



# SEARC

## AGRICULTURAL RESEARCH 2018

**K-STATE**  
Research and Extension

Kansas State University Agricultural Experiment Station and Cooperative Extension Service



**LYLE LOMAS**

Research Center Head and Animal Scientist

B.S., M.S., Animal Husbandry, University of Missouri  
Ph.D., Animal Husbandry, Michigan State University

Lyle provides administrative and research leadership and directs beef cattle research at the Kansas State University Southeast Agricultural Research Center. Lyle joined the staff in 1979 as an animal scientist and became head in 1986. His research interests are beef cattle nutrition and forage utilization by grazing beef cattle.



**JOE MOYER**

Forage Agronomist, Emeritus (on staff from 1978-2016)

B.S., M.S., Ph.D., Agronomy, Kansas State University

Joe has been a staff member since 1978. His research evaluates forage grass and legume cultivars and management practices and forage utilization by grazing beef cattle.



**GRETCHEN F. SASSENATH**

Cropping Systems Agronomist

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

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.

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### 2018

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# Effects of Various Grazing Systems on Grazing and Subsequent Finishing Performance

*L.W. Lomas and J.L. Moyer*

## Summary

A total of 320 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, and 2017. Daily gains of steers that grazed MaxQ fescue, wheat-bermudagrass, or wheat-crabgrass were similar ( $P > 0.05$ ) in 2010, 2016, and 2017. 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 Max Q 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 Max Q 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.

## 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 Kansas State University Southeast Agricultural Research Center in the past 20 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 2010-2017, 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); and March 28, 2017 (669 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). The 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, and 100 lb/a of 'Everest' hard red winter wheat on September 27, 2011, September 25, 2012, September 23, 2013,

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September 29, 2014, September 22, 2015, and October 4, 2016, respectively. All pastures were fertilized with 80-40-40 lb/a of N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O on March 3, 2010; January 27, 2011; January 25, 2012; February 19, 2013; January 28, 2014; February 10, 2015; February 11, 2016; and February 13, 2017. 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; and June 13, 2017. 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; and September 22, 2017. An additional 5 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, and February 21, 2017, 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 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); and September 12, 2017 (168 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); and November 14, 2017 (231 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:

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

All steers were slaughtered in a commercial facility, and carcass data were collected. Cattle that grazed these pastures in 2017 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, and 7 for 2010, 2011, 2012, 2013, 2014, 2015, and 2016, respectively. Grazing performance for 2017 is presented in Table 8. 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 had 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 Max Q 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 and MaxQ fescue and greater ( $P < 0.05$ ) for wheat-bermudagrass than MaxQ fescue. Overall gain for Max Q 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.

Hotter, 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 2010, 2011, 2013, 2014, 2015, 2016, and 2017.

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**Table 1. Effects of forage system on grazing and subsequent performance of stocker steers, Southeast Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>500 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>600 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>500 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>500 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>600 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>500 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>600 = 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 performance of stocker steers, Southeast Agricultural Research 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

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

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

*L.W. Lomas and J.L. Moyer*

## Summary

In 2016 and 2017, 128 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. Fescue cultivars evaluated were high-endophyte 'Kentucky 31,' low-endophyte Kentucky 31, 'HM4,' and 'MaxQ.' In 2016, 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 years. Steer gains and gain/a were similar ( $P > 0.05$ ) between pastures fertilized with nitrogen (N) in the spring and those interseeded with ladino clover during both 2016 and 2017. Fescue cultivar or legume treatment had little effect on finishing performance or carcass characteristics of steers grazed in 2016. Steers that grazed high-endophyte Kentucky 31 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.

## 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 tall fescue cultivars with the non-toxic endophyte should be an effective way of increasing gains of cattle grazing tall fescue. However, these cultivars lack the competitiveness 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) and March 28, 2017 (597 lb). '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 of N on February 10, 2016, and February 16, 2017. All pastures were fertilized with 40 lb/a of N and P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O as required by soil test on September 13, 2016 and September 11, 2017.

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 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 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) and December 6, 2017 (253 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, Kalamazoo, MI), 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 were fed a finishing diet for 98 days and were then slaughtered in a commercial facility, and carcass data were collected on each individual steer. Cattle that were grazed during 2017 were being finished for slaughter at the time that this report was written.

## Results and Discussion

Grazing and finishing performance for 2016 is pooled across legume treatment and presented by tall fescue cultivar in Table 1 and pooled across fescue cultivar and presented by legume treatment in Table 2. There were no significant interactions ( $P > 0.05$ ) between fescue cultivar and legume treatment for cattle performance. However, there was a significant ( $P < 0.05$ ) fescue cultivar  $\times$  legume interaction for average available forage dry matter (DM). 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 grazing 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. 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. Steer gains were similar ( $P > 0.05$ ) between pastures fertilized with an additional 80 lb/a of N and those interseeded with ladino clover. 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 ( $P > 0.05$ ).

Fescue cultivar had no effect ( $P > 0.05$ ) on finishing gain, dry matter intake, or feed:gain ratio. However, steers that had 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 had 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 was 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 was similar ( $P > 0.05$ ). Legume treatment had no effect ( $P > 0.05$ ) on finishing performance or carcass traits.

Grazing performance for 2017 is pooled across legume treatment and presented by tall fescue cultivar in Table 3 and pooled across fescue cultivar and presented by legume treatment in Table 4. Fescue cultivar and legume treatment had no effect ( $P > 0.05$ ) on grazing performance. However, average available forage DM of high-endophyte Kentucky 31 pastures was greater ( $P < 0.05$ ) than for low-endophyte Kentucky 31, HM4, or MaxQ. This was likely due to lower forage intake by cattle grazing the high-endophyte Kentucky 31 pastures. Average available forage DM of low-endophyte Kentucky 31, HM4, and MaxQ pastures were similar. Pastures fertilized with nitrogen in the spring had greater ( $P < 0.05$ ) average available forage DM than those that were interseeded with ladino clover.

## BEEF CATTLE RESEARCH

**Table 1. Effects of cultivar on grazing and subsequent finishing performance of steers grazing tall fescue pastures, Southeast Agricultural Research 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 <sup>1</sup>	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 <sup>2</sup>	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

<sup>1</sup>There was a significant ( $P < 0.05$ ) fescue cultivar  $\times$  legume interaction.

<sup>2</sup>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 interseeding ladino clover on grazing and subsequent finishing performance of steers grazing tall fescue pastures, Southeast Agricultural Research 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 <sup>1</sup>	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 <sup>2</sup>	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

<sup>1</sup>There was a significant ( $P < 0.05$ ) fescue cultivar  $\times$  legume interaction.

<sup>2</sup>600 = 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 cultivar on performance of steers grazing tall fescue pastures, Southeast Agricultural Research 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

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

**Table 4. Effects of interseeding ladino clover on performance of steers grazing tall fescue pastures, Southeast Agricultural Research 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

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

# 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 120 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, and 2017. Daily gains of heifers supplemented with corn or DDG were similar ( $P > 0.05$ ).

## 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), and March 17, 2017 (416 lb). Three pastures of heifers were randomly assigned to one of two supplementation treatments (three replicates per treatment) and grazed for 142, 182, 197, and 173 days in 2014, 2015, 2016, and 2017, respectively. Supplementation treatments were ground corn or DDG at 0.5% body weight per head daily. 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 of nitrogen and  $P_2O_5$  and  $K_2O$  as required by soil test on February 21, 2014, March 11, 2015, February 17, 2016, and February 14, 2017. Pastures were stocked with 1 heifer/a and grazed continuously until August 28, 2014, October 6, 2015, October 20, 2016, and September 6, 2017 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, and 4, for 2014, 2015, 2016, and 2017, respectively. Grazing gains and supplement intake were 2.00 and 2.8 lb/head daily and 2.10 and 2.9 lb/head daily (2014); 1.69 and 3.0 lb/head daily and 1.61 and 3.0 lb/head daily (2015); 1.65 and 2.8 lb/head daily and 1.64 and 2.9 lb/head daily (2016); and 1.71 and 2.8 lb/head daily and 1.87 and 2.9 lb/head daily (2017) for heifers supplemented with corn and DDG. Gains and supplement intake of heifers supplemented with corn were similar ( $P > 0.05$ ) to those of heifers that were supplemented with DDG. This 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.

**Table 1. Effects of supplementation with corn or dried distillers grains (DDG) on gains of heifer calves grazing smooth bromegrass pastures, Southeast Agricultural Research 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 Agricultural Research 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 Agricultural Research 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 Agricultural Research 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

# Evaluation of Supplemental Energy Source for Grazing Stocker Cattle

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

## Summary

A total of 144 steers grazing smooth bromegrass pastures were used to evaluate the effects of supplemental energy sources on available forage, grazing gains, subsequent finishing gains, and carcass characteristics in 2014, 2015, 2016, and 2017. 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 four years. In 2014, 2016, and 2017, 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 liveweight, 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 liveweight, 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.

## 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

Steers (144) 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); and March 21, 2017 (437 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, and 238 days in 2014, 2015, 2016, and 2017, 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 and 2017, 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 and 2017) and energy (3.3 lb of TDN in 2014 and 2015 and 3.4 lb of TDN in 2016 and 2017) per head daily. Pastures were fertilized with 100 lb/a of nitrogen (N) on February 24, 2014; February 12, 2015; February 11, 2016; and February 10, 2017. 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); and November 14, 2017 (238 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 metal feed 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 with a disk meter calibrated for smooth bromegrass.

After the grazing period, cattle were shipped to a finishing facility, implanted with Synovex S (Zoetis, Kalamazoo, MI), and fed a diet of 80% whole-shelled corn, 15% corn silage, and 5% supplement (dry matter basis) for 125 days, 97 days, and 98 days in 2014, 2015, and 2016, 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 2017 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, and 2016 in Tables 1, 2, and 3, respectively. Grazing performance is presented for 2017 in Table 4. 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 DM 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 four years. In 2014, 2016, and 2017, 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 liveweight, 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, 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.

Under the conditions of this study, supplementation of stocker cattle grazing smooth brome grass 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 no 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>600 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>600 = 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 Agricultural Research 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 <sup>1</sup>	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

<sup>1</sup>600 = 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 performance of steers grazing smooth bromegrass pastures, Southeast Agricultural Research 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

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

# Including Legumes in Bermudagrass Pastures

*J.L. Moyer and L.W. Lomas*

## Summary

Use of legumes in wheat-bermudagrass pastures did not affect summer cow gains in 2017. Forage availability was greater ( $P < 0.05$ ) where nitrogen (N) alone was used than where crimson clover and ladino clover were used in the Legume system. Estimated forage crude protein (CP) was similar ( $P > 0.05$ ) for the Legume and Nitrogen systems.

## 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 Agricultural Research 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 September 28, 2016. Legume pastures that had been previously interseeded with 'Will' ladino clover were interseeded with 26 lb/a of crimson clover using a no-till drill at on September 29, 2016. Nitrogen pastures were fertilized with 50 lb/a N on February 13 and May 10, 2016, and all pastures received 50-30-30 of N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O on July 7.

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. Final cow weights were taken on consecutive days before removal from the pastures on August 23 (141 days).

Forage CP, as estimated by the normalized difference vegetation index (NDVI), and available forage were monitored monthly during grazing with an automated instrument incorporating a Greenseeker (Trimble, Sunnyvale, CA), and rising plate meter.

## Results and Discussion

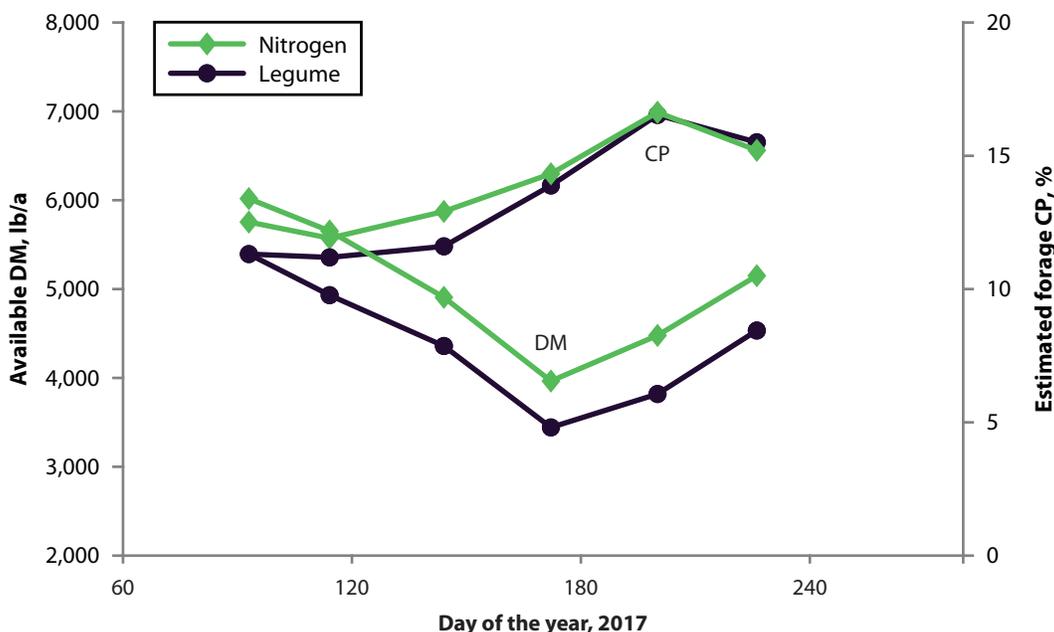
Average available forage dry matter is plotted by date for Nitrogen and Legume treatments in Figure 1. The Nitrogen treatment had greater ( $P < 0.05$ ) average available forage dry matter than the Legume treatment. The estimated crude protein concentration was similar ( $P > 0.05$ ) for the Nitrogen and the Legume systems on all sampling dates.

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

**Table 1. Performance of cows grazing wheat-bermudagrass pastures interseeded with wheat and fertilized with nitrogen or interseeded with legumes, Mound Valley Unit, Southeast Agricultural Research Center, 2017**

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	1296	1296
Cow final weight, lb	1644	1637
Cow gain, lb	348	341
Cow daily gain, lb	2.47	2.42
Cow gain, lb/a	278	273
Average available forage dry matter, lb/a	5,029a	4,414b

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



**Figure 1. Available forage dry matter (DM) and estimated crude protein (CP) concentration during the grazing season in wheat-bermudagrass pastures with or without interseeded legumes, Mound Valley Unit, Southeast Agricultural Research Center, 2017.**

# Evaluation of Tall Fescue Cultivars

*J.L. Moyer*

## Summary

Spring 2017 forage yield was higher for 'NFTF 1411' than for 12 of the 19 other tall fescue cultivar entries. Summer production was greatest for 'BarOptima PlusE34'. Fall production for 'PBU-B2' was higher than for all other entries except 'LE 14-84.' Total 2017 production was greatest for BarOptima PLUS E34, and 'NFTF 1044' yielded more than 15 other cultivars.

## Introduction

Tall fescue (*Lolium arundinaceum* Schreb.) is the most widely grown forage grass in southeastern Kansas. Its tolerance to extremes in climate and soils of the region is partly attributable to its association with a fungal endophyte, *Neotyphodium coenophialum*; however, most ubiquitous endophytes are also responsible for production of substances toxic to some herbivores, including cattle, sheep, and horses. Endophytes that purportedly lack toxins, but augment plant vigor have been identified and inserted into tall fescue cultivars adapted to the United States. These cultivars, and others that are fungus-free or contain a ubiquitous endophyte (i.e. Ky 31 EF and HE, respectively) are included in this test.

## Experimental Procedures

The trial was seeded at the Mound Valley Unit of the Southeast Agricultural Research Center in 10-in. rows on Parsons silt loam soil. Plots were 35 × 5 ft and were arranged in four randomized complete blocks. They were fertilized with a preplant treatment of 20-50-60 lb/a of N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O and seeded with 20 lb/a of pure, live seed on September 30, 2014.

Spring 2017 fertilization of 150-60-60 lb/a (N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O) was applied on February 22, and fall growth was supplemented with 50 lb/a of nitrogen (N) on September 25. Harvest was performed on a 3-ft strip of 16 to 20 ft of each plot. A flail-type harvester was used to cut to a 3-in. height on May 9, 2017. After harvest, forage was removed from the rest of the plot at the same height. A forage subsample was collected from each plot and dried at 140°F for moisture determination. Summer regrowth was similarly harvested on September 21, and fall growth was harvested on November 28.

## Results and Discussion

Spring 2017 yields ranged from 2.13 tons/a for Ky31 HE (12% moisture basis) to 2.84 tons/a for NFTF 1411 (Table 1). The latter yielded more ( $P < 0.05$ ) than 13 of the 19 other entries, and five entries yielded more than the three lowest-yielding entries.

Summer forage production was greater than usual, averaging 2.54 tons/a (Table 1). This was largely because precipitation at Mound Valley during July and August was well above average, 4.45 and 9.02 in., respectively, accompanied by cooler-than-average temperatures. BarOptima PLUS E34 yielded more in September than all except three

## FORAGE CROPS RESEARCH

other entries, with the highest-yielding four entries yielding more than two lower-yielding entries.

Fall production averaged 0.73 tons/a, with PBU-B2 and LE 14-84 yielding more than nine other entries (Table 1). Total forage production for 2017 was greater for BarOptima PLUS E34 than that of 17 other cultivars, the exceptions being NFTF 1044 and PBU-B2.

Total 3-year forage production of PBU-B2, PBU-B7, and NFTF 1044 exceeded 22 tons/a, which was greater than that of seven other entries (Table 1). Six entries exceeded the three-year forage production of 'Martin 2 ProTek.'

**Table 1. Forage yields (tons/a, 12% moisture) in 2017, and 3-year total yield for the tall fescue cultivar trial seeded in 2014, Mound Valley Unit, Kansas State University Southeast Agricultural Research Center**

Cultivar	2017 Forage yields				3-Year total yield
	May 9	September 21	November 28	Total	
BarOptima PLUS E34	2.60	3.15	0.74	6.48	20.22
Bar FAF 131	2.59	2.37	0.67	5.63	19.66
Tower ProTek	2.42	2.56	0.81	5.78	20.83
Martin 2 ProTek	2.54	2.23	0.66	5.43	18.98
AGRFA 148	2.69	2.57	0.61	5.86	20.01
NFTF 1051	2.21	2.79	0.70	5.69	21.25
NFTF 1044	2.81	2.89	0.68	6.37	22.09
NFTF 1411	2.84	2.43	0.56	5.82	19.50
GT 213	2.25	2.39	0.75	5.38	19.68
LE 14-84	2.32	2.52	0.90	5.74	20.11
LE 14-86	2.34	2.47	0.68	5.49	20.81
Teton II	2.48	2.30	0.81	5.59	20.42
Estancia	2.31	2.49	0.66	5.46	20.40
PBU-B1	2.33	2.42	0.75	5.50	21.38
PBU-B2	2.51	2.57	1.01	6.09	22.37
PBU-B5	2.41	2.48	0.82	5.72	20.97
PBU-B7	2.36	2.76	0.79	5.90	22.22
MV 14	2.53	2.57	0.72	5.82	20.68
Ky 31 HE	2.13	2.45	0.82	5.40	19.66
Ky 31 LE	2.46	2.44	0.52	5.42	20.68
Average	2.42	2.54	0.73	5.72	20.61
LSD (0.05)	0.31	0.45	0.17	0.52	1.95

# Nitrogen, Phosphorus, and Potassium Fertilization for Newly Established Tall Fescue

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

## Summary

Tall fescue production was studied during a fourth year of continuous research at two locations. In 2016, the fescue at Site 1 was affected by nitrogen (N) and phosphorus (P) fertilization in the spring, but the response was less defined in the fall harvest. At Site 2 in 2017, fescue production was mainly affected by N rate, with marginal response to potassium (K) fertilization.

## 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. Even when new stands are established, this is often true. The objective of this study was to determine whether N, P, and K fertilization improves yields during the early years of a stand.

## Experimental Procedures

The experiment was established on two adjacent sites in the fall of 2012 (Site 1) and 2013 (Site 2) at the Parsons Unit of the Kansas State University Southeast Agricultural Research Center. The soil at both sites was a Parsons silt loam soil with initial soil test values of 5.9 pH, 2.8% organic matter, 4.2 ppm P, 70 ppm K, 3.9 ppm  $\text{NH}_4\text{-N}$ , and 37.9 ppm  $\text{NO}_3\text{-N}$  in the top 6 inches at Site 1; and 6.5 pH, 2.2% organic matter, 6.7 ppm P, 58 ppm K, 6.8 ppm  $\text{NH}_4\text{-N}$ , and 12.3 ppm  $\text{NO}_3\text{-N}$  in the top 6 inches at Site 2. The experimental design was a split-plot arrangement of a randomized complete block. The six whole plots received combinations of  $\text{P}_2\text{O}_5$  and  $\text{K}_2\text{O}$  fertilizer levels allowing for two separate analyses: 1) four levels of  $\text{P}_2\text{O}_5$ , 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  $2 \times 2$  factorial combination of two levels of  $\text{P}_2\text{O}_5$  (0 and 50 lb/a) and two levels of  $\text{K}_2\text{O}$  (0 and 40 lb/a). Subplots were four levels of N fertilization consisting of 0, 50, 100, and 150 lb/a. Phosphorus and K fertilizers were broadcast applied in the fall as 0-46-0 (triple superphosphate) and 0-0-60 (potassium chloride). Nitrogen was broadcast applied in late winter as 46-0-0 (urea) solid. Fourth-year sampling and harvest dates from each site were as follows. Early growth yield as an estimate of grazing potential in early spring was taken at E2 (jointing) growth stage on April 22, 2016, at Site 1 and on April 19, 2017, at Site 2 from a sub-area of each plot not used for later spring and fall harvests. Spring yield was measured at R4 (half bloom) on May 13, 2016, at Site 1 and on May 15, 2017, at Site 2. Fall harvest was taken on September 21, 2016, at Site 1 and on September 13, 2017, at Site 2.

## Results and Discussion

Fourth-year production of tall fescue was measured at Site 1 in 2016 and at Site 2 in 2017. At site 1 in 2016, early yield at the E2 (jointing) growth stage, measured to estimate forage available if grazed early, was increased with 50 lb P<sub>2</sub>O<sub>5</sub>/a (Table 1), and was increased with N rates of 100 or 150 lb/a above yield with no N added. At the R4 stage of hay harvest in 2016, yield was increased by P fertilization, but with no difference between rates. Nitrogen fertilizer additions up to 150 lb/a increased R4 hay yield. Fall yields were unaffected by P fertilization. Apparent mineralization during the summer resulted greater fall yield with no N as compared to the 50 and 100 lb N/a rates applied in late winter. Total yield was maximized with P fertilization and N applied at 150 lb/a.

For the fourth year of production at Site 2 (2017), yield was mainly affected by N rate. Sampling at E2 and R4 and fall harvest yields were not affected by P fertilization (Table 2) and response to K fertilization was marginal (data not shown). Increasing N rates tended to increase yield at the E2 sampling, R4 hay harvest, and total (R4 + fall) yield, especially with K fertilization (data not shown), but response was less defined at the fall harvest (Table 2). Total yield averaged less than 3.5 ton/a, even at the 150 lb/a N rate.

**Table 1. Fourth-year yield of newly established tall fescue in the spring and fall 2016 as affected by the interaction of P<sub>2</sub>O<sub>5</sub> and nitrogen (N) fertilization rates at Site 1**

P <sub>2</sub> O <sub>5</sub>	Yield			
	Spring		Fall harvest	Total (R4 + Fall)
	E2 (jointing)	R4 (half-bloom)		
lb/a	----- ton/a, 12% moisture -----			
0	0.19	0.93	1.25	2.18
25	0.21	1.14	1.34	2.48
50	0.28	1.19	1.38	2.57
100 <sup>1</sup>	0.29	1.19	1.37	2.56
LSD (0.10)	0.07	0.16	NS	0.26
N				
lb/a				
0	0.10	0.18	1.40	1.58
50	0.12	0.89	1.12	2.01
100	0.34	1.53	1.23	2.76
150	0.42	1.84	1.60	3.44
LSD (0.05)	0.07	0.09	0.16	0.18

<sup>1</sup>The 100 lb P<sub>2</sub>O<sub>5</sub>/a rate was only applied at the beginning of the study (Fall 2012).

**Table 2. Fourth-year yield of newly established tall fescue in the spring and fall 2017 as affected by P<sub>2</sub>O<sub>5</sub> and nitrogen (N) fertilization rates at Site 2**

P <sub>2</sub> O <sub>5</sub>	Yield			
	Spring		Fall harvest	Total (R4 + Fall)
	E2 (jointing)	R4 (half-bloom)		
lb/a	----- ton/a, 12% moisture -----			
0	0.28	0.67	0.76	1.43
25	0.26	0.62	0.73	1.34
50	0.30	0.74	0.78	1.52
100 <sup>1</sup>	0.31	0.66	0.73	1.39
LSD (0.05)	NS	NS	NS	NS
N				
lb/a				
0	0.05	0.11	0.69	0.80
50	0.21	0.42	0.56	0.98
100	0.42	0.89	0.78	1.68
150	0.48	1.26	0.96	2.22
LSD (0.05)	0.08	0.13	0.08	0.18

<sup>1</sup>The 100 lb P<sub>2</sub>O<sub>5</sub>/a rate was only applied at the beginning of the study (Fall 2013).

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

*D.W. Sweeney and D. Ruiz-Diaz<sup>1</sup>*

## Summary

Under high-yielding conditions, corn yield in 2017 was not statistically affected by tillage. Applying nitrogen (N) fertilizer approximately doubled corn yield, but with no difference between N application methods.

## Introduction

Many crop rotation systems are used in southeastern Kansas. This experiment was 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 a rotation.

## Experimental Procedures

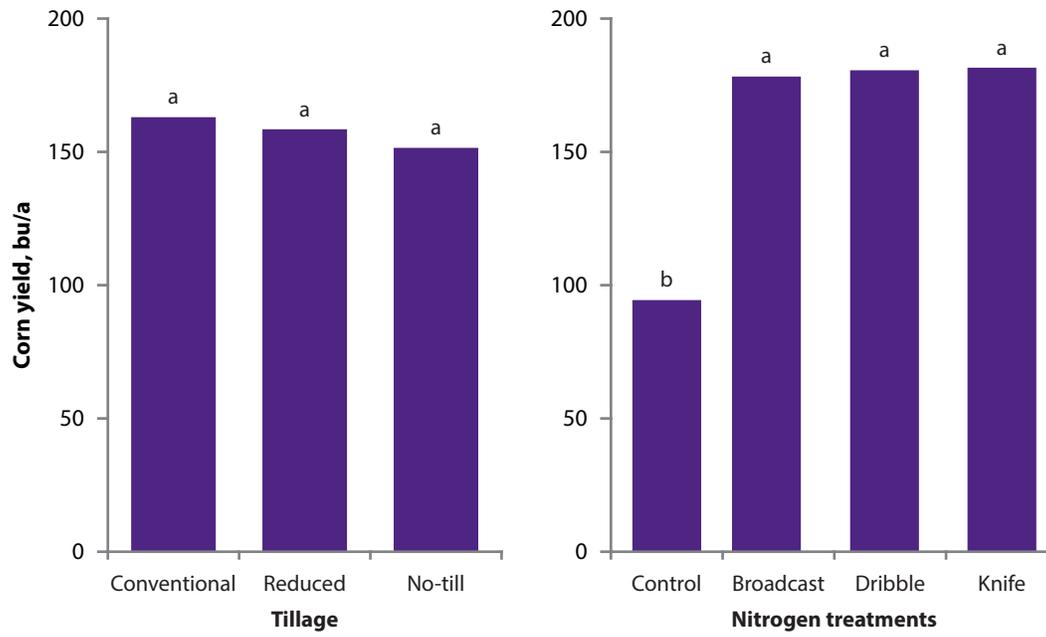
A split-plot design with four replications was initiated in 1983 with tillage system as the whole plot and N treatment as the subplot. In 2005, the rotation was changed to begin a short-season corn/wheat/double-crop soybean sequence. Use of three tillage systems (conventional, reduced, and no-till) continued in the same areas used during the previous 22 years. The conventional system consisted of chiseling, disking, and field cultivation. Chisel operations occurred in the fall preceding corn or wheat crops. The reduced-tillage system consists of disking and field cultivation prior to planting. Glyphosate (Roundup) was applied to the no-till areas. The four N treatments for the crop were: no N (control), broadcast urea ammonium nitrate (UAN; 28% N) solution, dribble UAN solution, and knife UAN solution at a 4 in. depth. The N rate for the corn crop grown in odd years was 125 lb/a. Corn was planted on April 11, 2017.

## Results and Discussion

Overall, yields were high in 2017. Tillage did not statistically affect corn yields (Figure 1). In general, adding N by any placement method approximately doubled the yield obtained without N. However, corn yield in 2017 was not affected by N placement method or by the interaction of tillage by N treatments.

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<sup>1</sup>Department of Agronomy, Kansas State University, Manhattan, KS.



**Figure 1. Effect of tillage and nitrogen placement on corn yield in 2017. Within a graph, bars with the same letter are not significantly different according to LSD (0.05).**

# Timing of Side-Dress Applications of Nitrogen for Corn in Conventional and No-Till Systems

*D.W. Sweeney, D. Shoup, and D. Ruiz-Diaz<sup>1</sup>*

## Summary

Corn yield and yield components were affected by tillage and nitrogen (N) side-dress options in 2017. Corn yields were 14% greater with conventional tillage than with no-till. Yields were improved by either splitting N rate between pre-plant and side-dress or adding additional side-dress N as compared with applying 150 lb/a pre-plant. Side-dress applications of 50 lb N/a at V10 following 150 lb/a applied pre-plant resulted in greatest corn yield.

## 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. Side-dress or split applications 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 side-dress N fertilization compared with pre-plant N applications for corn grown on a claypan soil.

## Experimental Procedures

The experiment was established in spring 2015 on a Parsons silt loam soil at the Parsons unit of the Kansas State University Southeast Agricultural Research Center. The experiment was a split-plot arrangement of a randomized complete block design with four blocks (replications). Whole plot tillage treatments were conventional tillage (chisel, disk, and field cultivate) and no tillage. Sub-plot nitrogen treatments were six pre-plant/side-dress N application combinations that include 1) a no-N control, 2) 150 lb N/a applied pre-plant, 3) 100 lb N/a applied pre-plant with 50 lb N/a applied at the V6 (six-leaf) growth stage, 4) 100 lb N/a applied pre-plant with 50 lb N/a applied at the V10 (ten-leaf) growth stage, 5) 150 lb N/a applied pre-plant with 50 lb N/a applied at the V6 growth stage, and 6) 150 lb N/a applied pre-plant with 50 lb N/a applied at the V10 growth stage. The N source for all treatments was liquid urea-ammonium nitrate (28% N) fertilizer. Pre-plant N fertilizer was applied on March 16, 2017, side-dress N at V6 on May 25, 2017, and side-dress N at V10 on June 12, 2017, to appropriate plots. All N was broadcast applied with 7-stream pattern fertilizer nozzles. Corn was planted on April 11 and harvested on September 11, 2017.

## Results and Discussion

In 2017, corn yielded 18 bu/a more with conventional tillage than with no-tillage, likely because of 16% greater stand (Table 1). Adding N fertilizer, generally, more than doubled yields obtained in the no-N control. Splitting the N fertilizer to apply 100 lb N/a preplant followed by 50 lb N/a at the V6 or V10 growth stages improved yields by

<sup>1</sup>Department of Agronomy, Kansas State University, Manhattan, KS.

more than 15 bu/a greater than all N applied pre-plant. Adding 50 lb N/a extra at the V6 growth stage to a 150 lb N/a preplant application did not improve yields more than that obtained with 150 lb N/a applied split pre-plant and side-dress. However, delaying the extra 50 lb N/a side-dress application to the V10 stage improved yield by nearly 20 bu/a. These effects of N timing on corn yield in 2017 appeared to be related to the combined responses in kernel weight, ears/plant and kernels/ear.

**Table 1. Tillage and nitrogen (N) side-dress application effects on yield and yield components of corn in 2017**

Treatment	Yield bu/a	Stand number/a	Kernel weight mg	Ears/plant	Kernels/ear
Tillage					
Conventional <sup>1</sup>	147.3	22300	225	0.93	789
No-till	129.0	19200	230	0.90	800
LSD (0.10)	16.6	1300	NS	NS	NS
N timing <sup>2</sup>					
No-N control	56.1	20900	178	0.82	483
150 PP	134.8	20900	220	0.92	814
100 PP/50 V6	152.0	20500	232	0.95	866
100 PP/50 V10	151.1	20600	240	0.92	850
150 PP/50 V6	157.8	20800	246	0.96	826
150 PP/50 V10	177.0	20900	250	0.94	929
LSD (0.05)	15.2	NS	19	0.08	80

<sup>1</sup>Conventional tillage: chisel, disk, and field cultivate.

<sup>2</sup>Nitrogen treatments: Control, no N fertilizer; 150 PP, 150 lb N/a applied pre-plant with no side-dress N; 100 PP/50 V6, 100 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V6 (six-leaf) growth stage; 100 PP/50 V10, 100 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V10 (ten-leaf) growth stage; 150 PP/50 V6, 150 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V6 growth stage; and 150 PP/50 V10, 150 lb N/a applied pre-plant with 50 lb N/a side-dress applied at V10 growth stage.

# Response of Soybean Grown on a Claypan Soil in Southeastern Kansas to the Residual of Different Plant Nutrient Sources and Tillage<sup>1</sup>

*D.W. Sweeney, P. Barnes,<sup>2</sup> and G. Pierzynski<sup>3</sup>*

## Summary

The residual from previous high-rate turkey litter applications, which were based on nitrogen (N) requirements of the previous grain sorghum crop, increased 2017 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 marginally affected by residual treatments, the greatest dry matter production at the R6 growth stage was where the N-based litter had been applied and incorporated.

## 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 were applied prior to planting grain sorghum each spring. Individual plot size was 1 acre. The five treatments, replicated twice, were:

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

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

<sup>2</sup>Department of Biological and Agricultural Engineering, Kansas State University, Manhattan, KS.

<sup>3</sup>Department 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 2017, the residual effects of turkey litter and fertilizer amendments affected soybean yield, pods/plant, and seeds/pod (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 and the number of seeds/pod were greater where N-based turkey litter had been applied than in the other residual treatments. Dry matter production was marginally affected by residual treatment through the R4 growth stage. However, at R6, dry matter production was greatest where turkey litter had previously been applied on an N-basis (high rate) and incorporated.

**Table 1. Residual effect of turkey litter and fertilizer amendments on soybean yield, yield components, and dry matter production during 2017**

Residual amendment <sup>1</sup>	Yield bu/a	Stand (× 1000) plants/a	Seed weight mg	Pods/ plant	Seeds/ pod	Dry matter			
						V4	R2	R4	R6
Control	22.7	122	143	30	2.0	440	1420	4130	3830
Fert-C	45.1	123	155	37	2.1	530	2360	5380	5760
TL-N	64.0	115	174	51	2.3	560	2920	5950	5540
TL-N-C	62.5	125	177	43	2.4	570	3300	5830	7650
TL-P-C	40.2	118	154	31	2.1	520	2290	4840	5460
LSD (0.05)	15.6	NS	NS	9	0.1	NS	1110	NS	1070

<sup>1</sup>Control, 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. Kirkham<sup>1</sup>*

## Summary

Sweet corn production was not greatly affected by target population, limited irrigation, or a fungicide applied for stomatal control.

## 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 may 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 Agricultural Research 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 2.5 cm at VT [tassel]) and three fungicide treatments (none or application 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 number of marketable ears, total fresh weight, and individual ear weight was determined. Sweet corn was replanted on May 24, 2017, after herbicide removal of poor original stand resulting from equipment malfunction. Sweet corn was picked by hand on August 1, 2017.

## Results and Discussion

In 2017, even though increasing the sweet corn target population from 15,000 to 30,000 seeds/a increased stand, the number of ears/a harvested and total fresh weight were not significantly increased perhaps because of a reduction in the number of ears/plant. Sweet corn was little affected by limited irrigation or a fungicide applied for stomatal control.

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<sup>1</sup>Department of Agronomy, Kansas State University, Manhattan, KS.

# Crop Production Summary, Southeast Kansas – 2017

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

## Summary

Crop production in southeast Kansas in 2017.

## Introduction

Crop production is dependent on many factors, most notably, environmental conditions during the growing season. Here, we summarize the environmental conditions during the 2017 growing season in comparison to previous years and the historical averages. Information on crop yields is taken from reported values and yields from variety trials in southeast and east central Kansas.

## 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 and eastern Kansas, focusing on crops grown at Parsons, Columbus, and Erie. Please see individual variety results at the K-State Crop Performance Test webpage (<http://www.agronomy.k-state.edu/services/crop-performance-tests/>).

Weather information was collected 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.

## Results and Discussion

### *Weather*

#### **Rainfall**

Total rainfall for 2017 was the highest in the past seven years (Figure 1A), with more than 49 in. of rainfall for the year. A very wet spring from April to mid-June was followed by continuous showers throughout the summer. A strong storm system brought more than 4 in. of rain on August 16, to bring the summer growing season rainfall total to more than 38 in. of rain, much greater than the 7-year average of 24.14 in. (Figure 1B). Late fall and winter rainfalls were less, and closer to average.

#### **Temperature**

Temperatures in 2017 were below average. A two-week warm period in mid-July was the only significant high-temperature period in the growing season, with 16 days above 90°F (Figure 1A) and only one day above 95°F.

#### **Wind**

Kansas is known for its windy days. One measure of wind is “wind run”, which is the cumulative miles of wind received in a day. Early spring is our windiest period, with average wind run exceeding 5500 miles per day (Figure 3). Late summer is the least

windy period. The 2017 spring was windier than average, with monthly wind run exceeding 6000 miles per day. Conversely, the late summer was less windy than normal, with average monthly wind run falling below 3000 miles per day.

### **Crop Production**

Twenty hard red wheat cultivars were grown at Parsons in 2017. The hard red winter wheat yields (57.1 bu/a) were greater than the 7-year average yield of 43.8 bu/a in southeast Kansas, and ranged from 36.5 to 69.9 bu/a (Figure 4). Fourteen soft red wheat cultivars produced an average of 77.8 bu/a, which was greater than the 7-year average yield of 64.7 bu/a and ranged from 60.9 to 91.9 bu/a. Fungal pressure was greater in 2017, primarily because of the high rainfall during late spring and early summer (Figure 1B). Fungicide studies showed a yield increase in 2017 from 35 bu/a to 62 bu/a with fungicide use (Sassenrath, unpublished data).

Twenty eight cultivars of full season corn were tested at Erie, with average yield (159 bu/a) very near the 7-year average yield (152 bu/a), and a range from 127 to 188 bu/a (Figure 5A). This was greater than the 7-year county average yield of 100 bu/a. Twenty-seven short season corn varieties were tested at Parsons, with an average yield of 142 bu/a, and a range of 124 to 152 bu/a (Figure 5B). This is slightly greater than the county average yield for 2017 of 132 bu/a, and greater than the 7-year county average yield.

Twenty two cultivars of soybeans from maturity groups (MG) 3-4 were tested, with an average yield of 46.7 bu/a, and a range of 33 to 55 bu/a, which equaled the 7-year average, and was greater than the county average of 37 bu/a (Figure 6A). Forty-five cultivars of soybeans from MG 4-5 were tested, with an average yield equivalent to the earlier maturity and the 7-year average. The range was similar from 36 to 55 bu/a.

Grain sorghum yields were higher in 2017 for the 22 cultivars tested, with an average yield of 135 bu/a and a range from 51 to 186 bu/a (Figure 7). This is quite a bit higher than the average variety trial yield of 85 bu/a, and 7-year average yield from southeast Kansas of 63 bu/a. Note that many of the lowest-yielding sorghum cultivars had the highest percentage of lodging (Table 1). It is possible that lodging resulted from larger seed heads, as the average wind run was slightly below normal in 2017 (Figure 3).

Fourteen cultivars of oil-seed sunflowers were grown in 2017, with an average yield of 722 lb/a and a range from 553 to 947 lb/a (Figure 8). This is well below the state average. Note, however, that county-level data for sunflower production are not available as the total acres of oil-seed sunflowers planted in southeast Kansas is low, so most of the yield data are from irrigated sunflower production in western Kansas counties.

### **Conclusions**

2017 was a very average year for crop production, with near-average yields in most crops. The notable exception was sorghum that yielded significantly more than in previous years. In contrast, weather conditions were substantially different than normal, with rainfall 15 inches greater than average. Temperatures were also cooler than average during the summer growing season, which would be expected to increase corn and soybean yields.

## CROPPING SYSTEMS RESEARCH

**Table 1. Sorghum yield data from the southeast Kansas Variety Trials 2017 Parsons, Kansas Grain Sorghum Performance Test, Labette County**

Brand	Name	Yield bu/a	PAVG ----- % -----	MOIST	Test weight lb/bu	Plant height in.	Days bloom	Lodge %	Plants per acre
Check	Early	91.2	67.3	13.5	60.3	46.8	48.5	0	70312
Check	Late	<b>180.7</b>	133.4	13.6	61.6	55.3	56.3	0	75599
Check	Medium	126.2	93.2	13.4	60.6	50.3	49.3	0	75046
Chromatin	CHR0029	167.0	123.3	13.7	61.1	60.5	60.3	0	73231
Chromatin	CHR0072	118.4	87.4	13.6	63.4	51.3	57.0	0	72758
Chromatin	CHR2042	143.9	106.2	13.7	61.6	62.5	56.8	1	73626
DEKALB	DKS28-05	94.0	69.4	13.3	60.3	44.5	47.3	0	75599
DEKALB	DKS37-07	146.1	107.9	13.5	61.8	51.0	53.3	0	68418
DEKALB	DKS38-16	167.3	123.6	13.5	63.6	51.5	53.5	0	72758
DEKALB	DKS45-23	<b>171.6</b>	126.7	13.6	62.9	59.8	57.0	0	74336
DEKALB	DKS51-01	<b>172.2</b>	127.1	13.6	61.5	61.8	57.5	0	75757
DEKALB	DKS53-53	<b>186.2</b>	137.5	13.8	61.5	60.5	59.5	0	70390
Dyna-Gro	GX15371	50.6	37.4	14.1	63.2	58.5	61.0	83	75993
Dyna-Gro	GX16367	<b>169.7</b>	125.3	13.5	61.1	62.5	56.3	0	65498
Dyna-Gro	GX16833	81.8	60.4	14.0	62.7	60.8	60.5	53	71811
Dyna-Gro	GX16855	79.6	58.7	13.8	62.1	64.3	59.0	71	57370
Dyna-Gro	GX17818	130.8	96.6	13.9	61.0	55.3	61.8	30	69996
Dyna-Gro	M60GB31	142.3	105.1	13.3	66.0	54.8	54.8	0	70943
Dyna-Gro	M73GR55	117.1	86.5	14.2	61.1	64.8	64.3	39	69917
Dyna-Gro	M74GB17	149.2	110.2	13.7	61.9	62.3	57.8	1	67234
Golden Acres	5556	129.5	95.6	13.4	61.7	50.0	51.5	0	72284
Golden Acres	3960B	164.4	121.4	13.5	61.8	53.0	54.0	0	70312
	Average	135.4	100.0	13.6	61.9	56.4	56.2	13	71327
	CV (%)	8.7	8.7	1.8	--	3.2	1.6	--	5
	LSD (0.05)	16.7	12.3	0.3	--	2.5	1.3	--	5022

\*Yields in bold in the top LSD group. Yields must differ by more than the LSD value to be considered statistically different. Planted: 6/7/2017. Harvested: 10/26/2017. 150-46-0 N, P, K.

Available online at <https://www.agronomy.k-state.edu/services/crop-performance-tests/documents/sorghum/17gs-LBD.pdf>.

# CROPPING SYSTEMS RESEARCH

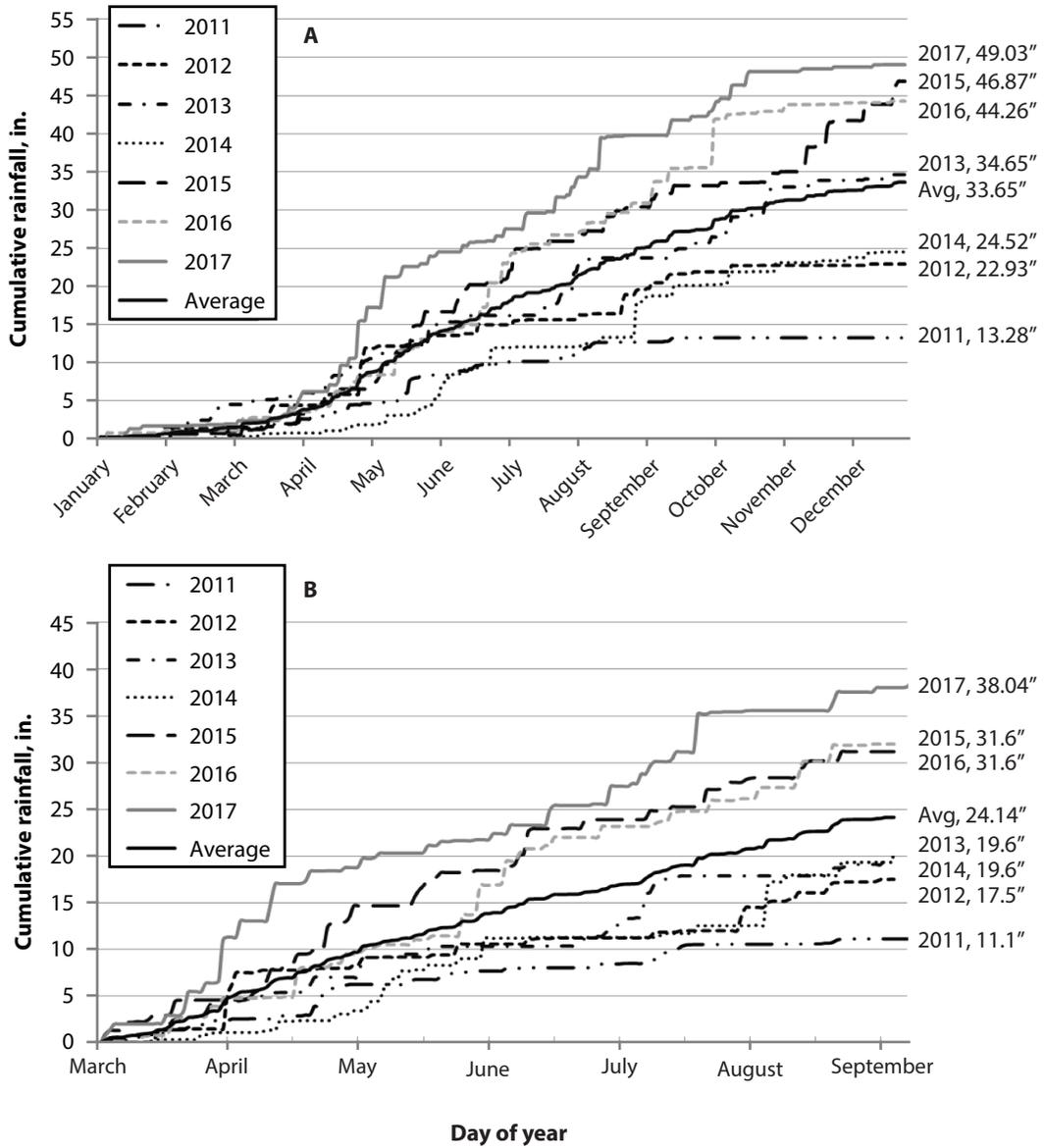
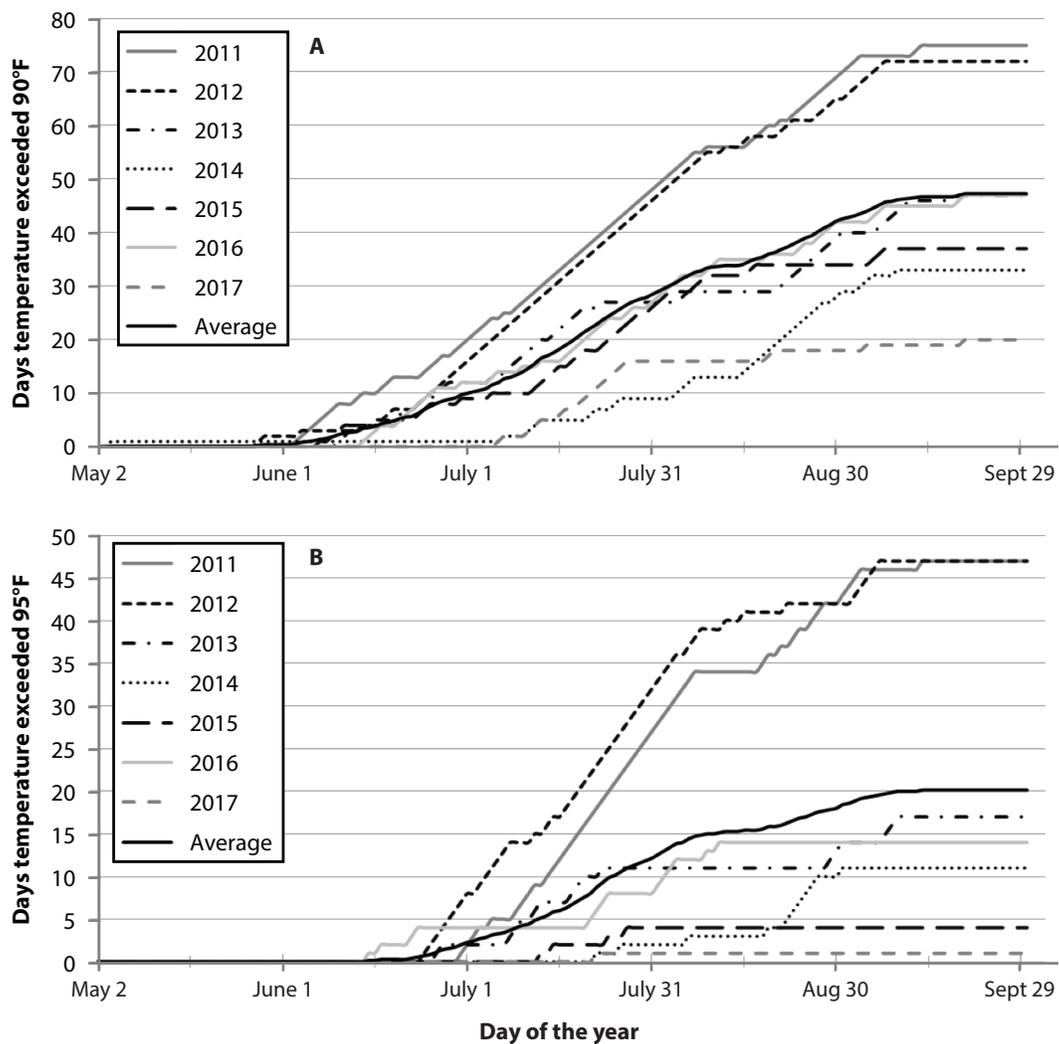


Figure 1. Cumulative rainfall at Parsons during the calendar year (A) and the summer crop production season (B). Seven-year average included for comparison. Rainfall total in inches given after each year.

# CROPPING SYSTEMS RESEARCH



**Figure 2. Temperature patterns and extremes at Parsons during 2017 and preceding years during the year (A) and the summer growing season (B).**

# CROPPING SYSTEMS RESEARCH

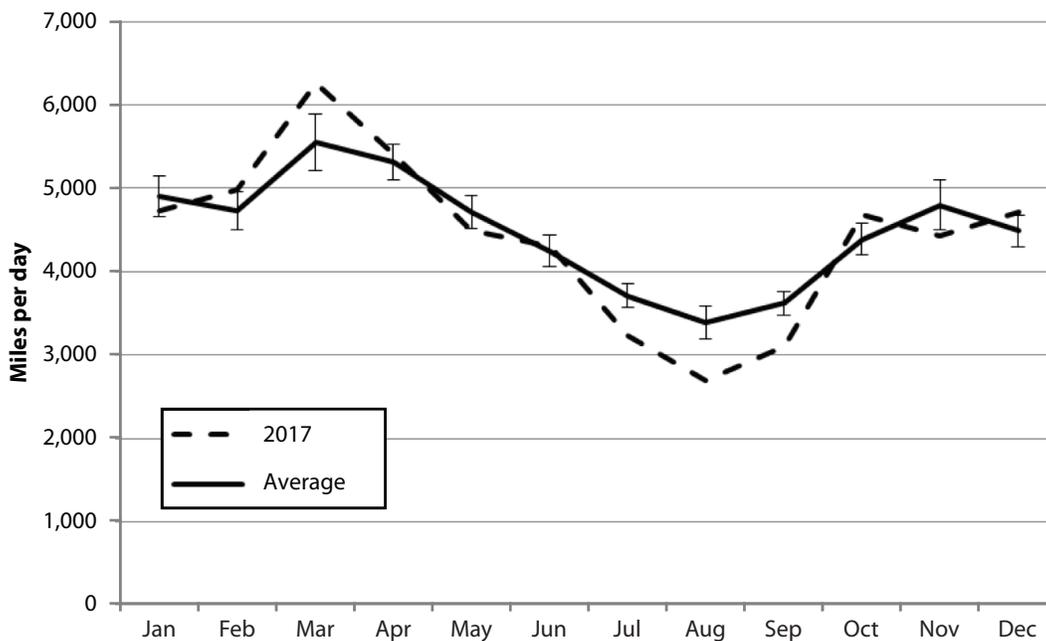


Figure 3. Average monthly wind run in southeast Kansas.

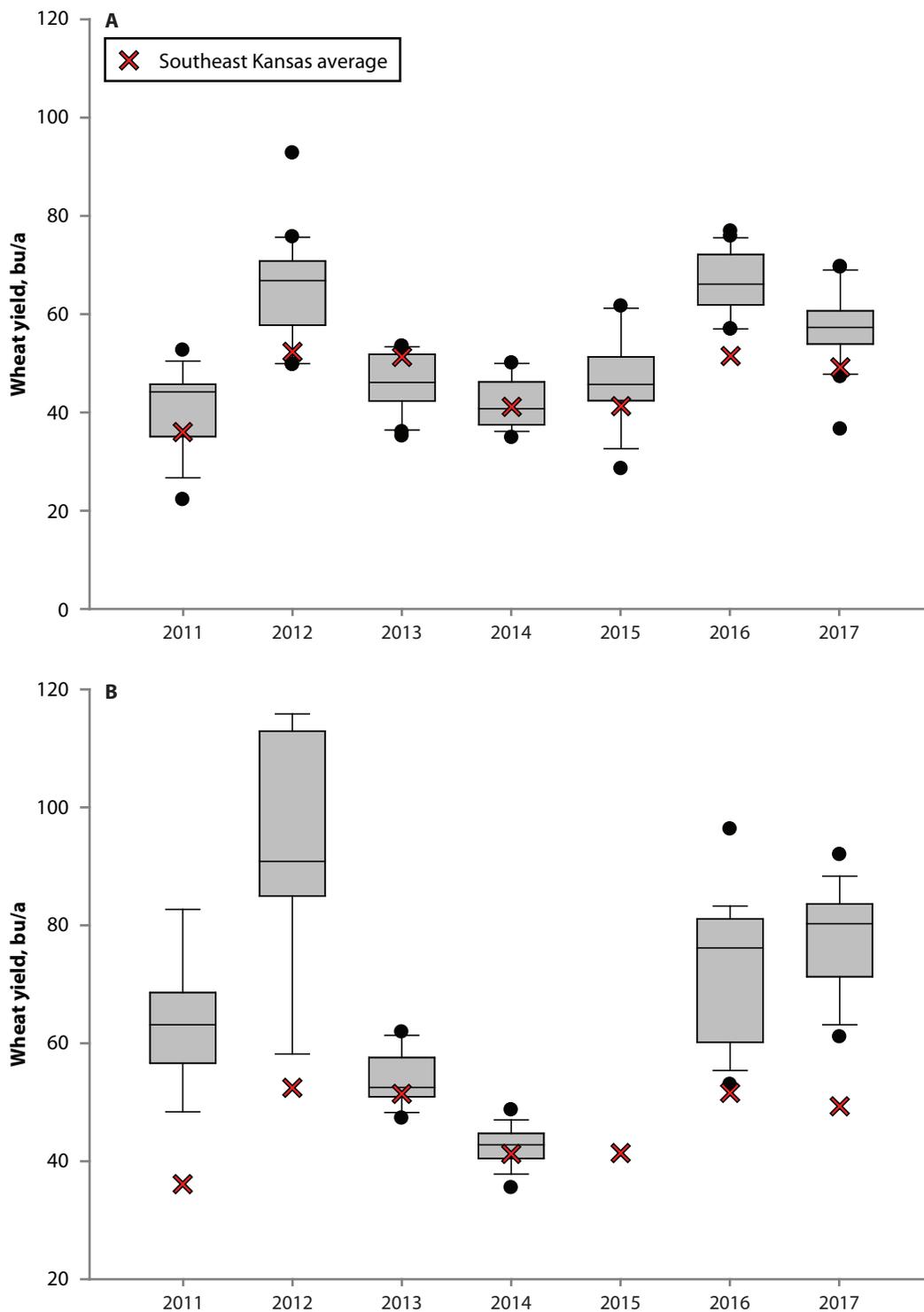


Figure 4. Winter wheat yield for (A) hard red wheat and (B) soft wheat from variety trials in southeast Kansas from 2011 through 2017. The line in the middle of the box plots is the median yield of all varieties. The upper and lower quartiles are given by the upper and lower edges of the boxes. The maximum and minimum values are given by the upper and lower “whiskers” extending from the box. Outliers are given as solid circles. For comparison, average reported yields from southeast Kansas are highlighted as a red X.

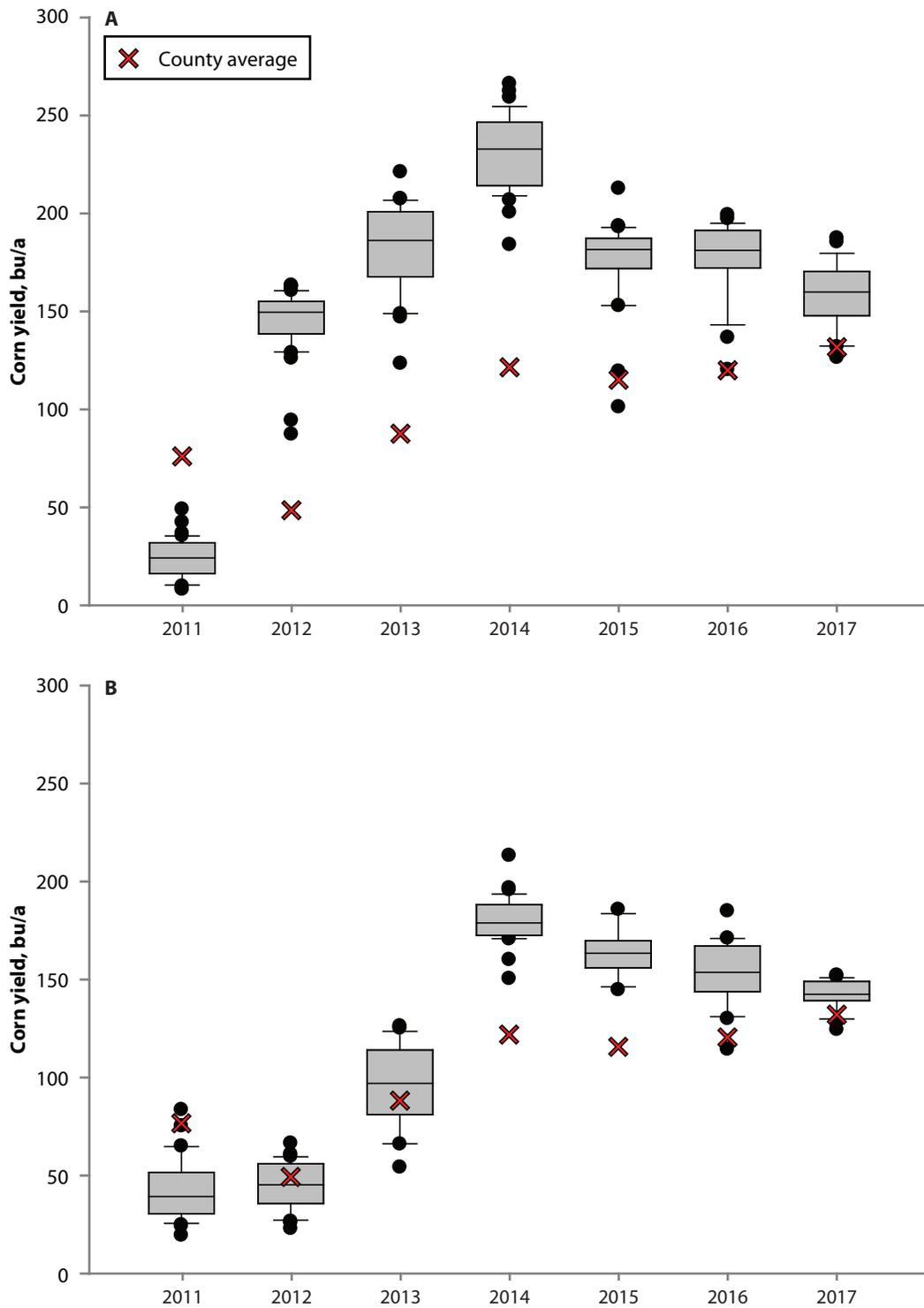


Figure 5. Full season corn at Erie (A) and short season corn at Parsons (B) from variety trials grown from 2011 through 2017. For comparison, average reported county yields from southeast Kansas are highlighted as a red X. 2016 corn variety trial data from Franklin County was used, as variety trial data from southeast Kansas was not available.

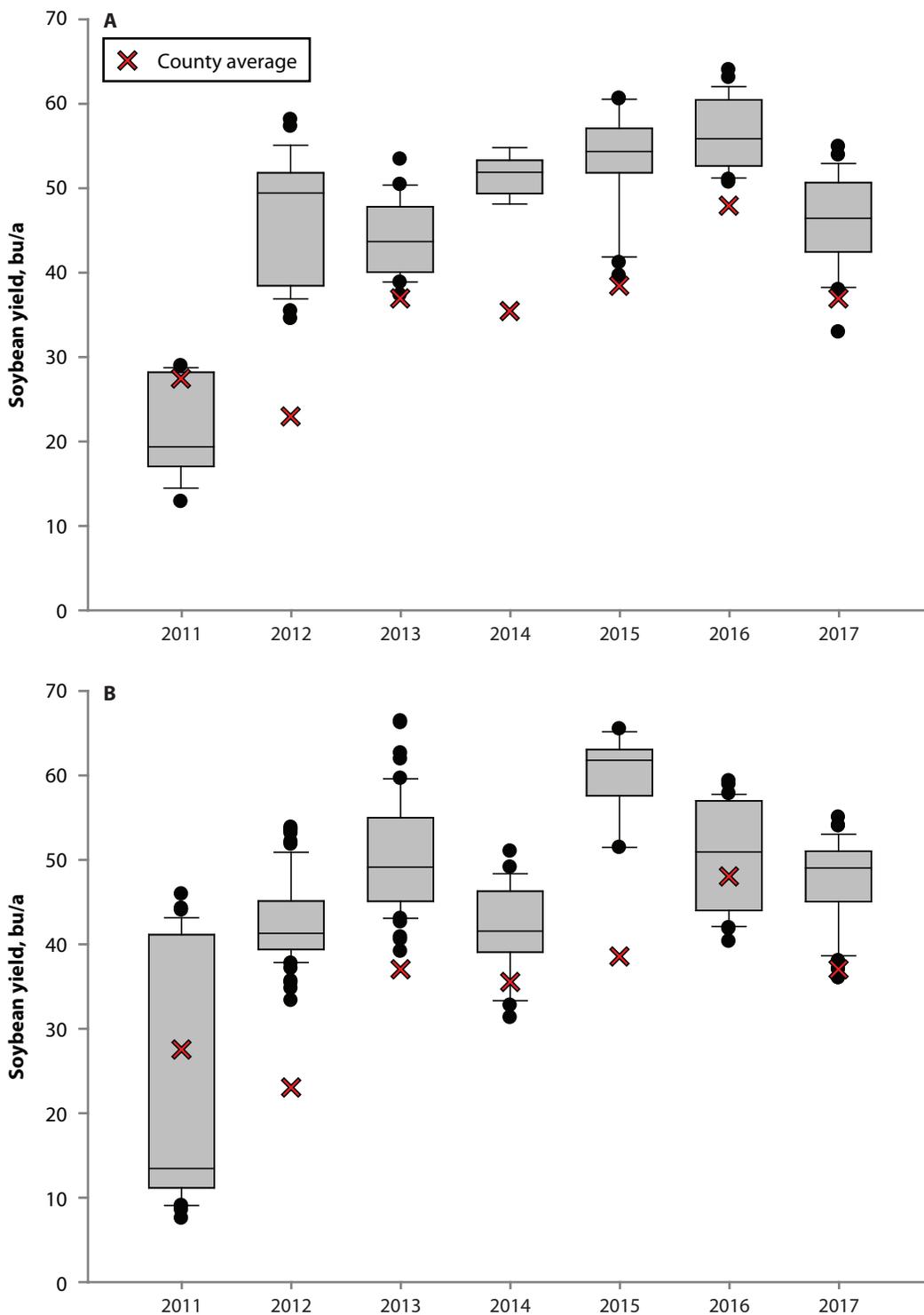


Figure 6. Soybeans from (A) MG3-4 and (B) MG4-5 from variety trials grown from 2011 through 2017. For comparison, average reported county yields from southeast Kansas are highlighted as a red X.

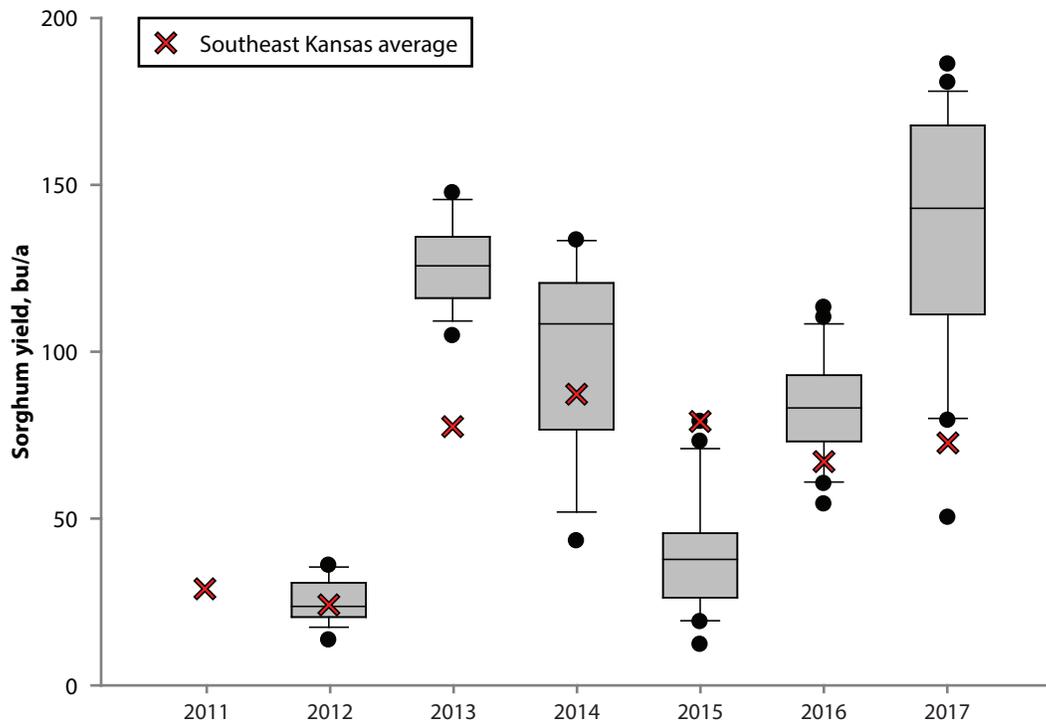


Figure 7. Grain sorghum from variety trials grown from 2011 through 2017. For comparison, average reported yields from southeast Kansas are highlighted as a red X.

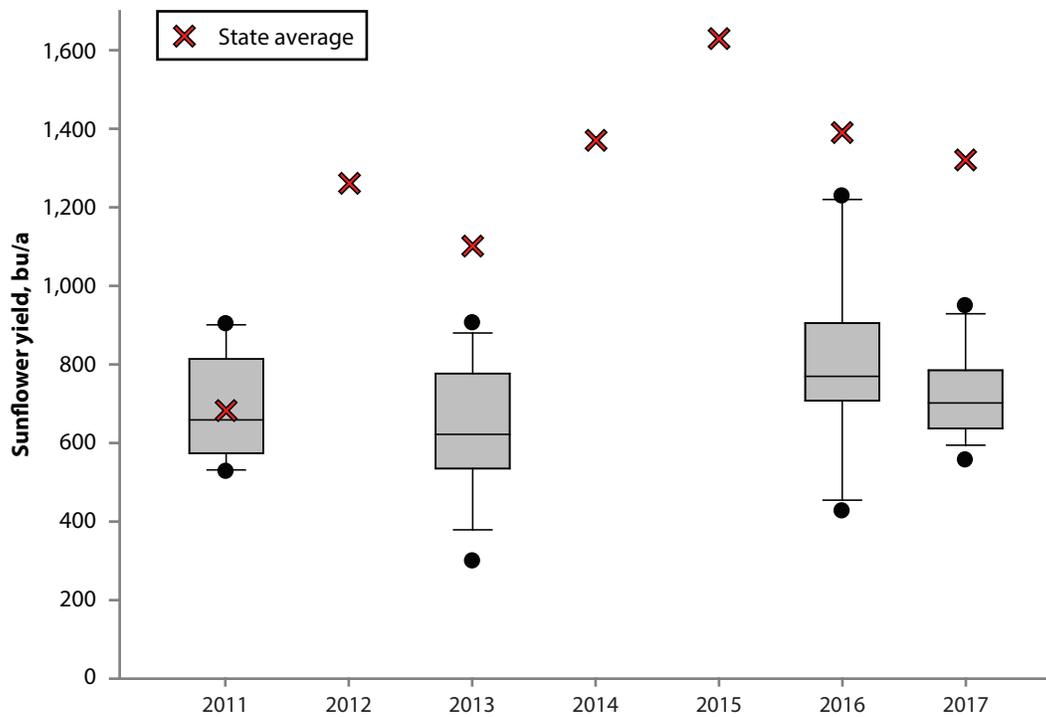


Figure 8. Oil-seed sunflowers from variety trials grown from 2011 through 2017. For comparison, average reported Kansas state yields are highlighted as a red X.

# Electrical Resistivity Tomography of Claypan Soils in Southeastern Kansas

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

## Summary

Crop production and yield in southeast Kansas are highly variable. This may be attributed to many factors, including the variability of soil properties within a field. The relationship between soil and crop yield can be determined by studying bulk properties at the surface such as soil conductivity, crop production maps, and terrain; however, this does not give a complete picture of the underlying causes. Electrical resistivity tomography (ERT) measures changes in soil properties with depth, creating an image of the soil subsurface. Previous researchers believed that the claypan structure in southeastern Kansas was fairly consistently present across fields. The ERT analysis conducted in this study showed that the depth to claypan and the structure of the claypan is actually highly variable. Understanding the subsurface stratigraphy may help to improve crop production and yield by highlighting the ongoing subsurface processes.

## Introduction

Claypan soils cover approximately 10 million acres across several states in the central United States. The soils are characterized by a highly impermeable clay layer within the profile that impedes water flow and root growth. While some claypan soils can be productive, they must be carefully managed to avoid reductions to crop productivity due to root restrictions, water, and nutrient limitations. Clay soils are usually resistant to erosion but may exacerbate erosion of the silt-loam topsoil.

Soil production potential is the capacity of soil to produce at a given level (yield per acre). The productive capacity is tied to soil characteristics, which can be highly variable within a field. In this project, we have used imagery analysis to study the aerial images and terrain of fields during different productive times of the year to identify where soil samples should be collected for more discrete analysis. Soil samples provide valuable information; however, the amount of data obtained from a relatively small area within a field does not provide sufficient information to delineate the subsurface characteristics. To address the limitations of sampling, we have also employed the use of yield maps collected from commercial yield monitors on production-scale combines and surface electrical conductivity measurements (Sassenrath and Kulesza, 2017).

Soil conductivity is a measurement of how well a representative volume of soil conducts electricity. Soil conductivity is a function of the soil clay content, moisture content, and other measurable soil properties (Kitchen et al., 2003); as such, it has become a valuable tool for mapping in-field variability. The main advantage of a soil conductivity measurement is that the entire surface of a field can be imaged. The disadvantage of a soil conductivity measurement is that data are only collected near the surface (10 – 30 inches) and the measurements are relative measurements. This means that the conductivity mappers can identify changes in soil properties, but they cannot directly tell researchers what caused these changes.

Electrical resistivity tomography (ERT) is a popular near-surface geophysical measurement for geophysical and engineering applications. The term “near-surface” generally means down to around 30 feet in the subsurface. Electrical resistivity is the reciprocal measurement of electrical conductivity; therefore, both systems measure differences in the same soil properties. ERT measurements are different than surface electrical conductivity measurements because ERT collects a “slice” of data into the subsurface, as opposed to only changes at the surface area. Relative measurements, similar to those collected in an electrical conductivity survey, are collected; however, in ERT studies the data are mathematically inverted to yield the true electrical resistivity of the soil with depth. This allows an interpretation of the changing soil properties with depth to reduce the required amount of sampling. A disadvantage of an ERT survey is that the data acquisition is stationary so mapping an entire field is not feasible. We have used a coupled process of imagery and terrain analysis, yield maps, and electrical conductivity measurements to guide the locations of ERT surveys in this project (Tucker-Kulesza et al. 2017).

### Experimental Procedures

Crop production fields were selected in collaboration with farmer co-operators. Yield information was collected at harvest. Yields were recorded with commercial yield monitors on production-scale combines. A Veris 3100 system was used to measure soil electrical conductivity for the entire field. The Veris system measures apparent electrical conductivity ( $EC_a$ ) through the field using two arrays of electrodes on coulter. The arrays measure  $EC_a$  at two depths in the field: 0-10 inches and 0-30 inches. The minimum depth, 0-10 inches, was used because this is the depth of interest for this study. The boundary condition for a designated “low yield” area and “high yield” area was determined using the electrical conductivity data and the crop yield data for the field.

ERT surveys were used to measure the apparent resistivity of the underlying soil profile. These surveys began in a low crop yield area and ended in a high crop yield area to show the change in soil subsurface material. Setup for an ERT survey included attaching 56 stainless steel electrodes to 56 stainless steel stakes and driving the stakes into the ground so that the electrodes sit just above the surface (Figure 2). The spacing between each electrode determined the survey depth, therefore, 0.5 feet spacing was used to provide detailed information on the upper soil layers (less than 5 feet). The sequence of measurements, or array type, in an ERT survey affects the resolution of the results and the data collection time. A strong gradient was selected as it collects high resolution data near the surface in approximately one hour. A terrain analysis was conducted to measure the elevation at each electrode. ERT data were mathematically inverted to determine the electrical resistivity of the subsurface using geophysical mathematical procedures. Soil samples were collected in discrete locations throughout the field and will be tested to determine soil type and soil erosion properties in the next phase of this research.

### Results and Discussion

Figure 1A shows the  $EC_a$  across the field. High  $EC_a$  measurements are indicative of soils with high clay content. The high  $EC_a$  measurements directly correlated to areas of low crop yield in the field as shown in Figure 1B. The black line in Figure 1B shows where

the ERT surveys were conducted. Three surveys were collected starting in the middle of the low crop yield area and working north to the high yield area in Figure 1B. The surveys shown in Figure 3 overlap with each other such that the middle of Figure 1A is the starting point of Figure 1B and the middle of Figure 1B is the starting point of Figure 1C.

The first survey (Figure 3A), starts in the middle of a low crop yield area. A low resistivity layer, shown in purple, of approximately 10 Ohm-m was measured from the surface to approximately 0.46 ft. The electrical resistivity of clay is generally 1-20 Ohm-m (Everett 2013), indicating that this layer is likely a clayey soil. This highly impermeable clay layer is exposed at the surface. Although Figure 3A shows the soil in the lower layer had a resistivity of 20 Ohm-m, it was in fact higher, indicating a sandy soil beneath the clay layer at the surface (yellow to red zone). The upper level of 20 Ohm-m was set to improve visualization of the shallow soils of interest near the surface.

The ERT survey conducted in the transition area between the low and high crop yield area (Figure 2B) shows the impermeable clay layer thinning as the region of measurements moves towards a high crop yield area. Figure 3C was conducted in a high crop yield area. No low resistivity areas (10 Ohm-m or less) were noted in this section of the field. This is significant because it was originally thought that claypan soils were uniform throughout the region. The ERT profiles show that the claypan layer is not present in certain areas of the field. Rather than being overlain with topsoil, the clay layer is not present under the high-yielding region of the field. This is contrary to previous research that indicated a persistent clay layer, with differing depth to clay layer. Soil samples were collected from each survey shown in Figure 3. The soil classification will be performed to further explore differences in soil textural information between these different locations.

## Acknowledgments

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 (CBET #1705823). The authors gratefully acknowledge the support of the Kansas State University Women in Engineering Program. The authors thank Lonnie Mengarelli, Garth Blackburn, and Adam Harris for their contribution to the field measurements. We gratefully acknowledge the cooperation of the participating farmer in providing us access to his land. The findings in this report are those of the authors and may not reflect the views of the USDA or the National Science Foundation.

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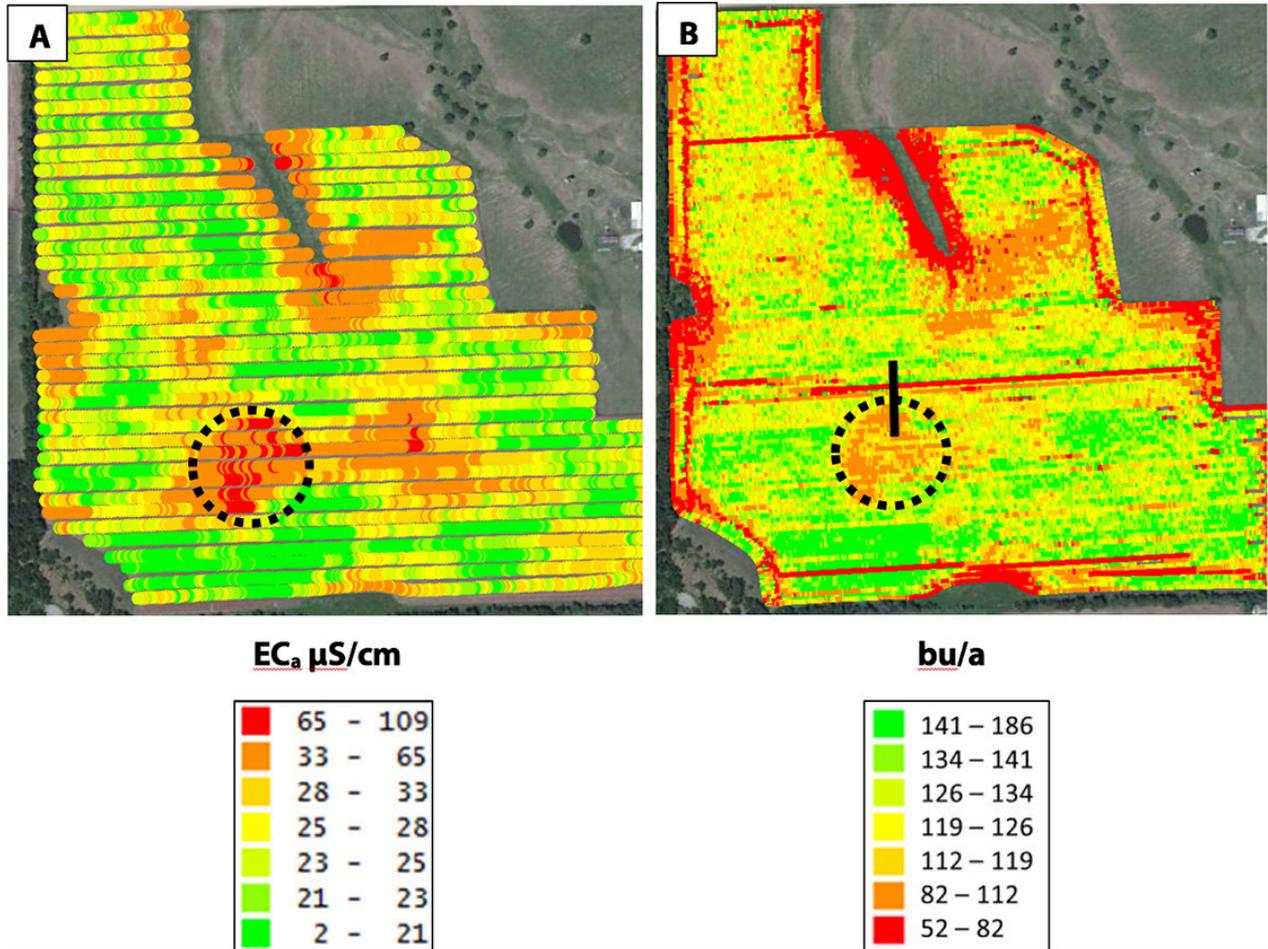


Figure 1. Experimental site: (A) Apparent electrical conductivity (EC<sub>a</sub>) map. High EC<sub>a</sub> indicates high clay content. (B) Corn crop yield map. Note that low crop yield is correlated with high EC<sub>a</sub>. The black line shows where ERT surveys were collected.



**Figure 2. ERT survey experimental setup. Each stainless steel stake is 12 in. long and placed at half-foot intervals across the survey. The stainless steel electrodes are attached to the stainless steel stakes where an electrical current is transmitted through each electrode. The apparent resistivity measurements are recorded for each electrode and stored for later analysis to build the soil profile images presented in Figure 3.**

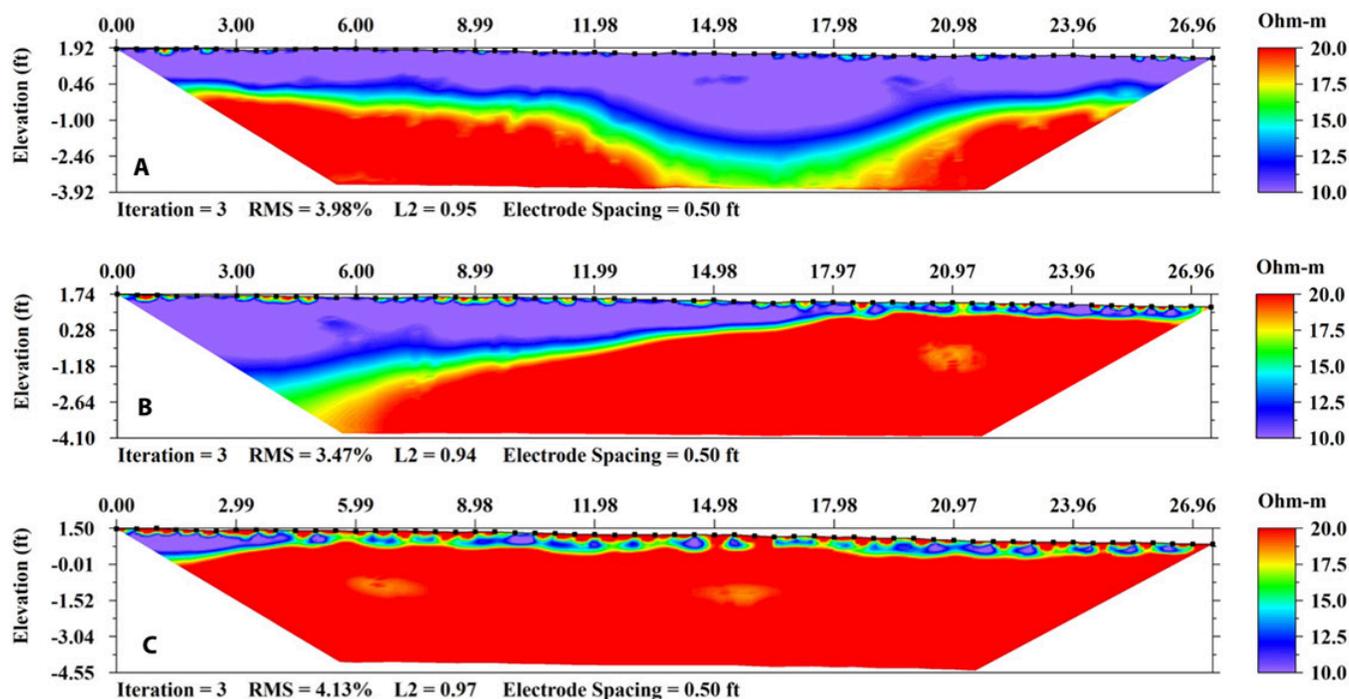


Figure 3. ERT survey results: (A) Low crop yield area; (B) transition area between a low and high crop yield; and (C) high crop yield area.

# Soil Health Profile in Claypan Soils

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

## Summary

Soil health is critical for crop growth and agricultural sustainability. Soil microbial properties are a primary component of soils and a potential indicator of the soil health status. Little is known about the soil microbial properties in claypan soils. Our research confirmed that changes in soil management practices, including tillage and production system, affected the activity of soil microorganisms in surface soils and the degree of increase in enzyme activity in subsoils. A greater concentration of microbial biomass and fungi in the hay meadow systems indicated an increased soil health in this production system. Our research also indicated the vertical stratification of soil properties in claypan soil. Management practices determined the microbial properties in surface soils, while parent materials determined the microbial properties in soils in the claypan layer.

## Introduction

Healthy soil is the foundation of a sustainable agronomic production system. Microorganisms include bacteria (such as actinomycetes), fungi, and protozoa. Soil microorganisms, or microbes, exist in large numbers in soils and are critical for decomposition of organic residues and nutrient recycling. Soils with ample and diverse microbial populations can provide more essential nutrients for crop growth and development. Soil microbial properties are considered one of the major indicators of soil health.

Soil microbial properties can be measured by the activity and the composition of microorganism populations. Phospholipid fatty acids (PLFA) are the primary components of cell membranes. They can be used to estimate the total amount, or biomass, of bacterial and fungal microbes in the soil. The assay measures the amount of phospholipid fatty acids per weight of soil (nmol PLFA/g soil) and is expressed as the PLFA microbial biomass. Microorganisms within the soil release enzymes that degrade organic material to release nutrients needed to support the microbial community. These nutrients are also used to support plant growth. One of the major groups of soil enzymes, hydrolases, decomposes soil material to release carbon, nitrogen, and phosphorus. By measuring the enzymatic activity of these hydrolases within the soil profile, calculated as the amount of substrate decomposed over time for a given weight of soil (nmol/hr/g soil), we can determine the activity of the microbial community.

Claypan soils have a dense, impermeable subsoil that impedes root system development. The soils can be productive, but the productive capacity is often limited by shallow topsoil depth. The poorly drained clayey layer saturates the surface soils, impairs root growth, and exacerbates soil erosion compared to well-drained soils. Crop production on claypan soils requires careful management to maintain productive capacity. It is important to understanding the role of soil microbial properties integrated with soil physical and chemical properties to provide optimal management practices in claypan soils. Little is known about soil microbial properties in claypan soils or how the textural changes in claypan soils impact microbial activity and communities.

In this report, we present how management practices influenced soil microbial properties and describe how soil texture mediates changes in soil microbial properties with depth in claypan soil.

## Experimental Procedures

Soil samples were collected from a field at the Southeast Research and Extension Center research station in Columbus, KS. The soil type is a Parsons silt loam. Three management practices were selected: conventional tillage row crop production (CT), no-till row crop production (NT), and hay meadow (HM). Soil samples were collected and partitioned into 7 different depth intervals (0-2, 2-6, 6-10, 10-14, 14-18, 18-22, and 22-30 in.). The samples were processed for soil texture analysis, nutrient content, soil microbial community composition by phospholipid fatty acid (PLFA) analysis, and soil microbial activity by extracellular enzyme activities analysis (Hsiao et al., 2018).

## Results and Discussion

The results demonstrate a noteworthy impact of management practices on soil microbial properties at both the surface soil and within the claypan layer. In the surface soil (0-6 in.), microbial biomass was nearly 10-fold greater in the HM than in the cropped soils in the top 2 in. of soil (Figure 1). The microbial biomass decreased rapidly at greater depth within the soil profile for all production systems. While the microbial biomass in the CT and NT systems were the same below 6 in., the biomass in the HM system was greater than the cropped systems throughout the soil profile, until the very deepest sampling interval (22-30 in.).

As with the microbial biomass observed in Figure 1, the HM system had much greater microbial community activity, as determined by the hydrolase activity (Figure 2). While the hydrolase activity initially decreased with depth within the soil profile (0 – 10 in.), the activity then increased in the lower soil profile within the clay layer. Within the claypan layer (below ~15 in.), the increase in enzyme activity in HM soils was the greatest. No difference in hydrolase activity was observed in the surface soils or in the subsurface soils for the cropped systems. This increase in microbial activity in HM soils within the clay layer may have important implications for optimal management of clay soils. In contrast to annual cropping systems, a long-term perennial grass system (such as the HM) has plants that occupy the land continuously, indicating the potential of grass systems to utilize more of the soil profile by establishing roots within the clay layer.

The claypan region of Kansas is part of the tallgrass prairie ecoregion. These soils perform well as prairie, potentially due to the ability of grasses to grow within the clay layer. By adapting production practices to include more grasses in the crop rotation, or using grasses as cover crops, we may be able to use more of the soil profile. Grasses are able to create rooting networks that extract more of the soil nutrients from lower soil layers, due in part to their denser rooting systems. Clark et al. (1998) demonstrated that gamagrass grew successfully within the clay layer, creating root channels that could then be utilized by other plants to grow to greater depths within a clay soil. Our results indicate the importance of management system to improve soil health. Reducing tillage and incorporating more grasses within our production systems can support the microbial communities, increasing the water and nutrient cycling within the soil and improving the productive capacity of soil.

## Acknowledgment

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

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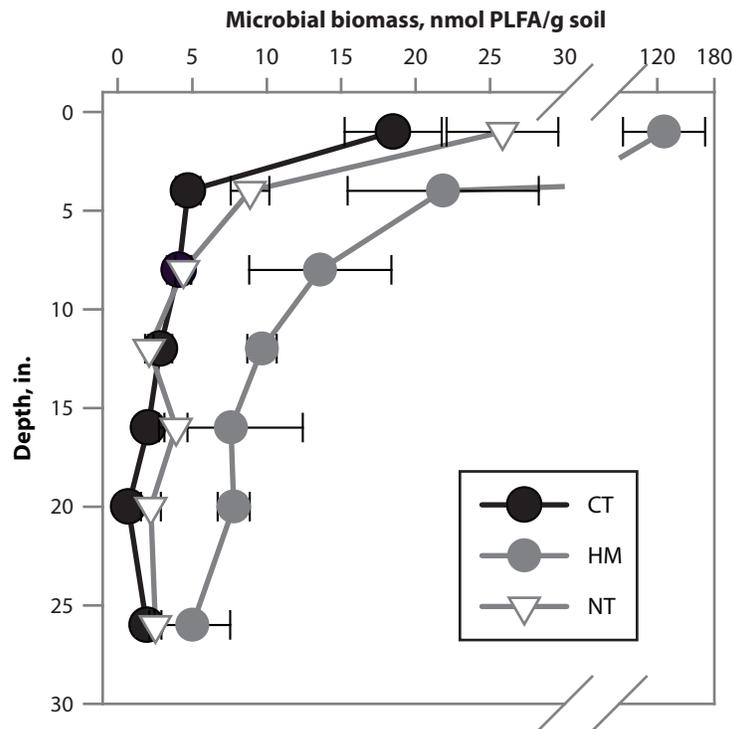


Figure 1. Change in microbial biomass with depth for three production systems, NT, no-till; CT, conventional till; and HM, hay meadow. Note the break in the axis between 30-120 nmol PLFA/g soil. The results are the average of all replications with standard error.

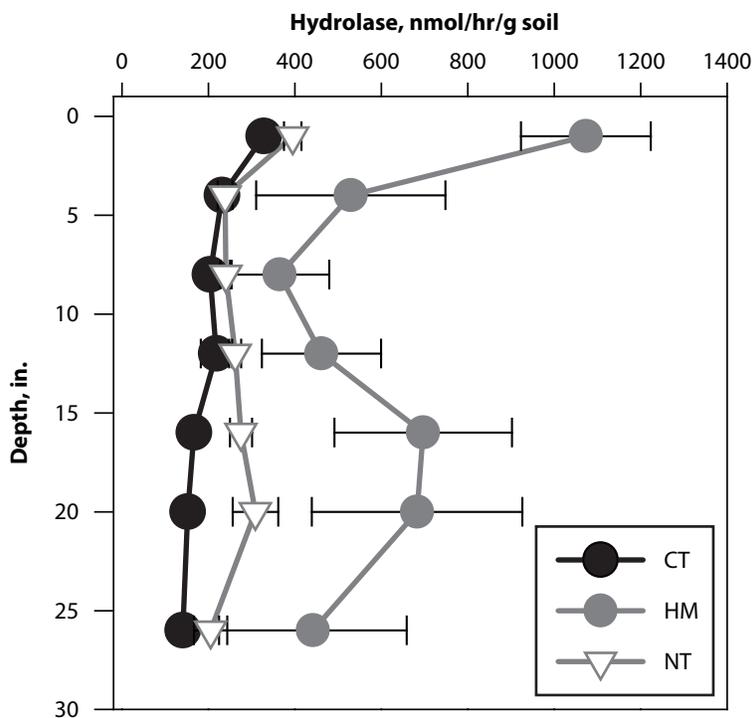


Figure 2. Change in soil enzyme activity with depth for three production systems, NT, no-till; CT, conventional till; and HM, hay meadow. The results are the average of all replications with standard error.

# Growth, Forage Quality, and Economics of Cover Crop Mixes for Grazing

*J.K. Farney, G.F. Sassenrath, C. Davis, D. Presley*

## Summary

Cover crops can improve soil health by diversifying the cropping system. Integrating grazing with cover crop production can also improve the return on investment and reduce costs of planting cover crops. We examined mixtures of three common cover crops: grasses, brassicas, and legumes. Each mixture contained one cover crop from each of the different plant types. The mixtures varied in total protein and fiber amounts, but all mixes would provide adequate forage and protein amounts for cattle. Key differences were observed between the cost to produce each ton of forage dry matter biomass or protein. Cover crop mixes with oats produced more dry matter and protein at the lowest cost.

## Introduction

Cover crops offer many potential benefits to crop production. They diversify the plant system, increase soil organic matter, and reduce erosion. However, they can be expensive to plant. By having cattle graze the cover crops, farmers can recover some of the expenses associated with growing cover crops. Grazing also increases the nutrients to the field, further enhancing the productive capacity of the soil.

Many cover crop mixtures are currently available on the market. However, it is not clear how useful the multi-species cover crop mixtures are, or their potential impact on economics of production. Moreover, many of the cover crop mixes being sold contain species that are potentially harmful to either humans or cattle. For example, some cattle are sensitive to hairy vetch (Farney et al., 2016). Buckwheat, a valuable and frequently used cover crop, causes serious allergic reactions in some human populations, making it especially unsuitable for growing regions that also produce wheat. To avoid cross-contamination of buckwheat with wheat, the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) requires an exclusion of buckwheat by 30 feet and two years from any commercial wheat production fields. NRCS has restricted the use of buckwheat in cover crop mixes for regions that grow wheat (NRCS, 2016).

Many plants are good for planting as cover crops. There are three general categories of plants that are commonly used as cover crops, each with a unique growth habit and rooting structure. In this study, we chose common plants from each of these major groups: grasses, brassicas, and legumes. The soils in southeast Kansas were developed under the tallgrass prairie. Grasses have a dense, fibrous rooting system that is ideally suited for growth in the claypan soils of this region. Studies of soil microbial activity indicate that grasses may enhance microbial activity at lower soil layers, better using more of the soil profile for extracting nutrients and water (Hsiao et al., 2018). The grasses chosen for this study included winter barley, winter oats, cereal rye, and winter wheat. Brassicas have a taproot that creates large holes in the soil called macropores. These macropores break up the soil structure. As the large taproot decays, it supports

microbial activity and further improves the soil structure. Brassicas also release unique compounds into the soil, such as glucosinolates, that have been shown to suppress disease organisms in the soil such as fungi and nematodes. The brassicas used in this study included tillage radish and purple-top turnip. Legumes improve the soil by increasing the soil nitrogen. Most legumes have a fibrous rooting system. The legumes used in this study included berseem clover and Austrian winter pea.

## Experimental Procedures

The sixteen cover crop mixtures were three-way mixes containing one of each of the three plant types. Mixtures were planted at the Kansas State University Southeast Research and Extension Center research field near Columbus, KS, on August 12, 2014, and August 21, 2015, after corn harvest. The planting rates were based on recommendations from the Midwest Cover Crop Selection Tool<sup>1</sup> for Cherokee County, KS, and adjusted to account for multiple species. Seeds were planted with a 10-ft Great Plains no-till drill at the following rates: winter barley, 30 lb/a; winter oats, 37.5 lb/a; cereal rye, 30 lb/a; winter wheat, 30 lb/a; tillage radish, 3 lb/a; purple-top turnip, 2.3 lb/a; berseem clover, 3.7 lb/a; and Austrian winter pea, 19 lb/a.

Total above-ground plant material was collected at three times: 45, 74, and 92 days after planting (DAP) and analyzed for total forage biomass; biomass of each of the cover crop types was analyzed using standard procedures (Farney et al., 2018a). Forage quality was measured as acid detergent fiber (ADF), neutral detergent fiber (NDF), and nitrogen (N). Crude protein (CP) was calculated from total N and total digestible nutrients (TDN) were calculated from ADF. Cost of producing the total dry matter (DM) and percent CP was based on cost of seed for each mixture.

## Results and Discussion

Total dry matter biomass production varied by year (Figure 1). The weather was warmer in 2014 than in 2015, and more biomass was produced in 2014 than in 2015. The brassicas had more growth in 2014 that reduced the growth of the grasses. In 2015, more biomass was produced by the grasses than by the brassicas. The grasses continued to grow even as temperatures decreased with later DAP, while the brassica production in 2014 slowed later in the growing period. The legumes contributed very little to the total biomass in either year, but did show slightly more growth in 2015, when the brassica's growth was less.

The barley and oats had the most biomass production in both years of the study (Figure 2). While the radish had more growth than the turnip in both years, only a significant portion of total biomass was produced by radish in 2014. Clover grew well in 2015; pea did not contribute much biomass in either year of the study.

Total dry matter increased as expected with later DAP, reducing cost per ton of dry matter (Figure 3). Interestingly, no difference was observed in either TDN or NDF at any of the sampling DAP. Crude protein decreased with DAP, as the total biomass increased. Cost per ton of protein was optimal at 74 DAP.

<sup>1</sup>Midwest Cover Crop Selection Tool at <http://mccc.msu.edu/covercroptool/covercroptool.php>.

Total biomass produced was greatest in the mixes containing oats (Figure 4). Dry matter production was most expensive in the rye/pea/turnip mix, at \$59/ton dry matter. The least expensive biomass production was the oats/clover, and either radish (\$18) or turnip (\$14.20). This was followed closely by the barley/clover, and either radish (\$21.40) or turnip (\$20.80).

Percent crude protein tended to be higher in the rye and wheat mixes, and less in the oat and barley mixtures. The overall range of crude protein was small; it varied from a low of 18% in the barley/clover/radish mix to a maximum of 24.7% in the rye/clover/turnip mixture. However, the cost per ton of protein was variable, with the most expensive in the rye/turnip/pea mixture at \$266.40/ton protein. Crude protein was the least expensive to produce in the oat/turnip/clover mix at \$76.60. Overall, the oat/clover and barley/clover mixes were the least expensive mixes to produce both dry matter and protein. The most expensive mixes included rye/pea and wheat/pea.

All of the mixtures would provide enough protein and fiber for cattle needs. Given the strong biomass and protein production and least cost, oat and barley are good choices for cover crops for fall grazing. By producing more biomass, these plants would provide more grazing capacity and potentially provide greater revenue per acre. Addition of a brassica is useful for improving soil health, but does add additional expense. Also, note that cattle do not prefer to graze brassicas prior to a frost due to their bitter taste. Legumes, while useful in providing nitrogen, did not add much biomass. The cost per acre of planting the legumes was comparable to that of the grasses, so including legumes in the mix would double the cost of planting the cover crops, without significantly increasing either the protein or the biomass produced (Farney et al., 2018b).

## Acknowledgments

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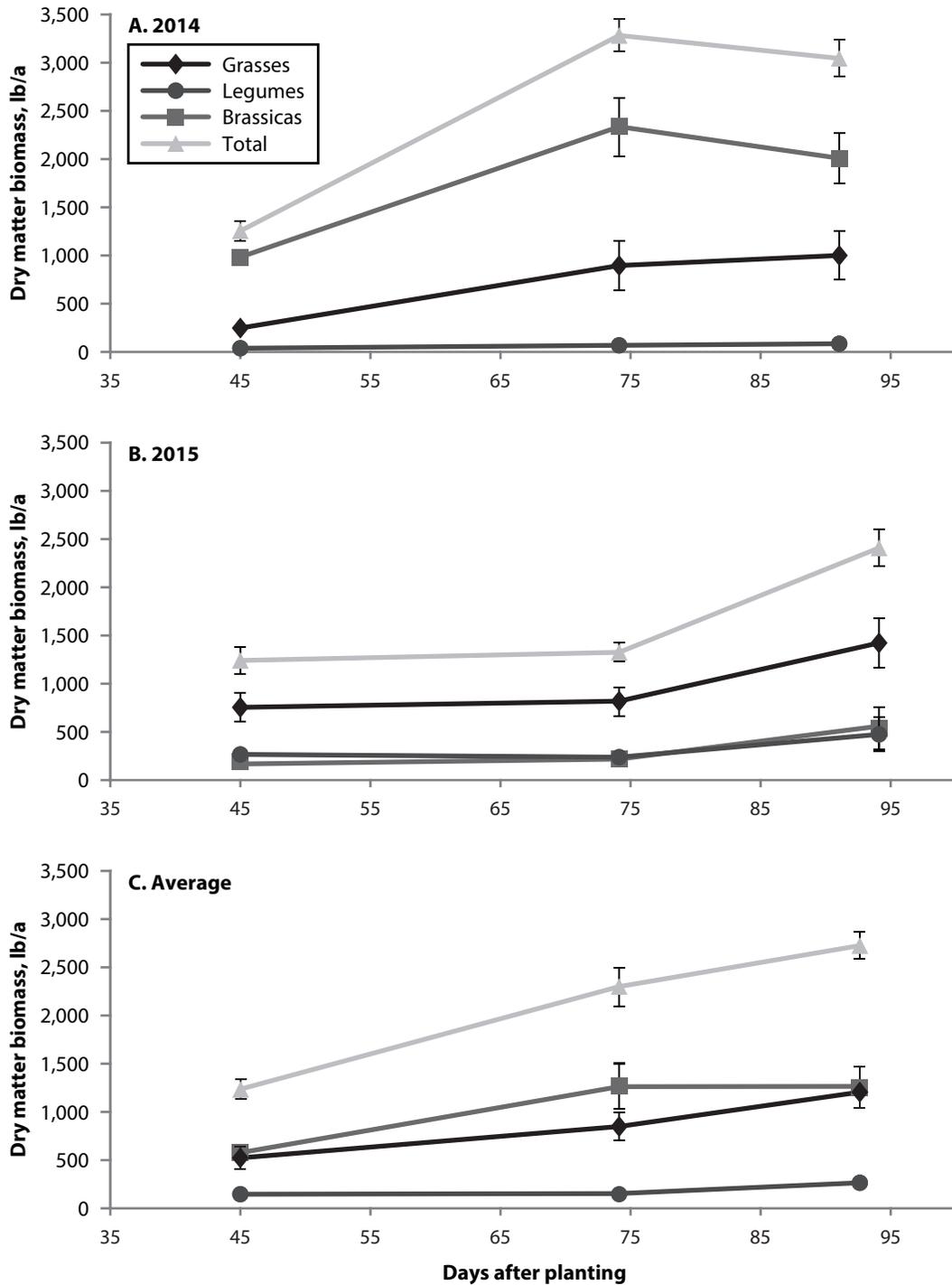


Figure 1. Forage dry matter biomass production, lb dry matter/acre, in the cover crop mixtures for days after planting for (A) 2014, (B) 2015, and (C) the two-year average.

# CROPPING SYSTEMS RESEARCH

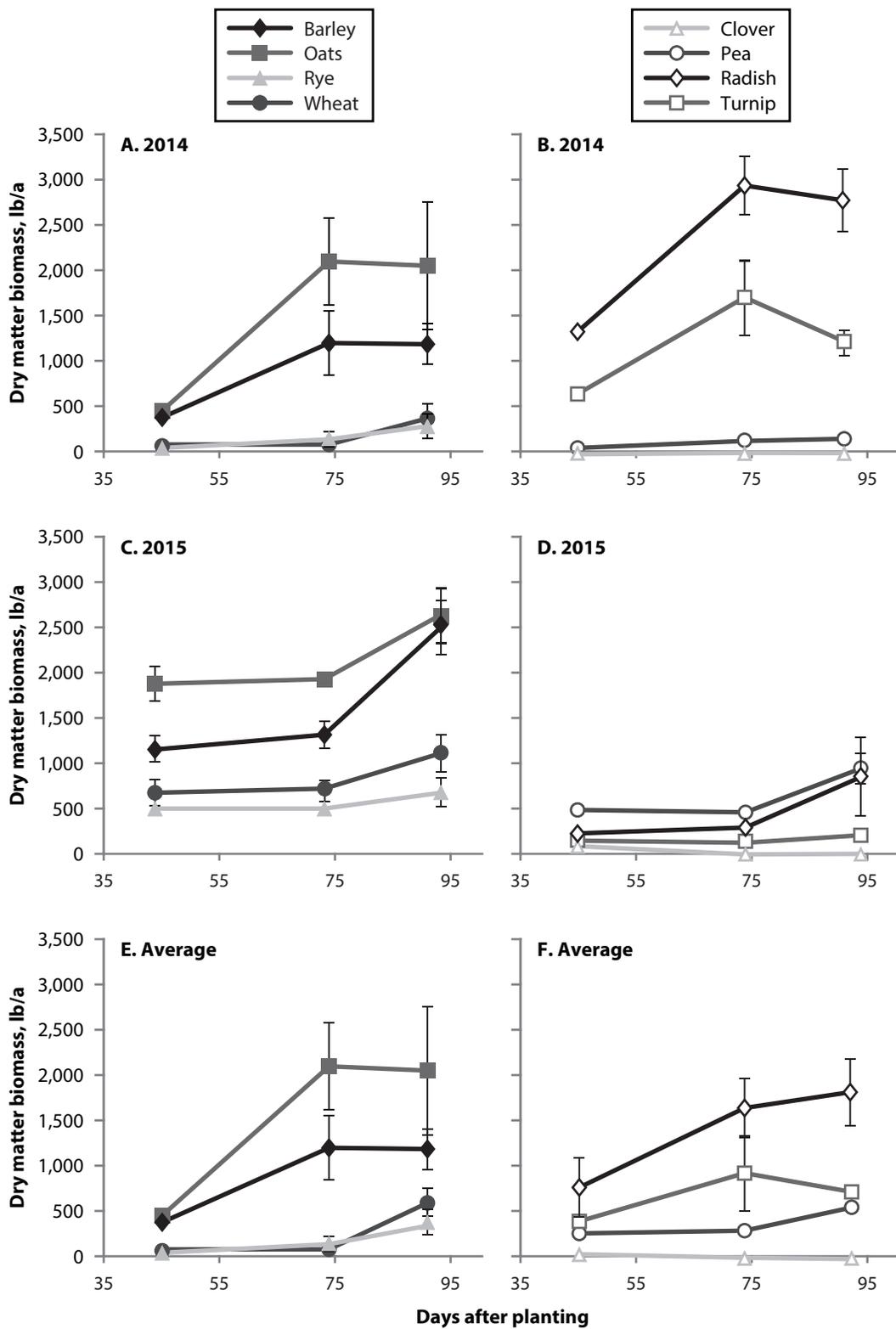


Figure 2. Forage dry matter biomass production, lb dry matter/acre, for each of the cover crops in the mixtures for days after planting for 2014 (A, B); 2015 (C, D) and the two-year average (E, F) for grasses (A, C, E); and brassicas and legumes (B, D, F).

# CROPPING SYSTEMS RESEARCH

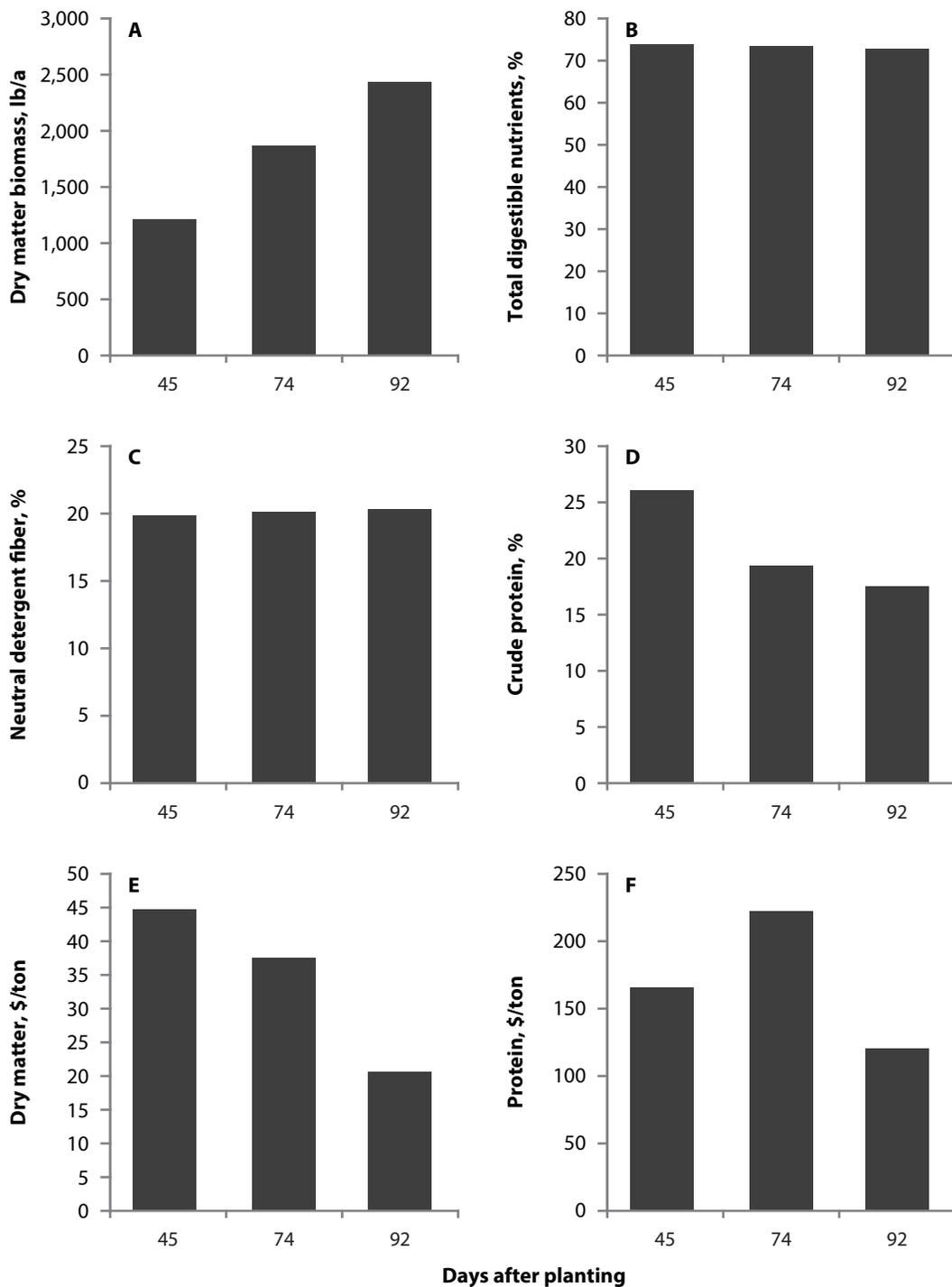
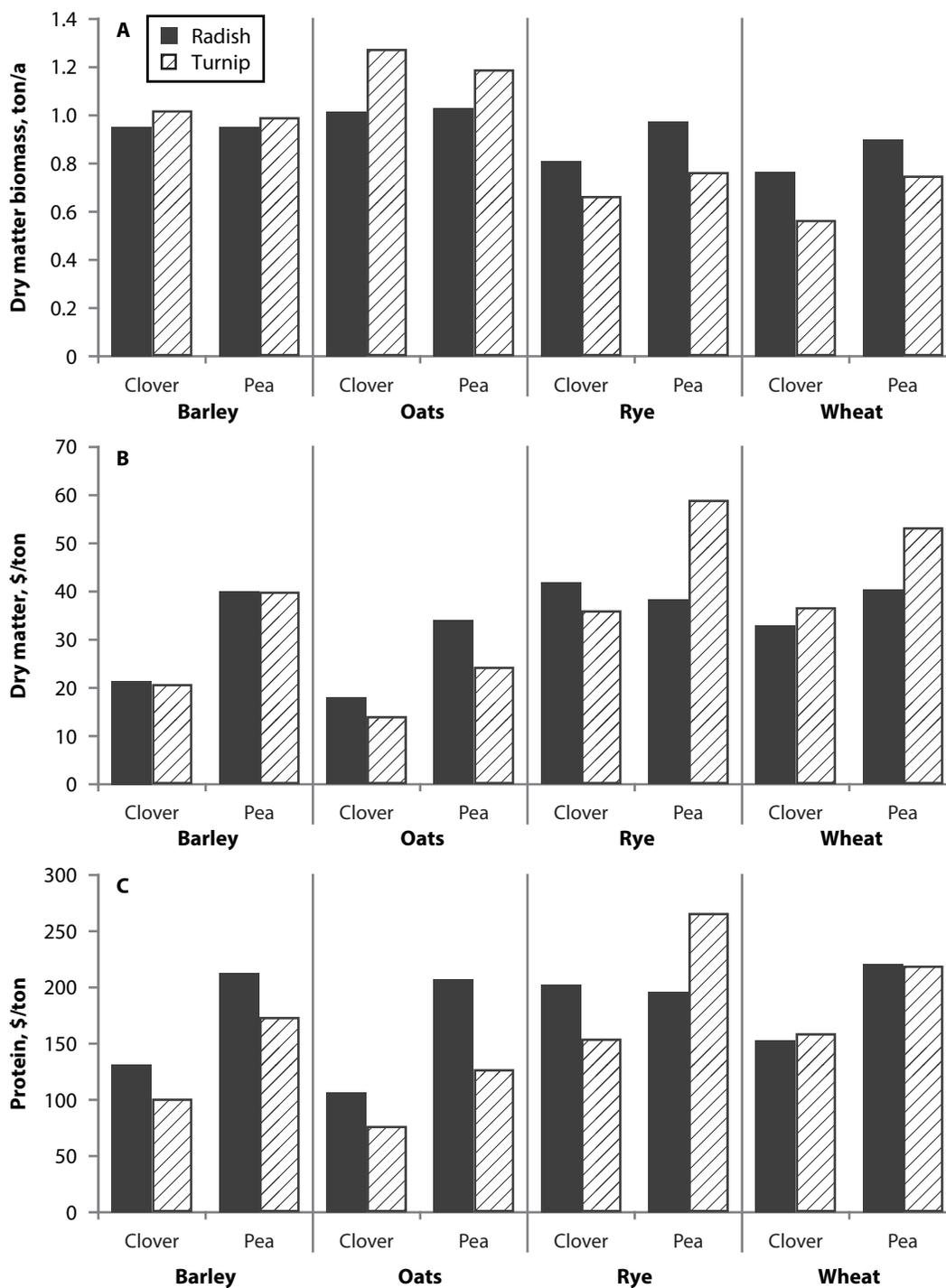


Figure 3. Change in forage biomass, quality, and cost for days after planting for (A) total forage dry matter biomass, lb dry matter/acre; (B) total digestible nutrients, %; (C) neutral detergent fiber, %; (D) crude protein, %; (E) cost per ton of dry matter produced, \$/ton; and (F) cost per ton of protein produced, \$/ton.

# CROPPING SYSTEMS RESEARCH



**Figure 4.** Forage biomass production and cost of cover crop mixes, averaged across both years. (A) Forage biomass dry matter production, lb dry matter/acre; (B) cost per ton of dry matter, \$/ton; and (C) cost per ton of protein, \$/ton.

# Exploring the Physical, Chemical and Biological Components of Soil: Improving Soil Health for Better Productive Capacity

*G.F. Sassenrath, K. Davis, A. Sassenrath-Cole, and N. Riding*

## Summary

Soil health depends on the physical, chemical, and biological composition of the soil. Improving the soil health can improve the productive capacity of the soil, producing more crops and of higher quality. Soil health is affected by management practices, including tillage, crop rotations, and cover crops.

## Introduction

“Soil health” is a term that is used to describe soil quality. The U.S. Department of Agriculture’s Natural Resources Conservation Service has defined soil health as, “The continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans (NRCS 2018).” For a farmer, soil health is the productive capacity of the soil, or the capacity of the soil to produce a crop or pasture. Healthy soils produce more and with better quality.

Soil health is critical for water and nutrient cycling. Soil captures rainwater and stores it for use by plants. Soil health is important to improve both the amount of water and nutrients that a soil can hold, and the availability of water and nutrients for plants. The storage of water and nutrients and subsequent transfer to plants are critical determinants of the productive capacity of the soil, and the soil health.

Here, we explore the fundamental components of soil, and how each component contributes to soil health and soil productive capacity.

## Soil Physical Components

Soil has physical, chemical, and biological components. The physical components of soil are well-studied and comprise the rocks and minerals that have been broken up over time into very small particles of sand, silt, and clay. These compounds are regularly measured to classify the texture of the soil. Sand is the coarsest material (50  $\mu\text{m}$  (microns) – 2 mm) and can be easily seen or felt in a soil sample as rough particles. Silt particles are smaller than sand (2 – 50  $\mu\text{m}$ ; Figure 1), while clay particles are very small (less than 2  $\mu\text{m}$ ) The relative proportions of sand, silt, and clay determine the soil textural classification, visualized on the US Soil Texture Triangle (Figure 2). The textural composition of soil is determined by the soil formation processes that are regulated by time, topography, climate, living organisms, and the parent material, for example the underlying rock. In southeast Kansas, limestone is a common parent material. Some soils are developed from erosion. Wind and water can carry soil and deposit it in new areas, creating loess (wind-blown) or alluvial (water-borne) soils. A silt loam soil has 20 to 50% sand, 75 to 90% silt, and 0 to 30% clay. In contrast, a silty clay loam has 0 to 20% sand, 60 to 70% silt, and 25 to 40% clay.

The US Soil Texture Triangle classifies soils by composition (Figure 2). Claypan soils, common to southeast Kansas, were formed by the downward movement of small clay particles in the soil profile, and accumulation of the clay particles into a clay layer. This clay layer restricts the movement of water within the soil profile as the clay particles tightly bind water. The clay layer can also restrict root growth because of its high bulk density. Bulk density is a measure of the soil structure and the weight of the soil within a given volume. A friable soil has lower bulk density, better soil structure, and allows easier seedling germination than a compacted soil with high bulk density.

Soil was sampled from several locations and at increasing depths in the soil profile in crop production fields in southeast Kansas and analyzed for soil texture. In a typical field in southeast Kansas the soil changes from silt loam on the surface to silty clay loam and silty clay with increasing depth in the soil profile (Figure 2A). After about 12 inches in the soil profile, the soil texture is clay.

One serious result of tillage is the loss of topsoil (Figure 2B). As the productive silt loam topsoil is eroded away, the unproductive clay layer is exposed, as measured by the clay soil at 3 inches at some locations in Field 2. This loss of topsoil and increase in clay content reduces the productive capacity of the soil. The change in soil texture also alters the electrical resistivity (Mathis et al., 2018), as clay has higher electrical conductivity (and hence lower electrical resistivity) than sand or silt. The change in electrical resistivity of soil with texture is being used to map the clay layer and understand mechanisms of erosion in clay soils.

Management practices, including tillage, crop rotations, and cover crops alter the structure of the soil (Figure 3). Historically, we thought tillage was required to provide good soil structure for crop production by breaking up soil compaction. More recent research has shown that while tillage initially breaks up the soil structure and reduces compaction, tillage is not good for soil structure in the long term as tillage actually increases the compaction of the soil (NRCS, 2018). Soils managed with reduced or no tillage have better soil structure, improving seedling establishment and plant growth. Reducing soil tillage also improves the biological components of the soil by maintaining roots and microbial networks which in turn improve the overall soil health. A good physical composition is the first ingredient of a healthy soil but changing the soil physical composition is very difficult. Soil structure can be managed however, to improve bulk density and aggregate stability, improving the soil health.

### **Soil Chemical Component**

The chemical components of soil include the pH, nutrients—such as nitrogen (N), phosphorus (P or DAP), potassium (K or potash)—and water. Soil health is critical for determining both the amount of water and nutrients that can be stored in the soil, and the availability of water and nutrients to plants.

The chemical component of soil depends in large part on the soil physical component. Soil physical characteristics determine, in part, how much water the soil can hold. Water fills the spaces, or pores, between the soil mineral particles and is held in the pores by the surface of these particles. Water is held within the pore spaces and on the surface of the particles by two forces. One of the forces is the attractive force between

water molecules. The other force is the attractive force between the mineral particle and water. The amount of water that can be held by the soil depends partially on the size of the mineral particles. Smaller mineral particles have greater surface area, smaller pore size, and stronger forces to hold water. The larger the individual pores, the lower the energy of attraction that holds the water within the pore and hence the less water that can be held within the soil. Large soil pores require more energy to hold water within the pore; instead, the water drains out of the soil quickly. As the pores become smaller, the attractive forces between the soil mineral particles and the water increase, holding the water in the pore. For this reason, clay soils, with very small soil particles and small pores, hold more water than sandy soils.

The soil physical characteristics also determine how much water is available to plants. As the soil mineral particles decrease in size, the pore size decreases, binding the water more tightly within the pores. However, while there may be more water in the soil it is no longer available to plants. The water is held so tightly in the pore spaces between the soil particles that plant roots are not able to remove it. Even though there is water in the soil, plants will wilt because of lack of water. The “plant-available water” is an important characteristic of soils that indicates how much water can be stored in the soil and how much of that water is available for the plant roots to take up. For a sandy soil, the large pores in the soil matrix do not hold water easily, limiting the amount of water that can be stored within the soil but making the water that is there readily available to plants. In contrast, a clay soil, with very small pores, can hold more water than sandy soils but the water is not readily available to plants as it is bound tightly within the soil matrix. Clay mineral particles bind water and nutrients very tightly because of the high cohesion, or binding, between the very small clay particles and the water or nutrients. Even when clay soils have high water or nutrient content, the plant may not be able to take up the water and nutrients because the clay particles bind them too tightly.

The soil chemical and physical components depend partially on the mineral elements of the soil, but also on the other components of soil—especially the biological components. The plant roots, soil microbes (bacteria and fungi), and decaying vegetation make up an important part of the soil and help give the soil good structure. A soil with good structure will form stable aggregates that allow easy infiltration of rainwater. The soil aggregates will hold water, yet release the water for greater availability for plants. While tillage initially increases the pore space in the soil, it destroys the soil structure by breaking apart soil aggregates, disrupting plant root and fungal hyphae networks, and reducing organic matter. Tilled soils eventually become more compacted because of this loss in soil structure. In contrast, no-till management preserves the plant and fungal networks, increases the organic matter in the soil, and creates soils with stable aggregates. Organic matter, from plant material and soil organisms, readily absorbs water and holds it until needed by plant roots. More soil organic matter increases the ability of the soil to absorb rain water rather than having it run off. As the organic matter in the soil increases, the plant-available water also increases. It has been estimated that for every 1% increase in soil organic matter, the plant-available water in the soil increases by more than 20,000 gallons per acre (NRCS, 2013; Bryant, 2015). During the rapid growing phase, corn in southeast Kansas uses about  $\frac{1}{4}$  inch of water per day (Figure 4). Every 4 days, a corn crop needs an additional 1 inch of soil water. Soils with greater amounts of organic matter increase both the amount of water held in the soil and the water available to that growing corn crop.

## Soil Biological Component

The final component of soil that is critical to the overall productive capacity of soil to provide a “vital living ecosystem” is the biological component. We are learning much more about the factors involved in the biology of soils and their role in soil health. The biological component includes the plants, animals, insects, earthworms, nematodes, arthropods, protozoa, fungi, and bacteria that live in the soil. The biological community is a very important component of soil health. While much of the soil biological community is visible, such as earthworms, much of the biological component is too small to be seen without magnification. This microscopic community, the microbial community or microbiome, is responsible for much of the recycling and transport of nutrients and water that occurs in the soil. A teaspoon of soil can contain a billion bacterial cells, several to hundreds of yards of fungal hyphae (Figure 5), thousands of protozoa, and 10-20 nematodes (Ingham, 2018). Some of these are beneficial, for example the *Rhizobium* bacteria that work with plants to fix nitrogen in legumes such as soybeans. Arbuscular mycorrhizal fungi (AMF) are a group of beneficial fungi that form close bonds with plants, actually growing into the root cells of vascular plants and helping the plants take up nutrients. Other microorganisms are detrimental, such as the fungus *Macrophomina phaseolina* that causes charcoal rot. The soil microbiome is truly a very dynamic, active, and diverse community. The microbial community performs much of the activities of breaking up and recycling plant residues, and capturing nutrients and water. The bacteria and fungi form close interactions with plants, creating symbiotic relationships that benefit both the plants and the microbes. The microbes mine nutrients and water from the soil and transfer these to the plants. In turn, the plants release sugars (carbohydrates) that the microbes need for an energy source. This dense, symbiotic network is the key to soil health.

Soil biological activity is more challenging to measure than physical or chemical properties. Changes in microbial activity have been observed for different production systems (Hsiao et al., 2108), with soils from a hay meadow having nearly 10 times greater microbial biomass than soils from cropped fields. The grasses were also more active deeper in the soil profile, as observed by an increase in enzyme activity within the clay layer (>12 inches depth in the soil profile). By creating dense networks within the soil, grass ecosystems are better able to use more of the soil profile, extracting more nutrients and water for plant growth.

## Results and Discussion

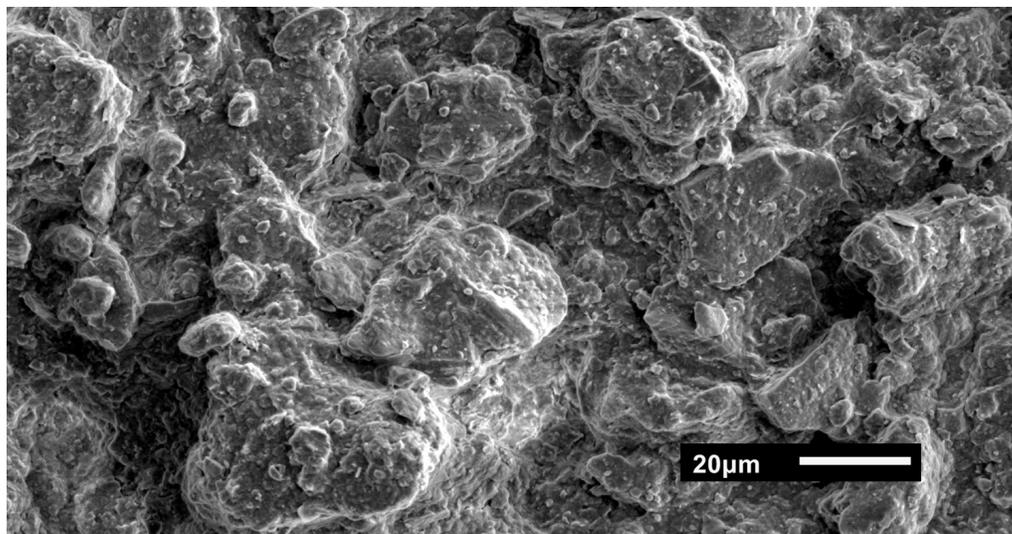
We cannot change the mineral composition of soils. We commonly manage the chemical composition through the addition of fertilizers and lime. We can improve the soil biological component through better management practices. Reducing tillage operations will improve soil health by preserving root and fungal networks and increasing the organic matter. This increase in organic matter and biological structure will improve the aggregate stability and productive capacity of the soil. Planting cover crops can also increase the organic matter in the soil. Grasses in particular offer benefits to the traditional prairie soils in southeast Kansas by developing a dense network of roots that grow into the clay layer. By improving the soil health, we can improve the resiliency of our soils—increasing the amount of water stored in the soil, reducing runoff, and increasing the water available for crop production.

## Acknowledgment

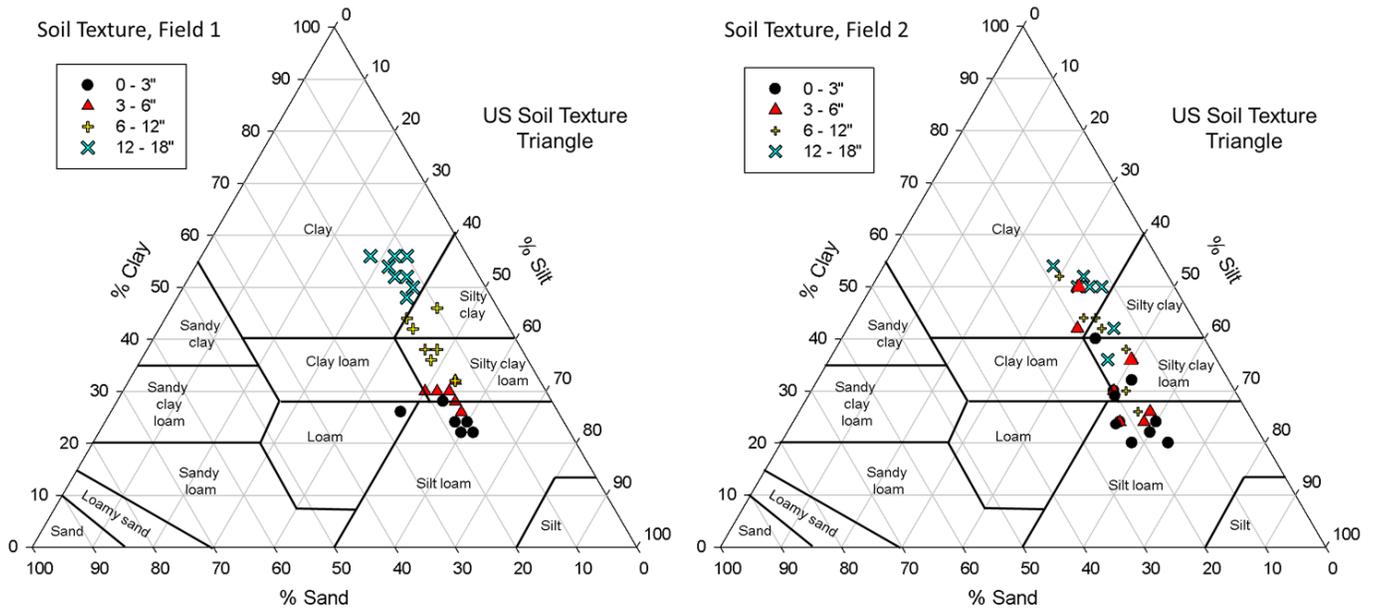
We gratefully acknowledge the cooperation of the participating farmers in providing us access to their land.

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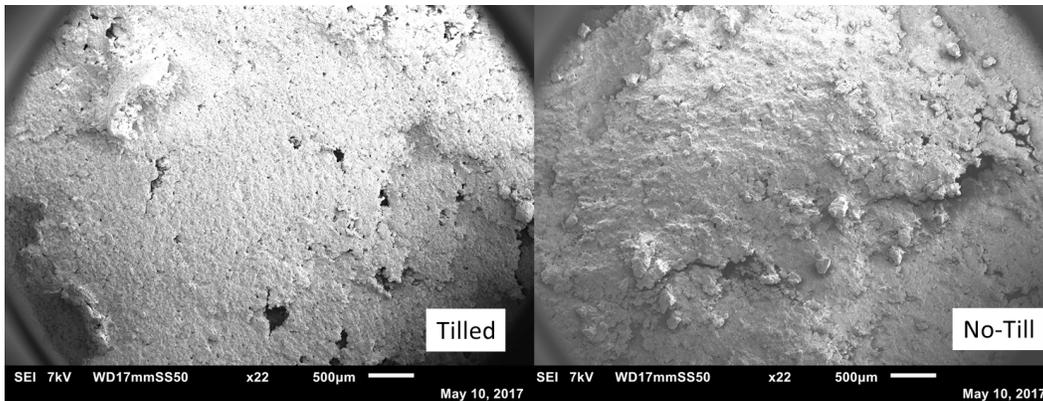
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**Figure 1.** Silt and clay particles in a Kenoma silt loam soil from Labette County, KS. Image magnified 700× with a scanning electron microscope. The white bar is 20 microns in length, roughly equivalent to 0.0008 inches, or about half the thickness of a human hair.



**Figure 2. Change in textural classification of soil profiles from two fields in southeast Kansas, based on the US Soil Texture Triangle for composition of sand, silt, and clay. (A) Field 1, with silt loam soil overlying soil with progressively greater percentage clay. (B) Field 2, silt loam topsoil has been lost through erosion, exposing the clay layer at a 3-inch depth at some locations in the field.**



**Figure 3. Scanning electron micrograph showing changes in soil structure between tilled and no-till fields for a Kenoma silt loam soil, Labette County, KS.**

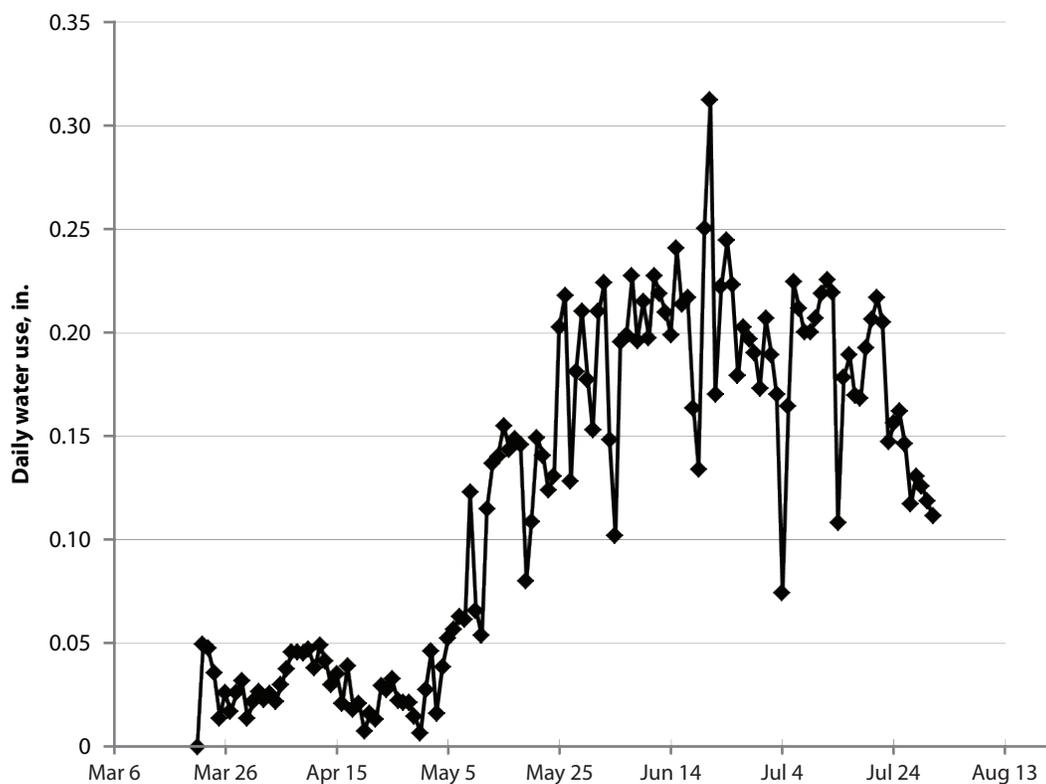


Figure 4. Corn water use calculated based on the Penman-Monteith evapotranspiration equation for a Kenoma silt loam soil in Labette County, KS, 2017.

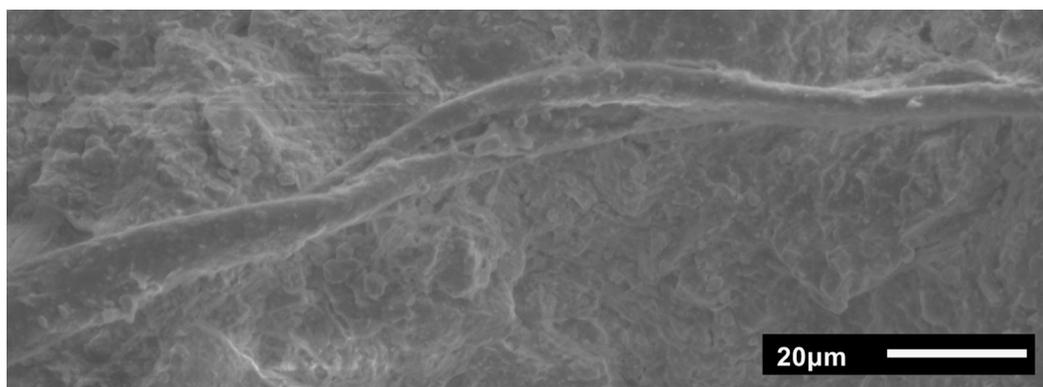
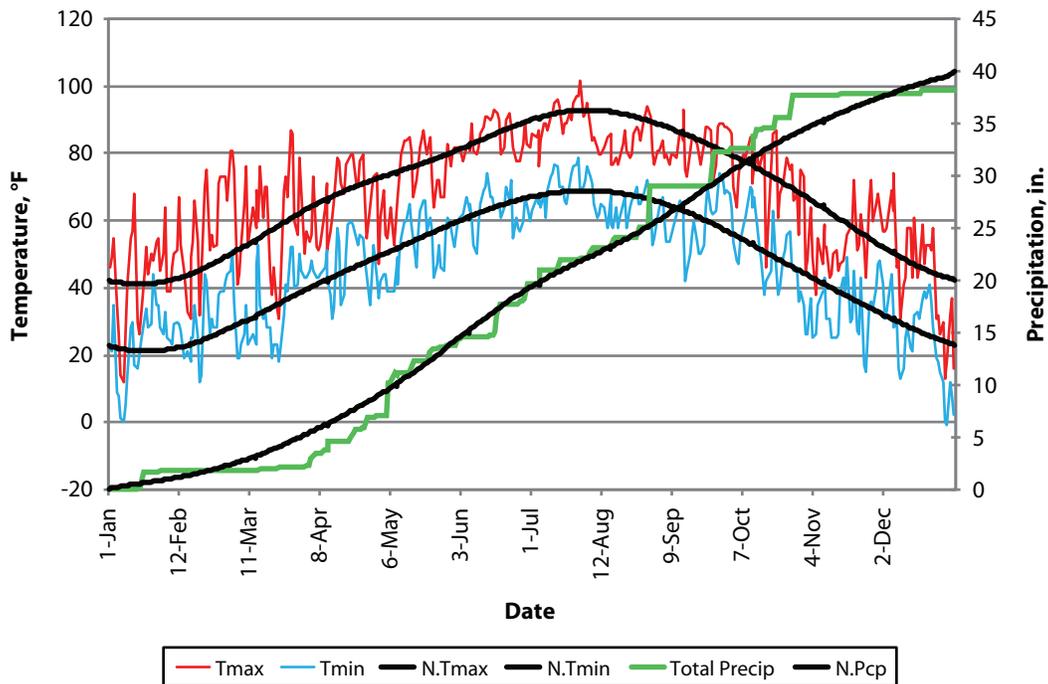


Figure 5. A strand of the microbial network in a Kenoma silt loam soil from Labette County, KS. Image magnified 850× with a scanning electron microscope.

# Annual Summary of Weather Data for Parsons – 2017



**SOUTHEAST AGRICULTURAL RESEARCH CENTER**

**2017 data**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Avg. Max	44.2	57.6	60.6	67.3	74.9	85.1	89.3	82.7	81.9	71.0	54.7	45.0	67.9
Avg. Min	23.6	30.0	36.4	46.5	53.6	63.4	69.4	62.6	59.2	47.7	34.3	23.8	45.9
Avg. Mean	33.9	43.8	48.5	56.9	64.2	74.3	79.3	72.7	70.6	59.4	44.5	34.4	56.9
Precip	1.72	0	1.64	3.8	7.13	5.48	3.35	5.97	3.61	5.08	0.15	0.28	38.17
Snow	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.6	1.4
Heat DD*	963	594	521	266	120	0	0	0	31	236	615	949	4293
Cool DD*	0	1	9	22	96	279	444	238	198	61	0	0	1346
Rain Days	6	0	9	13	12	12	8	7	6	8	3	2	86
Min < 10	5	0	0	0	0	0	0	0	0	0	0	4	9
Min < 32	25	17	11	1	0	0	0	0	0	3	13	21	91
Max > 90	0	0	0	0	0	6	13	3	1	0	0	0	23

**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	2.2	10.0	3.5	0.2	-0.8	0.7	-0.7	-7.6	0.6	1.4	-1.9	0.8	0.7
Avg. Min	1.8	4.0	1.4	2.0	-1.4	-0.7	0.9	-4.0	1.6	2.2	-1.0	-0.8	0.5
Avg. Mean	2.0	7.0	2.4	1.1	-1.1	0.1	0.0	-5.8	1.1	1.8	-1.5	0.0	0.6
Precip	0.31	-1.77	-1.55	-0.62	1.2	-0.05	-0.57	2.68	-1.08	1.22	-2.79	-1.78	-4.8
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	-63	-196	-70	-34	35	-8	-1	-1	-21	-25	41	1	-341
Cool DD	0	1	7	-1	0	-7	2	-180	12	32	-2	0	-137

\* 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.

## Research Center Personnel

Lyle Lomas, Research Center Head and Animal Scientist

Larry Buffington, Custodial Specialist

Jason Denton, Agricultural Technician II

TaLana Erikson, Research Technologist

Terry Green, Research Technologist

Adam Harris, Agricultural Technician II

Marla Sexton, Accountant I

Gretchen Sassenrath, Crop Production Agronomist

Lonnie Mengarelli, Research Assistant

Dekon Strickland, Agricultural Technician I

Joe Moyer, Forage Agronomist, Emeritus (on staff from 1978-2016)

Mike Cramer, Agricultural Technician Senior

Larry Sale, Agricultural Technician I

Daniel Sweeney, Soil and Water Management Agronomist

Garth Blackburn, Research Technologist

David Kerley, Agricultural Technician II

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# SEARC

## AGRICULTURAL RESEARCH

### 2018

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