilizing with N increased kernel weight, the number of ears/plant, and the number of kernels/ear compared with corn grown in the no-N control.

Table 1. Pre-plant application method and pre-plant/side-dress nitrogen (N) rates effects on yield and yield components of corn planted no-till on a claypan soil in 2018

Treatment	Yield	Stand	Kernel weight	Ears/plant	Kernels/ear
	bu/a	plants/a	mg		
Pre-plant N method					
Broadcast	101.1	16600	253	1.07	622
Knife ¹	115.6	17200	249	1.10	634
LSD (0.10)	4.4	NS	NS	NS	NS
Pre-plant/side-dress ²					
N rates (lb/a)					
0-0 (No-N control)	75.6	16700	227	1.00	521
0-150	113.2	16000	263	1.05	675
100-0	110.8	16600	249	1.11	625
100-50	116.8	17500	259	1.06	637
100-100	115.3	17300	256	1.13	638
150-0	114.5	16600	251	1.12	643
150-50	114.3	16800	257	1.14	641
150-100	121.2	16600	254	1.13	665
200-0	111.3	17800	243	1.06	609
LSD (0.05)	9.5	NS	15	0.11	70

¹Knife: subsurface band at 4 inch depth.

²Side-dress applications were made at the V10 growth stage.

Response of Soybean Grown on a Claypan Soil in Southeastern Kansas to the Residual of Different Plant Nutrient Sources and Tillage¹

D.W. Sweeney, P. Barnes,² and G. Pierzynski³

Summary

The residual from previous high-rate turkey litter applications, which were based on nitrogen (N) requirements of the previous grain sorghum crop, increased 2018 soybean yield more than that obtained from the residual of phosphorus (P)-based turkey litter applications (low rate), commercial fertilizer, or the control. Even though early soybean growth was sporadically affected by residual treatments, the dry matter production at the R6 growth stage tended to be where the N-based litter was applied.

Introduction

Increased fertilizer prices in recent years—especially noticeable when the cost of phosphorus spiked in 2008—have led U.S. producers to consider other alternatives, including manure sources. The use of poultry litter as an alternative to fertilizer is of particular interest in southeastern Kansas because large amounts of poultry litter are imported from nearby confined animal feeding operations in Arkansas, Oklahoma, and Missouri. Annual application of turkey litter can affect the current crop, but information is lacking concerning any residual effects from several continuous years of poultry litter applications on a following crop. This is especially true for tilled soil compared with no-till because production of most annual cereal crops on the claypan soils of the region is often negatively affected by no-till planting. The objective of this study was to determine if the residual from fertilizer and poultry litter applications under tilled or no-till systems affects soybean yield and growth.

Experimental Procedures

A water quality experiment was conducted near Girard, KS, on the Greenbush Educational facility's grounds from spring 2011 through spring 2014. Fertilizer and turkey litter based on rates of 120 lb N/a and 50 lb P₂O₅/a were applied prior to planting grain sorghum each spring. Individual plot size was 1 acre. The five treatments, replicated twice, were:

1. Control: no N or P fertilizer or turkey litter – no tillage;
2. Fertilizer only: commercial N and P fertilizer – chisel-disk tillage;
3. Turkey litter, N-based: no extra N or P fertilizer – no tillage;
4. Turkey litter, N-based: no extra N or P fertilizer – chisel-disk tillage; and
5. Turkey litter, P-based: supplemented with fertilizer N – chisel-disk tillage.

¹Partially funded by U.S. Department of Agriculture Natural Resource Conservation Service Conservation Innovation Grant.

²Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, KS.

³Department of Agronomy, Kansas State University, Manhattan, KS.

Starting in 2014 after the previously-mentioned study, soybean was planted with no further application of turkey litter or fertilizer. Prior to planting soybean, tillage operations were done in appropriate plots as in previous years. A sub-area of 20 × 20 ft near the center of each 1-acre plot was designated for crop yield and growth measurements. Samples were taken for dry matter production at V3-V4 (approximately 3 weeks after planting), R2, R4, and R6 growth stages. Yield was determined from the center 4 rows (10 × 20 ft) of the sub-area designated for plant measurements in each plot.

Results and Discussion

In 2018, the residual effects of turkey litter and fertilizer amendments affected soybean yield, stand, pods/plant, and dry matter production (Table 1). The two treatments which had previously received a high application rate of turkey litter based on N requirements, regardless of tillage system, resulted in greater yields than from plots that had received low rates of turkey litter (P-based), commercial fertilizer, or no fertilizer N or P. The number of pods/plant were greater where N-based turkey litter had been applied in no-till than where fertilizer, a low rate of turkey litter, or no fertilizer or litter had been applied. In addition, stand was slightly improved where fertilizer or the high rates of turkey litter had been applied. The effect of residual treatments on soybean dry matter production was sporadic. However, by R6, dry matter production was greater where turkey litter had previously been applied on an N-basis (high rate) than on a P-basis (low rate), with dry matter from the fertilizer treatment being intermediate.

Table 1. Residual effect of turkey litter and fertilizer amendments on soybean yield, yield components, and dry matter production during 2018

Residual amendment ¹	Yield bu/a	Stand (×1000) plants/a	Seed weight mg	Pods/ plant	Seeds/ pod	Dry matter			
						V3	R2	R4	R6
Control	25.5	96	143	33	2.0	60	790	2410	3530
Fert-C	41.3	102	150	3743	2.2	100	1440	2900	5150
TL-N	59.8	100	138	5160	2.2	100	1300	2830	6440
TL-N-C	63.0	103	146	4353	2.2	110	2370	4200	6530
TL-P-C	33.9	96	157	3134	2.0	80	1190	2570	3870
LSD (0.05)	15.6	4	NS	13	NS	NS	760	NS	1600

¹Control, no turkey litter or N and P fertilizer with no tillage; TL-N, N-based turkey litter application with no tillage; TL-N-C, N-based turkey litter application incorporated with conventional tillage; TL-P-C, P-based turkey litter application and supplemental N application incorporated with conventional tillage; and Fert-C, commercial fertilizer incorporated with conventional tillage.

Use of a Fungicide to Reduce Stomatal Conductance for Production of Sweet Corn Planted at Different Populations with Limited Irrigation

D.W. Sweeney and M.B. Kirkham¹

Summary

Sweet corn in 2018 was affected by irrigation, plant population, and a fungicide applied for stomatal control. Even though measured stomatal conductance was unaffected and no disease pressure was noted, applying fungicide at V6 more than doubled the number of harvested ears per acre and per plant, but an additional application at R1 did not increase harvested ears. Applying 1 inch of irrigation at the VT growth stage resulted in approximately 20% greater number of harvested ears per acre and ears per plant, but did not increase fresh weight. Under these dry conditions, increasing plant population tended to decrease harvested ears per acre and ears per plant, especially when no fungicide was applied or with no irrigation.

Introduction

Sweet corn is a potential value-added, alternative crop for producers in southeastern Kansas. Corn responds to irrigation, and timing of water deficits can affect yield components. Even though large irrigation sources, such as aquifers, are lacking in southeastern Kansas, supplemental irrigation could be supplied from the substantial number of small lakes and ponds in the area. However, this may not be enough to improve the water use of the plant. Reducing stomatal conductance and adjusting seeding rate could also help reduce water stress and/or improve water use efficiency. The objective of this study was to determine the effect of limited irrigation, seeding rate, and fungicide applied for stomatal control on sweet corn yield.

Experimental Procedures

The experiment was established in spring 2017 on a Parsons silt loam on the Parsons field of the Kansas State University Southeast Research and Extension Center. The experimental design was a split-plot arrangement of a randomized complete block with three blocks (replications). The whole plots were a 2 × 3 factorial of two irrigation schemes (no irrigation or 1 inch at VT [tassel]) and three fungicide treatments (none or application of Quilt Xcel at either V6 or at both V6 and R1 [silk] growth stages). Subplots were three target populations of 15,000, 22,500, and 30,000 plants/a. Sweet corn was harvested at R3 (milk) and the number of marketable ears, total fresh weight, and individual ear weight was determined. Sweet corn was planted on April 24, 2018. Sweet corn was picked by hand on July 9, 2018. Stomatal conductance was measured at the V8 and R2 growth stages.

¹Department of Agronomy, Kansas State University, Manhattan, KS.

Results and Discussion

Sweet corn in 2018 was affected by fungicide applied for stomatal control, irrigation, and plant population (Table 1). Even though dry weather resulted in overall low values, applying fungicide at the V6 growth stage more than doubled the number of harvested ears per acre and per plant, but an additional application at R1 did not increase harvested ears. Even though fresh weight per ear was greatest when numbers of ears were low, fungicide application resulted in more than a 50% increase in fresh weight per acre. Even though stomatal conductance measured at V8 and R2 was not affected by fungicide application (data not shown), no disease pressure was noted. Applying a limited amount (1 inch) of irrigation at the VT growth stage resulted in approximately 20% greater number of harvested ears per acre and ears per plant, but fresh weight per acre was not affected. Under these dry conditions, increasing plant population tended to decrease harvested ears per acre and ears per plant, especially when no fungicide was applied or with no irrigation (interaction data not shown).

Table 1. Effect of fungicide, irrigation, and population on sweet corn grown on a clay-pan soil

Treatment	Harvest		Fresh weight		Stand plants/a
	ears/a	ears/plant	ton/a	g/ear	
Fungicide timing ¹					
None	3700	0.19	1.67	547	22700
V6	9800	0.48	2.82	289	22100
V6/R1	10600	0.50	2.55	233	22900
LSD (0.05)	1700	0.08	0.82	221 ²	NS
Irrigation					
None	7300	0.35	2.23	363	22700
VT: 1 inch	8800	0.43	2.46	349	22300
LSD (0.05)	1400	0.07	NS	NS	NS
Seeding rate ³					
15000	8800	0.57	2.09	234	15200
22500	8100	0.35	2.54	403	23600
30000	7200	0.25	2.42	433	28800
LSD (0.05)	1000	0.05	NS	NS	850

¹Fungicide was Quilt Xcel applied at 14 oz/a.

²LSD shown is at the 0.10 level of probability.

³Seeding rate is in seeds/a.

Southeast Kansas Crop Production Summary – 2018

G.F. Sassenrath, L. Mengarelli, J. Lingenfelser, and X. Lin

Summary

This is a summary of the crop production conditions in southeast Kansas in 2018, and the results of the variety testing for corn, soybean, sorghum, sunflower, and wheat.

Introduction

Crop production is dependent on many factors including cultivar selection, environmental conditions, soil, and management practices. This report summarizes the environmental conditions during the 2018 growing season in comparison to previous years and the historical averages. Information on crop yields from the variety trials at Parsons and Columbus, KS, are reported.

The impact of temperature on crop growth can be described by calculating the accumulated “heat units” or growing degrees (Lin et al., 2019) and correlating cumulative growing degree days (GDD) to specific crop stage. Each crop is sensitive to a different range of temperatures. To better capture the dependence of crop development on temperature, a base temperature is used, below which crop growth and development is delayed or absent. Corn and soybeans grow best at temperatures from 50 to 86°F. The GDD for these crops are calculated as the average daily temperature minus 50°F. The daily GDD are then summed to determine the cumulative GDD. When a base temperature of 50°F is used this number is reported as GDD50. Note that the different soybean maturity groups may have different GDD requirements for each crop growth stage.

Winter wheat has three separate periods of growth: the initial germination and vegetative growth in the fall, the vernalization period during the winter, and the spring green up and reproductive stage in the spring. Wheat growth and development is sensitive to different temperatures during each of these stages, so developing a temperature model for wheat growth and development is a bit more complex. Details of wheat growth and development are given in the following publication in this volume (Zhao et al., 2019). Growing degree day information is now available on the Kansas Mesonet website (<http://mesonet.k-state.edu/agriculture/degreedays/>).

Experimental Procedures

The Kansas State University Crop Performance Tests were conducted in replicated research fields throughout the state. This report summarizes crop production for southeast Kansas, focusing on crops grown at Parsons, Columbus, and Erie, KS. Crop varieties were tested in river bottom fields (Lanton silt loam soil type) near Erie, KS, and upland (Parsons silt loam soil) at the Southeast Research and Extension Center in Parsons, and the research fields outside of Columbus, KS (Parsons silt loam soil). All crop variety trials are managed with conventional tillage. Individual variety results are available at the K-State Crop Performance Test webpage (<http://www.agronomy.k-state.edu/services/crop-performance-tests/>).

Wheat was drilled in 7.5-in. rows at 90 lb/a with an Almaco plot drill on November 1, 2017, in Parsons and harvested June 15, 2018. Fertilizer was applied before planting at a rate of 50-46-30 lb/a N-P-K, with an additional 60 lb N applied in the spring for both hard red and soft red cultivars. Finesse (1/3 oz/a) was applied with the fertilizer in the spring to control weeds. No fungicide was used in wheat.

Corn was planted in 30-in. rows on April 10 in Parsons (short-season varieties) and on April 11 in Erie (full-season varieties). Fertility of corn at Parsons was 180-50-50 lb/a N-P-K and 225-50-0 lb/a N-P-K at Erie. Weed control was Powermax (1 qt/a), Dual II Magnum (1.5 pt/a), atrazine (2 qt/a) and 2,4-D (2 qt/a). Corn was harvested August 28, 2018, in Parsons and September 17, 2018, in Erie.

Soybeans were planted in 30-in. rows on June 8, 2018, in Columbus and Erie, and harvested November 29, 2018, in Columbus and December 10, 2018, in Erie. Fertilizer was broadcast at 18-46-60 lb/a N-P-K diammonium phosphate (DAP) and potash in Columbus; no fertilizer was applied at Erie. Weed control was gramoxone (2 pt/a), Dual II Magnum (2 pt/a), metribuzen (1.5 lb/a) and Authority XL (6 oz/a). A post-emerge application of UltraBlazer (1 pt/a) and Cobra (12 oz/a) was made to control cocklebur.

Sorghum was planted on May 14, 2018, at a seeding rate of 87120 seeds/a in Parsons and harvested October 3, 2018. Fertilizer was applied at a rate of 150-46-50 lb/a N-P-K. Weed control was atrazine (2 qt/a) and 2,4-D Amine (2 qt/a).

Sunflowers were planted July 20, 2018 at a rate of 28,000 seed/a in 30-in. rows at Parsons. Plots were fertilized at a rate of 80-46-60 lb/a N-P-K. Weed control was Gramoxone (1 qt/a), Dual Magnum (1 pt/a) and Spartan (6 oz/a). Plots were harvested on December 12, 2018.

Weather information was downloaded from the Kansas Mesonet site (<http://mesonet.k-state.edu/weather/historical/>). Historical data from the Parsons and Columbus stations were used in preparing these reports. Rainfall is reported on a water year (WY) basis, that begins October 1 and ends September 30 of the next year. Cumulative rainfall during the summer growing season was also calculated. Growing degree days were calculated using a base temperature of 50°F.

Results and Discussion

Rainfall

Rainfall during the 2017-18 water year was very close to average throughout the year (Figure 1A). Initial rainfall in the fall was slightly higher than average, but a long dry period in November to February reduced total levels to normal. There were several rainy periods followed by long intervals without moisture, but overall, total rainfall levels (38.0 in.) were very close to the 7-year average (36.2 in.). Water-year rainfall totals ranged from a low of 20.5 in. in WY2012 to 51 in. in WY2017. Similarly, total rainfall during the summer growing season (March–October, 31.6 in.; Figure 1B) was very close to the 8-year average of 29.7 in. Summer rainfall can be quite variable, ranging from a low of 12.7 in. in 2011 to a high of 46.2 in. in 2017.

Temperature

Temperatures in 2018 were very close to average throughout the summer growing season (Figure 2A). An initial cool spell in early spring reduced the number of growing degree days in April, but temperatures quickly warmed up to near-normal temperatures. Extreme values of cumulative GDD50 were experienced in 2012 and 2017, which also had the greatest and least number of days, respectively, with maximum temperatures exceeding 90°F (Figure 2B). Higher temperatures reduce the yield of corn and soybeans. Again, days of high temperatures during 2018 were nearly normal (Figure 2B). A warm period in early summer increased the number of days with high temperatures, but this lasted only a short time.

Crop Production

Winter wheat was planted on 324,000 acres in southeast Kansas in 2018 and 7.7 million acres throughout Kansas. Twenty-one hard red wheat cultivars were grown at Parsons in 2018. The average yield of hard red winter wheat across all cultivars (51.3 bu/a) ranged from 41.4 to 62.9 bu/a and were slightly less than the 10-year average yield of 55.9 bu/a from the variety trials but higher than the state average yield of 38 bu/a (Figure 3). Eighteen soft red wheat cultivars produced an average of 60.8 bu/a and ranged from 54.2 to 66.1 bu/a, which was slightly less than the 10-year average yield of 61.4 bu/a from the variety trials but higher than the state average yield. Fungal pressure was much less in 2018. Fungicide studies showed no yield increase in 2018 with fungicide use (Zhao et al., 2019).

Corn was planted in 5.45 million acres in Kansas in 2018, with 92% of those corn acres harvested for grain and 7% harvested as silage. Seventeen varieties of full season corn were tested in river bottom ground at Erie, with an average yield (168 bu/a) higher than the 7-year average yield (136 bu/a) and a range from 114 to 199 bu/a (Figure 4A). This was greater than the state average yield for 2018 of 129 bu/a and the 10-year state average yield of 131 bu/a. Ten short-season corn varieties were tested in upland ground at Parsons, with an average yield of 73 bu/a, and a range of 61 to 83 bu/a (Figure 4B). This was less than the 7-year average variety test yield of 103 bu/a.

Soybeans were planted on 4.75 million acres in Kansas in 2018. Twenty-nine cultivars of soybeans from maturity groups (MG) 3-4 were tested, with an average yield of 54 bu/a and a range of 31.8 to 67.5 bu/a, which was greater than the state average yield of 43.5 bu/a (Figure 5A). This was also greater than the 8-year variety-testing average (47 bu/a) and the state 8-year average of 36 bu/a. Twenty-six cultivars of soybeans from MG 4-5 were tested, with an average yield of 57.9 bu/a and a range from 42.6 to 70.2 bu/a, which was greater than the 8-year variety test average yield of 47.8 bu/a (Figure 5B).

Grain sorghum was planted on 2.8 million acres in Kansas in 2018. Grain sorghum yields were lower in 2018 for the 29 cultivars tested, with an average yield of 69 bu/a and a range from 45 to 98 bu/a (Figure 6). This is lower than the 7-year average variety trial yield of 83 bu/a and 10-year average state yield of 74 bu/a.

Sunflowers were planted on 49,500 acres in Kansas in 2018. Twelve cultivars of oilseed sunflowers were grown in 2018, with an average yield of 1129 lb/a and a range from 569 to 1646 lb/a (Figure 7). This is greater than the 5-year variety test average of 798 lb/a, but fewer than the 10-year state average yield of 1425 lb/a.

Conclusions

2018 was an average year for climate conditions, with some early spring low temperatures, and a period of high temperatures in early summer. Rainfall was also average, with dry periods in fall-winter and mid-summer followed by rain to bring total precipitation to near-normal levels. Crop production was also average, with the exceptions being short-season corn and sorghum, which had lower than average yields.

Acknowledgment

This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478.

References

- Lin, X., Z. Zambreski, M. Knapp, R. Aiken, G. Sassenrath. 2019. Learn about the new monthly Kansas Ag-Climate Update. Agronomy eUpdate. Iss 731, Feb. 8th, 2019. https://webapp.agron.ksu.edu/agr_social/m_eu_article.throck?article_id=2098
- Zhao, H., X. Lin, G. Sassenrath, R. Lollato, E. De Wolf. 2019. Modeling wheat susceptibility to disease. Kansas Agricultural Experiment Station Research Reports: Vol. 5: Iss. 2.

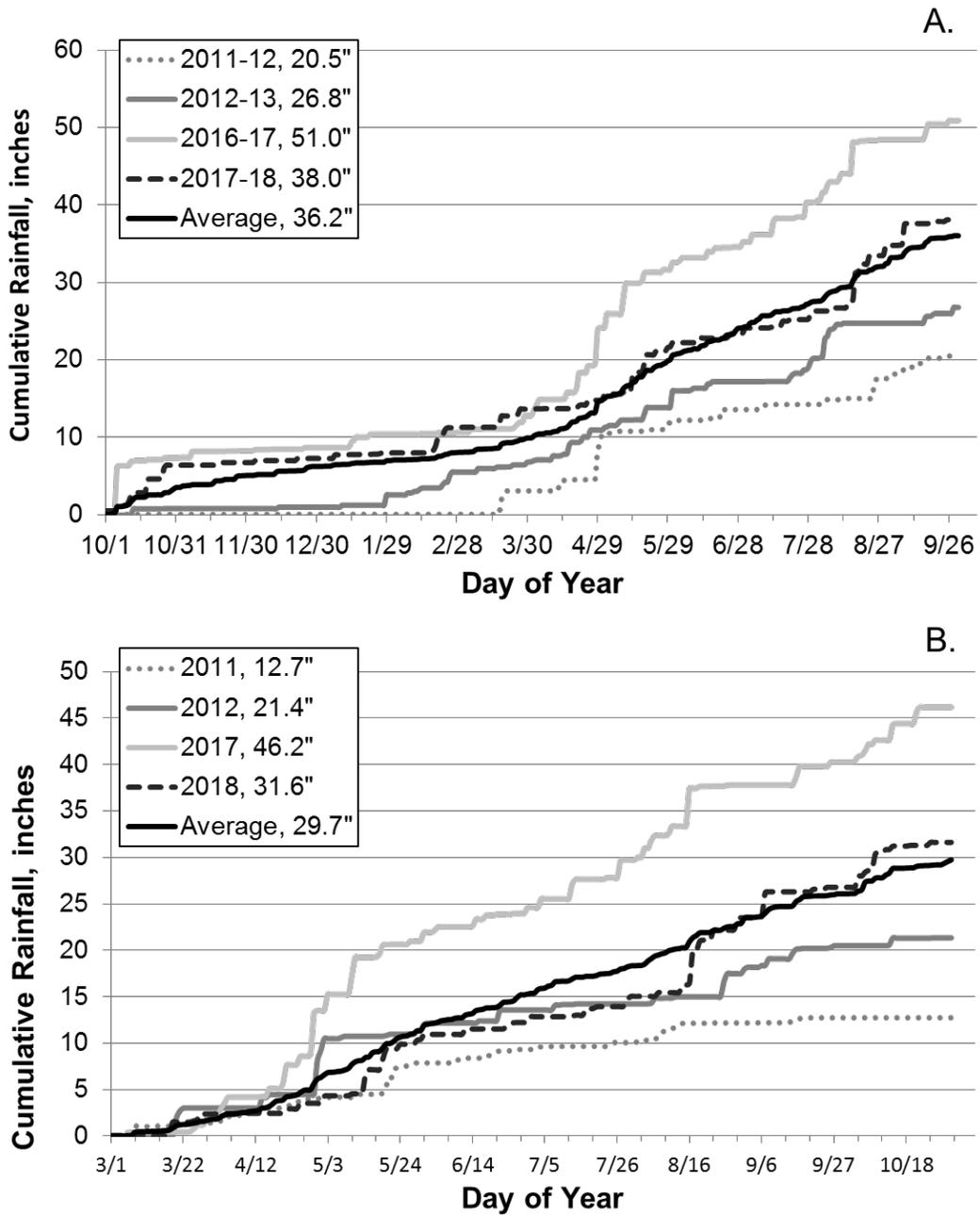


Figure 1. Cumulative rainfall (A) during the water year from October 1 through September 30 and (B) during the summer crop production season. Eight-year average included for comparison. Rainfall total in inches given after each year in legend.

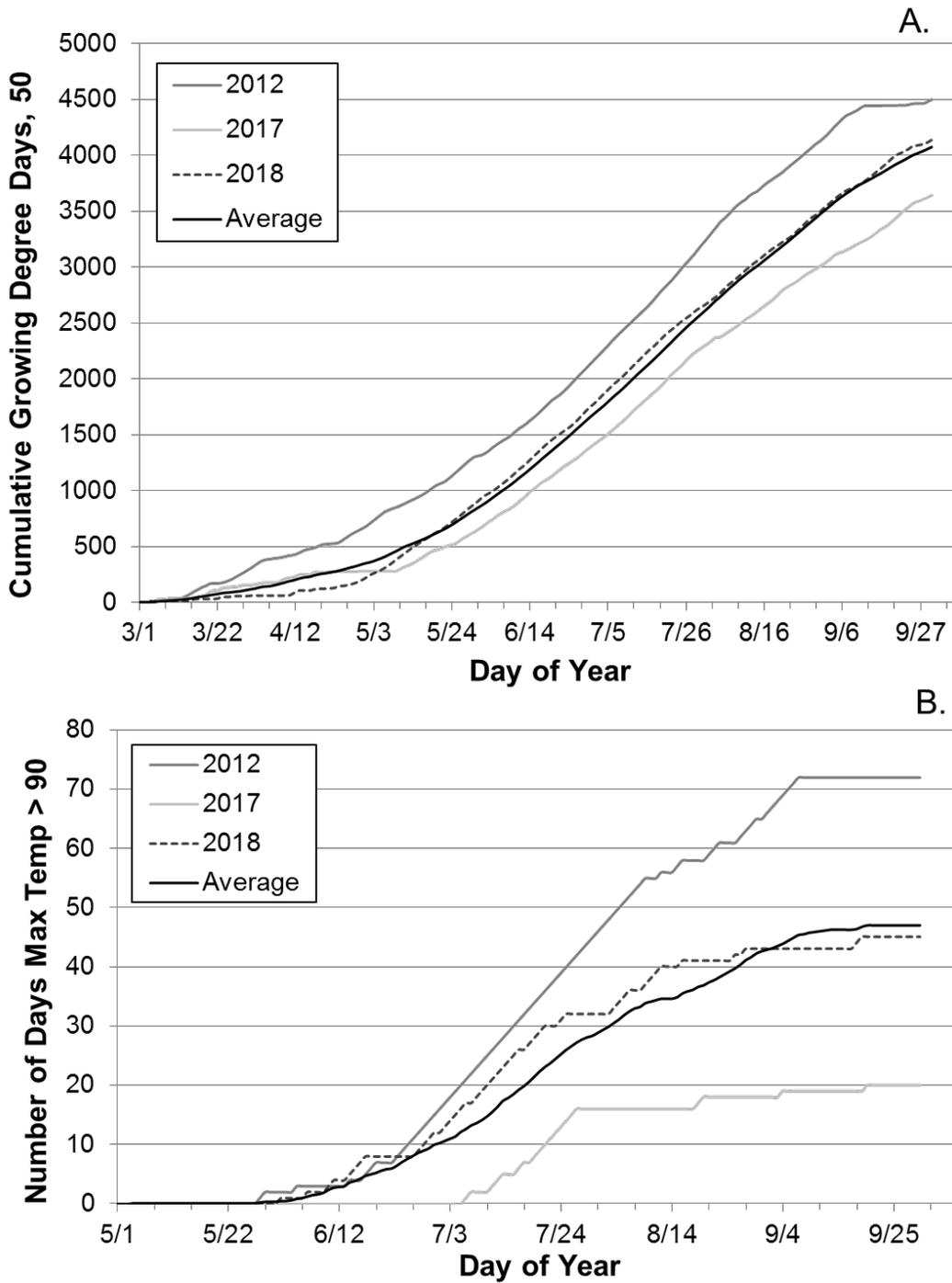


Figure 2. Temperature patterns and extremes during 2018 and preceding years. (A) Cumulative growing degree days (GDD) calculated with a base temperature of 50°F during the summer growing season. (B) Number of days the maximum temperature was greater than 90°F. Eight-year average included for comparison.

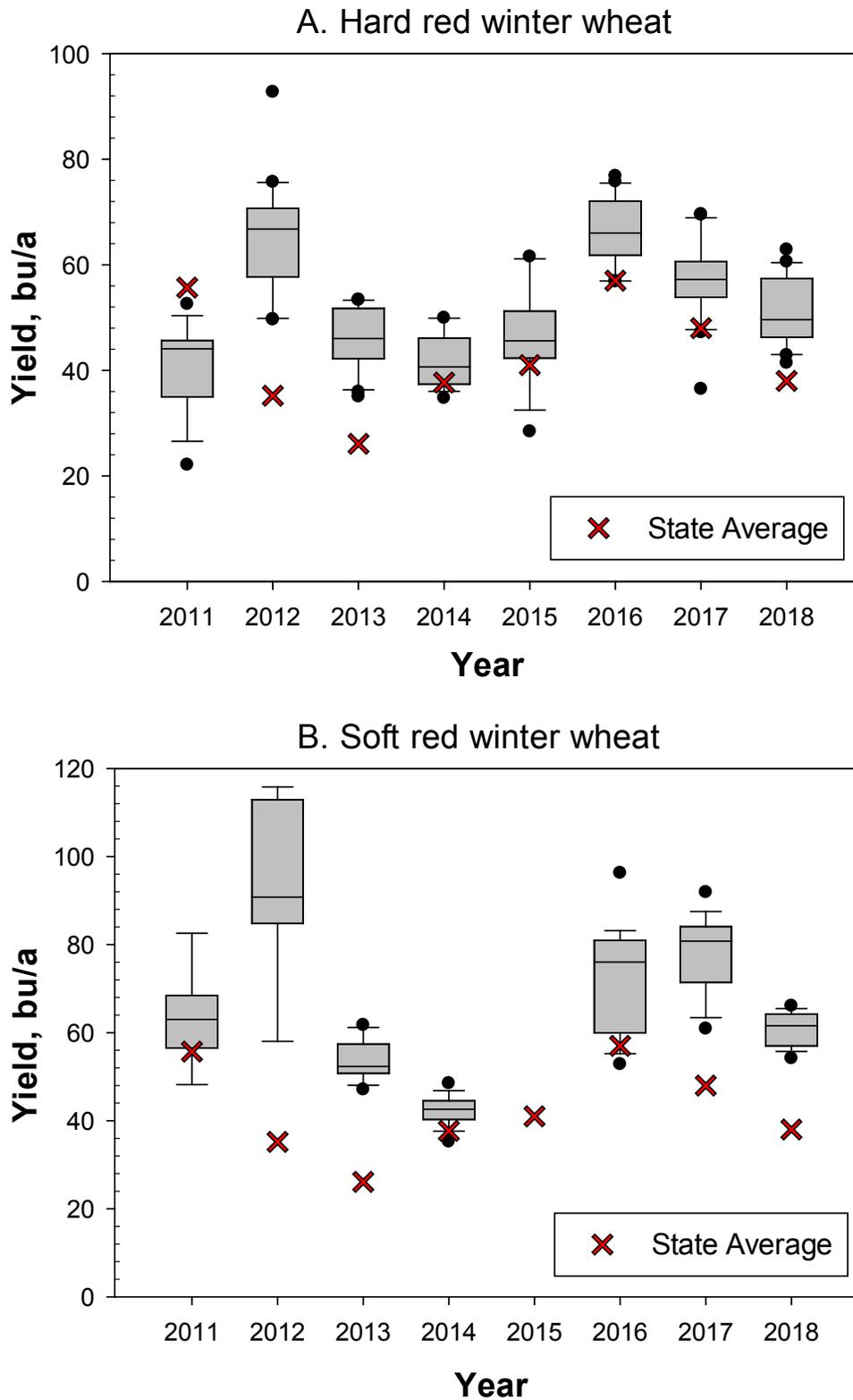
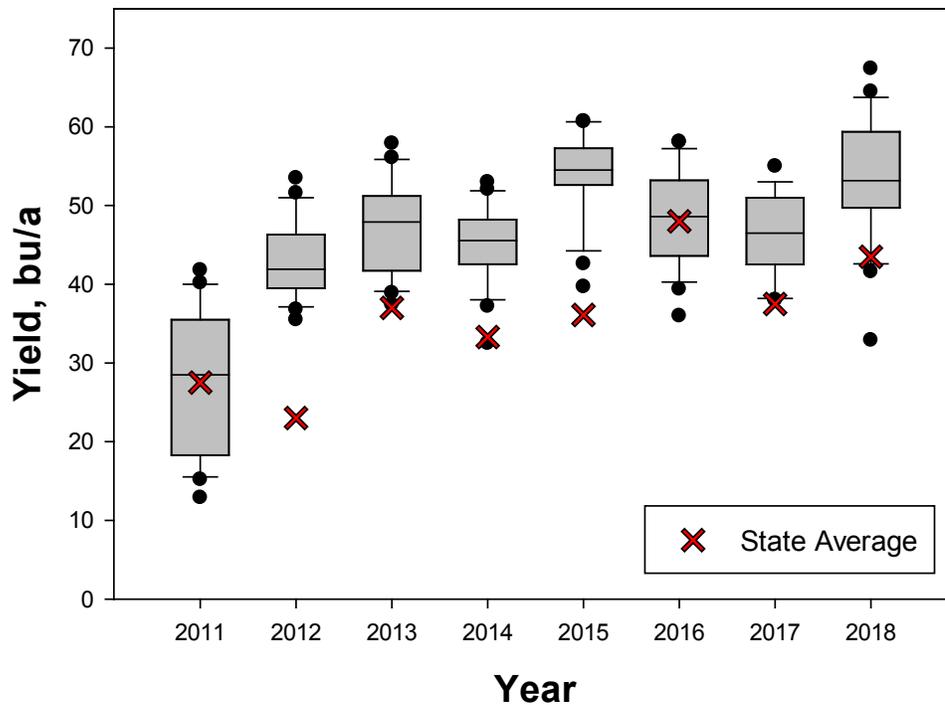


Figure 3. Winter wheat yield for (A) hard red wheat and (B) soft red wheat from variety trials in southeast and eastern Kansas from 2011 through 2018. The line in the middle of the box plots is the median yield of all varieties. The upper and lower quartiles are given by the upper and lower edges of the boxes. The maximum and minimum values are given by the upper and lower “whiskers” extending from the box. Outliers are given as solid circles. Note the difference in scale between the hard red and soft red variety results. For comparison, average reported yields from southeast Kansas are highlighted as a red X.

A. Soybeans, Groups 3-4



B. Soybeans, Groups 4-5

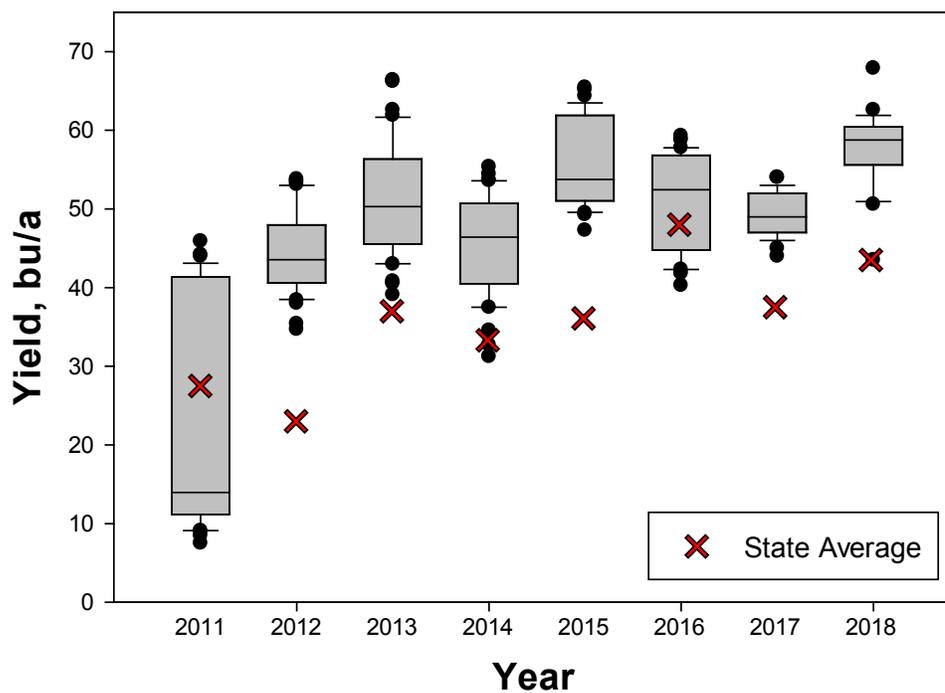


Figure 5. Soybeans from (A) MG3-4 and (B) MG4-5 from variety trials grown from 2011 through 2018. For comparison, average reported yields from Kansas are highlighted as a red X.

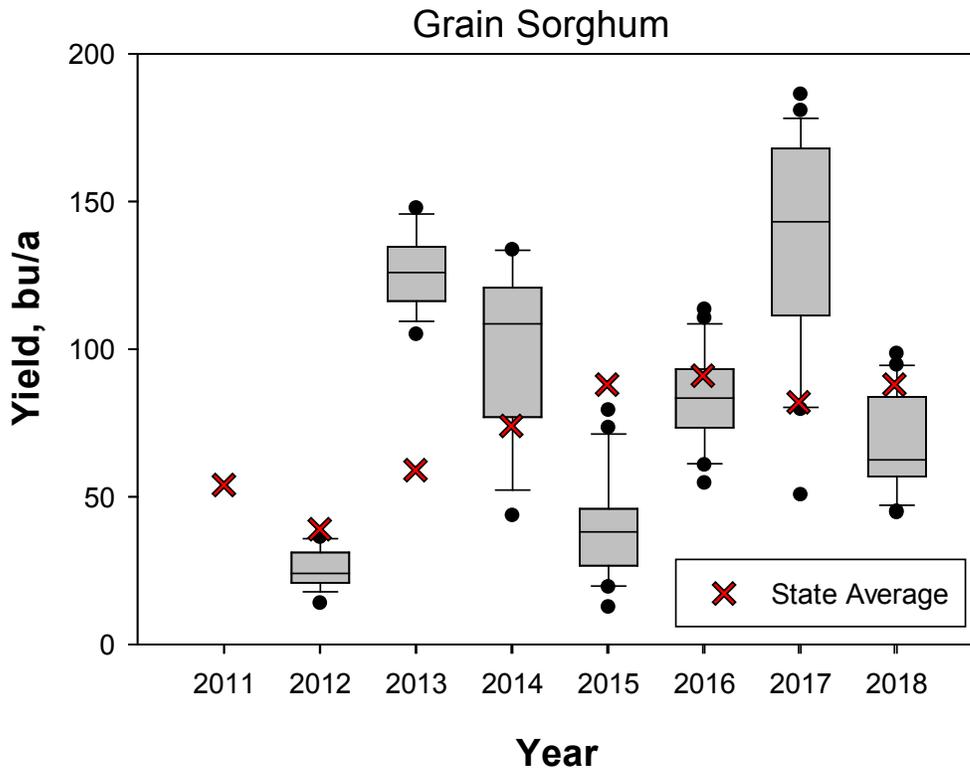


Figure 6. Grain sorghum from variety trials grown from 2011 through 2018. Yield was not available for the variety trials in 2011. For comparison, average reported yields from Kansas are highlighted as a red X.

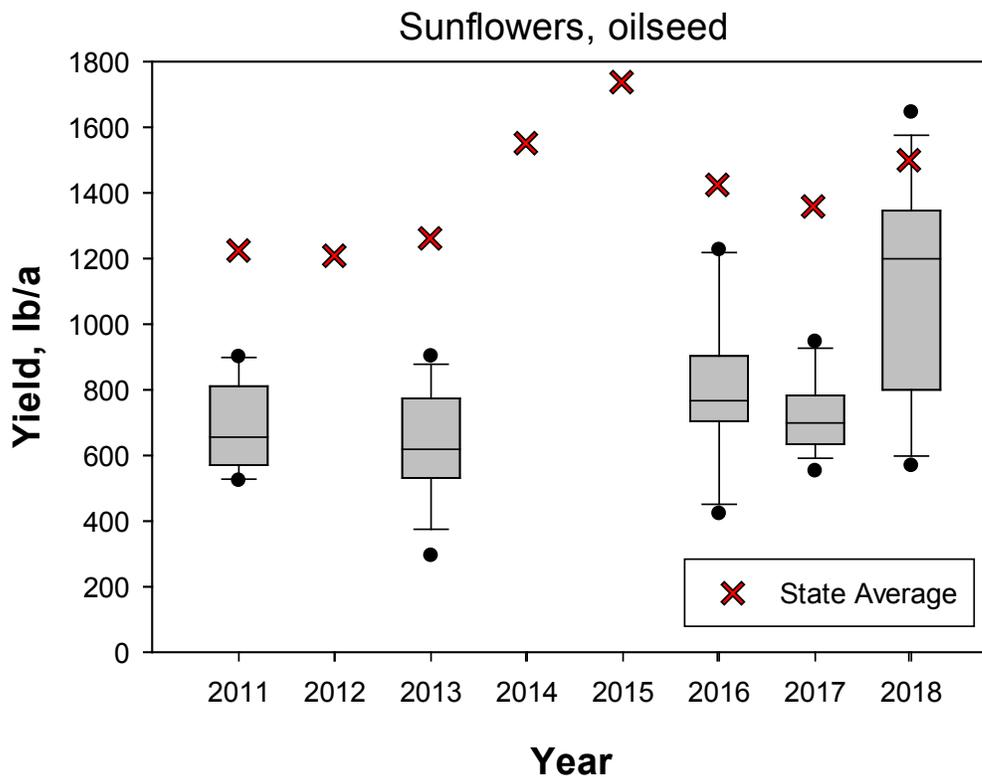


Figure 7. Oilseed sunflowers from variety trials grown from 2011 through 2018. Yield data were not available from the variety plots in 2012, 2014, or 2015. For comparison, average reported Kansas state yields are highlighted as a red X.

Controlling Soil-Borne Disease in Soybean With a Mustard Cover Crop

G.F. Sassenrath, C. Little, K. Roozeboom, X. Lin, and D. Jardine

Summary

Charcoal rot is a soil-borne disease that is prevalent in southeast Kansas. The disease infects multiple crops, including soybean, and causes yield reductions. A high-glucosinolate mustard with biofumigant properties reduced the population levels in soil and in soybean plants of the fungus (*Macrophomina phaseolina*) that causes charcoal rot. In this study, management practices that incorporate use of mustard as a cover crop in soybean production systems were tested. Results indicate that tillage increases the charcoal rot fungus. The mustard cover crop was tested in field studies for its impact on soil health, fungal disease and propagules, and soybean growth and yield.

Introduction

Charcoal rot is a plant disease caused by the fungus *Macrophomina phaseolina* (Tassi) Goid. It infects many plants, including soybeans. The disease limits yield and performance of soybean and reduces yield an average of more than 5% per year. The fungus is present in crop fields in southeast Kansas, and is particularly prevalent in hot, dry weather. The fungus infects plant stems, reducing the flow of water and nutrients through the root and stem, creating a charcoal-grey growth that gives the disease its name (Figure 1). As the disease progresses, the plant roots atrophy and die, and yield is lost because of the lack of nutrients and water transferred to the developing seeds.

Certain plants produce chemicals that act as biofumigants that control or reduce harmful soil pathogens including the charcoal rot fungus. These natural chemical agents have been shown to control bacterial diseases in potato production (Larkin et al., 2011) and cacao (Melnick et al., 2008). Mengistu et al. (2009) showed some suppression of charcoal rot infestation with altered tillage and use of cereal rye as a cover crop. Mustard, *Brassica juncea*, produces chemical compounds called glucosinolates. This mustard is used to make the brown mustard condiment; it is not the weedy mustard common to Kansas (Peterson, 2017). While mustard is related to canola, canola has been bred to reduce the amount of glucosinolates to improve its palatability. The high glucosinolate content in *B. juncea* can control soil-borne pathogens such as nematodes and the charcoal rot fungus, *M. phaseolina*.

The research outlined here tested the ability of the mustard plant to control charcoal rot in soybean production under different management systems. Incorporating a cover crop into the crop rotation may be a simple method of controlling soil-borne diseases, reducing the use of fungicides that may contaminate the environment.

Experimental Procedures

Mustard seed, cv. Mighty Mustard Pacific Gold (Johnny's Select Seed, Winslow, ME), was planted in early spring after the soil temperature was consistently above 55°F in replicated field plots at the Southeast Research and Extension Center research field near

Columbus, KS, and at the Kansas State University farm plots in Ashland Bottoms, near Manhattan, KS. The plants were allowed to grow until flowering (Figure 2). Alternative methods of managing the mustard residue were tested to determine the best production method for controlling the soil-borne fungal pathogen. Prior to planting soybeans, the field received a herbicide burndown to terminate the mustard cover crop. Four different cover crop treatments and one control with no cover crop were used to determine how to manage the mustard residue for optimal pathogen control, including:

- *control*: no mustard cover crop
- *no incorporation*: plant into standing mustard
- *no incorporation*: cover crop rolled
- *no incorporation*: cover crop mowed
- *incorporation*: cover crop disked (tillage)

Soil samples were collected prior to soybean planting and after cover crop termination for determination of the pathogen as measured by the number of colony forming units (CFUs). Soybeans (MG 4.1) were planted and grown to maturity. Soil and soybean plant samples were collected at the R7-R8 growth stage and measured for the amount of fungal infection. The numbers of CFUs from the fungi in the plant and soil samples were measured at the Department of Plant Pathology at K-State. Final yield was measured at harvest.

Results and Discussion

Previous research demonstrated that the mustard plant reduces charcoal rot pressure. The number of CFUs were reduced in soil by 8%, and in plants by 50% in plots treated with mustard seed cover crop compared to the untreated control (Sassenrath et al., 2017). In this study, results from Ashland Bottoms and Columbus, KS, indicate that the method of managing the cover crop also impacted the number of CFUs in the soil (Figure 3). Changes in CFUs were similar for both locations, though Columbus had a greater disease pressure and a greater reduction in disease with the mustard cover crop. Tillage (disking) increased the CFUs of the charcoal rot fungi, while planting directly into standing mustard cover crop or mowing the cover crop reduced the CFUs. The greatest reduction in CFUs was observed when soybeans were planted in rolled mustard cover crop. For both locations, the more intact the mustard cover crop plants remained, the greater the control of the charcoal rot fungus.

Treatments impacted soybean yields (Figure 4), but in very different ways for the two locations. Soybean yield was reduced at Ashland Bottoms for all cover crop treatments, most likely because of limited rainfall in 2018. Soybean yield showed the greatest reduction at Ashland Bottoms in the tilled plots, indicating insufficient soil moisture was most likely responsible for the reduced yields. Conversely, tillage increased yield at Columbus by slightly more than 6 bu/a over the other treatments. No differences in yield were observed for the other treatments at Columbus. The mustard cover crop did not reduce yield in any of the plots at Columbus.

This research indicates the potential for use of the mustard as a cover crop to control soil-borne disease in soybean. The mustard cover crop can significantly reduce the disease pressure. Greater improvements in disease pressure are observed for management practices that maintain the cover crop residue. More research is needed to further delineate changes in soil health parameters with mustard cover crops and management practices.

Acknowledgment

This research is supported by funding from the Kansas Soybean Commission and the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478.

References

- Larkin, R.P., Honeycutt, C.W., Olanya, O.M. 2011. Management of verticillium wilt of potato with disease-suppressive green manures and as affected by previous cropping history. *Plant Disease*. 95:568-576.
- Melnick, R.L., Zidack, N.K., Bailey, B.A., Maximova, S.N., Guiltinan, M., Backman, P.A. 2008. Bacterial endophytes: *Bacillus* spp. from annual crops as potential biological control agents of black pod rot of cacao. *Biological Control*. 46:46-56.
- Mengistu, A., Reddy, K.N., Zablotowicz, R.M., Wrather, A.J. 2009. Propagule densities of *Macrophomina phaseolina* in soybean tissue and soil as affected by tillage, cover crop and herbicide. *Plant Management Network*. 30 Jan. 2009.
- Peterson, D. 2017. Control of mustards in wheat. *Agronomy eUpdate*. 662: Nov. 17, 2017. https://webapp.agron.ksu.edu/agr_social/m_eu_article.throck?article_id=1605
- Sassenrath, G.F., Little, C.R., Hsiao, C.-J., Shoup, D.E., Lin, X. 2017. Cover crop system to control charcoal rot in soybeans. *Kansas Agricultural Experiment Station Research Reports*. Vol. 3: Iss. 2. <https://doi.org/10.4148/2378-5977.1383>.



Figure 1. Charcoal rot, caused by the fungus *Macrophomina phaseolina* causes a grey, charcoal-colored growth in infected soybean roots. The plant on the left is highly infected. The plant on the right has minor infection. As the disease progresses, the roots atrophy and die, limiting seed development and reducing yield.



Figure 2. Might Mustard (*Brassica juncea*) planted as a cover crop prior to soybean planting.

CROPPING SYSTEMS RESEARCH

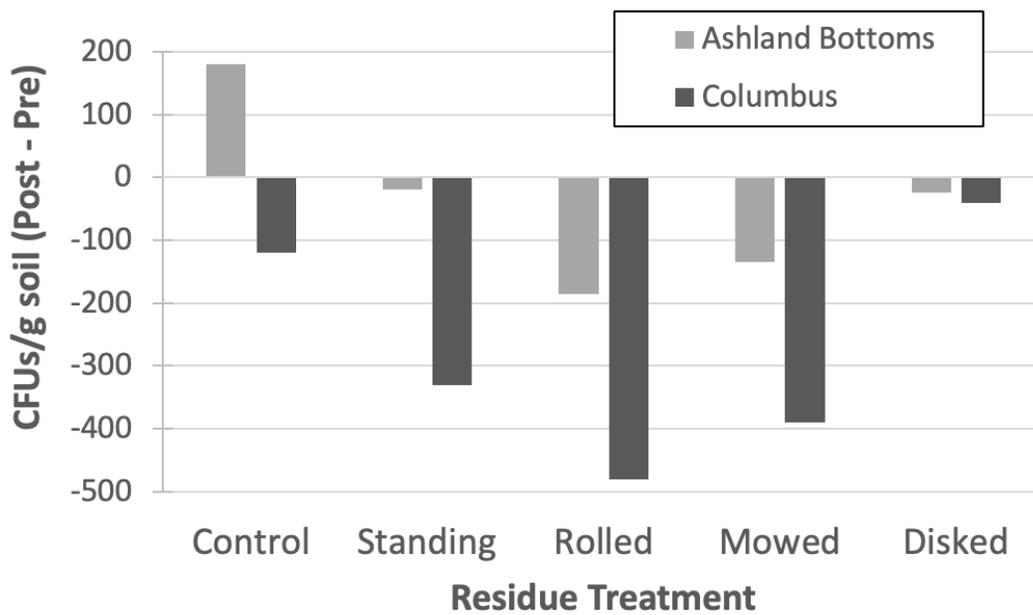


Figure 3. Difference between number of colony forming units (CFUs) of charcoal rot fungus before and after soybean growth.

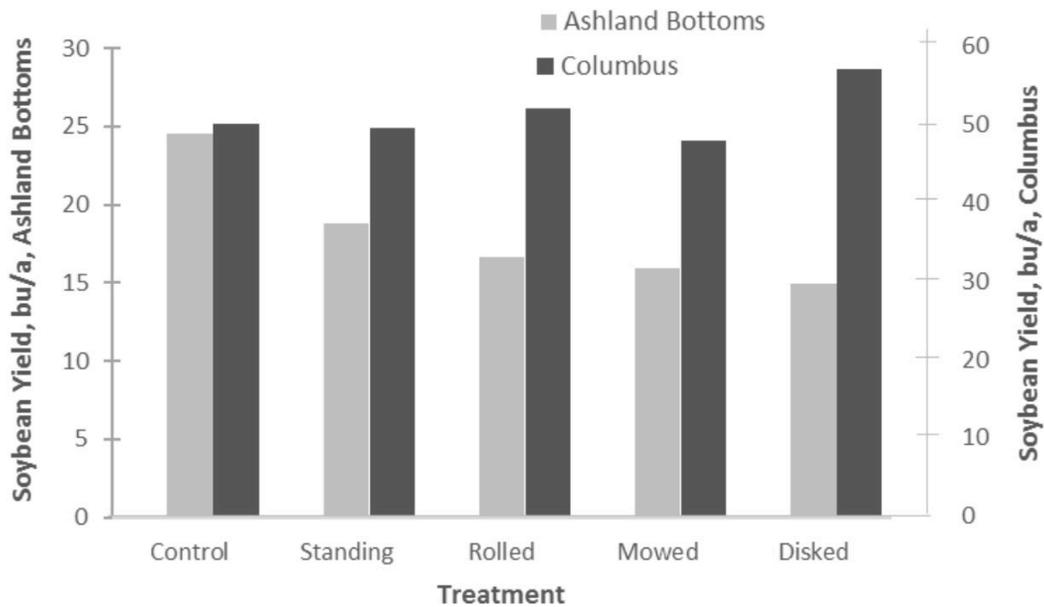


Figure 4. Impact of cover crop residue management method on soybean yield at Ashland Bottoms, KS (left axis), and Columbus, KS (right axis). Note difference in scale between reported yields at Ashland Bottoms and Columbus.

Corn Planting Date and Depth – Impacts on Yield

G.F. Sassenrath, L. Mengarelli, and X. Lin

Summary

Corn growth and production is dependent on environmental conditions during the growing season. Optimal corn growth occurs between 50 and 86°F. Early-season soil temperatures may reduce corn emergence. Conversely, later-planted corn may not have adequate moisture for good pollination and grain production. This research tested the impact of planting date and planting depth on corn yield. The yield decreased with later planting dates. Earlier planting dates had better yield at lower planting depths, but yield was reduced at deeper planting depths at later planting.

Introduction

Temperature and rainfall are important for crop growth and development. Growing degree days, or heat units, are a method of estimating the thermal time and can be related to the physiological growth of crops. Growing degree days (GDD) are calculated by subtracting a base or threshold temperature from the average daily temperature (Knapp et al., 2017), and are now available on the Kansas Mesonet website (<http://mesonet.k-state.edu/agriculture/degreedays/>). For corn, that base temperature is 50°F. Adding the daily GDD gives the cumulative GDD from a date, such as day of planting. Cumulative GDD is a useful tool to estimate crop development and predict crop stage for management inputs. In the early season, soil temperature is important for crop germination and emergence, and impacts stand establishment. Corn grows best between 50 and 86°F; high temperatures can limit grain filling (Ciampitti and Knapp, 2018).

Similarly, rainfall and timing of rainfall is important for crop development. Corn is a determinate crop that flowers only once. The strongly determinate nature of corn makes the flowering period (tasseling and silking) very sensitive to environmental conditions during that one growth period, as the plants cannot flower again if flowering fails due to an adverse environment. Poor environmental conditions, especially low rainfall, can reduce the fertilization of ovules, resulting in unfertilized ovules and reduced yield. If adverse weather conditions of either inadequate rainfall or temperatures that are too high or low continue, fertilized ovules may be aborted and reduce yield.

Climatic conditions cannot be managed. However, management practices can be implemented that make the best use of the environmental conditions. Corn planting in southeast Kansas begins in mid-March after soil temperatures are above 50°F. The later the corn is planted, the warmer the soil temperatures will be. However, previous research has demonstrated the need to time the flowering of corn to adequate moisture in rainfed environments (Sassenrath et al., 2016). Since our highest rainfall period occurs in late May, corn pollination ideally should be timed to occur prior to July 4.

This study was undertaken to explore the impact of planting date and planting depth on corn yield. Soil temperature and moisture change with depth in the soil profile. Planting at deeper depths may allow the corn roots to access more moisture. Conversely, shallower depths may have warmer temperatures and allow more rapid crop growth early in the season.

Experimental Procedures

Corn was planted in replicated plots at the Southeast Research and Extension Center fields in Parsons, KS, in 30 in.-rows at a rate of 23,100 seeds per acre with a Monosem planter. The field was managed with conventional tillage: chisel disk, fertilized with 180-46-60 N-P-K as urea, diammonium phosphate (DAP) and potash, and field cultivated. Weeds were controlled with a pre-emerge mix of glyphosate (2 qt/a), atrazine (1.5 lb/a), and 2,4-D (1 qt/a); and a post-emerge mix of Roundup (1 qt/a), atrazine (1 lb), and 2,4-D (1 qt/a). Roundup was sprayed as needed around V6.

Treatments included four cultivars of varying maturity: 96 day (P9697); 105 day (P0589); 115 day (P1151); and 118 day (P1862). Corn was planted at three planting dates: early (March 25, 2018); mid (April 17, 2018); and late (May 9, 2018); at planting depths of 1, 2, and 3 in.

Weather data were downloaded from the Kansas Mesonet Historical site at Parsons, KS. Growing degree days were calculated from date of planting for each of the planting dates, using a base temperature of 50°F. Daily GDD were summed to determine cumulative GDD50 for each planting date. Similarly, daily rainfall data were summed for each planting date to determine total rainfall for each planting date.

Results and Discussion

Averaged across all cultivars, the corn yield was highest at the earliest planting date. Yield also increased with greater planting depth at the early planting time (Figure 1). Yield was greatest at the 2- and 3-in. planting depths at the earliest planting date compared with the 1-in. depth. No differences in yield were observed with planting depth for the mid-planting date. Conversely, yields were reduced at the latest planting date, and decreased with planting depth. The late-planted 3 in. depth had the lowest yield.

Individual cultivars showed similar response to planting date and depth (Figure 2). The two mid-maturity cultivars performed the best at the early planting date, with yields increasing with planting depths greater than 1 in. The 105-day corn yielded the highest at 2-in. depth and early planting date, and the 115-day corn yielded the highest at the 3-in. depth and early planting date. The 118-day corn yield increased only slightly from the 1 in. to 2-3 in. planting depth. The early-maturing variety showed the strongest response to planting depth at the early planting date, increasing more than 3-fold from the 1 in. to 2-3 in. planting depth.

Yields of all varieties were less at the mid- and late-planting dates. The response to planting depth varied with the mid-planting date. Some cultivars showed increased yield at greater depths while others had lower yield at increased depth. Overall, the

differences in yield between treatments at the mid-planting date were not as great as at the early planting date.

Yields of all cultivars were lowest at the late-planting date. Moreover, yields for all cultivars decreased with increasing planting depth at the late planting time. At the 3-in. planting depth and late planting date, little differences were observed between cultivars.

Corn emergence (VE) is estimated to require 120 GDD50 (DeKalb, 2015). The mid-planted corn was planted 27 days after the early-planted corn, and the late-planted corn was planted 49 days after the early-planted corn. However, the cooler temperatures in spring 2018 delayed emergence of the early-planted corn. It reached 120 GDD50 around June 11, only 2 days before the mid-planted corn reached 120 GDD50 (Figure 3). Similarly, the late-planted corn reached 120 GDD50 11 days later than the early-planted corn, even though it was planted 49 days after the early planting. The rapid warm-up in the spring greatly accelerated the accumulation of heat units in the mid- and late-planted corn.

The vegetative stage of corn is estimated to be complete at tasseling (VT), which requires approximately 1135 GDD50 (DeKalb, 2015). Again, because of the more-rapid accumulation of heat units later in the season, the late-planted corn reached VT only 11 days after the early-planted corn (Figure 3). However, the late-planted corn received more than 2 in. less rain than the early-planted corn.

Summary

Planting date had a significant impact on corn yield, with corn yielding more at earlier planting dates. Although corn yield increased at the early planting date at greater planting depths, yield was reduced at the later planting date as depth increased. There was a difference in response to planting date and depth between corn cultivars of differing maturity; however, since we did not test multiple cultivars from each maturity group, we are not sure if it was because of the maturity or the individual variety. Later-planted corn acquired heat units much faster than early-planted corn, but also received less total rainfall. This may have accounted for the observed reduction in yield with later planting.

Acknowledgment

This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478.

References

- Ciampitti, I., Knapp, M. 2018. Effect of high night temperatures on corn yield. *Agronomy eUpdate*. Iss 701, July 6th, 2018. https://webapp.agron.ksu.edu/agr_social/eu_article.throck?article_id=1887
- DeKalb. 2015. Corn Growth Stages and Growing Degree Units. *AgKnowledge Spotlight*.
- Knapp, M., C. Redmond, D. Regier. 2017. New Mesonet growing degree day calculation web page. *Agronomy eUpdate*. Iss 619, March 17th, 2017. https://webapp.agron.ksu.edu/agr_social/eu_article.throck?article_id=1305

Sassenrath, G., Shoup, D.E., Lin, X., Coltrain, J., Geren, J., Helwig, D. 2016. Improving corn production in southeast Kansas. Kansas Agricultural Experiment Station Reports. Vol 2, Iss. 3. <https://doi.org/10.4148/2378-5977.1201>

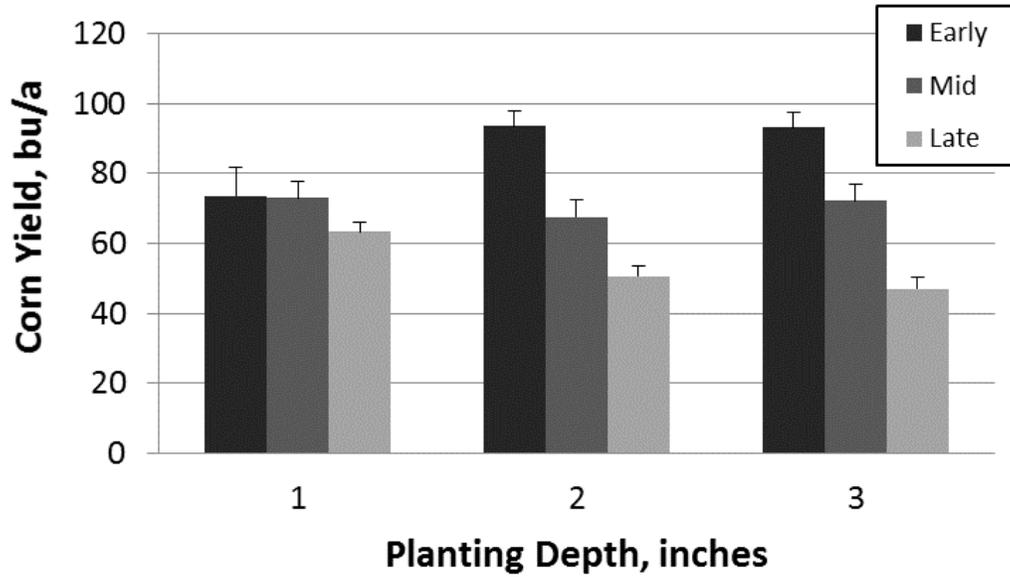


Figure 1. Impact of planting date and planting depth on corn yield.

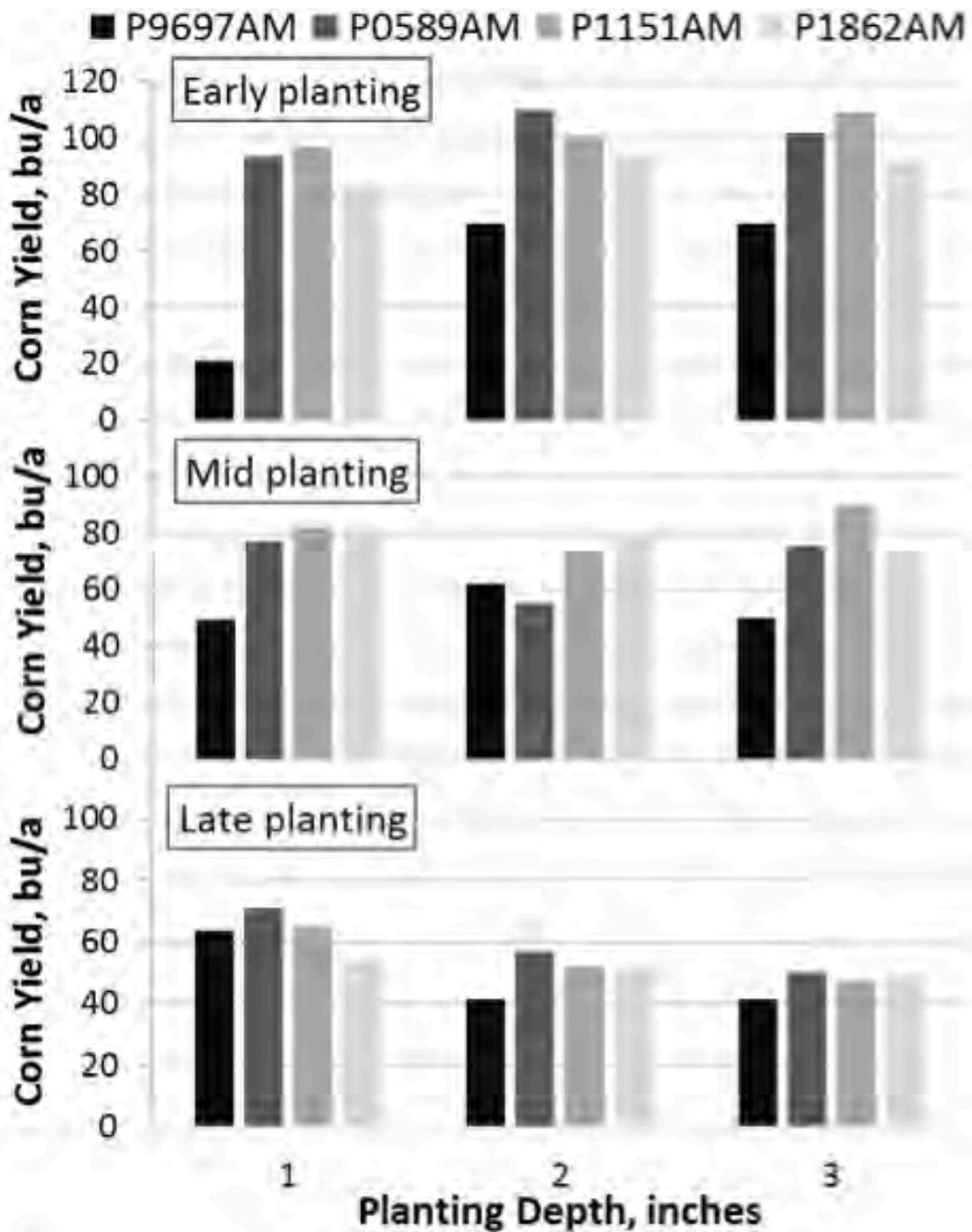


Figure 2. Change in corn yield for 96-day, 105-day, 115-day, and 118-day maturity for early (March 25), mid (April 17), and late (May 9) planting dates and at 1-, 2-, and 3-in. planting depths.

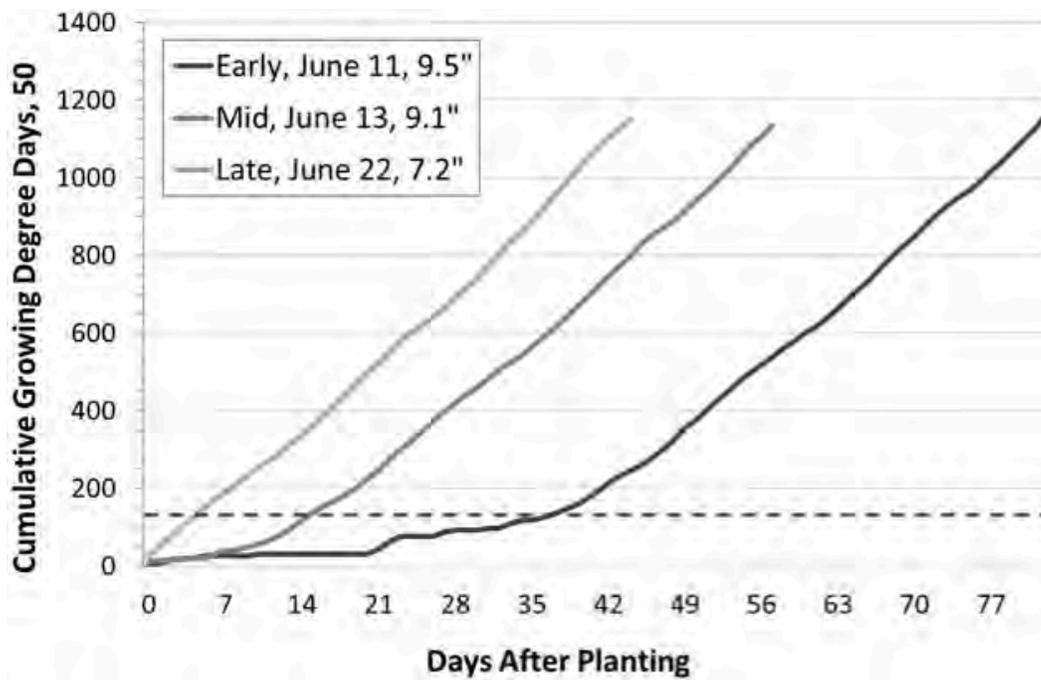


Figure 3. Cumulative growing degree day-50 (GDD50) for the early (black), mid (dark grey), and late (light grey) planting dates. Emergence requires about 120 GDD50 and is indicated by the dashed line. Estimated date of tasseling (VT) is given with total rainfall received for each planting date group.

Modeling Wheat Susceptibility to Disease

H. Zhao, G.F. Sassenrath, X. Lin, R. Lollato, and E. De Wolf

Summary

Fusarium Head Blight (FHB) or head scab is a disease caused by the soil-borne *Fusarium* fungus. The disease occurs frequently in southeast Kansas and can result in reductions in wheat yield and quality because of the mycotoxins developed by the fungus. Timely application of fungicides during the heading period of wheat is one option to reduce the fungus and control the infection rate. This study reports our research on use of fungicides to control head scab and improve wheat yield. We developed a model to predict wheat heading date. Accurate knowledge of wheat stage is the first step in developing a good production management tool for timely application of fungicide for disease control.

Introduction

Fusarium Head Blight (FHB), or head scab, is a disease that occurs frequently in southeast Kansas. The impacts of FHB have been well documented for decades and often result in significant reductions in yield and profitability (De Wolf et al., 2018). However, the most damaging aspect of FHB is the reduction in wheat quality caused by the mycotoxin deoxynivalenol (DON or vomitoxin) associated with the disease, often rendering wheat unfit for human consumption. This leaves the producer and grain elevators with a product that needs to be segregated and hopefully is good enough to market as a feed grain. In the event of extreme infection rates, however, the grain must be destroyed because of high DON levels that render the grain unusable even as an animal feed.

Extensive research has documented the potential of controlling FHB through a management system that integrates cultivar selection, fungicide application, residue management, and crop rotations (Wegulo et al., 2015). The hard red wheat cultivar Everest has been shown to have moderate levels of resistance to FHB and is commonly planted in southeast Kansas. Application of fungicides has been shown to provide some control for fusarium infection and is most efficacious when applied near wheat heading (De Wolf et al., 2003). High humidity and rainfall during the wheat heading period create conditions for optimal development of Fusarium head blight (De Wolf et al., 2003, 2018). Therefore, knowledge of the progression of wheat development and an accurate estimation of future climate are useful management tools for timely application of fungicides for control of FHB.

Here, we report the results of experiments testing the impact of fungicides on improving wheat yield over the past three years. To reduce input costs, farmers may limit the use of fungicides. However, weather conditions in southeast Kansas during wheat flowering tend to exacerbate FHB infection in wheat. As a first step in predicting the need for fungicide, we developed a model of wheat development to predict the potential time period of wheat heading. This information can then be linked with a climate prediction model to provide farmers with a management tool to determine potential disease susceptibility for timely application of fungicides.

Experimental Procedures

Field experiments tested the impact of fungicide use on wheat in 2016, 2017, and 2018. The hard red wheat variety Everest was planted in the fall of each year in replicated plots using a Great Plains grain drill at 7-in. row spacing. The fungicide Prosaro (Bayer Crop Science, Inc.) was applied to the wheat near heading (Feekes 10-10.1) at a rate of 6 oz/a. This fungicide has been shown to provide some control of FHB when applied near heading (De Wolf, 2018). Control plots received no fungicide.

Weather information was downloaded from the Kansas Mesonet historical website (<http://mesonet.k-state.edu/weather/historical/>). All weather data are reported during the wheat growing season from October through June. Wheat growth models use climatic information to estimate wheat development stage. Wheat growth can be modeled using accumulated thermal time. The accumulated thermal time is calculated as the sum of daily maximum and minimum crown temperature. Some models also account for deleterious temperatures through temperature correction factors that account for temperatures that are too high or too low. In this study, we used two previously published wheat phenology models, and modified one of the models to better capture environmental growing conditions in southeast Kansas.

Results and Discussion

Wheat has distinct stages of development that are described using the Feekes scale (Lollato, 2016). The scale is a useful tool to describe wheat development and time management inputs such as fungicides and fertilizers to the appropriate growth stage. Wheat heading occurs from Feekes 10.1 (first spikelet of head is visible) through Feekes 10.5 (all heads are out of the sheath). Flowering then begins at Feekes 10.51. The critical times for application of fungicides to control FHB infection occur just prior to and at heading.

Weather at Parsons, KS, shows a distinct rainfall pattern (Figure 1), with rainfall occurring in the fall, followed by a dry winter. The wettest period occurs during the spring. Wheat planting and establishment begin in the fall. The susceptibility of wheat to low ambient temperatures varies significantly during different growing stages. During the emergence stage around October, wheat growth is optimal at daily mean temperatures above 50°F. Wheat enters a dormant period during the freezing winter. During the dormant period, wheat undergoes the process of vernalization. During this time, wheat has the greatest resistance to low temperatures, but can possibly be damaged by temperatures below 23°F and certainly below 14°F. Fortunately, during this growth stage, the growing point is protected below the soil surface. Dormancy is broken in the spring, and wheat loses cold-hardiness and begins the rapid growth stage of stem elongation. At the completion of the vegetative stage, wheat enters the reproductive stage of heading and flowering. During this stage, wheat can be very sensitive to low temperatures. This is also the critical period for fungal diseases. High humidity and warm temperatures are particularly favorable for disease infection. Control of disease during this time period is the most critical. After flowering, grain filling continues until maturation of the wheat grain.

The potential rainfall patterns for southeast Kansas have a very high probability of rainfall during the critical flowering period (Figure 1). Yield increases were observed in two of the past three years with use of Prosaro fungicide (Figure 2). In 2016, wheat yield increased from 70 to 85 bu/a with use of fungicide. In 2017, yield increased from 36 to 61 bu/a with use of fungicide. No yield increase was observed in 2018 with use of fungicide.

Acknowledgment

This work is supported by the USDA National Institute of Food and Agriculture, Hatch project 1003478, with partial funding from the Kansas Crop Improvement Association.

References

- De Wolf, E.D., Madden, L.V., Lipps, P.E. 2003. Risk assessment models for wheat Fusarium Head Blight epidemics based on within-season weather data. *Phytopathology*. 93:428-435. doi: 10.1094/phyto.2003.93.4.428.
- De Wolf, E.D. 2018. Foliar fungicide ratings for wheat disease management 2018. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. EP130.
- Lollato, R.P. 2016. Wheat growth and development. Kansas State University Ag Exp Station and Coop Ext Serv. MF3300. <https://www.bookstore.ksre.ksu.edu/pubs/MF3300.pdf>
- Wegulo, S.N., Baenziger, P.S., Nopsa, J.H., Bockus, W.W., Hallen-Adams, H. 2015. Management of Fusarium head blight of wheat and barley. *Crop Protection* 73:100-107. doi:10.1016/j.cropro.2015.02.025

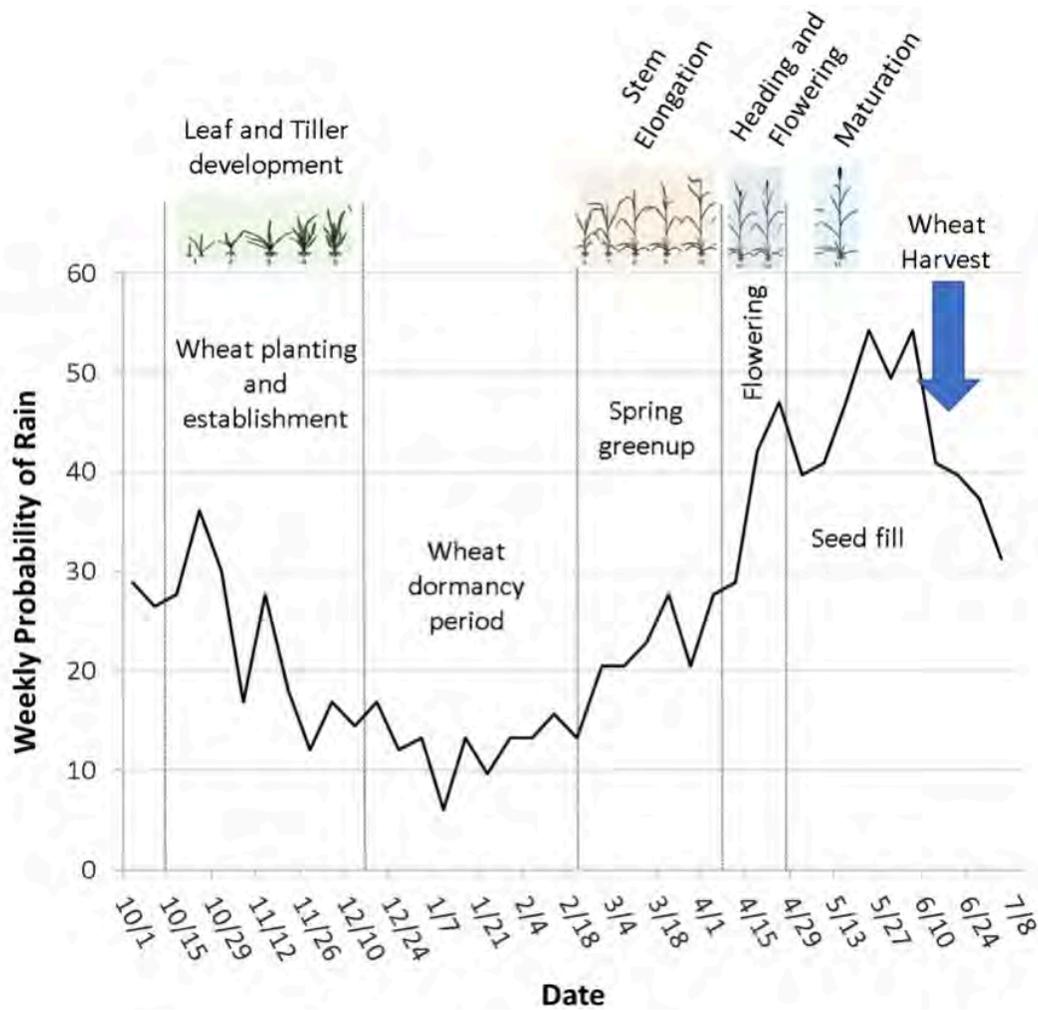


Figure 1. Wheat growth stages and probability of weekly rainfall in excess of one inch in Parsons, KS.

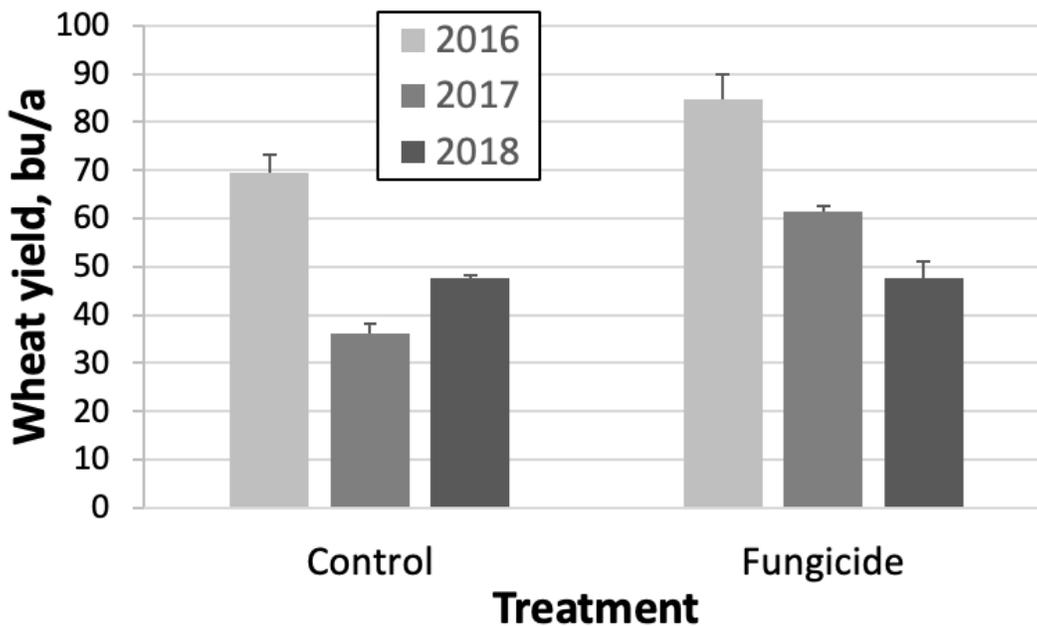


Figure 2. Impact of Prosaro fungicide use on wheat yield.

Using Cover Crops as an Effective Weed Control Method in Southeast Kansas

L.I. Chism, J.A. Dille, and G.F. Sassenrath

Summary

Weed control is important to optimize crop production. This study was conducted to compare the effectiveness of different methods of fall-implemented weed control strategies. These strategies included different cover crop mixes, chemical control, and mechanical control. The cover crop mixes included four different commonly-planted winter cover crops. The chemical control was a fall-applied burndown, and the mechanical control was vertical tillage. We found cover crop mixes that contained cereal rye provided the most weed control, with the chemical control being a close second. Spring oats die during the winter because of the low temperatures. The three cover crop mixes containing spring oats still provided 50% reduction in weed biomass the following spring. However, the fall tillage increased the amount of weed biomass.

Introduction

Weed control is critical for good crop production. Several different approaches to weed control are available. The most common forms of weed control include mechanical and chemical methods. Mechanical weed control uses implements to till the soil, disrupting weed growth and establishment. Mechanical tillage has been employed in agriculture for centuries. While well-established, mechanical weed control has limitations. The disturbance of the soil can impair soil quality by breaking down the soil structure. Tillage also contributes to soil and nutrient loss from wind and water erosion. More importantly, tillage can actually exacerbate weed control by redistributing weed seeds.

With the improvements in chemistry, weed control methods have shifted to chemical control. Recent advances have provided farmers with many herbicides that have specific actions for weed control. The use of pre-emergent residual herbicides has benefitted the producer by maximizing their efficiency and reduced the need for post-planting applications. However, chemical weed control does come with some limitations. We continue to see the development of weed populations that are resistant to several herbicides. As the number of resistant weeds increases, the need for more herbicide sites of action (groups) in a tank mix is needed to optimize weed control, increasing the cost of application. Environmental factors are also a concern with the use of herbicides, especially with some residuals such as atrazine, which can persist in the soil and contaminate water.

A third option that is emerging as a viable form of weed control is the use of cover crops. Cover crops are primarily planted for use other than harvesting. Utilizing cover crops can provide many benefits including weed control, retaining soil moisture, adding soil organic matter, reducing erosion, and improving soil aeration and nitrogen fixation, depending on the species. Cover crops can be planted at any time of the year but fall and spring are most common. For many of the rotations we see in Kansas, fall planted cover crops fit well without affecting the planting time of the subsequent cash crop.

Fall planted cover crops are also ideal in the sense that they provide a much longer time for weed suppression. Cover crops are typically terminated within a few weeks prior to planting a spring crop, but there are also other options to utilize cover crops. They can be grazed throughout the winter, providing additional profits for the grower.

Southeast Kansas has several unique challenges that limit good, consistent crop production. The rich silt loam topsoil is shallow in depth and overlies an unproductive claypan layer. Conventional tillage can further reduce this productive layer by increasing soil loss through erosion. Moreover, several weed species have become resistant to traditional chemical control methods, requiring use of more expensive chemical herbicides. One of the major goals for weed scientists, agronomists, and crop producers is to diversify and integrate our weed management practices in order to limit the evolution of herbicide-resistant weeds. Using cover crops as a weed control method offers farmers several advantages. In addition to reducing weed species, cover crops keep the soil covered, thereby reducing erosion. Cover crops may also improve the soil health, increasing crop productivity. Cover crops can also reduce the expense of weed control while providing additional benefits that are not easily accounted for, but can have long-term improvements to the crop system.

This experiment was located three miles south of Girard, KS, in an eight-acre field. The field was known to have high populations of winter annuals, such as marehail (horseweed), and summer annuals such as common waterhemp. These were the two weeds targeted for control. Tillage is the preferred form of weed control in southeast Kansas and is used at a much higher rate comparatively than in the rest of the state. In this study we tested the weed control benefits that could be provided by using cover crops.

Experimental Procedures

This study contained nine treatments with three replications. Six different cover crop mixes were planted within a week after corn harvest in September 2017 (Table 1). The cover crops chosen included two grasses: cereal rye, which produces high biomass amounts, and spring oats. The spring variety of oats was chosen to reduce the need for chemical burndown in the spring. One legume, clover, and a brassica, tillage radish, were also planted as cover crops. Clover will add to the soil health by fixing nitrogen. Tillage radish improves soil structure because of the large tap root that creates macro-channels in the soil. One advantage of tillage radish over other brassicas, such as purple top turnip, is that the tillage radish will winter-kill, which reduces the need for spring burndown chemicals prior to planting the cash crop. The chemical burndown and vertical tillage treatments were both performed after cover crops were planted. The chemical burndown was a tank mix of 32 oz/a glyphosate (Buckaneer Plus, 4 lb/gallon, Tenkoz, Inc.), 12 oz/a dicamba (Banvel, 4 lb/gallon, Arysta Lifescience, LLC), and 0.3 oz/a chlorsulfuron + metsulfuron (Finesse, 62.5% + 12.5%, DuPont, Inc.). The ninth treatment was fallow, where no weed control was done, which served as the check.

On May 17, 2018, weed species were identified and counted, and weed and cover crop biomass were harvested. Biomass was collected and recorded for a total of 10 ft² per plot, using quadrats placed in four separate locations throughout each individual plot (Figure 1). The weeds and cover crops within these quadrats were clipped at the ground using garden shears and put into paper bags. After the biomass was collected, it

was dried and weighed on campus in Manhattan to determine the final dry weight in pounds per acre.

Results and Discussion

After the biomass of the weeds was dried and weighed, they were compared to the non-treated check (Figures 2 and 3A). A percentage was then calculated to represent the weed control effectiveness (Figure 2). The first treatment contained cereal rye, the second treatment contained a cereal rye and clover mix, and the third contained cereal rye and radish. All three treatments containing cereal rye resulted in a reduction in weed biomass of 98% compared to the check (Figures 2 and 3D). Within those rye cover crop plots, most of the biomass was cereal rye (Figure 2). The fourth treatment of oats provided a reduction of weed biomass by 46%. The fifth treatment contained a mix of oats and clover which reduced weed biomass 55%. The sixth treatment was a mix of oats and radish, reducing weed biomass by 47%. While the three cover crop treatments containing oats had little to no cover crop biomass in the spring due to winter-kill of the cover crops, there was still an average of 50% reduction in weed biomass.

The chemical treatment, with fall applied glyphosate, Banvel, and Finesse, resulted in a 96% reduction in weed biomass (Figures 2 and 3C). While all other treatments contained a diverse population of weeds composed of winter annuals in May, the chemically-treated plots were primarily dominated by waterhemp. Surprisingly, the mechanical treatment of fall tillage increased the amount of weed biomass by 6% compared to the non-treated check (Figures 2 and 3B).

This experiment demonstrates the potential for using cover crops to control winter annuals, and the problems with tillage. Tillage increased weed production more than the untreated plots. While the chemical treatment was approximately the same in weed control, the chemical treatment resulted in a higher population of waterhemp. While we did not specifically test the waterhemp, it was potentially herbicide-resistant. Moreover, use of a rye cover crop would provide additional benefits by increasing the organic matter in the soil because of the high biomass produced. Increased productivity has been observed as soil organic matter increases. Use of rye as a cover crop may not be ideal in wheat-producing areas, but alternative grain crops are available for use as cover crops that are inexpensive and have good biomass production in our area. Research is continuing to examine other potential cover crops and their weed-suppressing potential. We are also comparing costs of production for chemical, mechanical, and cover crop weed control approaches. The goal is an integrated approach to weed control that improves the productivity and profitability of the agronomic system. Note, however, that many of the benefits of cover crops are found in soil health improvements—such as increased organic matter content—for which determination of explicit economic value is difficult.

Acknowledgments

This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478, with partial grant funding from the Kansas Natural Resources Conservation Service Conservation Innovation Grant. We gratefully acknowledge the cooperation of the participating farmers in providing us access to their land and working with us to implement the treatments.

Table 1. Cover crop mixes, chemical, and mechanical treatments

Treatments	
1	Rye
2	Rye + clover
3	Rye + radish
4	Oats
5	Oats + clover
6	Oats + radish
7	Chemical (32 oz glyphosate, 12 oz Banvel, 0.3 oz Finesse)
8	Tillage
9	Fallow (check)

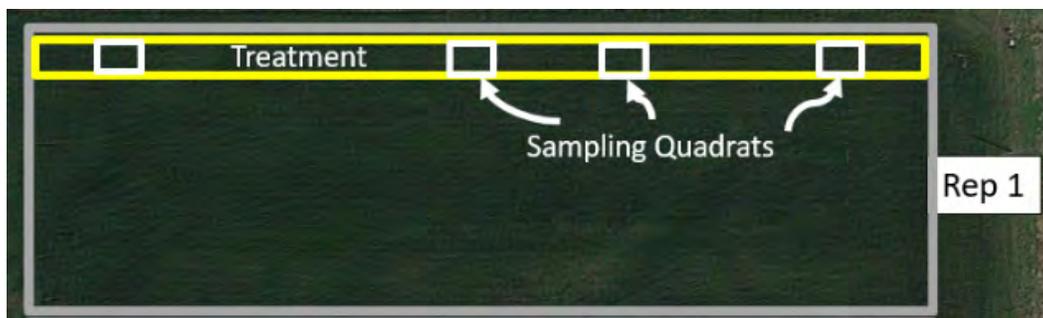


Figure 1. Aerial image of a portion of the crop field, demonstrating four sampling quadrats from a single treatment within a replication. All of the cover crop and weed biomass was collected from within each quadrat. The cover crop and weed biomass were separated, dried, and weighed to determine total production within each quadrat and each replicated plot.

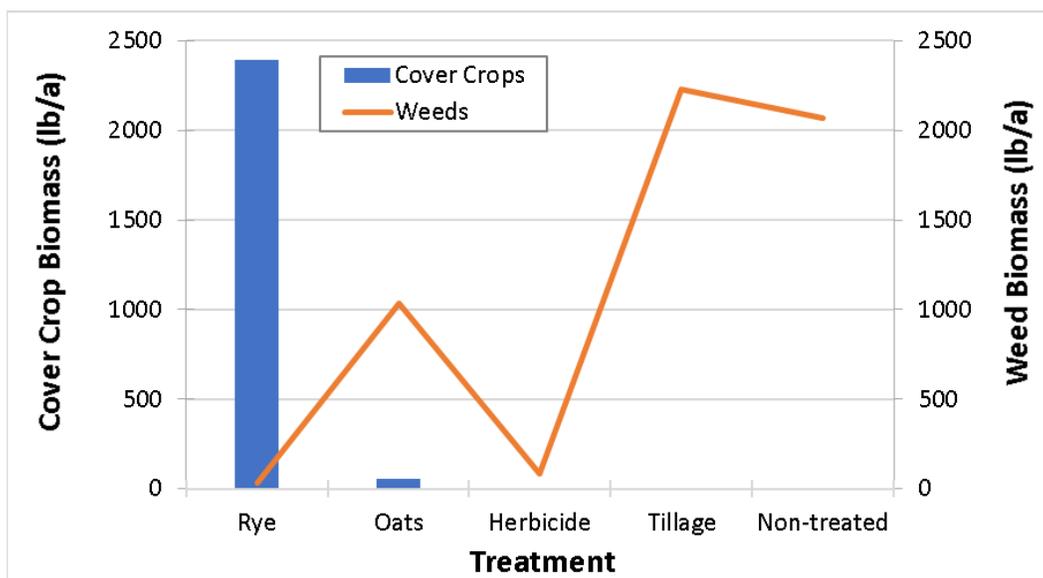


Figure 2. Weed biomass response to treatments (orange line, right axis) and total cover crop biomass production (blue bars, left axis).

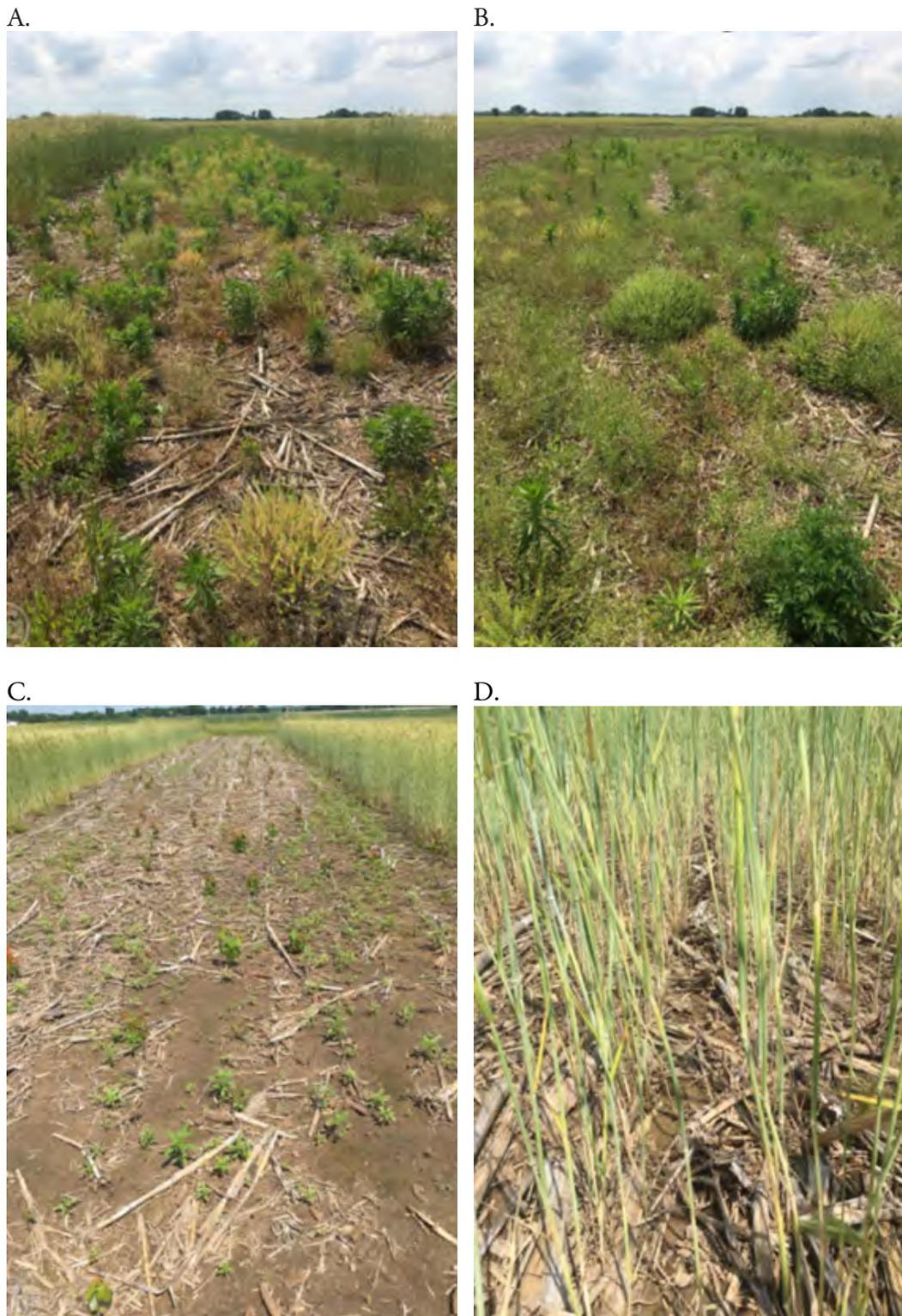


Figure 3. Pictures of plots in spring of 2018. A. Non-treated check. B. Mechanical control – vertical tillage in fall. C. Chemical control – fall-applied herbicide. D. Cereal rye cover crop.

Biomass Production of Single Species Cover Crop

G.F. Sassenrath and J.K. Farney

Summary

Cover crops can benefit agricultural production by improving soil health and productivity, reducing weeds, and providing biomass for grazing. In this one-year study, biomass production was measured in 17 different single species summer cover crops and a fallow control. Overall, grass species produced more biomass than brassicas, with legumes, broadleaves, and fallow yielding intermediate amounts of biomass. Within the grass species, pearl millet, brown midrib (BMR) sorghum, and sorghum sudan produced more biomass than proso millet; German millet and browntop millet had intermediate biomass production. Within the brassicas, both brown and yellow mustards produced more biomass than collards. There was no difference in biomass production within the broadleaf species or the legume species tested. Plots that produced higher amounts of biomass also had fewer weeds, indicating the potential for cover crops to reduce weed growth and establishment. The cost of biomass production varied widely between the cover crops, with the broadleaf and grass species being the least expensive. Choice of a cover crop depends on the goals. Based on cost, weed suppression, and grazing potential, the most suitable cover crops identified in this study were pearl millet, BMR sorghum, sorghum sudan, German millet, okra, and cowpea.

Introduction

Cover crops have a long history of use in agricultural production systems. The USDA 1938 Yearbook of Agriculture (USDA, 1938) refers to their use in maintaining soil organic matter. Sweet clover was commonly used as a green manure to provide nitrogen to the soil. A cover crop is typically grown during the dormant period following a grain crop and terminated before the planting of the next cash crop. Cover crops can also be used to provide grazing, reducing feed costs for cattle production. Cover crops are also valuable for reducing soil erosion and building the soil for improved productivity of the subsequent crop. Keeping the ground covered with a cover crop can also be a method of reducing weed pressure.

There are many new options of cover crops available to producers, many with highly-touted benefits. Multi-species cover crop mixtures are often promoted as being beneficial. However, these mixes can be quite expensive, though the exact benefits are not clear. Alternatively, single species cover crops have been demonstrated to provide sufficient biomass and nutritional quality for grazing and are potentially much more economically feasible (Farney et al., 2018a, b).

Research is needed on how cover crops grow. The actual impacts of cover crops on the agricultural system are not clear. This study was undertaken to determine how different types of cover crops grew in southeast Kansas. Total biomass production was measured. Impact of cover crop on weed production was also noted.

Experimental Procedures

Cover crops were planted in 10 × 40 ft. replicated plots at the Southeast Research and Extension Center research fields near Columbus, KS. Cover crops were selected based on recommendations from the Midwest Cover Crops Council Cover Crop Decision Tool for Cherokee County, KS (<http://mccc.msu.edu/covercroptool/covercroptool.php>). Plant species were selected for the following characteristics: biomass production (residue); grazing capacity; soil health-building ability; weed suppression; or nitrogen fixation (Table 1). Seventeen cover crops were chosen, with a fallow treatment that had no cover crops planted in it.

Cover crop seed was purchased from Green Cover Seed, Bladen, NE, and DeLange Seed, Inc., Girard, KS. Prices are based on purchase costs of 50 pounds.

Results and Discussion

Biomass Results

Biomass production varied by cover crop (Figure 1). The grasses had the highest biomass production, and of those, pearl millet, sorghum sudan, and BMR sorghum produced the greatest amount of biomass. Okra, cowpea, German millet, and sunn hemp produced intermediate amounts of biomass, roughly equivalent to that produced by the weeds in the fallow treatment. The weed species were mostly crabgrass and foxtail. Pigweed was found in some of the treatments.

Some interesting observations were made with weed pressure. For most of the cover crops with lower biomass (less than ~3000 lb dry matter/a), the weed pressure was high. One notable exception was the collards. The collards had the lowest biomass production (1435 lb/a), but no weed pressure. This may result from the compact growth habit of collards, with the growing point close to the soil surface, and large leaves that shaded out weeds (Figure 2). Collards also had the second-highest water content of any of the cover crops (data not shown); therefore, the dry matter measurement may not adequately capture the amount of plant material in the plots. Note that common vetch, mung bean, and spring forage pea all had biomass slightly greater than 4000 lb/a, but only mung bean had no weeds. This resulted in part because of the greater canopy coverage by the mung bean, effectively shading out weeds (Figure 2).

The biomass clippings reported here were taken nearly 60 days after those reported in Farney and Sassenrath (2019). As observed at the earlier harvest date, the highest biomass was produced by the grasses, particularly pearl millet, sorghum sudan, and BMR sorghum. The extra growth time appeared to allow the spring forage peas a greater biomass production than found in the earlier sampling period in July but was still insufficient to reduce weed pressure.

Costs to plant the species varied widely from a low of \$5/a for okra to a high of \$49.20/a for cowpeas (Table 1). Seeding rates were based on the average suggested planting rate. Costs for biomass production were cheapest for brassicas and grasses (Figure 3). Costs per ton of biomass were also low for cowpea and spring forage pea, but spring forage pea did not produce sufficient canopy to reduce weed pressure. Although collards were good at suppressing weeds and are reported to be excellent forage

(GreenCoverSeed.com), the cost per ton of biomass produced was the highest of all the 17 cover crops tested.

In summary—based on cost, weed control, and grazing potential—pearl millet, BMR sorghum, sorghum sudan, German millet, okra, and cowpea were all suitable cover crops. Brassicas such as mustard may improve the soil health. Yellow mustard in particular has higher glucosinolate concentrations than other brassicas and has been shown to reduce certain soil-borne diseases (Sassenrath et al., 2017, 2019). However, the mustards cost more than average per ton biomass produced and were not good at suppressing weeds. Moreover, they have limited grazing potential. Mung bean and sunn hemp were able to reduce weed pressure and are a potential source of additional nitrogen. However, the cost per ton of biomass for mung beans is high. Moreover, it is not clear whether sunn hemp is safe or palatable for cattle to graze. The safflowers, brown-top millet, and proso millet were inexpensive to produce, but did not reduce weed pressure. Cattle will not graze safflower, though the millets should be good forage quality.

Crop producers are accustomed to receiving accurate, detailed information about seed for crop production. Unfortunately, cover crop seeds are not nearly as well regulated, and information of specific genus and species for cover crops are often not available. Additional information, such as planting rates, fertility requirements, and germination are also often lacking. More critically, detailed information about potential toxicity of cover crop seed or foliage is not readily available. For a more detailed description of cattle preference to some of the plant species discussed in this section please refer to Farney (2019) in this experiment station report. Additionally, a detailed list of potential toxicity issues and management for toxicity issues can be found in the extension publication MF3244 (Farney et al., 2018). Many cover crops have potential toxicity concerns for cattle producers, and thus understanding the potential issues and management strategies will aid in selection of plants to use as both a cover crop and forage.

Acknowledgment

This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478.

References

- Farney, J.K. (2019) Cattle Preference for Annual Forages. Kansas Agricultural Experiment Station Research Reports: Vol. 5: Iss. 2.
- Farney, J.K., G.F. Sassenrath. 2019. Evaluating single and multi-species summer cover crops for biomass yield. Kansas Agricultural Experiment Station Research Reports: Vol. 5: Iss. 2
- Farney, J.K., D. Shoup, D. Rethorst, D. Blasi, J. Holman. 2018. Forage Crops Grazing Management: Toxic Plants. K-State Research and Extension. [MF3244](#).
- Sassenrath, G.F., Little, C.R., Hsiao, C.-J., Shoup, D.E., Lin, X. 2017. Cover crop system to control charcoal rot in soybeans. Kansas Agricultural Experiment Station Research Reports. Vol. 3: Iss. 2. <https://doi.org/10.4148/2378-5977.1383>.
- Sassenrath, G.F., Little, C.R., Roozeboom, K., Lin, X., Jardine, D. 2019. Controlling soil-borne disease in soybean with a mustard cover crop. Kansas Agricultural Experiment Station Research Reports: Vol. 5: Iss. 2.

USDA. 1938. Soils & Men. Yearbook of Agriculture. Government Printing Office.

Available online at: <https://naldc.nal.usda.gov/download/IND50000140/PDF>**Table 1. Benefits and agronomics of cover crops used in the study**

Cover Crop	Benefits*					Agronomics	
	Residue	Good grazing	Soil builder	Weed fighter	Nitrogen source	Seeding rate, lb/a	Price \$/a
Brassica							
Collards ¹	1	4	3	3	0	8	15.20
Brown mustard	1	0	2	3	0	8	15.60
Yellow mustard	1	0	2	3	0	8	29.25
Broadleaf							
Okra ¹	2	2	2	2	0	5	5.00
Baldy safflower	3	0	1	1	0	15	11.20
Safflower	3	0	1	1	0	15	11.20
Grass							
Brown midrib sorghum	4	3	4	4	0	20	33.30
Sorghum sudan	4	4	4	4	0	20	27.00
Brown top millet	3	3	3	3	0	20	13.00
German millet	3	3	3	3	0	20	10.00
Pearl millet	4	4	4	4	0	20	26.75
Proso millet	3	3	3	3	0	20	7.50
Legume							
Cowpea	1	3	3	2	4	50	49.20
Mung bean	1	2	1	1	3	15	5.10
Spring forage pea	1	3	1	1	3	50	31.20
Common vetch	1	0	2	2	3	25	5.70
Sunn hemp	4	1	3	3	4	15	18.60

*: 0 = poor; 1 = fair; 2 = good; 3 = very good; 4 = excellent; from the Midwest Cover Crops Council.

¹Information from GreenCoverSeed.com.

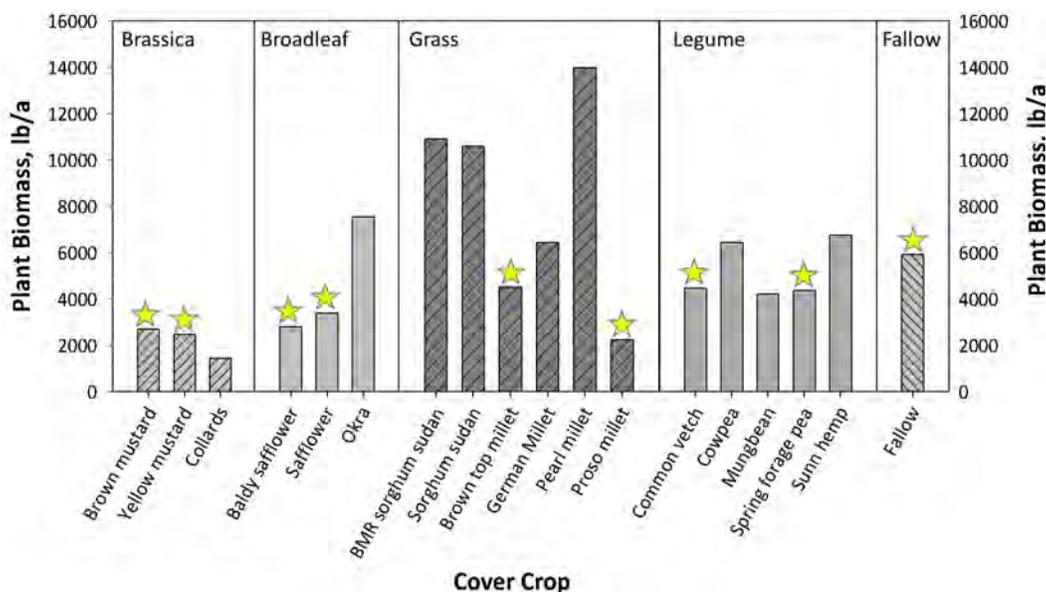


Figure 1. Biomass production from 17 single species cover crops and fallow. Averages of three replications are given. Plots with high weed pressure are indicated by a star. Fallow was entirely comprised of weeds.

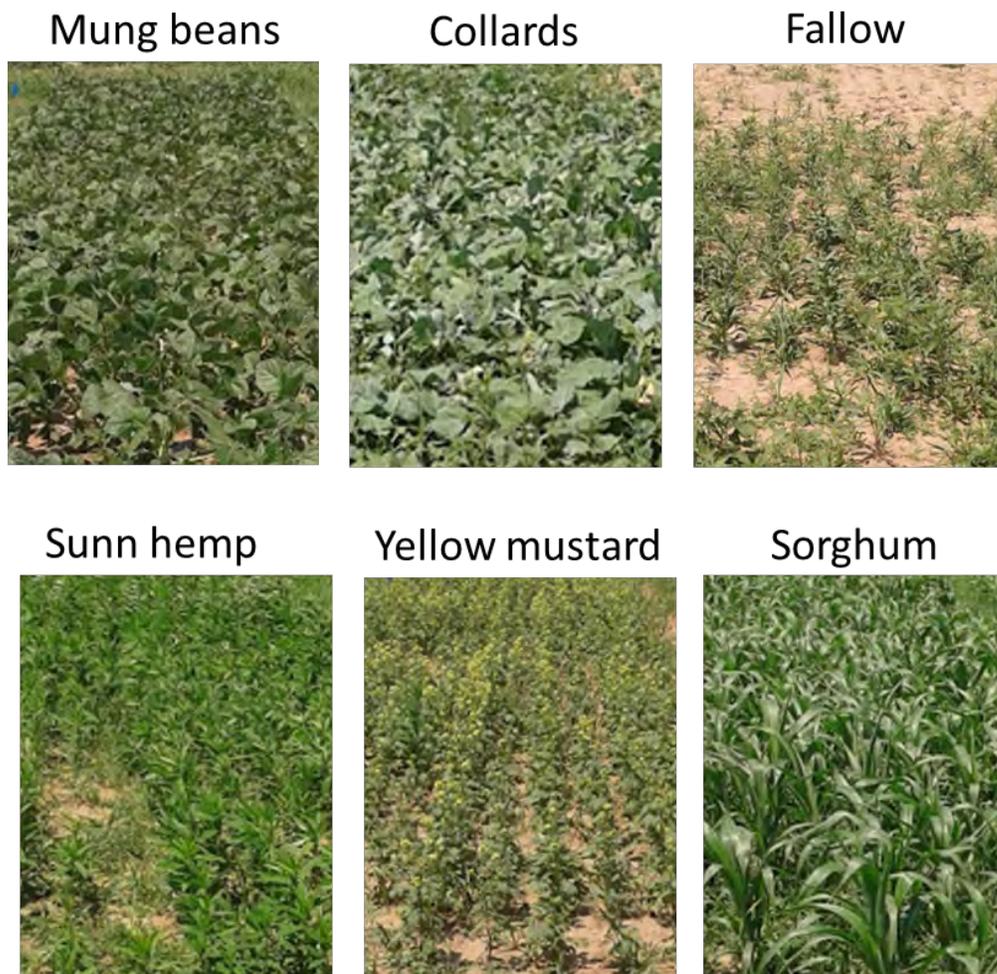


Figure 2. Cover crops in early summer 2018.

CROPPING SYSTEMS RESEARCH

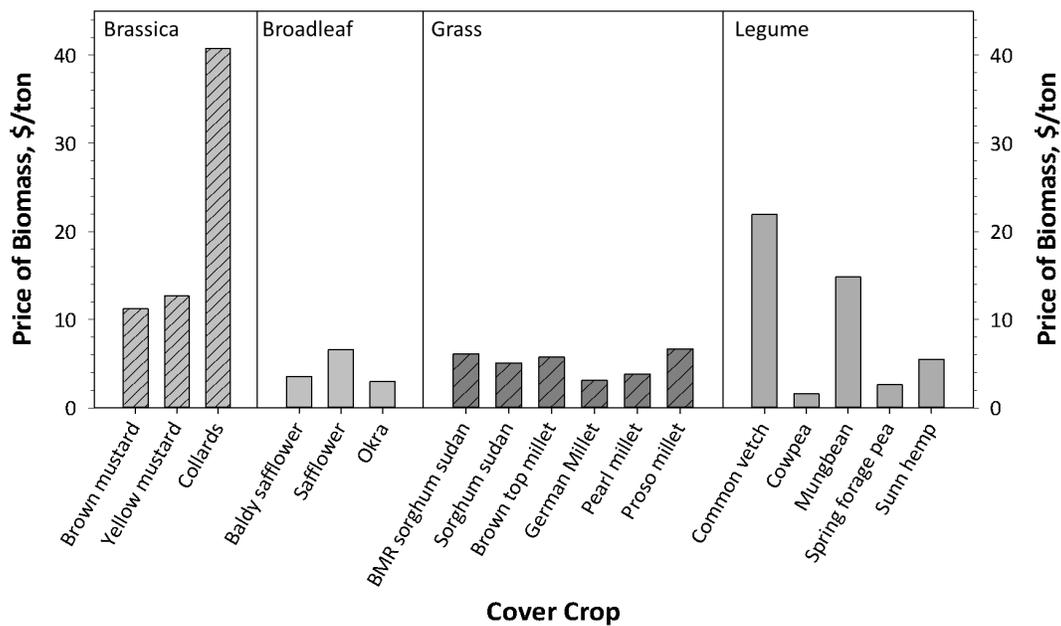


Figure 3. Cost of production per pound of biomass produced for the 17 cover crop species, \$/ton.

Characterization of Claypan Soils in Southeastern Kansas

M.A. Mathis II, S.E. Tucker-Kulesza, and G.F. Sassenrath

Summary

Soil erosion reduces topsoil depth. In areas with a claypan, removal of productive topsoil reduces crop yield where the claypan layer is near the surface. The topsoil and claypan layer each have unique characteristics that impact crop production and within-field variability. To better understand these differences, the soils from an area of low crop yield and high crop yield were collected and laboratory tests were performed to determine the soil classification and undrained shear strength. Understanding the soil properties and the interaction between the topsoil and claypan layers may aid in understanding the process by which topsoil is being eroded.

Introduction

Claypan soils are characterized by a highly impermeable clay layer within the soil profile that may act as a barrier to infiltrating water and root growth. Claypan soils are usually resistant to erosion and as a result the soil overlying the claypan layer may erode more easily. To better understand the difference in soil properties between the claypan layer and the topsoil, we closely examined different soil layers in two crop production fields in southeast Kansas.

Scientists and engineers classify soil differently. Scientists rely on soil particle size, while engineers rely on both particle size and behavior of the soil. Soil particle size generally indicates the type of soil (i.e., sand, silt, or clay). Sand particles range from 0.4 to 16 gnat's eye in size, while silt particles range from 0.016 to 0.4 gnat's eye in size and clay particles are less than 0.016 gnat's eye in size (Coduto et al., 2011). The "behavior" that engineers use also indicates the range of water content over which soil is moldable (i.e., plastic). There are different soil classification systems. Agronomists commonly use the United States Department of Agriculture soil texture classification, which is based only on particle size (NRCS, 2019), while engineers use the Unified Soil Classification System (USCS; ASTM, 2017b).

Engineers classify soils using the USCS, which relies on both particle size distribution and the Atterberg limits test, which measures the plasticity behavior of the soil. Particle size distribution is used to characterize the soil based upon the range of soil particle sizes in a soil sample. In this research, the soil samples are classified as either lean clay or fat clay according to the USCS. Lean clay has a particle size less than 0.016 gnat's eye and a low plasticity. Fat clay has a particle size less than 0.016 gnat's eye and a high plasticity.

The particle size distribution is based on a wet and dry sieve test of the soil to determine the distribution (in percent) of soil particle sizes. First, a wet sieve test is conducted to determine the percentage of silt and clay-sized particles. The wet sieve has a mesh of 200 openings per square inch (i.e., P_{200}). Soil particles larger than this sieve size are retained on the sieve and are dry sieved separately. Next, a dry sieve test is conducted to

determine the distribution of soil particles larger than the 200-openings per square-inch sieve. Conversely, silt and clay-sized particles are finer than a 200-openings per square-inch sieve and pass through the sieve. Finally, a hydrometer test is conducted to determine the distribution of silt and clay-sized particles. A final particle size gradation curve can then be generated from the wet sieve test, dry sieve test, and hydrometer test to establish the soil particle distribution within the sample. Classification of fine-grained soils (i.e., silt and clay-sized particles) is not based solely on size gradation. The Atterberg limits test is used to fully classify the soil according to the USCS. Specifically, the Atterberg limits test is used to distinguish between clay and silt soils, and low or high plasticity.

The liquid limit (LL) and plastic limit (PL) are determined by the Atterberg limits test. The LL is the water content at which the lower limit of viscosity occurs. The PL is the water content at which the soil deforms permanently and cracks. The plasticity index (PI) is a measure of the range of water contents between the LL and PL. The soil will form without cracking at water contents within the PI. In general, the higher the PI, the greater the amount of clay present and the more plastic the soil.

The undrained shear strength (S_u) indicates the soil strength and has been correlated with the resistance of the soil to erosion. There are three failure mechanisms of material: compression, tension, and shear. Because soil is inherently in compression in the subsurface, this is not a failure mechanism; rather soil typically fails in shear. Soil has very little tensile strength, and there are limited applications where soil could fail in tension. The undrained shear strength can be determined by the unconsolidated undrained triaxial test. The shear strength is a soil's ability to resist forces that cause the structure of the soil to fail. Soil strength may aid in determining how susceptible soil layers are to erosion between two distinct soil layers.

The hydraulic conductivity (k) test indicates the rate of fluid flow through a soil. The larger the k the more permeable the soil, and the smaller the k the more impermeable the soil. Typical k values for a lean clay and a fat clay are $3.34E-06$ ft/s and $4.21E-06$ ft/s, respectively. The rate at which water flows through the soil may aid in understanding the interaction of water flow between two distinct soil layers.

The soil properties between an area of low crop yield and high crop yield were determined to understand how the soil properties of these two areas differ. Disturbed and undisturbed soil samples were collected based on the measured electrical resistivity tomography (ERT) surveys performed in two crop production fields (Mathis et al., 2018). Disturbed samples are samples that do not keep in situ properties of the soil (i.e., structure, density, or the stress conditions) and are not considered representative of underground soils in the collection process. Undisturbed samples are samples that keep their structural integrity of the in situ soil. Soil classification tests, hydraulic conductivity, and undrained shear strength tests were performed to fully measure the soil properties between high-yielding and low-yielding soils. Understanding the soil properties between the low- and high-yielding subsoil compositions will help determine if the underlying claypan layer is contributing to the undermining of the overlying topsoil (Mathis et al., 2019). Measuring soil properties is important to engineers for designing infrastructure against foundation cracking or failure of bridge supports. Understanding

soil properties can assist agronomists to better understand how management practices, such as tillage, impact the loss of soil from a field through erosion.

Experimental Procedures

Soil sample locations were determined from the ERT surveys performed in two crop production fields in a low- and high-yield area (Mathis et al., 2018). A total of four samples were collected from each site: two disturbed samples (i.e., one low yield area and one high yield area) and two undisturbed samples (i.e., one low yield area, one high yield area). The undisturbed samples were taken within close proximity of the disturbed samples (i.e., within 10 ft). The disturbed and undisturbed samples were collected via a direct push method using a tractor-mounted Giddings soil sampler (Giddings Machine Company, Windsor, CO). The disturbed samples were collected from the field in 2.5-ft long \times 0.24-ft diameter plastic tubes. The undisturbed samples were collected from the field in 1.0-ft long \times 0.24-ft diameter thin-walled Shelby tubes. The water content of each sample was determined according to the standard protocol ASTM D2216-10 (ASTM, 2010) before being sealed at both ends and stored in a moisture room until performing soil classification and strength tests in the laboratory. The water content for each sample was determined to record in situ moisture conditions.

The disturbed soil samples were used to classify the samples collected in the low and high yielding areas from both fields. Most of the samples contained two layers with distinctly different soil characteristics; therefore, the soil properties were recorded for each layer (i.e., Top (T) of sample and Bottom (B) of sample). These samples were classified according to the USCS (ASTM, 2017b). The USCS classifies soils according to particle size via a wet sieve analysis, ASTM C117-17 (ASTM, 2017a), a dry sieve analysis, ASTM C136/C136M (ASTM, 2015a), and LL, PL, and PI, ASTM 4318-17e1 (ASTM, 2017c). The hydrometer test was also performed on each sample according to ASTM D7928-17 (ASTM, 2017d). A final size gradation curve was generated combining the particle size distribution data from the wet sieve analysis, dry sieve analysis, and hydrometer analysis. The P_{200} sieve analysis was determined from the data collected after performing the wet sieve test and indicates the percent fines (i.e., silt and clay-sized particles) passing a 200-openings per square-inch sieve.

Undisturbed samples collected in a low- and high-yielding area were used for the unconsolidated-undrained (UU) triaxial compression test ASTM D2850-15 (ASTM, 2015b). Similar to the disturbed samples, the T and B of the undisturbed sample were tested per sample to determine S_u between a low- and high-yield area (e.g., one sample will have a S_u for the T of the sample and a S_u for the B of the sample).

Ongoing research will include performing hydraulic conductivity tests according to ASTM D5084-16a (ASTM, 2016). The hydraulic conductivity (k) indicates the rate of a fluid flow through a soil.

Results and Discussion

Table 1 summarizes the soil parameters and classification of the samples collected from site 1. Two distinct soil layers were present in sample 1 and sample 2. The two distinct soil layers in both samples were characterized according to the USCS as a lean clay overlying a fat clay and had nearly the same initial water content (ω). Both samples contained more than 85% of silt and clay-sized particles passing a 200-openings per

square-inch sieve (i.e., P_{200}). Figure 1A shows the hydrometer test, which was used to determine the particle size distribution of fine-grained (i.e., silt- and clay-sized particles) soil. Figure 1B shows a final particle size gradation curve generated from the wet sieve test, dry sieve test, and hydrometer test. The particle size gradation curves allow for the determination of coarse-grained and fine-grained soil particles. The PI determined for the T and B of sample 1 were relatively low, with the B portion of the sample having a relatively higher PI than the T portion of the sample. Sample 1 was collected from the low-yielding area. Interestingly, the B portion of sample 2 had a PI that was about six times greater than the T portion of the sample. Sample 2 was collected from the high-yielding area. This indicates the fat clay soil in the B portion of sample 2 has a significantly higher plasticity than the T portion.

The two undisturbed samples collected in thin-walled Shelby tubes were collected within close proximity of the disturbed samples in the low- and high-yielding area at site 1. The T and B of these samples were tested in an unconsolidated undrained triaxial test. Figure 2A shows the plotted compressive strength versus axial strain collected during the unconsolidated undrained triaxial test on sample 2-T and sample 2-B. The S_u of the sample was determined from the unconsolidated undrained triaxial test by taking the maximum force loaded on the cylindrical sample over the testing period and dividing by two. Axial strain is the measure of the change of height of the sample relative to the initial height of the sample. Figure 2B shows sample 2-B after performing the unconsolidated undrained triaxial test. The initial parameters of sample 2-B had a height of 5.58 in., a diameter of 2.83 in., and a volume of 35.0 in.³. The S_u value was about two times higher in the B portion than the T portion of the sample 1. The underlying fat clay layer had an S_u of 14.9 psi and the overlying lean clay layer had an S_u of 6.82 psi. The underlying fat clay layer is likely more resistant to erosion than the overlying lean clay layer because of its higher S_u . This supports our hypothesis that the underlying soil (i.e., fat clay) may be enhancing the erosion of the overlying topsoil layer (i.e., lean clay) by the process of undermining at site 1. Interestingly, the T and B of sample 2, collected in the high-yielding area, shared similar S_u results as sample 1 in that the underlying soil layer (i.e., fat clay) had a higher S_u relative to that measured in the topsoil layer (i.e., lean clay). The T and B of sample 2 yielded S_u of 4.76 and 9.30 psi, respectively. The S_u for the T and B portions of sample 2 should be similar in the high-yielding area because no underlying claypan layer was present, although two distinct soil layers were observed from the disturbed sample. The difference between T and B S_u values may be attributed to the presence of a higher strength soil where sample 2 was collected.

Table 2 shows the soil parameters and classification of the samples collected from site 2. As with site 1, two disturbed samples were collected (i.e., one in a low-yielding area and one in a high-yielding area) and used for classifying the soil between the two areas. Unlike site 1, only one soil layer was observed from the disturbed samples collected in site 2. The samples from the low- and high-yielding area both classified as a lean clay and contained more than 85% silt and clay-sized particles passing a 200-opening per square-inch sieve (i.e., P_{200}), though the initial water content (ω) was higher in the high-yielding area. The PI was low for both samples but sample 3, which was collected in the low-yielding area, had a relatively higher PI than sample 4. This indicates that sample 3 has a higher plasticity than sample 4. The T and B of the undisturbed samples collected in the low- and high-yielding areas were tested using the unconsolidated undrained

triaxial test to determine the S_u even though only one distinct layer was observed in the disturbed samples. Testing the T and B portion of the undisturbed samples would confirm the presence of one soil layer if the S_u were similar. The T and B S_u for sample 3, collected in the low-yielding area, were 4.06 psi and 8.70 psi, respectively. As with site 1, the low-yielding area at site 2 had a relatively higher S_u in the B portion than the T portion of sample 3. This indicates a relatively stronger soil in the B portion of sample 3 than the T portion even though one distinct soil layer was observed from the disturbed sample. Interestingly, the T and B portion of sample 4, which was collected in the high-yielding area, had a S_u of 6.09 psi and 6.82 psi, respectively. This confirms the presence of one distinct soil layer in the high-yielding area at site 2 because there is no underlying claypan layer present.

The S_u follows a similar trend between the T and B portion of the undisturbed samples collected in the low-yielding area between site 1 and site 2. However, the S_u for the T and B portion of sample 1 is about two times larger than the T and B portion of sample 3 between sites. The S_u for the T and B portion of sample 2 and sample 4 in the high-yielding areas doesn't seem to follow any trend between site 1 and site 2. The B portion of sample 2 had a higher S_u relative to the B portion of sample 4. Unlike sample 4 from site 2, the S_u value for the T and B portions from sample 2 at site 1 were not similar. Further investigation will include performing the unconsolidated undrained triaxial test on samples collected in the low- and high-yielding area at both sites to confirm the first set of S_u values (i.e., T and B portion of undisturbed samples) obtained from samples 1, 2, 3, and 4.

The hydraulic conductivity test will be performed on the T and B portion of undisturbed samples collected in the low- and high-yielding area at both sites to determine the flow of water between the topsoil and claypan layer. The flow of water between the layers will aid in better understanding the mechanism by which the topsoil is eroding due to an underlying claypan layer.

This research has concluded that the presence of a claypan layer (i.e., fat clay) near the surface resulted in low crop yield. The presence of topsoil (i.e., lean clay) at the surface and no underlying claypan layer resulted in higher crop yield. Erosion test results indicated that the claypan layer (i.e., fat clay) was characterized as low erodibility. Conversely, the topsoil layer (i.e., lean clay) characterized moderate erodibility (Mathis et al., 2019). Results from this study indicated the low erodibility soils had higher strength and the moderate erodibility soils had lower strength. Therefore, the presence of a high strength soil underlying a low strength soil is likely increasing the rate of erosion of the more erodible soil by undermining at the interface between the two soil types. Data from this research will aid in the improvement of soil management practices and existing erosion models at field and watershed scales.

Acknowledgment

This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478, and partial funding through a grant from the National Science Foundation, Environmental Sustainability program. The authors gratefully acknowledge the support of the Kansas State University Women in Engineering Program. The authors thank Lonnie Mengarelli and Dekon Strickland for their contribution to the field measurements. We gratefully acknowledge the cooperation of the participating farmer in providing us access to their land.

References

- ASTM. 2010. D2216-10: Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass. West Conshohochon, PA: ASTM Int.
- ASTM. 2015a. C136/C136M-14: Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates. West Conshohochon, PA: ASTM Int.
- ASTM. 2015b. D2850-15: Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils. West Conshohochon, PA: ASTM Int.
- ASTM. 2016. D5084-16a: Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter. West Conshohochon, PA: ASTM Int.
- ASTM. 2017a. C117-17: Standard Test Method for Materials Finer than 75- μm (No.200) Sieve in Mineral Aggregates by Washing. West Conshohochon, PA: ASTM Int.
- ASTM. 2017b. D2487-17: Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System). West Conshohochon, PA: ASTM Int.
- ASTM. 2017c. D4318-17e1: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity of Soils. West Conshohochon, PA: ASTM Int.
- ASTM. 2017d. D7928-17: Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis. West Conshohochon, PA: ASTM Int.
- Coduto, D. P., Kitch, W.A., & Yeung, M.R. 2011. Geotechnical engineering: Principles and practices. Upper Saddle River, NJ: Pearson.
- Mathis II, M.A., Tran, T.V., Tucker-Kulesza, S.E., Sassenrath, G.F. 2019. Erosion mechanism of claypan soils in southeastern Kansas. Geo Congress, 2019. March 24-27, 2019. Philadelphia, PA. In press.
- Mathis, M.A. II, Tucker-Kulesza, S.E., Sassenrath, G.F. 2018. Electrical Resistivity Tomography of Claypan Soils in Southeastern Kansas. Kansas Agricultural Experiment Station Research Reports: Vol. 4: Iss. 3. <https://newprairiepress.org/kaesrr/vol4/iss3/13/>
- NRCS 2019. Soil Texture Calculator. https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054167

Table 1. Soil parameters and classification of site 1

Location	Sample	ω	LL	PI	P_{200}	USCS classification	S_u
							psi
Low crop yield-1	1-T	27.3	30	14	89	Lean clay	T = 6.82
	1-B		53	29	85	Fat clay	B = 14.9
High crop yield-1	2-T	25.8	27	9	89	Lean clay	T = 4.76
	2-B		76	51	95	Fat clay	B = 9.30

T = top of sample; B = bottom of sample; ω = percent water content; LL = Lower Limit, %; PI = Plasticity Index, %; P_{200} = percent soil particles passing through a 200-openings per square-inch sieve; S_u = undrained shear strength, psi.

Table 2. Soil parameters and classification of site 2

Location	Sample	ω	LL	PI	P_{200}	USCS classification	S_u
							psi
Low crop yield-2	3	24.7	31	14	88	Lean clay	T = 4.06
							B = 8.70
High crop yield-2	4	35.6	30	11	85	Lean clay	T = 6.09
							B = 6.82

T = top of sample; B = bottom of sample; ω = percent water content; LL = Lower Limit, %; PI = Plasticity Index, %; P_{200} = percent soil particles passing through a 200-openings per square-inch sieve; S_u = undrained shear strength, psi.

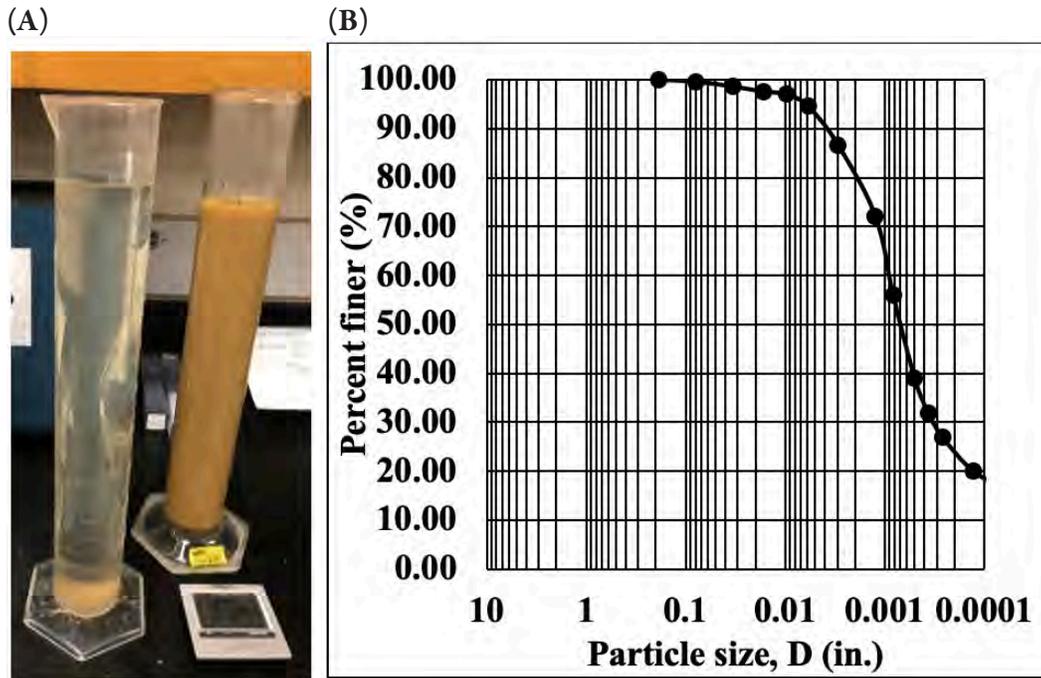


Figure 1. (A) The hydrometer test was used to determine the particle size distribution of soil particles that passed a 200-openings per square-inch sieve (i.e., P_{200} , silt and clay soil particles). The graduated cylinder in front with the clear liquid contains the water with dispersant. The cylinder in back with the cloudy liquid contains the soil sample in the water-dispersant solution used to measure soil particle size. (B) The data from the wet sieve test, dry sieve test, and hydrometer test were used to generate a particle size gradation curve. The particle size gradation curve plots the soil particle passing percentage vs. the particle size and allows for the determination of coarse-grained and fine-grained soil particles.

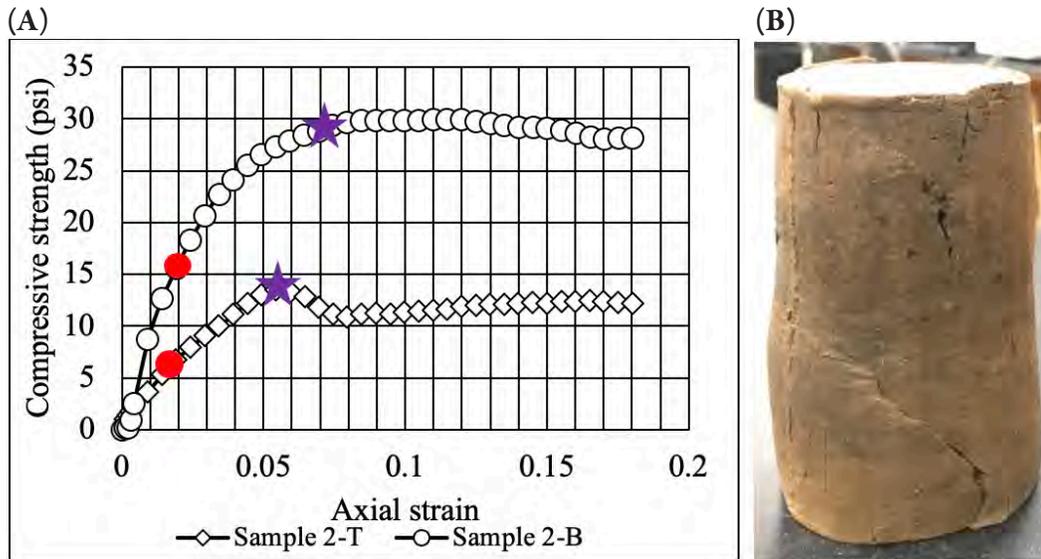


Figure 2. Unconsolidated-undrained triaxial test results. The solid red dot represents the undrained shear strength of the sample and the purple star represents the maximum axial load applied to the sample. (A) Sample 2-T (diamond-shaped points) produced an undrained shear strength (S_u) at failure equal 6.82 psi and axial strain equal to 0.017. Sample 2-B (circle-shaped points) produced an S_u at failure equal to 15.0 psi and an axial strain equal to 0.020. (B) Sample 2-B test specimen after performing the unconsolidated undrained triaxial test.

Changes in Soil Microbiology Under Conventional and No-Till Production During Crop Rotation

C.-J. Hsiao, G.F. Sassenrath, L. Zeglin, G. Hettiarachchi, and C. Rice

Summary

Soil microbial activity is important for crop production. Soil microbes are involved in nutrient and water cycling within the soil, and interact with crop plants to provide the basic nutrient and water resources needed for crop production. Claypan soils have unique physical characteristics that impact soil biology. This study explored the temporal changes in soil microbiology in a claypan soil under conventional and no-till production during a crop rotation of corn/winter wheat/soybean/fallow commonly planted in southeast Kansas. We found soil microbial activity changed more in the top two inches of soil than in the lower soil layers. Wheat resulted in higher soil microbial activity and biomass than corn. Soybeans had a more stable microbial activity in the soil than either corn or wheat. The no-till plots had greater microbial biomass and activity than conventionally tilled systems, and the temporal changes in soil microbial properties were more apparent in no-till plots. These results offer an interesting insight into the soil biological properties that impact soil health for crop production.

Introduction

Soil is the foundation on which our world depends, one of the major components in ecology, and the link between air and water. Soils are rich ecosystems. Soil microbes decompose organic matter, allowing growth of plants, animals, insects, and microbes. Microbial communities can respond to environmental changes more rapidly than plant communities. Therefore, soil microbial properties can potentially indicate how well the soil microenvironment supports growth and hence the productive capacity of the soil.

Enzymes in the soil have specific activities and can be used as indicators of soil quality. Hydrolases are enzymes that break particular chemical bonds, decomposing material in the soil such as plant biomass and residue. Beta-glucosidase (bG) is a hydrolase involved in the degradation of cellulose, a component of plant residue. The activity of bG is an indication of the carbon cycling within the soil. Similarly, acid phosphatase (AP) is a hydrolase involved in phosphorus cycling, releasing inorganic P from soil organic matter into forms that are available to plants. N-acetyl glucosaminidase (NAG) cleaves the amino sugar from chitin and is involved in nitrogen cycling within the soil. These enzyme activities are essential for organic matter decomposition and nutrient cycling. Soil microbial activity is determined by the bacterial and fungal components of the soil. The microbial components and community structure can be determined using the phospholipid fatty acid (PLFA) analysis that detects relative components of microbial cell walls. The microbial biomass and fungal to bacterial ratios are also indicative of soil quality. Microbial biomass is the measure of the mass of living microorganisms in soil. Both fungi and bacteria degrade plant residues, but fungi are generally more efficient

at assimilating and storing nutrients than bacteria. Fungi are also more sensitive to changes in the soil environment due to management practices. In general, soils with greater fertility have greater soil microbial biomass. The fungal population will increase faster than that of bacteria in fertile soil, leading to a higher fungal to bacterial ratio.

While soil microbial properties are important in soil function, most studies of soil microbial properties have primarily focused on the spatial variability. The temporal variability in soil microbial properties, especially the influence of various crops on soil biological components, is poorly characterized. This study examined changes in key soil quality indicators as a function of time in a corn/winter wheat/soybean/fallow rotation sequence in claypan soil and across different tillage practices.

Experimental Procedures

The research was conducted at the Southeast Research and Extension Center research fields near Columbus, KS. The fields are Parsons silt loam soil. The fields have been in a crop rotation of corn/winter wheat/soybeans for more than five years. Tilled plots were tilled using a chisel and disk prior to planting corn, and disk harrow after harvesting corn and prior to planting wheat. No-till was used prior to planting soybeans in both tilled and no-till plots.

Soil samples were taken every other month for two years using a 1-in. soil corer. Soil samples were taken at 0- 2-in. depth, dried and ground. Standard sample analysis was performed to determine the content of water and carbon (Hsiao et al., 2018). Soil nutrient analysis was performed at the Kansas State University Soil Testing Laboratory. Only total carbon is reported here. Soil enzyme activities were measured using standard protocols (Hsiao et al., 2018). Soil microbial biomass was estimated using phospholipid fatty acid analysis (Hsiao et al., 2018), and was used to determine the amount of fungi and bacteria in the soil.

Results and Discussion

Soil water content was higher in no-till (NT) than conventional tillage (CT) after corn harvest and during wheat growth (Figure 1A). Soil water content decreased after corn flowering, increased after corn harvest and remained constant during the wheat growing period. The low water content after corn flowering resulted from two potential reasons: the higher water consumption during corn growth and lower precipitation. Soil water content was highest during the winter, and decreased in summer.

Active carbon tended to be higher under NT than CT management (Figure 1B). Temporal patterns in both CT and NT soils followed similar trajectories, indicating a consistent influence of crop stage on soil microbial properties. Active carbon increased in the winter in both wheat production and fallow compared to the summer growth in both corn and soybeans in both NT and CT soils (Figure 1B). The greater proportion of labile C substrates during wheat growth and winter fallow may be a consequence of the buildup of crop residue from the preceding crop, senescent roots, and wheat root exudates. The higher active C also led to greater soil extracellular enzyme activities and microbial biomass (Figures 2 and 3A).

Enzyme activities (Figure 2) and microbial biomass (Figure 3A) increased during the winter wheat production period, and tended to be higher in NT than in CT management. The temporal pattern showed a decline in activity during corn growth, a rapid and substantial increase during wheat production, nearly level activity or declining activity during soybean production, followed by an increase during the winter fallow period (Figure 2A, 3A). This temporal pattern was most apparent in bG and microbial biomass. While the overall pattern was similar in AP and NAG, it was not nearly as robust. The pattern was also more pronounced in NT than in CT management. In our study, soybean production was followed by a fallow period prior to planting corn. Soybean produces only one-third of the amount of residue that is produced by corn, resulting in lower soil organic matter and enzyme production after soybean harvest compared to after corn harvest. Soybean residue decomposes rapidly in soils due to low lignin content and C:N ratio. Therefore, soybean residue input could have increased microbial biomass as well as bG and NAG activities during the fallow period after soybean harvest as the soybean residue rapidly broke down.

The fungal to bacterial ratios were higher in winter and lower in summer (Figure 3B), probably because fungi are the major decomposer of plant residues and biomass in the topsoil.

These results demonstrate the temporal changes during the crop growing season and the impact of management practices on soil microbial properties. Most of the changes in soil microbial properties occur in the very top 0–2 in. of soil, irrespective of tillage management. No-till production has greater microbial biomass and activity than conventional tilled systems. Incorporating wheat in the crop rotation may provide additional soil C inputs and further improve microbial properties. Changes in management practices and crop rotation systems can have profound impacts on the health of the soil, and hence on its productive capacity.

Acknowledgment

This work is supported by the U.S. Department of Agriculture National Institute of Food and Agriculture, Hatch project 1003478.

References

- Hsiao, C.-J., G.F. Sassenrath, L.H. Zeglin, G.M. Hettiarachchi, and C.W. Rice. 2018. Vertical changes of soil microbial properties in claypan soils. *Soil Biol. Biochem.* 121:154–164.

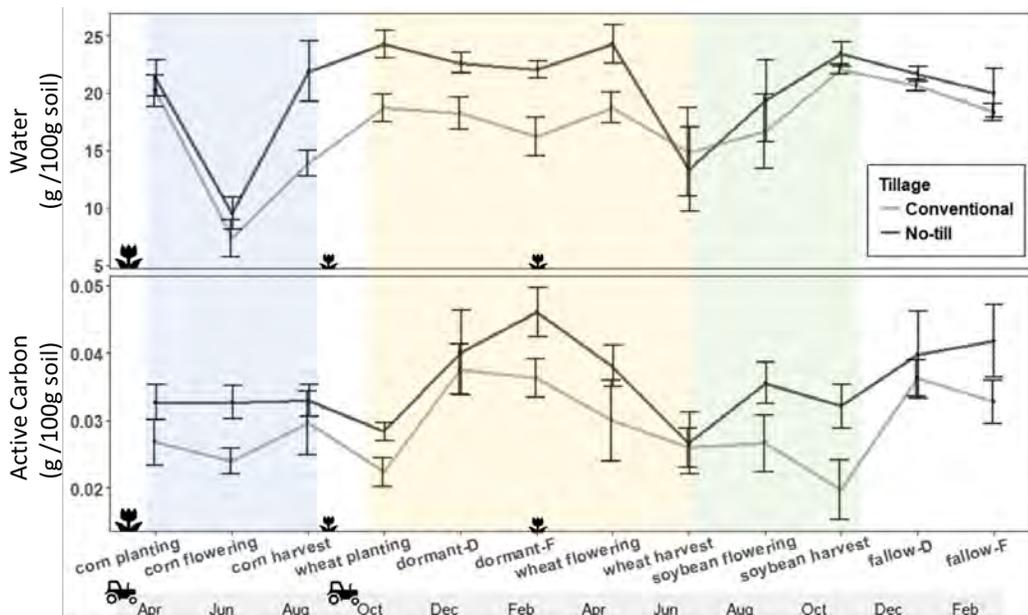


Figure 1. Temporal changes in soil water and active carbon for conventional tillage and no-till during the crop development stages. Dormant-D, wheat dormant stage in December; dormant-F, wheat dormant stage in February; fallow-D, fallow in December; fallow-F, fallow in February. Crop sequence is corn/wheat/soybean/fallow in two years. Crop stages are indicated by shaded areas: corn (blue), wheat (yellow), soybean (green), and fallow (white). Flowers (🌻) indicate mineral fertilizer application; tractors (🚗) indicate tillage event. Results are given as the average of all replications with standard error.

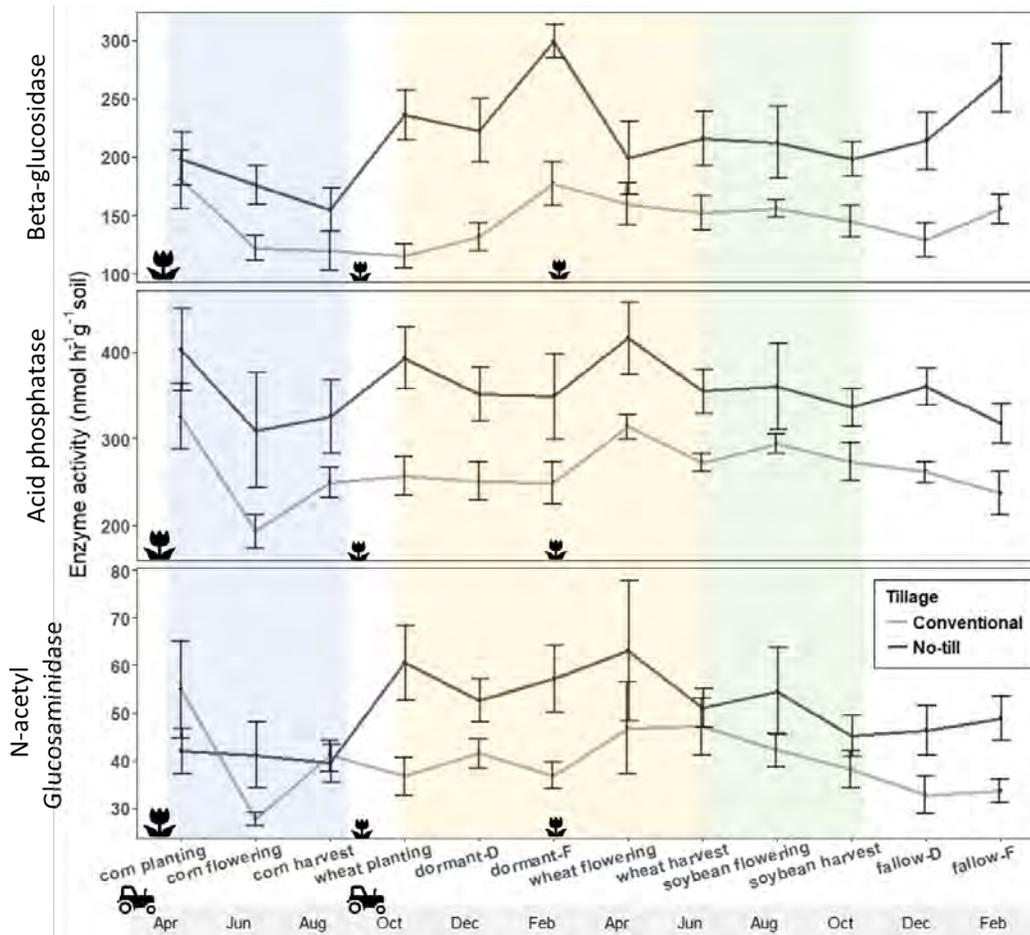


Figure 2. Temporal changes in soil enzyme activities for conventional tillage and no-till during the crop development stages. Dormant-D, wheat dormant stage in December; dormant-F, wheat dormant stage in February; fallow-D, fallow in December; fallow-F, fallow in February. Crop sequence is corn/wheat/soybean/fallow in two years. Crop stages are indicated by shaded areas: corn (blue), wheat (yellow), soybean (green), and fallow (white). Flowers (🌻) indicate mineral fertilizer application; tractors (🚜) indicate tillage event. Results are given as the average of all replications with standard error.

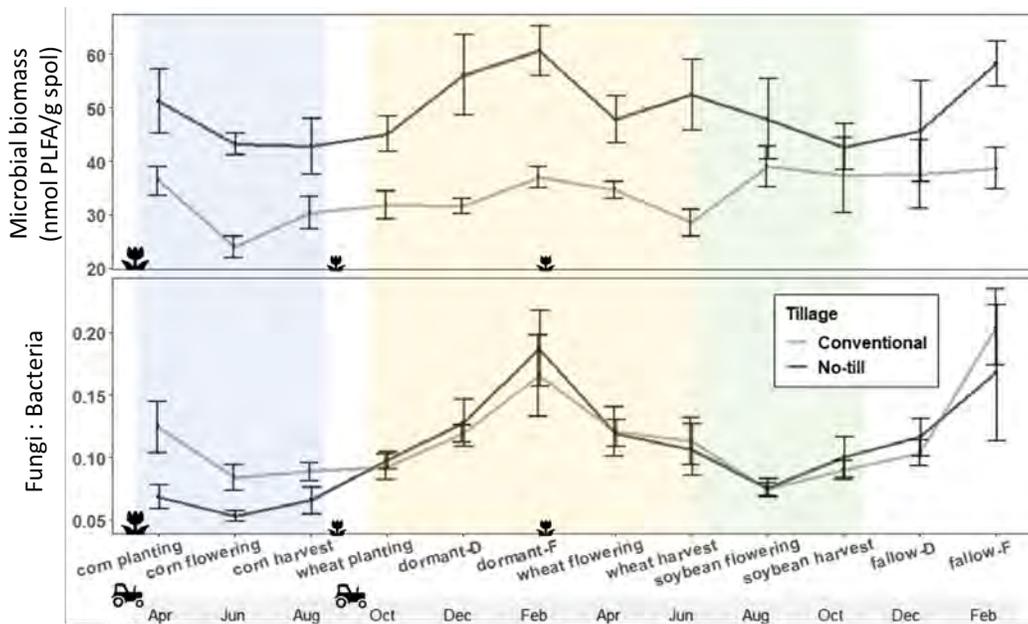


Figure 3. Temporal changes in microbial biomass and the ratio of fungi to bacteria for conventional tillage and no-till during the crop development stages. Dormant-D, wheat dormant stage in December; dormant-F, wheat dormant stage in February; fallow-D, fallow in December; fallow-F, fallow in February. Crop sequence is corn/wheat/soybean/fallow in two years. Crop stages are indicated by shaded areas: corn (blue), wheat (yellow), soybean (green), and fallow (white). Flowers (🌻) indicate mineral fertilizer application; tractors (🚜) indicate tillage event. Results are given as the average of all replications with standard error.

Annual Summary of Weather Data for Parsons - 2018

2018 Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max	41.8	46.4	58.7	61.7	83.8	88.1	91.7	86.2	81.6	68.0	50.1	46.8	67.1
Avg. Min	18.3	22.3	34.5	36.0	60.4	67.2	67.5	67.2	61.8	46.3	28.3	26.5	44.7
Avg. Mean	30.0	34.3	46.6	48.8	72.1	77.6	79.6	76.7	71.7	57.1	39.2	36.6	55.9
Precip	0.66	3.2	2.50	1.3	7.64	1.42	3.41	8.76	3.35	5.01	1.76	2.98	41.94
Snow	3.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1	0.0	5.0
Heat DD*	1084	859	571	489	5	0	0	0	22	297	775	879	4979
Cool DD*	0	0	0	4	224	379	453	362	222	53	0	0	1696
Rain Days	7	12	5	6	11	4	11	11	6	13	9	5	100
Min < 10	8	3	0	0	0	0	0	0	0	0	0	0	11
Min < 32	26	23	11	13	0	0	0	0	0	1	19	26	119
Max > 90	0	0	0	0	0	11	23	10	3	0	0	0	47

Normal values (1981-2010)

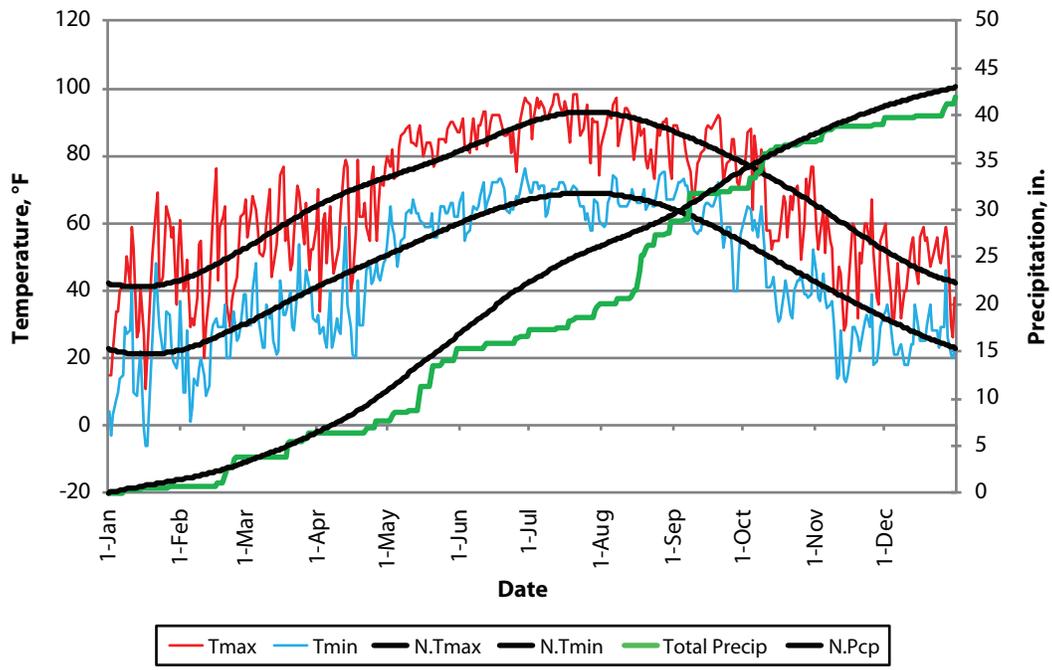
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max	42.0	47.6	57.1	67.1	75.7	84.4	90.0	90.3	81.3	69.6	56.6	44.2	67.2
Avg. Min	21.8	26.0	35.0	44.5	55.0	64.1	68.5	66.6	57.6	45.5	35.3	24.6	45.5
Avg. Mean	31.9	36.8	46.1	55.8	65.3	74.2	79.3	78.5	69.4	57.6	46	34.4	56.4
Precip	1.41	1.77	3.19	4.38	5.93	5.53	3.92	3.29	4.69	3.86	2.94	2.06	42.97
Snow	2.8	1.7	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.7	8.7
Heat DD	1026	790	590	299	85	8	1	1	52	260	574	948	4632
Cool DD	0	0	2	23	96	285	442	418	186	29	2	0	1483

Departure from normal

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max	-0.2	-1.2	1.6	-5.4	8.1	3.7	1.7	-4.1	0.3	-1.6	-6.5	2.6	-0.1
Avg. Min	-3.5	-3.8	-0.5	-8.5	5.4	3.1	-1.0	0.6	4.2	0.8	-7.0	1.9	-0.7
Avg. Mean	-1.9	-2.5	0.5	-7.0	6.8	3.4	0.3	-1.8	2.3	-0.5	-6.8	2.2	-0.4
Precip	-0.75	1.43	-0.69	-3.13	1.71	-4.11	-0.51	5.47	-1.34	1.15	-1.18	0.92	-1.03
Snow	0.7	-1.2	-1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	-2.7	-3.7
Heat DD	58	69	-20	190	-81	-8	-1	-1	-31	37	201	-69	345
Cool DD	0	0	-2	-19	128	94	11	-56	36	24	-2	0	213

*Daily values were computed from mean temperatures. Each degree that a day's mean is below (or above) 65°F is counted for one heating (or cooling) degree day.

SOUTHEAST RESEARCH AND EXTENSION CENTER



Acknowledgments

We thank the following individuals, organizations, and firms that contributed to this year's research programs through financial support, product donations, or services.

AgChoice, Parsons and Weir, KS
AgriMAXX Wheat Co., Mascoutah, IL
Agseco, Girard, KS
American Bank, Baxter Springs, KS
Bartlett Co-op Association
Beachner Grain, St. Paul, KS
Beason Farm, Elk City, KS
Boehringer-Ingelheim, St. Joseph, MO
Jeff Clark, Columbus, KS
Dennis Clutter, Girard, KS
Coffeyville Livestock Market,
Coffeyville, KS
Columbus Chamber of Commerce,
Columbus, KS
Commercial Bank
Community National Bank & Trust
CONICYT, Chile
Deere and Company, Moline, IL
DeLange Seed, Inc., Girard, KS
Dow AgroSciences, Indianapolis, IN
Ernie and Sharon Draeger,
Columbus, KS
Dyna-Gro Seed, Richmond, CA
East Kansas Agri-Energy, Garnett, KS
Elanco Animal Health, Indianapolis, IN
Rich Falkenstein, Oswego, KS
Farmer's Cooperative Association, Inc.,
Baxter Springs and Columbus, KS
Fastenal, Parsons, KS
Faulkner Grain, Chetopa, KS
FMC Corporation, Edgerton, MO
FRMS, Columbus, KS
Frontier Farm Credit, Parsons, KS
Hershel George, Uniontown, KS
Greenbush Southeast Kansas Education
Service Center, Girard, KS
Heritage Tractor, Pittsburg, KS
Jessee Dean Insurance, Galena, KS
Joe Harris, St. Paul, KS
Kansas Alliance for Wetlands & Streams,
Independence, KS
Kansas Center for Sustainable Ag &
Alternative Crops, Manhattan, KS
Kansas Crop Improvement Association,
Manhattan, KS
Kansas Forage & Grassland Council,
Manhattan, KS
Kansas Soybean Commission,
Topeka, KS
Labette Bank, Altamont, KS
Limagrain Cereal Seeds, Ft. Collins, CO
McCune Farmers Union Coop,
McCune, KS
Merck Animal Health, Summit, NJ
MFA Incorporated, Columbia, MO
Midwest Fertilizer, Oswego, KS
Mix 30, Springfield, IL
MM Ranch, Chanute, KS
Modern Ag, Columbus, KS
Joe Murnane, Girard, KS
Steve Murphy, Girard, KS
National Science Foundation,
Arlington, VA
Natural Ag Solutions, LLC., Moran, KS
O'Malley Implement Co.,
Independence, KS
Parsons Livestock Market, Parsons, KS
Pioneer Hi-Bred International,
Johnston, IA

Primetime Video, Joplin, MO
Producers Coop, Girard, KS
R&F Farm Supply, Erie, KS
Marty Reichenberger, Independence, KS
Ridley Block Operations, Pittsburg, KS
South Coffeyville Stockyards,
South Coffeyville, OK
Syngenta/AgriPro, Berthoud, CO
T&T Agronomy, LLC, Coffeyville, KS

Emmet & Virginia Terril, Catoosa, OK
Thomas Implement, Inc., Altamont, KS
U.S. Department of Agriculture
National Institute of Food
and Agriculture
U.S. Department of Agriculture
Natural Resources Conservation
Service
Westbred, LLC, Bozeman, MT
Zoetis, Madison, NJ

Research and Extension Personnel

Dr. J.D. McNutt, Professor, Research Center Head

Larry Buffington, Custodial Specialist

Marla Sexton, Accountant I

Karen Walters, Office Specialist IV

Dr. Jaymelynn Farney, Associate Professor, Beef Systems Specialist

Chuckie Hessong, Snap-Ed Regional Specialist

Beth Hinshaw, Extension Specialist 4-H Development

Dr. Lyle Lomas, Professor, Animal Scientist

Micah Day, Animal Science Technician II

TaLana Erikson, Research Technologist

Terry Green, Research Technologist

Hunter Metcalf, Seasonal Worker

Bethany O'Brien, Animal Science Technician II

Larry Sale, Agricultural Technician I

Gayle Price, Professor, Extension Specialist FCS

Dr. Gretchen Sassenrath, Professor, Crop Production Agronomist

Lonnie Mengarelli, Research Assistant

Steve Spencer, Microcomputer Support Technician

Dr. Daniel Sweeney, Professor, Soil and Water Management Agronomist

Garth Blackburn, Research Technologist

Dekon Strickland, Agricultural Technician I



From left to right. Front row: Dr. Jaymelynn Farney, Beth Hinshaw, Chuckie Hessong, Dr. Gretchen Sassenrath, Gayle Price, Dr. Daniel Sweeney, Larry Buffington, Larry Sale, Dr.J.D. McNutt

Back row: TaLana Erikson, Steve Spencer, Lonnie Mengarelli, Karen Walters, Dekon Strickland, Terry Green, Garth Blackburn, Dr. Lyle Lomas, Marla Sexton

SEREC

AGRICULTURAL RESEARCH

2019

Copyright 2019 Kansas State University Agricultural Experiment Station and Cooperative Extension Service. Contents of this publication may be freely reproduced for educational purposes. All other rights reserved. In each case, give credit to the author(s), Agricultural Research 2019, Southeast Research and Extension Center, Kansas State University, April 2019. Contribution no. 19-286-S from the Kansas Agricultural Experiment Station.

Chemical Disclaimer

Brand names appearing in this publication are for product identification purposes only. No endorsement is intended, nor is criticism implied of similar products not mentioned. Experiments with pesticides on nonlabeled crops or target species do not imply endorsement or recommendation of nonlabeled use of pesticides by Kansas State University. All pesticides must be used consistent with current label directions. Current information on weed control in Kansas is available in *2019 Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland*, Report of Progress 1148, available from the Distribution Center, Umberger Hall, Kansas State University, or at: bookstore.ksre.ksu.edu (type Chemical Weed Control in search box).

Kansas Agricultural Experiment Station Research Reports are available at: <http://newprairiepress.org/kaesrr>
Publications from Kansas State University are available at: www.ksre.ksu.edu