NCCC-31 Report
Ecophysiological Aspects of Forage Management
Lincoln, NE
June 20-22, 2017

Wyoming- MA Islam

1. Impact Nugget:
The research at the University of Wyoming has made selection for well-adapted high performing accessions/lines which resulted in development of cultivars that are suitable for Wyoming and neighboring states. As a result, this contributed to the improvement of productivity of local and regional producers and would provide economic benefits in the long-run.

2. New Facilities and Equipment:
Installed Moisture Neutron Probe for determining moisture levels in different experimental plots.

3. Unique Project Related Findings:
The weather in Wyoming in 2016 was comparatively dry compared to 2015 allowing to compare growth and yield performance of accessions/lines of consecutive two different years.

4. Accomplishments:
Forages are very important in Wyoming and the mainstay of livestock production. Alfalfa is an important forage crop in the US and produces quality forage and persistent when grown as sole stands. However, the bloating characteristic and poor tolerance for acidic soils make other legumes such as birdsfoot trefoil and sainfoin viable alternatives. The major objective of this study is to assess the effects of different ratios of grass-legume mixtures on forage yield, quality, and persistence. Additional objectives are to determine the cost effectiveness of establishing sole grass (fertilized with N), sole legumes, and grass-legume mixtures and how efficient these practices are utilizing irrigation water. Data being collected include plant height, percentage of weed, water use efficiency, nutrient use efficiency, cost and revenue ratio, and forage yield and quality. It is anticipated that the results will help recommend the best grass-legume mixture ratios that will be profitable to Wyoming producers.

Demand for new and suitable plant materials is a long-term issue and is increasing continuously especially in the Intermountain West regions. The objective of this study is to evaluate different advanced lines of C3 grasses with the inclusion of some local checks in relation to their growth, yield, and quality response to irrigation, drought, and planting time. Species used in this study include tall fescue (seven lines), tall wheatgrass (three lines), western wheatgrass (five lines), and wildrye (two lines). Data collected on different growth parameters, persistence, and forage quality from 2009 - 2016 seems to be different among species and lines. Long-term data collection will help select and develop superior and well-adapted cultivars.

5. Impact Statements:

The research programs in University of Wyoming have made selection for well-adapted high performing accessions/lines which resulted in development of cultivars that are suitable for Wyoming and neighboring states. This contributed to the improvement of productivity of local and regional producers and in the long-run, would provide economic benefits.

Studies on determining cost effectiveness of establishing sole grass (fertilized with N), sole legumes, and grass-legume mixtures and how efficient these practices are utilizing irrigation water have positive impacts. Results will help recommend the best grass-legume mixture ratios that will be profitable to Wyoming producers by reducing production cost significantly.

6. Published Written Works:

Peer-Reviewed Journal Articles

Adjesiwor, A.T. and Islam, M.A. 2016. Rising nitrogen fertilizer prices and projected increase in maize ethanol production: the future of forage production and the potential of legumes in forage production systems. *Grassland Science* 62:203-212. doi: 10.1111/grs.12130.

Tracy, B.F., Albrecht, K., Flores, J., Hall, M., Islam, M.A., Jones G., Lamp, W., MacAdam, J.W., Skinner, H., and Teutsch, C. 2016. Evaluation of alfalfa-tall fescue mixtures across multiple environments. *Crop Science* 56:2026-2034. doi: 10.2135/cropsci2015.09.0553.

Sintim, H.Y., Adjesiwor, A.T., Zheljazkov, V.D., Islam, M.A., and Obour, A.K. 2016. Nitrogen application in sainfoin under rain-fed conditions in Wyoming: Productivity and cost implications. *Agronomy Journal* 108:294–300. doi: 10.2134/agronj2015.0317.

Book Chapter (Refereed)

Islam, M.A. and Adjesiwor, A.T. 2016. Forage Crops and Their Photosynthesis. *In*: Handbook of Photosynthesis, 3rd Edition (M. Pessarakli, Ed.), pp. 523-531. CRC Press, Taylor & Francis Publishing Company, Florida.

Reviewed Proceedings

Islam, M.A. and Aryal, P*. 2016. Planting Time and Grass Mixtures Affect Forage Kochia Establishment. Proceedings of the International Range Congress, July 3-4, 2016, Saskatchewan, Canada. (*Graduate student)

Abstracts

Islam, M.A. 2016. Legume Adoption Practices in the Central Great Plains of USA and Their Benefits in the Face of Climate Change. Proceedings of the International Conference on Envisioning Our Common Future December 22-23, 2016 Dhaka University, Bangladesh.

Islam, M.A. 2016. Plant Diversity for Resilient Production and Environmental Benefits in the Changing World. Proceedings of the International Conference on Changing the World through Japan's Scientific Endeavors "Japan's Rapidly Aging Society" November 12, 2016 Harvard University, Boston, MA (Japan-US Science Forum in Boston).

Islam, M.A. 2016. Managing Plant Diversity for Resilient Forage Systems and Environmental Benefits in the Mountain West. Proceedings of the ASA-CSSA-SSSA International Annual Meetings November 7-9, 2016 Phoenix, AZ (American Society of Agronomy, Crop Science Society of America, Soil Science Society of America).

Nilahyane, A., Islam, M.A., Garcia y Garcia, A., and Mesbah, A.O. 2016. Corn for silage response to water in a semi-arid environment. Proceedings of the American Society of Agricultural and Biological Engineers (ASABE) Annual Meetings July 17-20, 2016. Orlando, FL.

Extension publications

Islam, M.A. 2016. Silage: Production and Feeding – Part V. Wyoming Livestock Roundup, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, Vol. 26, No. 86, December 17, 2016.

Islam, M.A. 2016. Silage: Production and Feeding – Part IV. Wyoming Livestock Roundup, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, Vol. 26, No. 86, October 22, 2016.

Brummer, J.E., MacAdam, J.W., Shewmaker, G., and Islam, M.A., 2016. Establishing Birdsfoot Trefoil in the Mountain West. 2016. Bulletin 1 AG/Forages/2016-02pr, Utah State University Extension Publications at DigitalCommons@USU, pp. 1-9, September 2016. Paper 1585. Available at: http://digitalcommons.usu.edu/extension_curall/1585/ (verified January 23, 2017)

Sarkar*, S. and Islam, M.A. 2016. Response of bird's-foot trefoil cultivars to producer's field. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 169-170. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Horn, B.E., Islam, M.A., Smith, D., Jeliazkov, V., and Garcia y Garcia, A. 2016. Perennial cool-season grasses for hay production and fall grazing under full and limited irrigation. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 149-150. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Ashilenje, D.S. and Islam, M.A. 2016. Evaluation of forage productivity and environmental benefits of meadow bromegrass in various mixtures with popular legumes under irrigation. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 143-144. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Sarkar*, S. and Islam, M.A. 2016. Bird's-foot trefoil response to planting method and harvesting frequency. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 113-114. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Baskota*, S. and Islam, M.A. 2016. Evaluation of quinoa and fenugreek in Wyoming conditions. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 97-98. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Nilahyane*, A., Islam, M.A., and Garcia y Garcia, A. 2016. Quality response of irrigated silage corn under on-surface and sub-surface drip irrigation systems. 2016 Field Days

Bulletin, University of Wyoming Agricultural Experiment Station, pp. 67-68. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Nilahyane*, A., Islam, M.A., and Garcia y Garcia, A. 2016. Effect of irrigation on physiological traits of corn for silage grown under on-surface drip-irrigation system. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 65-66. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Ashilenje*, D.S., Islam, M.A. 2016. Alfalfa growth forms, light capture, and nitrogen fixation interact to influence durability of legume in meadow bromegrass mixtures. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 27-28. Available at http://www.uwyo.edu/uwexpstn/_files/docs/2016-field-days-bulletin.pdf (verified January 23, 2017; *graduate student).

Islam, M.A. 2016. Silage: Production and Feeding – Part III. Wyoming Livestock Roundup, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, Vol. 26, No. 86, August 26, 2016.

Islam, M.A. 2016. Silage: Production and Feeding – Part II. Wyoming Livestock Roundup, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, Vol. 26, No. 86, June 24, 2016.

Islam, M.A. 2016. Silage: Alsike Clover: A High Quality Forage Legume for High Elevations. Wyoming Livestock Roundup, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, Vol. 26, No. 86, April 23, 2016.

Islam, M.A. 2016. Forage Variety Selection and Stand Establishment. *Factsheet*, Master Hay Grower, Cokeville, WY, March 3, 2016.

Islam, M.A. 2016. The Agronomy in Alfalfa. *Factsheet*, Alfalfa U – Loveland CO, High Plains Journal, Loveland, CO, February 25, 2016.

Islam, M.A. 2016. Silage: Production and Feeding – Part I. Wyoming Livestock Roundup, the Weekly News Source for Wyoming's Ranchers, Farmers, and Agribusiness Community, Vol. 26, No. 86, February 20, 2016.

7. Scientific and Outreach Oral Presentations

Islam, M.A. 2016. Managing Plant Diversity for Resilient Forage Systems and Environmental Benefits. Symposium - Resiliency in Forages and Grazinglands ASA-CSSA-SSSA International Meetings. November, 8, Phoenix, AZ. (*Invited presentation*) Attendance: 52.

Islam, M.A. 2016. Grazing Alfalfa without a Fear of Bloat: A Seminar on Sabbatical Work in Canada. Department of Plant Sciences Seminar, October 28, 2016. UW, WY. Attendance: 33.

Islam, M.A. and Aryal, P. 2016. Planting Time and Grass Mixtures Affect Forage Kochia Establishment. International Rangeland Congress, July 17-22, 2016. Saskatoon, Saskatchewan, Canada. (*Invited presentation*) Attendance: 47.

Islam, M.A. 2016. Forage Crop Research at UW, USA: Germplasm Search, Evaluation, and Cultivar Development. Agriculture and Agri-Food Canada Lethbridge Research Center Seminar. April 21, 2016. Lethbridge, Canada. (*Invited presentation*) Attendance: 46.

Islam, M.A. 2016. Summer Experience in Japan: People, Culture, Education, and Research. Department of Plant Sciences Seminar, February 19, 2016. UW, WY. Attendance: 31.

Islam, M.A. 2016. Grass-legume Mixture for Forage Yield and Economic Benefits. Wyoming Forage Field Day, June 14, 2016. ShREC, WY. Attendance: 95.

Islam, M.A. 2016. Quinoa: A Potential Specialty Crop for Wyoming. Wyoming Master Gardener Association and Wyoming Farmers Market Association State Conference. April 1, 2016. Riverton, WY. Attendance: 23.

Islam, M.A. 2016. Fenugreek – A Specialty Crop: Some Pros and Cons. Wyoming Master Gardener Association and Wyoming Farmers Market Association State Conference. April 1, 2016. Riverton, WY. Attendance: 21.

Islam, M.A. 2016. Forage Variety Selection. Master Hay Grower, March 3, 2016. Cokeville, WY. Attendance: 27.

Islam, M.A. 2016. Agronomy in Alfalfa. Alfalfa U – Loveland CO High Plains Journal, February 25, 2016. Loveland, CO. Attendance: 54.

8. Fund leveraging, specifically, collaborative grants between stations and members

USDA-NIFA Alfalfa and Forage Research Program. 2016-2019. Islam, M.A., Burmmer, J., and Min, D. The silent decline in soil potassium levels and its effect on alfalfa productivity in the central and western US. $250,000.

UW School of Energy Resources. 2016-2019. Stahl, P.D., Coupal, R.H., Islam, M.A., McLaughlin, J.F., and Norton, J.B. Use of coal residues as soil amendments. $242,000.

UW AES Global Perspectives Grant. 2016. Islam, M.A. Identification and evaluation of germplasm for development of improved forage cultivars. $4,000.

UW CES Internal Grant. 2015-2016. Islam, M.A. Request for funds for replacing outdated computer, and portable projector, portable projection screen, and portable mike system. $2,197.

9. Other relevant accomplishments and activities

Forage production, management, quality, and economic returns have been presented at Wyoming Forage Field Day, Agriculture Experimentation Field Days, and local and regional workshops/meetings.

Utah-Jennifer MacAdam

New Facilities and Equipment:
Picarro 2201-I for Picarro CO_2 analyzer to measure concentrations of ^{13}C in both CO_2 and CH_4.
Shimadzu 2700 UV/VIS spectrophotometer to measure optically dense samples

Impact Statements:
Gains of steers were significantly greater on birdsfoot trefoil than on cicer milkvetch or on a combination of tall fescue and meadow brome grass pastures. Birdsfoot trefoil ribeye steaks were liked for most characteristics as well as the ribeye steaks of grain-finished beef, while the ribeye steaks of grass-finished beef were less well-liked than the ribeye steaks of birdsfoot trefoil or grain-finished beef. The omega-3 fatty acid concentration of steaks of the birdsfoot trefoil- and grass-finished beef were similar and higher than the omega-3 fatty acid concentration of steaks of the grain-finished beef. Enteric methane of mother cows and heifers was significantly less on perennial legume pastures (birdsfoot trefoil and cicer milkvetch) than on meadow bromegrass pastures.

Publications:
Refereed Journal Articles

Chail, A., J.F. Legako, L.R. Pitcher, T.C. Griggs, R.E. Ward, S. Martini, and J.W. MacAdam. 2016. Legume finishing provides beef with positive human dietary fatty acid ratios and consumer preference comparable with grain-finished beef. Journal of Animal Science 94:2184-2197.

Hunt, S.R., J.W. MacAdam and T.C. Griggs. 2016. Seeding rate, oat companion crop and planting season effects on irrigated organic birdsfoot trefoil stands in the Mountain West USA. Crop Science 56: 463-473.

Tracy, B.F., K. Albrecht, J. Flores, M. Hall, A. Islam, G. Jones, W. Lamp, J.W. MacAdam, H. Skinner, and C. Teutsch. 2016. Evaluation of alfalfa–tall fescue mixtures across multiple environments. Crop Science 56: 2026-2034.

Villalba, J.J., C. Spackman, B.M. Goff, J.L. Klotz, T. Griggs, and J.W. MacAdam. 2016. Interaction between a tannin-containing legume and endophyte-infected tall fescue seed on lambs' feeding behavior and physiology. Journal of Animal Science 94: 845-857.

Extension Bulletin

Brummer, J., J.W. MacAdam, G. Shewmaker, and A. Islam. 2016. Establishing birdsfoot trefoil in the Mountain West. Electronic Bulletin. AG/Forages/2016-02pr. Utah State University Cooperative Extension Service, Logan.

Popular Press Article

Creech, J.E. 2016. Considerations when switching from alfalfa to corn (9th ed., vol. 17, pp. 21-22). Progressive Forage Grower.

Published Abstracts

Chail, A., J. Legako, S. Martini, R.E. Ward, and J.W. MacAdam. 2016. Comparison of proximate composition, pH and fatty acids of beef ribeye steaks from forage and conventional feedlot finished cattle. Meat Science 112: 147. www.sciencedirect.com/science/article/pii/S0309174015002430

Gardner, T., J. Legako, T. Murphy, K. Yardley, A. Chail, and J.W. MacAdam. 2016. Effect of beef finishing diet and retail display on oxidative volatile compounds and their relationship with beef color. Meat Science 112: 147. www.sciencedirect.com/science/article/pii/S0309174015002429

Khan, M.G., S.Y. Yang, J.-S. Eun and J.W. MacAdam. 2016. Nitrogen excretion of lactating dairy cows fed alfalfa hay- or birdsfoot trefoil hay-based high-forage diet. ADSA ASAS Joint Annual Meeting, 19-23 July 2016, Salt Lake City, UT.

Kreykes, M., K. Cassida, E. van Santen, J.W. MacAdam, and T. Griggs. 2016. Forage yield, quality, and root characteristics of birdsfoot trefoil-tall fescue pastures. Annual Meeting of ASA/CSSA/SSSA, Phoenix, AZ, Nov. 6-9,2016. Online https://scisoc.confex.com/scisoc/2016am/webprogram/Paper99596.html (poster)

MacAdam, J.W., K.A. Beauchemin, A.I. Bolletta, and L.R. Pitcher. 2016. Reduced enteric methane emissions on legume vs. grass irrigated pastures. ADSA ASAS Joint Annual Meeting, 19-23 July 2016, Salt Lake City, UT.

MacAdam, J.W. and T.C. Griggs. 2016. Source and implications of elevated non- fibrous carbohydrates in the perennial legume birdsfoot trefoil (Lotus corniculatus L.). *In* Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.

Pieper, M., J.E. Creech, S.L. Hines, G. Cardon, and R. Ramirez. 2016. Silage corn hybrid response to row spacing and plant density in the Intermountain West. Madison, WI: American Society of Agronomy. scisoc.confex.com/scisoc/2016am/webprogram/Paper101330.html

Presentations:

Allen, L. 2016. Irrigation of pasture. Rich County Crop School, USU Extension, Woodruff, Utah.

Allen, L., and A. Torres-Rua. 2016. Verification of reduced consumptive use from deficit irrigated pastures in the Upper Colorado River Basin using Landsat data. Improving Irrigation Water Management - Latest Methods in Evapotranspiration and Supporting Technologies. US Committee on Irrigation and Drainage, October 11-13, 2016, Fort Collins, Colorado.

Reeve, J. 2016. Use of cover crops in orchards, vinyeards and vegetables. Western Colorado Horticultural Society Annual Conference, January 20-21, 2016.Grand Junction, CO.

Grants with NCCC-31 Members:

USDA NIFA AFRI Plant Breeding for Agricultural Production Program. *Increasing legume grazing for higher beef gain on pastures: An improved high-tannin birdsfoot trefoil cultivar with trans-regional potential*. Grant# 2013-67013-21408. $402,500. 9/17/13-9/16/18. van Santen, PI; MacAdam, Cassida, Shewmaker, Kallenbach, Griggs, Goff & Johnson, Co-PIs.

Other Grants:

USDA NIFA AFRI Agroecosystem Management Program. *Tannin-containing legumes in pasturelands and their ecological services*. Grant# 2016-67019-25086 $499,884. 6/1/16-5/31/20. Villalba PI; MacAdam Co-PI.

USDA NIFA AFRI Food Security Program. *Legume-finished beef: Achieving current production with greater environmental, economic and social sustainability*. Grant# 2016-69004-24855 $150, 000. 2/15/16-2/14/18. Villalba PI; MacAdam Co-PI.

USDA NIFA AFRI Climate and Microbial Processes in Agroecosystems program. *Microbial carbon-use efficiency in agroecosystems: The effect of drought and N availability on soil microbial production and respiration*. $750,000. Grant# 2016-67004-24920, $714.080. 2/15/16-2/14/19. Stark PI; MacAdam Co-P.I.

USDA-ARS Poultry Production and Product Safety Research Unit
Fayetteville, AR
Amanda Ashworth and Taylor Adams

1. Impact Nugget:

Ammonia and dust emitted from poultry houses can be captured with a scrubber ("ARS Air Scrubber") and the solution used in lieu of inorganic-N. Fescue plots fertilized with scrubber solutions containing nitrogen captured from poultry house emissions resulted in equivalent or greater yields than recommended ammonium nitrate fertilizer applications.

Compatible legume-intercrop candidates, such as partridge pea and red clover, may enhance switchgrass yield and forage quality while displacing inorganic-N in integrated biofuel/forage systems, thereby reducing greenhouse gas emissions and groundwater acidification by 5% and by 27%, respectively.

Runoff volumes, sediment, metal concentration, and loads are lowest for hayed and rotationally grazed systems with a fenced riparian buffer and highest for continuously overgrazed pastures.

2. New Facilities and Equipment:
Auto-analyzer (Skalar, San-system)
Soil moisture sensors (Decagon, 5TM; 75 total)
Soil moisture loggers (Decagon, EM50; 18 total)
PAR bar (Decagon, AccuPAR)
GPS cattle collars (Lotek, GPS3300LR; 10 total)
pH meter (Symphony, B30PCI)

3. Unique Project Related Findings:

One of the biggest environmental problems associated with the poultry industry is ammonia emissions from poultry houses, which cause air and water pollution. Scientists at Fayetteville, AR have developed the "ARS Air Scrubber," which captures ammonia and dust emitted from poultry houses. Researchers found that when tall fescue plots were fertilized with scrubber solutions containing nitrogen captured from poultry house emissions using alum, potassium bisulfate, sodium bisulfate, or sulfuric acid, the yields were equal to or greater than ammonium nitrate fertilizer applications at the same rate of nitrogen (100 pounds per acre). Impacts of this research could be substantial, considering in Arkansas alone over 100 million pounds of ammonia are emitted each year from poultry houses which could be captured and used as fertilizer.

USDA-ARS, in collaboration with universities have also identified successful and cost-effective legume intercrops for displacing fertilizer nitrogen in 4,000 switchgrass acres without affecting bio-feedstock composition and reducing greenhouse gas emissions by 5% and groundwater acidification by 27% compared to the current recommended fertilizer-nitrogen rate (60 lbs ac^{-1}).

4. Accomplishment Summaries:

Integrating Legumes and Soil Amendment Alternatives into Grasslands for the Reduction of Nitrogen Inputs:

a) Switchgrass composition and yield response to alternative soil amendments under intensified heat and drought conditions. Switchgrass and guinea grass have been proposed as sustainable alternatives to fossil fuels in subtropical and tropical environments, respectively; although still requiring non-renewable inputs, notably, fertilizer- N. Furthermore, climatic intensification forecasts suggest southeastern USA may emulate more tropical or subtropical growing conditions resulting in altered N dynamics and plant physiology. Results indicate desired feedstock characteristics can be manipulated by harvest timing. Pigeon pea and sunn hemp intercrops, and biochar (1 Mg ha^{-1}) may result in equivalent yields as N fertilizer per harvest. Switchgrass adaptation and competitiveness was moderate (5–30% weed cover) under an intensified climate. Growth can therefore be maintained under a stochastic climate due to its C_4 pathway and competitive growth on marginal soils (Ashworth et al., 2016a).

b) N_2 fixation of common and hairy vetch when intercropped into switchgrass. Among all chemical scarification and mechanical pretreatment methods for hairy and common vetch seed techniques for the reduction of hard seed, chemical scarification (sulfuric acid) and mechanical pretreatment (0.7 kg of pressure for one minute) improved common vetch germination by 60% and 50%, respectively, relative to controls. Under optimum scarification methods, biological nitrogen fixation was 59.3 and 43.3 kg N ha^{-1} when seeded at 7 kg pure live seed ha^{-1} for common and hairy vetch, respectively (Ashworth et al., 2017b).

c) *Biomass and forage/biomass yields of switchgrass as affected by intercropped cool and warm-season legumes.* It is hypothesized that legumes may be interseeded into switchgrass to increase available soil N and enhance yields. In the integrated harvest system, switchgrass yields and crude protein levels from red and crimson clover intercrops were not different from the current recommended rate (67 kg N ha^{-1}). Therefore, compatible legume-intercrop candidates, such as partridge pea and red clover, may enhance switchgrass yield and forage quality while displacing synthetic N in integrated biofuel/forage systems (Warwick et al., 2016).

d) Displacing inorganic-N in Lignocellulosic feedstock production systems. In this study (Ashworth et al., 2016d), overwintering harvests increased P and K remobilization, ethanol yield, fermentable sugars, and in-field dry-down, although yield losses occurred (22%). November harvests had greater tissue N and fermentable substrates, leading to greater soil nutrient removals. Consequently, harvests manipulated the desired feedstock traits, whereas soil amendments had little effect on feedstock characteristics. Results suggest that legume intercrops (partridgepea) and biochar may supply analogous N to synthetic fertilizers, thereby displacing inorganic N without altering feedstock quality. However, for inorganic N alternatives to be competitive on a break-even cost basis, greater biomass yields need to be obtained under these management practices.

Pasture Management Impacts on Water Quality

a) Long-term effects of grazing management and buffer strips on soil erosion from pastures. High grazing pressure can lead to soil erosion in pastures, causing increased sediment delivery to waterways. The objectives of this research were to evaluate the impact of grazing management and buffer strips on soil erosion by assessing soil physical properties, hydrology, and sediment loads from pastures fertilized with broiler litter. Field studies were conducted for 12 yr on 15

small watersheds. Runoff volumes, sediment concentrations, and loads were lowest for the hayed and rotationally grazed with a fenced riparian buffer and highest for continuously grazed. The Revised Universal Soil Loss Equation, Version 2 was reasonably effective at predicting soil loss for the rotationally grazed, rotationally grazed with a buffer strip, and rotationally grazed with a fenced riparian buffer treatments, but it greatly overpredicted soil loss from the continuously grazed systems. Converting a pasture to a hay field or using rotational grazing in conjunction with a fenced riparian buffer appear to be effective options for reducing soil erosion and runoff to waterways from pasture soils (Pilon et al., 2017a).

b) Effects of grazing management and buffer strips on metal runoff from pastures fertilized with poultry litter. Metal runoff from fields fertilized with poultry litter may pose a threat to aquatic systems, although buffer strips located adjacent to pastures may reduce nutrients and solids in runoff (Pilon et al., 2017b). The continuous grazed system had the highest metal concentrations and loads of all treatments. Rotational grazing with a fenced riparian buffer and hay treatments resulted in lower concentrations of total Al, Cu, Fe, potassium, manganese, and total organic carbon in the runoff. Rotational grazing with a fenced riparian buffer and converting pastures to hayfields appear to be effective management systems for decreasing concentrations and loads of metals in surface runoff from pastures fertilized with poultry litter.

Bioenergy Feedstock Systems Research

a) Switchgrass growth and effects on biomass accumulation, moisture content, and nutrient removal. Moisture content declined to levels appropriate for storage (≤ 200 g kg^{-1}, wet basis) by 15 December. Interception of PAR plateaued at 96% in late July 2009 and mid-June 2010, whereas LAI declined early July both years. Peak N uptake occurred August 2009 and July in 2010 (80 and 141 kg N ha^{-1}, respectively). Peak biomass yields occurred August-September when N and K uptake and moisture contents were still elevated. Delaying harvests to late fall or winter reduces fertilizer replacement needs and moisture content, but a trade-off in yield will occur. Quantifying these intra-seasonal changes allows for simulating productivity trade-offs and applying those to economic and environmental analyses (Ashworth et al., 2017a).

b) Dual-use bioenergy-livestock feed potential of giant miscanthus, giant reed, and miscane. High yielding perennial grasses could integrate bioenergy-livestock operations, thereby, offsetting diversions of cropland to lignocellulosic crops, but research is needed to determine chemical composition and digestibility of leaf and stem fractions that might affect downstream reside uses. Giant miscanthus leaf tissue had greatest acid detergent lignin and cellulose, and lowest concentrations of N and total nonstructural carbohydrates in ratoon crops. Results suggest all species' residue has positive feedstock attributes for thermochemical bioenergy conversion, albeit giant miscanthus has very little potential value as fodder. Miscane stem and giant reed leaf tissue have potential value as livestock feed, although giant reed is not currently recommended for planting. Further research is needed on dietary composition, acceptability, voluntary intake, and live weight gain before any of these species are recommended as livestock feed (Burner et al., 2017).

c) Evaluation of small grain cover crops to enhance switchgrass establishment. Establishment failures are a challenge to wide-scale use of switchgrass for biomass feedstock and/or forage production. Small grain cover crops, because of their allelopathic properties, may inhibit (direct allelopathy) or enhance (competition reduction) switchgrass establishment, and provide indirect benefits such as soil conservation and forage/grain production during the establishment year. Switchgrass can be planted following small grains without an apparent

penalty or advantage to stand density or yield, while offsetting lost production during establishment (Keyser et al., 2016).

d) Expanding the harvest window for switchgrass based on phosphorus and potassium remobilization. It is hypothesized that switchgrass remobilizes phosphorus and potassium to belowground plant organs during maturation and senescence, although field curing conditions at that time may be undesirable. Shoot P and K concentrations in cultivars did not decline from mid-September to late October, nor did P and K in crowns and roots increase from mid-September to mid-November. Harvest timing of upland and lowland switchgrass cultivars may therefore be extended to earlier in the fall (mid-September) based on lack of attenuating declining trends of P and K in shoots of switchgrass cultivars in the Southeast (Bacon et al., 2016).

Methods for Non-destructively Measuring Soil Carbon in Agrograsslands

a) Comparison of near infrared reflectance spectroscopy with combustion and chemical methods for soil carbon measurements in agricultural soils.

To understand effects of agrograssland management practices on soil organic carbon (SOC) dynamics, rapid and inexpensive testing techniques, such as near-infrared reflectance (NIR) were further developed. Once calibrated, NIR is capable of rapid analysis with less soil preparation than traditional combustion techniques. Researchers determined that NIR produced better estimates of total SOC than those extrapolated from Walkley–Black organic matter techniques and can therefore be used by others interested in an economical method for SOC determination (Wight et al., 2016a; Wight et al., 2016b).

5. Impact Statements:

One of the biggest environmental problems associated with the poultry industry is ammonia emissions from poultry houses, which cause air and water pollution. Scientists at Fayetteville, AR have developed the "ARS Air Scrubber," which captures ammonia and dust emitted from poultry houses. This year we found that when tall fescue plots were fertilized with scrubber solutions containing nitrogen captured from poultry house emissions using alum, potassium bisulfate, sodium bisulfate, or sulfuric acid, the yields were equal to or greater than ammonium nitrate fertilizer applications at the same rate of nitrogen (100 pounds per acre). The potential impact of this research is enormous, since in Arkansas alone over 100 million pounds of ammonia are emitted each year from poultry houses which could be captured and used as fertilizer in pasture systems.

The USDA-ARS, in collaboration with universities has identified successful and cost-effective legume intercrops for displacing fertilizer nitrogen in 4,000 switchgrass acres without affecting bio-feedstock composition and reducing greenhouse gas emissions by 5% and groundwater acidification by 27% compared to the current recommended fertilizer-nitrogen rate (60 lbs ac^{-1}).

One long-term (20 year) study initiated in 2003 on 15 small watersheds to assess impacts of pasture management strategies (overgrazing, rotational grazing, buffer strips, riparian buffer strips and haying) on pasture hydrology, erosion and nutrient and pathogen runoff determined: runoff volumes, sediment concentrations, metal concentrations, and loads were lowest for the hayed and rotationally grazed with a fenced riparian buffer and highest for the continuously grazed pasture system. Therefore, rotational grazing with a fenced riparian buffer and hay

systems appear to be effective management systems for decreasing concentrations and loads of metals, erosion, and nutrients in surface runoff from pastures fertilized with poultry litter.

All impacts stated above demonstrate how best management practices for forage and grassland systems can improve air and water quality.

6. Published Written Works.

Refereed Journal Articles

Ashworth, A.J., A.C. Rocateli, C.P. West, K.R. Brye, and M. Popp. 2017a. Switchgrass growth and effects on biomass accumulation, moisture content, and nutrient removal. Agronomy Journal. 109: 1-9.

Ashworth, A.J., F.L. Allen, K.S. Warwick, P.D. Keyser, G.E. Bates, D.D. Tyler, P.L. Lambdin, and D.H. Pote. 2017b. N_2 fixation of common and hairy vetch when intercropped into switchgrass. Agronomy. Special issue: Rhizobium-legume Symbiosis Effects on Plants. 7: 1-10.

Ashworth, A.J., F.L. Allen, A.M. Saxton, and D.D. Tyler. 2017c. Impact of crop rotations and soil amendments on long-term no tilled soybean yield. Agronomy Journal. 109: 938-946.

Burner, D.M., A.J. Ashworth, D.H. Pote, J. Kiniry, D.P. Belesky, J.H. Houx, III, P. Carver, and F.B. Fritschi. 2017. Dual-use bioenergy-livestock feed potential of giant miscanthus, giant reed, and miscane. Agricultural Sciences. 8: 97-112.

Ashworth, A.J., F.L. Allen, D.D. Tyler, D. Pote, and M.J. Shipitalo. 2017d. Earthworm populations are affected from long-term crop sequences and bio-covers under no-tillage. Pedobiologia – Intern. J. of Soil Ecology. 60: 27-33.

Pilon, C., P.A. Moore, Jr., D.H. Pote, J.H. Pennington, J.W. Martin, D.K. Brauer, R.L. Raper, S.M. Dabney, and J. Lee. 2016a. Long-term effects of grazing management and buffer strips on soil erosion from pastures. J. Environ. Qual. 46:364-372.

Pilon, C., P.A. Moore, Jr., D.H. Pote, J.W. Martin, and P.B. DeLaune. 2017. Effects of grazing management and buffer strips on metal runoff from pastures fertilized with poultry litter. J. Environ. Qual. 46:402-410b.

Ashworth, A.J., S.A. Weiss, P.D. Keyser, F.L. Allen, D.D. Tyler, A. Taylor, K.P. Beamer, C.P. West, and D.H. Pote. 2016a. Switchgrass composition and yield response to alternative soil amendments under intensified heat and drought conditions. Agriculture, Ecosystems & Environment. 233:415-424.

Keyser, P.D., A.J. Ashworth, F.L. Allen, and G.E. Bates. 2016. Evaluation of small grain cover crops to enhance switchgrass establishment. Crop Sci. Soc. Am. J. 56: 2062-2071.

Ashworth, A.J., F.L. Allen, A.M. Saxton, and D.D. Tyler. 2016b. Long-term corn yield impacted by cropping rotations and bio-covers under no-tillage. Agronomy Journal. 108: 1-8.

Wight, J., F.L. Allen, A.J. Ashworth, N. Labbe, T. Rials, and D.D. Tyler. 2016a. Comparison of near infrared reflectance spectroscopy with combustion and chemical methods for soil carbon measurements in agricultural soils. Commun.in Soil Sci. and Plant Analysis. 47: 731–742.

Ashworth, A.J., F.L. Allen, A.M. Saxton, and D.D. Tyler. 2016c. Long-term cotton yield impacts from cropping rotations and bio-covers under no-tillage. J. of Cotton Sci. 20: 95-102.

Bacon, J.L., A.J. Ashworth, F.L. Allen, C.E. Sams, D.D. Tyler, W.E. Hart, and J.F. Grant. 2016. Expanding the harvest window for switchgrass based on phosphorus and potassium remobilization. Crop Sci. Soc. Am. J. 56:1-8.

Warwick, K., F.L. Allen, P.D. Keyser, A.J. Ashworth, D.D. Tyler, A.M. Saxton, and A.M. Taylor. 2016. Biomass and forage/biomass yields of switchgrass as affected by intercropped cool and warm-season legumes. J. of Soil and Water Conservation. 70:374-384.

Ashworth, A.J., P.D. Keyser, F.L. Allen, D.D. Tyler, A.M. Taylor, and C.P. West. 2016d. Displacing inorganic-nitrogen in lignocellulosic feedstock production systems. Agronomy Journal. 108:1-8.

Wight, J., A.J. Ashworth, and F. Allen. 2016b. Organic substrate, clay type, texture, and water effects on NIR carbon measurements. Geoderma. 261:36-43.

Other Creative Works
None

Poster and Oral Presentations

Ashworth, A.J., H.D. Toler, R.M. Augé, and F.L. Allen. 2017. Effect of grassland diversity on primary productivity across diverse environments and over 50 years: a meta-analysis. Southern Pasture & Forage Crop Improvement Conference. Knoxville, TN.

Dold, C., A.L. Thomas, T.J. Sauer, A.J. Ashworth, and D. Philipp. 2017. Long-term above-ground biomass production in an oak-pecan silvopastoral agroforestry system. North American Agroforestry Conference. Blacksburg, VI.

Ashworth, A.J., F.L. Allen, M. J. Shipitalo, D.D. Tyler, and D. Pote. 2016. Earthworm abundance and diversity are affected by long-term crop sequences and bio-covers under no-tillage. [CD-ROM]. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America (ASA, CSSA, and SSSA), International Meetings, Madison, WI.

Popular Articles
Ashworth, A.J., F.L. Allen, A.M. Saxton, and D.D. Tyler. 2017. Diverse Rotations and Poultry Litter Improves Soybean Yield. Crop, Soils, Agronomy News. June, 2017 Issue; pg. 14.

Ashworth, A.J., F.L. Allen, A.M. Saxton, and D.D. Tyler. 2017. Diverse Rotations and Poultry Litter Improves Soybean Yield. American Advancement for Science. Public Press Release. May, 2017. https://www.eurekalert.org/pub_releases/2017-05/asoa-dra051117.php.

Ashworth, A.J., F.L. Allen, A.M. Saxton, and D.D. Tyler. 2017. Diverse Rotations and Poultry Litter. Phys.Org. Public Press Release. May, 2017. https://phys.org/news/2017-05-diverse-rotations-poultry-litter-soybean.html.

Ashworth, A.J., F.L. Allen, D.D. Tyler, D. Pote, and M.J. Shipitalo. 2017. Earthworms Work Wonders for Soils. USDA, Blog. April, 2017. https://www.usda.gov/media/blog/2017/04/21/earthworms-work-wonders-soils.

Ashworth, A.J., F.L. Allen, A.M. Saxton, and D.D. Tyler. 2016. Crop Sequences and Bio-covers Impact Corn Yields. Crop, Soils, Agronomy News. June, 2016 Issue; pg. 13.

7. Outreach Oral Presentations (Scientific presentations are listed above)

8. Current funding leveraged.

2017 USDA-Agricultural Research Service funding Opportunity in Antimicrobial Resistance, "Effects of Conservation Pasture Management on Antimicrobial Resistance Bacteria in Water and Soil Systems: Longitudinal Analysis of Samples Collected over 13 Years" $74,860 for 2017-2019 with Amanda Ashworth, Cammy Willet, Philip Moore, Phillip Owens, and Dan Pote.

2017 USDA-Conservation Innovation Grant, "Improving Management Strategies for Reducing Soluble Phosphorus Losses from Poultry Litter in Pasture Systems" $149,662 for 2017-2019 with Michael Popp, Amanda Ashworth, Philip Moore, John Pennington, Phillip Owens, Dan Pote, Taylor Adams, and Karen Lindsey.

2017 USDA- National Institute of Food and Agriculture, "Beefing up livestock, poultry and agroforestry enterprises for military veteran farmers" $599,944 for 2017-2019 with Dan Donoghue, Annie Donoghue, Amanda Ashworth, Joan Burke, Komala Arsi, Sarah Wright, Harold Goodwin, Shibu Jose, Shaun Francis, Anne Fanatico, and Margo Hale.

2015 USDA-Agriculture and Food Research Initiative, "Enhancing Agro-grassland Sustainability through Innovation and Improved Soil Biodiversity" $383,772 for 2016-2019 with Patrick Keyser, Amanda Ashworth, Robert Auge, Ernest Bernard, Jennifer DeBruyn, and Heather Toler.

2015 CORE Foundation, "Mapping functional soil properties for forage and crop production in the Arequipa Region in Peru" $410,000 for 2015-2018 with Phillip Owens and Amanda Ashworth.

2015 USDA-Agriculture and Food Research Initiative, Critical Agricultural Extension and Research. “Improving Success and Reliability of Native C4 Grass Establishment for Forage and Biofuel Production” $149,999 for 2014-2018 with Patrick Keyser, Dennis Hancock, Amanda Ashworth, and Jennifer Johnson.

Arkansas- Dirk Philip

1. Impact Nugget

The group from the University of Arkansas is engaged in applied research and extension activities pertaining to the use of warm season annuals and perennial, and cool season perennial forage crops. We are in the process of developing recommendations on the use of interseeded forages into alfalfa stands to extend stand life while maintaining nutritive value.

2. New Facilities and Equipment

None

3. Unique Project-Related Findings

After several years of production, alfalfa (*Medicago sativa* L.) stands start thinning with a reduction in dry matter (DM) yields which is compounded by a usual drop of DM yields during the summer months. Various options exist for interseeding forages into these alfalfa stands to maintain quantity and quality. We tested teff (*Eragrostis teff* [Zucc.] Trotter), red clover (*Trifolium pretense* L.) and Italian ryegrass [*Lolium perenne* L. ssp. Multiflorum (Lam.) Husnot] and planted those in either spring or fall. Teff as a true summer annual was planted in spring only. Each species was planted separately into alfalfa and also in mixes of ryegrass+red clover and teff+red clover. The grasses were not combined. A non-interseeded alfalfa plot served as control. Seeding rates were 30 lbs/acre for Italian ryegrass, 8 lbs/acre for red clover, and 6 lbs/acre for teff. First-year results from 2016 indicated that alfalfa DM yields averaged 3,416 lbs/acre with no treatment differences observed ($P>0.05$) but with a date effect ($P<0.01$). There was a steep drop-off in DM yield at the last harvest of the year in October with 1,112 lbs/acre compared with previous months ($P<0.01$). The distinctly different seasonal growth curves of tested forage species were reflected in varying DM contribution to alfalfa yield and species composition throughout the year. In June, ryegrass and red clover were present, but they contributed only <5% to the overall plot DM. By August ryegrass and red clover disappeared, probably due to heat stress, but teff DM contribution peaked with 33% on average. By October, teff still averaged 18% in DM contribution despite its pronounced summer-annual growth characteristics. The success of interseeding and DM production of the forage species tested in alfalfa stands depends on either fall or spring planting. Teff was able to keep up with the rapid alfalfa growth in spring while ryegrass may have to be planted in fall to adequately compete with alfalfa the following spring.

4. Accomplishment Summaries

During 2016-2017, Arkansas (Department of Animal Science, Philipp et al.) published data on variety of basic forage-agronomy research topics. Outreach activities included the delivery of our findings during in-service training sessions, field days, and through various extension publications. A summary of all publications from 2016-2017 is included at the end of this document.

5. Impact Statements

Issue:

Alfalfa has not been widely planted in the southern US due to pest pressure and less favorable climatic conditions than in northern states. Alfalfa is also subject to auto toxicity which makes it impossible to reseed alfalfa to close gaps in soil cover that develop over time, especially with herbicide-resistant alfalfa. A range of forages could potentially be interseeded but those have to complement alfalfa's seasonal growth curve and nutritive value. We selected teff, a summer annual; Italian ryegrass, a cool-season annual; and red clover, a bi-annual legume to be tested after a fall- and spring-planting. Finding appropriate forages would help extend alfalfa stand life and maintain summer yield decline.

Action:

Teff, Italian ryegrass, and red clover were planted into a 7-year-old thinning glyphosate-resistant alfalfa in either fall or spring. Teff as a true summer annual was planted in spring only. Each species was planted separately into alfalfa and also in mixes of ryegrass+red clover and teff+red clover. The grasses were not combined. A non-interseeded alfalfa plot served as control. Seeding rates were 30 lbs/acre for Italian ryegrass, 8 lbs/acre for red clover, and 6 lbs/acre for teff. Plots were harvested each time a regularly scheduled alfalfa hay cut took place. Forages were planted into the alfalfa stand using a no-till drill in fall after the last cut (mid-October) and in spring before growth ensued (early March). Teff was planted after the hay cut in late May as this species requires a higher soil temperature to emerge. Dry matter yield, species composition, and forage nutritive value were determined at each harvest.

Impact:

Depending in initial soil cover and alfalfa canopy density, all three species were successfully established with teff contributing up to 30% of dry matter yield while the other two species did not contribute more than 5% of dry matter during the first year of our study. However, with the alfalfa stand thinning even further, we expect those numbers to raise for both Italian ryegrass and red clover. With presenting forages for interseeding into thinning alfalfa stands, producers have the option of extending stand life renovating alfalfa stands at another location on the farm.

Contact:

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Cooperators: Robert Rhein, Barenbrug Seed Co.

Funding: This project was supported in part by Barenbrug Seed Co.

6. Published Written Works

Smith, W. B., K. P. Coffey, J. D. Tucker, D. S. Hubbell, III, E. B. Kegley, D. Philipp, J. D. Caldwell, and A. N. Young. 2017. Using soybean hulls to meet dietary energy requirements for gestating cows having restricted access to poor-quality hay. Prof. Anim. Sci., Vol. 33, Issue 1, p 101-107

Clark, J.K., B.C. Shanks, K.S. Jogan, D. Philipp, K.P. Coffey, N.E. Jack, J.D. Caldwell, and R.T. Rhein. 2016. Effects of Forage Species and Poultry Litter Application Timing on Forage Preference by Horses. J. Anim. Sci., 94:4985-4992

Philipp, D., and R. Rhein. 2016. Teff, pearl millet, and sorghum-sudangrass yields in Northwest Arkansas. ANSC Report Series.

Long, J., K. Coffey, J. Caldwell, D. Philipp, R. Rhein, and A. Young. 2016. Calcium and magnesium absorption and retention by growing goats offered diets with different calcium sources. Discovery, Vol. 17, Fall Semester.

Abstracts:

Niyigena, V., K. P. Coffey, W. K. Coblentz, D. Philipp, A. N. Young, R. T. Rhein, H. Bartimus. 2016. Correlation of fermentation characteristics with intake and digestibility of alfalfa silage in gestating ewes. ASAS, Salt Lake City.

Philipp, D., and K. Coffey. 2016. Valuation of grassland ecosystems services for sustainable livestock production. Southern Forage and Crop Improvement Conference (SPFCIC), West-Monroe. LA.

Bartimus, H.L., Montgomery, T.G., Philipp, D., Cater, J., Coffey, K.P., Shanks, B.C. 2016. Mob grazing effects on cattle performance in southeastern Arkansas. ASAS Midwestern Section, Des Moines, IA.

Niyigena, V., K. P. Coffey, W. K. Coblentz, D. Philipp, A. N. Young, R. T. Rhein, J. K. Clark. 2016. Effect of delayed wrapping and wrapping source on intake and digestibility of alfalfa silage in sheep. ASAS Midwestern Section, Des Moines, IA.

Long, J.E., K. P. Coffey, J. D. Caldwell, D. Philipp, R. T. Rhein, A. N. Young. 2016. Calcium and magnesium absorption and retention by growing goats offered diets with different calcium sources. ASAS Midwestern Section, Des Moines, IA.

Extension publications:

Jennings, J, Simon, K., Philipp, D., and Beck, P. 2016. Interseeding alfalfa in bermudagrass sods. FSA 3141 (original manuscript).

7. Scientific Outreach and Oral Presentations

Philipp, D., and K. Coffey. 2016. Valuation of grassland ecosystems services for sustainable livestock production. Southern Forage and Crop Improvement Conference (SPFCIC), West-Monroe. LA.

Philipp, D. 2016. Research update at NCCC-31 meeting. Annual committee meeting, Corvallis, OR.

8. Funding Leveraging (collaborative grants)

None

9. Other Activities

Extension activities related to forage production and management. Research described in this report were covered during in-service training sessions and presentation of producers during field days.

Texas A&M AgriLife -Jamie L. Foster

Impact Nugget
Texas A&M AgriLife Research has improved the resource efficiency of forage production by developing summer dormant cool-season grasses, refining best management practices of novel and existing grasses and legumes, evaluating the impact of supplementation on grazing cattle, and furthering the understanding of the fundamentals of the water footprint when forages are integrated into agriculture systems.

New Facilities and Equipment
No new facilities or equipment in 2016.

Accomplishments
Texas A&M AgriLife Research evaluated the nutritive value as impacted by management of forage sorghum and small grains, evaluated the potential for Teff, Brachiaria, or summer-dormant cool-season grasses to be incorporated into Texas forage systems, determined the potential of cool-season legume hay cover crops or warm-season legume dual crops to secure soil and the impact on water footprint, determined the feasibility and effectiveness of incorporating co-products, such as distillers grains and lipid-extracted algae into agriculture systems, released native grass, legume and other herbaceous forb cultivars, and disseminated results to land owners.

Impact Statements
Sorghum lines among BMR types are not equal in their nutritive value, recommendations on those which have the least lodging and greatest potential for sorghum silage were recommended to land owners. Texas A&M AgriLife is in the final stage of developing 3 cultivars of tall fescue, 2 of orchardgrass, and 2 cultivars of perennial ryegrass. Cotton and sorghum production is not reduced by use of cool-season legumes cut for hay or cowpea grown as a dual crop, water footprint is still under long-term evaluation. We have generated data on relatively new warm-season annual forage, teff, for the forage producers in the Rolling Plains of Texas.

Book Chapters
Fagundes, G.M., E.C. Modesto, T. Saldanha, C.E. Moreira da Fonseca, J.P. Muir, J.V., V. Carneiro de Souza, A. Barros da Silva, R. Martins da Silva, J. Barbosa da Silva, and I.C. da Silva Bueno. 2016. Effect of flavonoid compounds from *Flemingia macrophylla* on milk composition of lactating goat in the tropics. In: C.A. Combs, editor, Tannins: Biochemistry, Food Sources and Nutritional Properties. Nova Science Publishers Hauppauge NY, USA. p.169-186.

Peterson, J.L, L.A. Redmon, and M.L. McFarland. 2016. Outreach programs for awareness of water resources sustainability and adoption of best management practices. In: D.H. Chen, editor, Sustainable water management and technologies. Taylor & Francis/CRC Press, Boca Raton, FL. p. 195-226.

Refereed Journal Articles

Adams, R.P., M.M. Skopec, and J.P. Muir. 2016. Comparison of leaf terpenoids and tannins in *Juniperus osteosperma* from woodrat (*Neotoma stephensi*) browsed and not-browsed trees. Phytologia 98:17-25.

Apolinário, V.X.O., J.C.B. Dubeux, Jr., A.C.L. Mellow, J.M.B. Vendramini, M.A. Lira, M.V.F. Santos, and J.P. Muir. 2016. Decomposition of arboreal legume fractions in a silvopastoral system. Crop Sci. 56:1356-1363.

Apolinario, V.X.O., M.D.A. Lira, J.C.B. Dubeux, Jr., E.V.S.B. Sampaio, S.O. de Amorim, N.G.M. Silva and J.P. Muir. 2016. Arboreal legume litter nutrient contribution to a tropical silvopasture. Agronomy J. 108:2478-2484.

Blackmon, T.K., J.P. Muir, R.D. Wittie, D.H. Kattes, and B.D. Lambert. 2016. Legume nitrogen and phenolic concentration comparisons between simulated and insect herbivory. J. Plant Interactions 11:61-66.

Clary, C.R., L. Redmon, T. Gentry, K. Wagner, and R. Lyons. 2016. Nonriparian shade as a water quality best management practice for grazing-lands: A case study. Rangelands. 38:129-137.

Corriher-Olson, V., M.F. Rouquette Jr., G.R. Smith, and V.A. Haby. 2016. Persistence of alfalfa sod-seeded into bermudagrass pastures on coastal plain soils. Crop Forage Turfgrass Management. 2. doi: 10.2134/cftm2014.0096

Faria de Oliveira, O., M.V. Ferreira dos Santos, M. Vieira da Cunha, J.C. B. Dubeux, Jr., J.P. Muir, A.C.L. de Mello, M.A. Lira Andrade, and F.N.P. de Barros. 2016. Botanical composition of Caatinga rangeland and diets selected by grazing sheep. Tropical Grasslands-Forrajes Tropicales. 4:71–81.

Knutson, A., V.A. Corriher, and E. Vafaie. 2016. Efficacy of selected insecticides for control of fall armyworm in bermudagrass hay. Arthropod Management Tests. 40:F20. doi: 10.1093/amt/tsv149

Naumann, H.D., C. Cooper, J.R. Bow, and J.P. Muir. 2016. Condensed tannin characteristics of Limpopo, South Africa arboreal species retaining leaves in the dry season. African J. of Ecology. (at press).

Muir, J.P., J.L. Foster, and J.R. Bow. 2016. Establishment-year native perennial bunchgrass biomass yields. Crop Science. 56:2827-2832.

Muir, J. P., T. H. Terrill, J. A. Mosjidis, J.-M. Luginbuhl, J.E. Miller, and J.M. Burke. 2017. Season progression, ontogenesis and environment affect *Lespedeza cuneata* herbage condensed tannin, fiber and crude protein content. Crop Science. 57:515-524.

Rothlisberger-Lewis, K.L., **J.L. Foster**, and F.M. Hons. 2016. Soil carbon and nitrogen dynamics as affected by lipid-extracted algae application. Geoderma. 262:140-146.

Symposium Proceedings

De Oliverira, O.F., M.V. Ferreira dos Santos, J.C. Dubuex Jr., J.P. Muir, M.V. da Cunha, N. Cherry, L.O. Tedeschi, and W. Crossland. 2016. Methane suppression and larval migration inhibition by *Bauhinia cheilantha* submitted to sheep grazing at three different levels of forage allowances. In: A. Iwaasa, H.A. (Bart) Lardner, M. Schellenberg, W. Willms, and K. Larson, editors, Proc. 10th Int. Grassland/Int. Rangeland Congress, Saskatoon, SK, Canada, 29 Jun-5 Jul. p. 372.

Ferreira dos Santos, M.V., I.V. de Queiroz, J.C. Dubuex Jr., J.P. Muir, C.Ca. Lira, T.C. de Souza, and D.E. Simoes. 2016. Crude protein and phenol precipitated protein from *Desmanthus pernambucanus* (L.) Thellung submitted to different harvesting regimes. In: A. Iwaasa, H.A. (Bart) Lardner, M. Schellenberg, W. Willms, and K. Larson, editors, Proc. 10th Int. Grassland/Int. Rangeland Congress, Saskatoon, SK, Canada, 29 Jun-5 Jul. p. 375

Foster, J.L., and C.L. Mackowiak. 2016. Complimentary uses of forage crops. In: R. Lemus, editor, Proceedings of the 70th Southern Pasture Forage Crop Improvement Conference, Monroe, LA, May 2-4. p. 9-11.

Poster Presentations

Aiosa, M.L., G.R. Smith, C.B. Neely, R.W. Jessup, C.L.S. Morgan, V.A. Corriher-Olson, A. Somenahally, and F.M. Rouquette Jr. 2016. Cowpea as a cover crop and nitrogen source in a double cropping system with forage rye. ASA-CSSA-SSSA Annual Conference, Phoenix, AZ. 8 Nov.

Bean, M.E., J.L. Foster, C.L.S. Morgan, G.D. Morgan, and R.H. Mohtar. 2016. Semi-arid cropping rotation system under no-till management. ASA Southern Branch Meeting, San Antonio, TX. 7-9 Feb. (Abstr.)

Bean, M.E., J.L. Foster, C.L.S. Morgan, G.D. Morgan, and R.H. Mohtar. 2016. Semi-Arid Cropping Rotation System under No-Till Management. Soil Survey and Land Resource Workshop, College Station, TX. 4-5 Feb. (Abstr.)

Brown, M.W., and L.A. Redmon. 2016. The Lone Star Healthy Streams Program: Reducing Bacterial Contamination in Surface Water. ASA-CSSA-SSSA Annual Conference, Phoenix, AZ. 8 Nov.

Cooper, C.E., G.W. Moore, J.P. Muir, and C.L.S. Morgan. 2016. Burn severity and soil type affect oak growth and nutritive value. ASA-CSSA-SSSA Annual Conference, Phoenix, AZ. 8 Nov.

Farthing, T., J. Muir, D. Cawthon, and D. Murray. 2016. Coastal Bermudagrass Suppression in Texas Grasslands for Native Bird Habitat Restoration. North American Ornithological Conference, Washington D.C. 16-20 August. p. 279.

Farthing, T., J. Muir, D. Cawthon, and D. Murray. 2016. Coastal bermudagrass suppression in Texas grasslands. VII International Scientific Symposium for Young Scientists, PhD Students and Students of Students of Agriculture Colleges, Bydgoszcz, Poland. 15-17 September. p. 54.

Griffith, K., C. Adams, J. Creasap Gee, J.L. Foster, S. Grogan, S. Karhoff, R. Michitsch, M. Scarpace, A. Schraeder, and M.R. Zwonitzer. 2016. Agronomy Feeds the World PlantingScience Module for urban agriculture. Northeast Region Urban Agriculture and Sustainability Meeting, University of the District of Columbia, 26 Jun. (Abstr.)

Griffith, K., C. Adams, J. Creasap Gee, J.L. Foster, S. Grogan, S. Karhoff, R. Michitsch, M. Scarpace, A. Schraeder, and M.R. Zwonitzer. 2016. Development of Agronomy Feeds the World Module for the PlantingScience program. ASA-CSSA-SSSA 2016 International Meetings, Pheonix, AZ. 6-9 Nov. (Abstr.)

Hassell, A, J.L. Foster, and J.P. Muir. 2016. Nitrogen and carbon yield of annual warm-season legumes. ASA Southern Branch Meeting, San Antonio, TX. 7-9 Feb. (Abstr.)

Lesak, M. M., J.L. Foster, K. C. McCuistion, M. K. Clayton, and T. Teinert. 2016. Management of Invasive Old World Bluestems to Restore Native Grasslands. 69th Annual Society for Range Management, Corpus Christi, TX. 1-3 Feb. (Abstr.)

Singh, B.B., B. Angira, L.L. Masor, M. Zhang, H-B Zhang, J.L. Foster, J.A. Asiwe, Y.V. Singh, and D. Hays. 2016. Breeding next generation cowpea varieties for adaptation to changing climates and cropping systems. Pan-African Grain Legume and World Cowpea Conference, Livingstone, Zambia. 28 Feb-4 Mar. (Abstr.)

Smith, W.B., J.L. Foster, J.P. Banta, L.A. Redmon, L.O. Tedeschi, and F.M. Rouquette. 2016. Bermudagrass cultivar and supplementation levels of DDGS effects on stocker cattle performance. ASA-CSSA-SSSA 2016 International Meetings, Pheonix, AZ. 6-9 Nov. (Abstr.)

Muir, J.P., T.H. Terrill, J.A. Mosjidis, J-M Luginbuhl, J.E. Miller, and J.M. Burke. 2016. Harvest regimens to maximize *Sericea lespedeza* crude protein and condensed tannins. 70th Southern Pasture and Forage Crop Improvement Conference, Monroe, LA. 2-4 May. p. 17.

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Norris, A., M. Miller, and J.P. Muir. 2016. Autumn and winter dynamics of white-tailed deer browse nutritive values in the southern Cross Timbers. Society for Range Management Annual meetings, Corpus Christi, TX. 31 Jan-2 Feb.

Norris, A., M. Miller, and J.P. Muir. 2016. Autumn and winter dynamics of white-tailed deer browse nutritive values in the southern Cross Timbers. ASA Southern Branch Meeting, San Antonio, TX. 7-9 Feb. (Abstr.)

Norris, A., M.S. Miller, J.P. Muir, R.M. Harp, and L.A. Kinman. 2016. Autumn and winter dynamics of white-tailed deer browse nutritive values in the southern Cross Timbers and Prairies. 70th Southern Pasture and Forage Crop Improvement Conference, Monroe, LA. 2-4 May. p. 18.

Nuti, L.C., J.P. Muir, E.A. Duffus, Y. Jung, A.A. James, and N.M. Cherry. 2016. Cutting interval and water application influence yields and condensed tannin content. Joint Annual Meeting (AnSci, Dairy Sci, Western AnSci, Canadian AnSci), Salt Lake City, UT. 19-23 July.

Smith, W.B., F.M. Rouquette, Jr., J.L. Kerby, L.O. Tedeschi, J.L. Foster, J.P. Banta, K.C. McCuistion, T.J. Machado, and L.A. Redmon. 2016. Performance of stocker cattle grazing 'Tifton 85' bermudagrass supplemented with dried distillers' grains on per animal and per area bases: A 2-year summary. Joint Annual Meeting (AnSci, Dairy Sci, Western AnSci, Canadian AnSci), Salt Lake City, UT. 19-23 July.

Smith, W.B., J.L. Foster, J.P. Banta, L.A. Redmon, L.O. Tedeschi, and F.M. Rouquette. 2016. Bermudagrass cultivar and supplementation levels of DDGS effects on stocker cattle performance. ASA-CSSA-SSSA 2016 International Meetings, Pheonix, AZ. 6-9 Nov. (Abstr.)

Smith, W.B., J.L. Foster, K.C. McCuistion, L.O. Tedeschi, E. van Santen, and F.M. Rouquette, Jr. 2016. A novel technique for model evaluation and selection for in situ degradation parameters from cattle supplemented with varying levels of DDGS. 5th Grazing Livestock Nutrition Conference, Park City, UT, July 17-19. (Abstr.)

Smith, W.B., J.L. Foster, K.C. McCuistion, S.J. Abatti, M. Lesak, and F.M. Rouquette, Jr. 2016. In situ degradation parameters of three chronological maturities of 'Tifton 85' bermudagrass from cattle supplemented with varying levels of distillers' dried grains. ASAS Southern Section Meeting, San Antonio, TX. 7-9 Feb. (Abstr.)

Tomlin, L., H.L. Neely, C.B. Neely, J.L. Foster, K.L. Lewis, R.W. Schnell, and P.B. DeLaune. 2016. Double cropping in wheat: The relative impacts of roots and tillage on soil health. ASA-CSSA-SSSA 2016 International Meetings, Pheonix, AZ. 6-9 Nov. (Abstr.)

Whitney, T.R., and J.P. Muir. 2016. Effects of using ground redberry juniper and urea in supplements fed to Rambouillet ewe lambs on growth, blood serum and fecal N. Joint Annual Meeting (AnSci, Dairy Sci, Western AnSci, Canadian AnSci), Salt Lake City, UT. 19-23 July.

Zwonitzer, M.R., C. Adams, J. Creasap Gee, **J.L. Foster**, K. Griffith, S. Grogan, S. Karhoff, R. Michitsch, M. Scarpace, and A. Schraeder. 2016. Agronomy Feeds the World: A new PlantingScience module. ASA-CSSA-SSSA 2016 International Meetings, Pheonix, AZ. 6-9 Nov. (Abstr.)

Popular Articles

Corriher-Olson, V. East Texas Pasture Management Program Set February 12 at Overton. Jan. 21, 2016. AgriLife Today.

Corriher-Olson, V. Weed or Forage. April 2016. The Progressive Farmer. Clay Coppedge.

Corriher-Olson, V. Forage producers face annual battle with weeds. May 23, 2016. AgriLife Today.

Corriher-Olson, V. Identification first step in forage weed control. May 23, 2016. Southwest Farm Press. Reprinted from AgriLife Today.

Corriher-Olson, V. Sunshine and no rain have Texas producers working full spead ahead. June 19, 2016. AgriLife Today. Reprinted in Abilene Reporter News

Corriher-Olson, V. Tackling Toxic Weeds. May 2016. MyFarmLife.com. Becky Mills.

Corriher-Olson, V. Plan ahead for fall and winter forages. August 21, 2016. AgriLife News. Reprinted in Angus Media.

Corriher-Olson, V. Fall armyworms are on the march. August 26, 2016. AgriLife News. Reprinted in East Texas Press and Longview News Journal. Video Clip included.

Corriher-Olson, V. East Texas: Timing fertilization of winter pastures proves tricky amid drought, above-average temperatures. November 19, 2016. AgriLife News.

Corriher-Olson, V. In the Know: Forage Height to Promote Growth. July 25, 2016. Quarter Horse News Magazine.

Corriher-Olson, V. Pasture Conditions good in high plains this spring. May 15, 2016. DTN The Progressive Farmer.

Corriher-Olson, V. Sprigging Season Has Arrived. March 8, 2016. Hay & Forage Grower.

Corriher-Olson, V. Texas Crop & Weather Report: Farmers seek advice as ryegrass makes way for bermudagrass. March 23, 2016. AgriLife News.

Corriher-Olson, V. Time to think winter: management of annual ryegrass/legume winter pasture. August 29, 2016. Bryan College Station Eagle.

Corriher-Olson, V. Texas Crop & Weather Report. June 14, 2016. AgriLIfe News.

Corriher-Olson, V. Road Trip Report: Texas. June 12, 2016. Hay & Forage Grower.

Corriher-Olson, V. Road Trip Report: Texas. July 10, 2016. Hay & Forage Grower.

Corriher-Olson, V. Road Trip Report: Texas. August 7, 2017. Hay & Forage Grower.

Corriher-Olson, V. Road Trip Report: Texas. September 4, 2016. Hay & Forage Grower.

Corriher-Olson, V.Road Trip Report: Texas. October 2, 2016. Hay & Forage Grower.

Corriher-Olson, V. Road Trip Report: Texas. October 30, 2016. Hay & Forage Grower.

Scientific and Outreach Presentations

Corriher-Olson, V.A. 2016. Warm-season annual legumes. Southern States Forage Conference, Texarkana, AR, Mar 31.

Foster, J.L. 2016. Spring Pasture Management. Living the Country Live. Nationally syndicated talk show guest. Jan. 26.

Foster, J.L. 2016. Texas A&M AgriLife Research Sustainable Solutions for Beef Production Systems Project at Beeville & Welder Wildlife Refuge. Managing Natural Resources with UAVs: Present & Future Possibilities Workshop. Kingsville, TX, Sept. 16.

Foster, J.L. 2016. Remote Sensor Applications to Forages and Rangelands. Visiting students from Guatemala. Corpus Christi, TX, Aug. 17.

Muir, J.P. 2016. XXV Congresso da Associação Latino-Americana de Produção Animal, Pernambuco Brazil. “Enhancing food security in Latin America with forage legumes.”

Muir, J.P. 2016. American Society of Agronomy Annual Meeting, Bioenergy Symposium Phoenix USA, 2016. “Cellulosic feedstock vs. Forage.”

Collaborative Grants between Stations and Members Awarded in 2016

Hays, D., F. Hons, H. Neely, J. Foster, K. Lewis, N. Rajan, R. Lacey, R. Jessup, and X. Wu. 2016. Developing ground penetrating radar (GPR) for enhanced root and soil organic carbon imaging: Optimizing bioenergy crop adaptation and agro-ecosystem services. DOE ARPA-E. 2016-2019. Co-Investigator. $5,018,984.

Knutson, A., F. Mitchell, V. Corriher-Olson, and J.P. Muir. 2016. Developing IPM practices for Bermudagrass stem maggot. $27,980. USDA-National Institute of Food and Agriculture.

Muir, J.P. 2016. Indicators and Soil Conservation Practices for Soil Health and Carbon Sequestration. (co-PI with Bellows at Tarleton State University). $312,000. Southern SARE, USDA.

Muir, J.P. 2016. Developing IPM Practices for Bermudagrass Stem Maggot in Forage Production (co-PI) 2016. $27,980. Southern IPMC.

Muir, J.P. 2016. Tarleton. Green thumbs, green plates, green attitudes. (co-PI). $298,000. NIFA, NLGCA.

Oregon State- David B. Hannaway

Project-related Activities

2016 Meeting

Group members met in Corvallis, OR to discuss research findings and plan future collaborations. Oregon State University formally joined NCCC-031 following participation in annual meeting as a guest.

DLF Field Day

Participated in grass and legume breeding evaluation field day in Philomath, OR. Discussed breeding objectives with research director.

Field Experiment Design

Assisted OSU colleague in designing field experiments to evaluate water-use efficiency of various forage species and cultivars. 14 acres of experimental plots have been established involving 4 irrigation treatments.

"MatchClover" Website Design

Developed design for a "MatchClover" web segment with a graphic artist and web designer. Segment will be part of the Forage Information System.

Alfalfa Modeling

Discussed alfalfa modeling with Chinese colleagues at Northwest Ag & Forestry University, China Agricultural University, Nanjing Agricultural University, and Jiangsu Academy of Agricultural Sciences. Subsequent discussions with Lincoln University (NZ) colleagues and students involved transitioning from APSIM to APSIM-X (open source) modeling platform.

Mine Spoil Restoration

Discussed restoration of coal mined areas of US and Indonesia with USDA scientist and Bogor Agricultural University faculty. Developed a study plan for PhD candidate involving the use of biochar from various sources to improve forage growth and mitigate damage caused by open-pit mining.

Rocky Karst Land Restoration

Discussed with Guizhou Province Governor the need for restoring degraded rock karst areas and improving the forage-livestock sector. Developed a proposal involving characterizing geophysical, climatic, and soil conditions and field demonstrations involving matching forage and woody species characteristics with prevailing conditions.

OSU AES Collaborative Project

Initiated work on Hatch-funded OSU AES Collaborative Project: "Developing seasonal production profiles of key Oregon forage species using crop modeling and field validation for sustainable forage-livestock systems."

Collaboration will include campus-based, branch experiment station-based, and county-based faculty with forage-livestock system expertise.

Grass Phenology Modeling

Discussions with grass seed industry colleagues from DLF, Barenbrug, GrasslandsOregon, and FFR regarding their desire to develop a universal maturity index for phenological development of cool-season grass species and cultivars. Visiting scholar from China compiled Plant Protection Office data and began modeling effort for key species. Poor predictive ability of algorithms indicated the need for another approach.

Subsequent discussions with Lincoln University faculty and students revealed their interest and PhD project on ryegrass phenological development using controlled environment chambers for temperature and photoperiod.

Project-related Publications

Hannaway, David B., Linda Brewer, Steve Fransen, Glenn Shewmaker, Shannon Williams, and Sarah Baker. 2017. Planning and Sowing Grasslands. Chapter 10. IN: Improving Grassland and Pasture Management in Agriculture. Athole Marshall and Rosemary Collins, eds. Burleigh Dodds Sci. Pub., Cambridge, CB22 3HJ.

Project-related Presentations

Hannaway, David B. 2017. A Proposal Presented to Guizhou Governor SUN: "Restoring Desertified Rocky Karst Landscapes and Strengthening Guizhou's Forage-Livestock Sector." Guiyang, Guizhou Province, PRC. March 21.

Hannaway, David B. 2017. Using GIS and Spatial Analysis Techniques for Species Suitability Modeling & Mapping. Lincoln University, Christchurch, NZ. March 8.

Hannaway, David. 2017. MatchClover – Web Based Tools for Matching Clovers to Climates, Soils and Intended Uses. Oregon Clover Growers' Annual Meeting. February 8. Wilsonville, Oregon.

Hannaway, David B. 2016. Improving Alfalfa Cultivar Selection by GIS Mapping of Fall Dormancy and Winter Survival Index Zones and Modeling Seasonal and Annual Yield. Jiangsu Academy of Agricultural Sciences. August 18.

Hannaway, David B. 2016. Oregon Forages. NCCC-031 Annual Meeting. Corvallis, OR. Jun. 16.

Hannaway, D.B. 2016. Forages: the seeds of sustainability. American Society of Seed Analysts Annual Meeting. June 6. Portland, Oregon and Seed Technology. 37(2):198. Abstract.

Hannaway, David B., Patti Sohn, and Ken Cuffe. 2016. MatchClover – a Progress Report. Oregon Clover Commission. West Salem, Oregon. May 11.

Hannaway, D.B. 2016. Improving Alfalfa Cultivar Selection by GIS Mapping of Fall Dormancy and Winter Survival Index Zones and Modeling Seasonal and Annual Yield. Northwest Agriculture & Forestry University. March 2.

Shewmaker, G.E., D.B. Hannaway, and S.C. Fransen. 2016. Forages and Grasslands in the Pacific Northwest. Abstract for American Forage and Grassland Council Annual Meeting 10-13 Jan., Baton Rouge, LA.

Project-related Plans for 2017-2018

- Collect and summarize data from field experiments for species production profiles.

- Develop MatchClover web segment as a model for broader species selection segment.
- Initiate “change of duty station” and sabbatical leave at Lincoln University (New Zealand) involving alfalfa crop simulation and grass phenology research.

Kentucky-R.L. McCulley

1. Impact Nugget: The University of Kentucky has shown that the ability of tall fescue pastures of the eastern U.S. to sequester carbon belowground and reduce greenhouse gas emissions depends on complex interactions between the presence (less so the strain) of the symbiotic fungus, *Epichloë coenophiala*, within the plant and the surrounding environment. However, *E. coenophiala* strain is quite important in governing tall fescue's ability to resist and recover from likely future changes in climate.

2. New Facilities and Equipment: We acquired a new large capacity freeze-drier, through the generosity and leftover funds associated with the USDA-ARS Forage Animal Production Research Unit.

3. Unique Project Related Findings: Using a DNA-based approach, endophyte presence altered soil fungal communities, increasing the relative abundance of taxa within the Glomeromycota phylum and decreasing genera in the Ascomycota, but had no measurable impact on soil prokaryotic communities (Rojas et al. 2016). However, using microscopy to quantify root arbuscular mycorrhizal fungi (AMF) and dark septate endophyte (DSE) colonization rates, no effect of endophyte presence was observed (Slaughter & McCulley 2016). In both studies, endophyte strain had no impact on the observed trends.

4. Accomplishment Summaries:

Research at the University of Kentucky is assessing the potential to use grass-fungal endophyte symbioses to improve pasture resilience to climate change and mitigation potential. We have a new warming (+3^{o}C) and altered precipitation (reduced frequency) manipulative climate change field experiment that has been running for over a year now and is testing several fescue cultivars and clone pairs, as well as a native grass – *Elymus canadensis* – for endophyte effects on plant production response to the climate treatments. We continue, in collaboration with scientists from Finland, Spain, New Zealand, and Australia, to assess endophyte effects on greenhouse gas emissions and soil carbon sequestration potential worldwide. We have just begun an experiment to assess whether symbiotic diversity impacts pasture ecosystem function. We present our work to relevant industry, farmer, and scientific communities, via publications and presentations.

5. Impact Statements:

Tall fescue (*Lolium arundinaceum* (Schreb.)) is a cool-season perennial grass within which can live a fungal endophyte (*Epichlo*e *coenophiala*) that can provide enhanced edaphic and climactic stress tolerance to the host compared to non-infected individuals. Our prior research demonstrated that a variety of root exudate compounds released from tall fescue were differentially affected by tall fescue cultivar, endophyte genotype and their interaction. Changes in root exudates and associated microbial communities could influence soil processes, including carbon and nitrogen cycling, but these effects may differ depending on fescue and endophyte genetics. Because new fescue cultivars, harboring unique (so-called 'novel') *Epichloë coenophiala* genotypes are increasingly being adopted by forage producers, and because of the important role soil microbes play in determining soil carbon sequestration and

soil-to-atmosphere greenhouse gas flux, it is important to understand how fescue cultivar, fungal strain, and environment interactions on belowground organisms. Our research clearly demonstrates that these interactions are complex and endophyte effects are unlikely to be consistent across locations, cultivars, or over time. *Epichloë* presence can significantly impact root and soil microbial communities, and associated nutrient cycling parameters, but it is not yet clear what factors govern these responses.

Humans are dramatically increasing nutrient availability worldwide, which can have effects on how species interact (niche overlap) and the ecosystem services they provide, such as the stabilization of plant production over time. Research conducted at the University of Kentucky and a global network of sites found that elevated resource supply reduced niche dimensionality and diversity and increased both productivity and compositional turnover. These results point to the importance of understanding niche dimensionality in ecological systems that are undergoing diversity loss in response to multiple global change factors. Furthermore, results from this project illustrate that eutrophication increases the sensitivity of grassland biodiversity to annual fluctuations in climate.

Invasive, exotic grasses are increasing in tallgrass prairie, and their dominance may be contributing to the decline of grassland butterflies through alterations in forage quality. Tall fescue (*Schedonorus arundinaceus* (Schreb.)), an exotic grass covering millions of acres in the United States, can host a fungal endophyte, *Epichloë coenophiala*. Alkaloids produced by the endophyte are known to be toxic to some foliar-feeding pest insects. Endophyte-infected tall fescue is commonly planted in hayfields, pastures, lawns, and is invading natural areas, but effects of the endophyte on non-pest insects such as butterflies are relatively unknown. We investigated the role that exotic grasses such as endophyte-infected tall fescue and Kentucky bluegrass (*Poa pratensis*) might play in the decline of grass skippers (Hesperiidae). We examined growth and survival parameters of tawny-edged skippers (*Polites themistocles*) that were reared on endophyte-infected tall fescue (E+), endophyte-free tall fescue (E-), and Kentucky bluegrass (KBG). Interestingly, results showed that the endophyte did not affect growth and survival of larvae compared to uninfected tall fescue, even though significant amounts of loline alkaloids (average 740 ppm) were measured in endophyte-infected plant material. Larvae feeding on KBG grew faster with greater survival rates than larvae on both tall fescue treatments. These results confirm that tall fescue invasion and dominance may be deteriorating the quality of grassland habitats for native insects; however, this effect does not appear to be linked to endophyte infection. These results highlight one way in which invasive grasses may be altering pollinator habitat and associated insect communities.

6. Published Written Works.

1) Slaughter, L.C. and R.L. McCulley. **2016.** Aboveground *Epichloë coenophiala* – grass associations do not affect belowground fungal symbionts or associated plant, soil parameters. Microbial Ecology 72: 682-691.
2) Guo, J., R.L. McCulley, T.D. Phillips, and D.H. McNear, Jr. **2016.** Fungal endophyte and tall fescue cultivar interact to differentially effect bulk and rhizosphere soil processes governing C and N cycling. Soil Biology & Biochemistry 101:165-174.

3) Harpole, W.S., L.L. Sullivan, E.M. Lind, J. Firn, P.B. Adler, E.T. Borer, J. Chase, P.A. Fay, Y. Hautier, H. Hillebrand, A.S. MacDougall, E.W. Seabloom, R. Williams, J.D. Bakker, M.W. Cadotte, E.J. Chaneton, C. Chu, E.E. Cleland, C. D'Antonio, K.F. Davies, D.S. Gruner, N. Hagenah, K. Kirkman, J.M.H. Knops, K.J. La Pierre, R.L. McCulley, J.L. Moore, J.W. Morgan, S.M. Prober, A.C. Risch, M. Schuetz, C.J. Stevens, and P.D. Wragg. **2016.** Addition of multiple limiting resources reduces grassland diversity. Nature 537(7618):93-96.

4) Saikkonen, K., T.D. Phillips, S.H. Faeth, R.L. McCulley, I. Saloniemi, and M. Helander. **2016**. Performance of endophyte infected tall fescue in Europe and North America. PLOS ONE 11(6):e0157382. doi: 10.1371/journal.pone.0157382.

5) Tredennick, A.T., P.B. Adler, J.B. Grace, W.S. Harpole, E.T. Borer, E.W. Seabloom, T.M. Anderson, J.D. Bakker, L.A. Biederman, C.S. Brown, Y.M. Buckley, C. Chu, S.L. Collins, M.J. Crawley, P.A. Fay, J. Firn, D.S. Gruner, N. Hagenah, Y. Hautier, A. Hector, H. Hillebrand, K. Kirkham, J.M.H. Knops, R. Laungani, E.M. Lind, A.S. MacDougall, R.L. McCulley, C.E. Mitchell, J.L. Moore, J.W. Morgan, J.L. Orrock, P.L. Peri, S.M. Prober, A.C. Risch, M. Schutz, K.L. Speziale, R.J. Standish, L.L. Sullivan, G.M. Wardle, R.J. Williams, and L.H Yang. **2016**. Comment on "Worldwide evidence of a unimodal relationship between productivity and plant species richness". Science 351(6272):457.

6) Rojas, X., J. Guo, J.W. Leff, D.H. McNear Jr., N. Fierer, and R.L. McCulley. **2016**. Infection with a shoot-specific fungal endophyte (*Epichloë*) alters tall fescue soil microbial communities. Microbial Ecology 72:197-206.

7) Smets, W., J.W. Leff, M.A. Bradford, R.L. McCulley, S. Lebeer, and N. Fierer. **2016**. A method for simultaneous measurement of soil bacterial abundances and community composition via 16S rRNA gene sequencing. Soil Biology & Biochemistry 96:145-151.

8) Flores-Moreno, H., P.B. Reich, E.M. Lind, L.L. Sullivan, E.W. Seabloom, L. Yahdjian, A.S. MacDougall, L. Reichmann, J. Alberti, S. Baez, J.D. Bakker, M.W. Cadotte, M.C. Caldeira, E.J. Chaneton, C. D'Antonio, P.A. Fay, J. Firn, N. Hagenah, W.S. Harpole, O. Iribarne, K.P. Kirkman, J.M.H. Knops, K.J. La Pierre, R. Laungani, A.D.B. Leakey, R.L. McCulley, J.L. Moore, J. Pascual, and E.T. Borer. **2016**. Climate modifies response of non-native and native species richness to nutrient enrichment. Philosophical Transactions of the Royal Society B 371(1694): 20150273.

9) Helander, M., T. Phillips, S.H. Faeth, L.P. Bush, R.L. McCulley, I. Saloniemi, and K. Saikkonen. **2016**. Alkaloid quantities in endophyte-infected tall fescue are affected by the plant-fungus combination and environment. Journal of Chemical Ecology 42(2):118-126. doi: 10.1007/s10886-016-0667-1.

10) Jokela, K.J., D.M. Debinski, and R.L. McCulley. **2016**. Effects of non-native grass species and endophyte infection on the development and survival of Tawny-edged skippers (Lepidoptera: Hesperiidae). Environmental Entomology 45(1):142-149. doi: 10.1093/ee/nvv151.

7. Scientific and Outreach Oral Presentations.

1) Slaughter, L.C., J.A. Nelson, A.E. Carlisle, M. Bourguignon, R.D. Dinkins, T. Phillips, and R.L. McCulley. **2016**. Tall fescue-*Epichloë coenophiala* associations affect belowground fungi and host, symbiont response to climate change. ASA-CSSA-SSSA Annual Meeting, Phoenix, AZ.
2) Slaughter, L.C. and R.L. McCulley. **2016**. Tall fescue – *Epichloë coenophiala* associations affect belowground fungi and host, symbiont response to climate change. Mycology Society of America Annual Meeting, Berkeley, CA.

8. Fund leveraging. None to report between stations or members of NCCC-31.

9. Other relevant accomplishments and activities. McCulley has received two recent NIFA-AFRI grants to evaluate fungal endophyte effects on tall fescue pasture soil health and climate resiliency. Work is under-way.

University of Maryland- Bill Lamp
Graduate students: Rebecca Wilson, Rebecca Eckert, Morgan Thompson
Support staff: Claire Hirt, Alison Post, Cullen McAskill

1. Impact Nugget:

Understanding the complex interactions between insect pest populations, injury, and forage crop physiology can aid producers to optimize yield, quality, and stand persistence. For example, potato leafhopper, *Empoasca fabae*, causes short-term disruption of gas exchange and translocation in alfalfa physiology, yet the interaction between the pest and crop can be managed by the producer. By integrating management practices, producers can reduce leafhopper injury and maintain forage crop production in a profitable and environmentally-safe manner.

2. New Facilities and Equipment.

No new facilities or equipment to report.

3. Unique Project Related Findings.

1) In separate alfalfa fields consisting of a leafhopper-susceptible variety, a leafhopper-resistant variety, and a mixture of tall fescue with a leafhopper-susceptible variety, we observed a trend for decreasing leafhopper injury with higher rates of an insecticide especially for the susceptible variety.

2) By using a hand-held IR thermometer to measure alfalfa canopy temperatures, we were able to observe cooler canopies in alfalfa plots with fewer leafhoppers. This suggests that canopy radiation can be used to assess stress caused by the leafhopper.

3) We developed a standardized bioassay for screening *Medicago truncatula* lines for resistance to potato leafhopper injury. The technique will be used to examine variation within *M. truncatula* to leafhopper injury. By comparing gene regulation in susceptible and resistant lines, we may be able to identify potential genetic mechanisms for resistance in alfalfa varieties.

4. Accomplishment Summaries.

We completed the first production year of a planned three years to determine the loss induced by potato leafhopper in fields with a leafhopper-susceptible variety, a leafhopper-resistant variety, and a mixture of tall fescue with a leafhopper-susceptible variety. Four rates of an insecticide were used to manipulate leafhopper densities in plots within each field. In the one growth cycle when leafhoppers were present in economic numbers, we found no significant effect of insecticide treatment on yield, although quality samples are still pending. The proportion of hopperburn stems varied among fields such that the strongest response to injury was found in the susceptible variety (15% in full insecticide rate versus 72% in no spray plots), compared with the mixture (42% in full rate versus 62% in no spray plots) and the resistant variety (10% in full rate versus 18% in no spray plots). Stem heights showed a significant stunting from leafhoppers in all fields, with alfalfa heights reduced by 31.1% in the susceptible field, 30.9% in the mixed field, and 10.7% in the resistant field. We will use this information to measure economic impact of the leafhopper, and compare costs to benefits within the field types.

Within the same plots, we measured canopy temperature using a handheld IR gun, and calculated the difference between ambient air temperature and canopy temperature as a measure of transpiration rate. At 14 days after cutting, before the alfalfa showed any symptoms of hopperburn, we observed higher air-canopy temperature differences in the full rate of insecticide

plots compared to no insecticide (susceptible: 5.2±0.9 ^{o}C vs 3.9±1.8; resistant: 3.2±1.3 ^{o}C vs 2.7±0.9; mixture: 5.7±1.2^{o}C vs 3.3±2.1). These data suggest the susceptible variety and mixture experienced injury to transpiration, whereas the resistant variety did not. There was, however, high variation in our temperature measurements. Radiation sensing may provide a valuable tool to assessing insect injury if we can reduce the variation in measurements.

5. Impact Statements.

Leafhopper injury can be a significant loss to alfalfa production. By providing management options to producers, we hope to reduce their losses by enabling them to optimize their strategy for alfalfa pest management. Resistant varieties, in particular, may be a valuable tool now, while in the past variety selection did not reflect increased profit margins. The use of alternative methods to assess insect injury, such as through radiation sensing, may provide an easier and quicker means to develop a response to insect pests. By investigating the complex insect-plant interactions that lead to leafhopper injury, and incorporating that understanding with the management tools available to producers, ecophysiological research can aid to make forage production more sustainable in light of variable pest populations in the future.

6. Published Written Works. Include scientific publications, trade magazine articles, books, posters, websites developed, and any other relevant printed works produced. Please use the formatting in the examples below.

Leslie, A.W. , and W.O. Lamp. 2017. Taxonomic and functional group composition of macroinvertebrate assemblages in agricultural drainage ditches. Hydrobiologia 787: 99-110.

Spadafora, E. , A.W. Leslie, L.E. Culler, R.F. Smith, K.W. Staver, and W.O. Lamp. 2016. Macroinvertebrate community convergence between natural, rehabilitated, and created wetlands. Restoration Ecology 24: 463-470.

Sulc, M., W.O. Lamp, and M. Collins. 2017. Integrated pest management in forages. In Forages: The Science of Grassland Agriculture, M. Collins, C.J. Nelson, and K.J. Moore (eds.), 7th ed., Vol. I. Wiley, NY. (in press)

Tracy, B., K. Albrecht, J. Flores, M. Hall, A. Islam, G. Jones, W. Lamp, J. MacAdam, H. Skinner, and C. Teutsch. 2016. Evaluation of alfalfa-tall fescue mixtures across multiple environments. Crop Science 56: 2026-2034.

Venugopal, P.D. , G.P. Dively, A. Herbert, S. Malone, J. Whalen, and W.O. Lamp. 2016. Contrasting role of temperature in structuring regional patterns of invasive and native pestilential stink bugs. PLoS ONE 11(2): e0150649.

7. Scientific and Outreach Oral Presentations. Include workshops, colloquia, conferences, symposia, and industry meetings in which you presented and/or organized. See below for formatting.

Invited speaker, “Bt Maize and Streams: Risk of Exposure and Hazard to Aquatic Insects”, as part of the 2016 symposium “Aquatic Entomology Around the World”, International Congress of Entomology, Orlando, FL, USA.

Lamp, W.O., R. Kaji, C. Regan, A. Post, and G. Dively. 2016. Degradation of Cry proteins and ecological processing of post-harvest Bt and non-Bt corn debris in an agricultural stream. Eastern Branch Meeting of the Entomological Society of America, Philadelphia, PA.

8. Fund leveraging, specifically, collaborative grants between stations and members.

(Funded) 2015-2018, USDA-Alfalfa and Forage Research Program, Bill Lamp as lead PD with Mark Sulc (Ohio State Univ.) and Kenneth Albrecht (Univ. of Wisconsin) as co-PDs, “Potato Leafhopper Threshold Revised for Alfalfa Host Resistance and Alfalfa-Grass Mixtures”, $215,000. The purpose of this grant is to determine economic loss relationships for potato leafhopper in alfalfa cropping systems, to examine the effect of the leafhopper on nitrogen fixation, and to extend new information on economic thresholds.

(Pending) 2017-19, USDA-Alfalfa and Forage Research Program, lead PD with Mark Sulc and James Jasinski (Ohio State University) and Yong-Lak Park and Tom Griggs (West Virginia University) as co-PDs, “Proximal and remote sensing of alfalfa canopies for early detection of insect stress and rapid integrated pest management decision-making”, $249,853. The purpose of this grant is to develop proximal (handheld) and remote (UAVs) sensors of alfalfa canopies for rapid decision-making concerning leafhopper injury.

Texas Tech University-Chuck West
Graduate students: Lisa Baxter, Yedan Xiong, Krishna Bhandari, Madhav Dhakal
Support staff: Philip Brown, Paul Green

1. Impact Nugget:

Inclusion of alfalfa (*Medicago sativa*) mixed with grasses offers a potentially profitable means of transitioning land use from high-irrigation row crops to low-irrigation forage-beef stocker systems in the Southern High Plains where Ogallala groundwater resources are rapidly depleting. The alfalfa-grass system resulted in a lower water footprint for stocker liveweight gain than the grass-alone system, indicating that alfalfa's reputation as a water-wasting crop does not apply to well-managed pasture systems. The Old World bluestem, WW-B.Dahl (*Bothriochloa bladhii*), strongly deters fire ant and harvester ant infestations, two insects that reduce forage availability in other types of grass pastures. Progress was made in calibrating ALMANAC and APSIM growth models for WW-B.Dahl. Such models are useful in conducting drought-risk analyses for grazing and for predicting cattle carrying capacity in the face of variable water supplies.

2. New Facilities and Equipment.

We continued testing and refining our use of stationary and portable capacitance probes for monitoring soil water content to 1 m depth. We also finished testing image analysis tools for assessing ground cover, alfalfa composition, and biomass, consisting of normal (RGB) photography with ImageJ® software, a Black Comet CXR-SR hyperspectral spectrometer for calculating NDVI values, PowerPoint®, and height.

3. Unique Project Related Findings.

1) Digital image analysis using ImageJ® photo analysis was the most accurate and fastest method of nondestructive determination of quantifying alfalfa and sweetclover content in pasture mixtures with WW-B.Dahl.

2) A combination of ImageJ photo analysis and canopy height was the most accurate model for nondestructive assessment of forage mass in a mixture of alfalfa and tall wheatgrass.

3) Including alfalfa in mixture with grasses significantly enhanced ADG and LWG/ha of beef steers over grass-alone receiving N fertilizer on pastures, both receiving around 20 cm of irrigation. Inclusion of a "protein bank" of and alfalfa-tall wheatgrass mixture was a novel technique for concentrating limited water resources on small land area to provide forage of high nutritive value.

4) The increased beef productivity by integrating alfalfa in the grazing system reduced the water footprint of beef stocker production (m^3 of water received/kg of beef gain).

5) WW-B.Dahl Old World bluestem grass almost completely suppressed infestations by fire ants and harvester ants without mitigating beneficial insects.

4. Accomplishment Summaries.

The overall aim is to help irrigated row-crop producers in the Texas High Plains adapt to declining water supplies by integrating grazing into the cropping system. Our strategy is to develop forage management systems that diversify agricultural land use away from continuous row-crop monoculture receiving high irrigation input toward profitable, low-water-use grazing systems. Two elements that show promise are 1) the production of the Old World bluestem variety WW-B.Dahl as the main warm-season perennial grass, and 2) use of alfalfa as a legume

component thanks to its high nutritive value and ability to fix atmospheric nitrogen. A novel aspect is that cattle are limit-grazed each week on a small-area alfalfa-tall wheatgrass mixture to help meet protein and energy needs, referred to as a protein bank. We calculated the amount of water input of two systems, grass alone receiving N fertilizer and grass with alfalfa and no N fertilizer, and water footprint for producing a kg of liveweight gain.

Tests were conducted to identify nondestructive methods of assessing legume content (dry weight composition) of mixtures with grasses (Baxter et al., 2017a). When growing with WW-B.Dahl, legume content was best predicted with visual estimate and photo-point using PowerPoint; however, the former was much faster. When growing with tall wheatgrass, the best method was visual estimate. Image analyses using ImageJ or spectral reflectance (NDVI) worked poorly with both mixtures because of difficulty in discerning between grass and legume.

Tests were conducted to identify nondestructive methods of assessing forage mass in alfalfa-tall wheatgrass mixture (Baxter et al., 2017b). The best method was a model that combined ImageJ analysis with canopy height. The published paper in Agronomy Journal includes Appendices explaining how to program and run macros in ImageJ for automating calculations of canopy cover. ImageJ is now a useful tool in our research program when canopy cover data are desired.

In a 3-yr stocker grazing trial (Baxter et al., 2017c) comparing WW-B.Dahl grass growing alone but receiving 67 kg ha^{-1} of N fertilizer, mean ADG was 0.79 kg anim-d^{-1} and LWG was 118 kg ha^{-1}. This grass-alone system also included some grazing of a dryland native grass mixture and dryland teff. In the other treatment consisting of WW-B.Dahl with alfalfa and yellow sweetclover and receiving no N fertilizer, ADG was 0.94 kg anim-d^{-1} and LWG was 188 kg ha^{-1}. This grass-legume system also included other pastures of alfalfa-tall wheatgrass (protein bank), dryland native grass mix, and dryland teff. Results indicated a promising role for alfalfa in low-water-input pastures.

In the same 3-yr grazing trial (Baxter et al., 2017d), water footprint was calculated to express the amount of water input (from effective rain + irrigation + livestock drinking) per kg of LWG produced. Water footprint is the reciprocal of water use efficiency. Water footprint was calculated on LWG data from grazing only and also on LWG from grazing plus simulated gain from extra forage harvested as hay for a total of 6 methods of calculation. In 5 cases out of 6, water footprint was lower for the grass-alfalfa system than for the grass-alone system. For example, for LWG from grazing only, the water footprint was 25.4 m^3 kg^{-1} of LWG for grass-legume vs. 28.2 m^3 kg^{-1} for grass-alone.

The ALMANAC and APSIM crop growth models were calibrated to improve the simulation WW-B.Dahl growth. Validations indicated that progress was made. This effort is on-going.

5. Impact Statements.

WW-B.Dahl Old World bluestem provides a very desirable warm-season perennial grass as the backbone of a beef stocker grazing system requiring very low water input from irrigation (up to 23 cm per year), which is one-third to one-half of that required to produce cotton and one-fourth to one-third of that required to produce corn. Our modeling work will lead to a decision aid tool for producers to most profitably allocate a dwindling water supply among fields while maintaining profitability.

Alfalfa shows great promise to improve low-irrigation pastures in the Texas High Plains both in mixture with WW-B.Dahl and when growing with the cool-season grass tall wheatgrass. This is despite the reputation of alfalfa as a highly water-consumptive crop. Our management takes

advantage of the deep-rootedness of alfalfa and its much superior nutritive value over WW-B.Dahl. The result is a lower overall water footprint (greater water-use efficiency) of a grazing system including alfalfa (with respect to animal productivity) receiving no N fertilizer over grass alone receiving N fertilizer.

All impacts stated above demonstrate how ecophysiological research on pastures contributes to prolonging the sustainability of agriculture in the Texas High Plains.

6. Published Written Works.

Refereed Journal Articles

Ashworth, A.J., P.D. Keyser, F.L. Allen, D.D. Tyler, A.M. Taylor, and C.P. West. 2016. Displacing inorganic nitrogen in lignocellulosic feedstock production systems. Agron. J. 108:109-116. doi:10.2134/agronj15.0033.

Smith, S.A., M.P. Popp, D.R. Keeton, C.P. West, K.P. Coffey, L.L. Nalley, and K.R. Brye. 2016. Economic and greenhouse gas emission response to pasture species composition, stocking rate, and weaning age by calving season, farm size, and pasture fertility. Agric. Res. Econ. Rev. 45:98-123. doi:10.1017/age.2016.11.

Ashworth, A.J., S.A. Weiss, P.D. Keyser, F.L. Allen, D.D. Tyler, A. Taylor, K.P. Beamer, C.P. West, and D.H. Pote. 2016. Switchgrass composition and yield response to alternative soil amendments under intensified heat and drought conditions. Agric. Ecosystems Environ. 233:415-424. doi:10.1016/j.agee.2016.09.041.

Oliveira, J.A., C.P. West, E. Afif, and P. Palencia. 2017. Comparison of miscanthus and switchgrass cultivars for biomass yield, soil nutrients, and nutrient removal in northwest Spain. Agron. J. 109:122-130. doi:10.2134/agronj2016.07.0440.

Ashworth, A.J., A.C. Rocateli, C.P. West, K.R. Brye, M.P. Popp. 2017. Switchgrass growth and effects on biomass accumulation, moisture content, and nutrient removal. Agron. J. 109: [In press].

Baxter, L.L., C.P. West, C.P. Brown, and P.E. Green. 2017a. Nondestructive determination of legume content in grass-legume pastures. Crop Forage Turfgrass Manag. Vol. 3(1). doi:10.2134/cftm2016.12.0088. Available online: https://dl.sciencesocieties.org/publications/cftm/abstracts/3/1/cftm2016.12.0088

Baxter, L.L., C.P. West, C.P. Brown, and P.E. Green. 2017b. Comparing nondestructive sampling techniques for predicting forage mass in alfalfa-tall wheatgrass pasture. Agron. J. 109: [In press] doi: 10.2134/agronj2016.12.0738

Baxter, L.L., C.P. West, C.P. Brown, and P.G. Green. 2017c. Stocker beef production on low-water input systems in response to legume inclusion. I. Forage and animal responses. Crop Sci. 57: [In press] doi: 10.2135/cropsci2017.02.0112.

Baxter, L.L., C.P. West, J.O. Sarturi, C.P. Brown, and P.G. Green. 2017d. Stocker beef production on low-water input systems in response to legume inclusion. II. Water footprint. Crop Sci. 57: [In press] doi: 10.2135/cropsci2017.05.0289.

Other Creative Works
None

Poster and Oral Presentations

Sugg, J.D., P.R. Campanili, C.P. West, L.L. Baxter, J.O. Sarturi, and S.J. Trojan. 2016. Evaluation of *Eragrostis tef* (Zucc.) as a forage option for grazing beef cattle in the Southern High Plains. Proc. Am. Soc. Anim. Sci. Western Section, Am. Dairy Sci. Assoc., and Canadian Soc. Anim. Sci. Joint Annual Meeting, 19-23 July, Salt Lake City, UT.

Longing, S., C. Jewett, B. Rendon, S. Discua, R. Cox, C. McKenney, N. McIntyre, and C. West. 2016. An assessment of bee richness and community structure across different agroecosystems on the Southern High Plains (Texas, USA). 2016 Int. Cong. Entomology / Entomol. Soc. Am. Annual Meeting, Orlando, FL, 30 Sept.

Baxter, L.L., and C.P. West. 2016. Comparison of productivity and efficiency of grass-only and grass-legume beef stocker grazing systems in the Southern High Plains. In Annual meetings abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Baxter, L.L., and C.P. West. 2016. Developing novel non-destructive sampling techniques for assessing botanical composition in grass-legume pastures. In Annual meetings abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Xiong, Y., C.P. West, and T. McLendon. 2016. Fractionating rainfall into vegetative interception and soil infiltration in perennial grassland. In Annual meetings abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Bhandari, K., C.P. West, S.D. Longing, D.M. Klein and V. Acosta-Martinez. 2016. Arthropod community composition of ‘WW-B.Dahl’ Old World bluestem pasture systems. In Annual meetings abstracts [CD-ROM]. ASA, CSSA, and SSSA, Madison, WI.

Baxter, L.L., and C.P. West. 2017. Comparison of productivity and efficiency of grass-only and grass-legume beef stocker grazing systems in the Southern High Plains. Presented at: American Forage and Grassland Conference, Roanoke, VA. 24 Jan.

Baxter, L.L., and C.P. West. 2017. Evaluation of winter annual cover crops under multiple residue managements: Impacts on soil water depletion and cash-crop productivity. Poster presented at: American Forage and Grassland Conference, Roanoke, VA. 24 Jan.

Baxter, L.L., and C.P. West. 2017. Comparison of traditional and novel non-destructive sampling techniques for site-specific assessment of botanical composition in grass-legume pastures. Poster presented at: American Forage and Grassland Conference, Roanoke, VA. 23 Jan.

Bhandari, K., C.P. West, S.D. Longing, and V. Acosta-Martinez. 2017. Arthropod and soil microbial community composition of 'WW-B.Dahl' Old World bluestem pasture systems. Presented at: American Forage and Grassland Council, Roanoke, VA. 23 Jan.

Xiong, Y., C.P. West. 2017. Comparison of ALMANAC and APSIM for simulating Old World bluestem growth. Presented at: American Forage and Grassland Council, Roanoke, VA. 23 Jan.

Baxter, L.L., and C.P. West. 2017. Comparison of productivity and efficiency of grass-only and grass-legume beef stocker grazing systems in the Southern High Plains. Presented at: Southern Branch of the American Society of Agronomy, Mobile, AL. 6 Feb.

West, C., D. Malinowski, and T. McLendon. 2017. Responses of grassland communities to climate changes in Texas and Oklahoma. Proceedings of 71st Southern Pasture and Forage Crop Improvement Conference. 5-7 June, Knoxville, TN. Available at: http://agrilifecdn.tamu.edu/spfcic/files/2013/02/Proceedings-71st-SPFCIC.pdf.

West, C.P., L.L. Baxter, C.P. Brown, and P.E. Green. 2017. Water use for beef production on pastures in West Texas. Presented at: Universities Council on Water Resources Conference, 13-15 June, Fort Collins, CO.

Popular Articles
None

7. Outreach Oral Presentations (Scientific presentations are listed above)

West, C.P. 2017. Linking climate to groundwater conservation. Climate Outlook Forum: Managing Risk and Thinking Ahead. 26 April, Clovis, NM. USDA-ARS Southwest Climate Hub, Las Cruces, NM.

West, C.P. 2017. Water footprint in High Plains agriculture. 9 May. Science by the Glass, Texas Tech Climate Science Center.

8. Fund leveraging, specifically, collaborative grants between stations and members.

Long-term agro-ecosystems research and adoption in the Texas Southern High Plains. USDA Southern SARE Large Systems Research program. $300,000. $100,000 per year from 2014-2017. Lead PI.

Sustaining agriculture through adaptive management resilient to a declining Ogallala Aquifer and changing climate. Meagan Schipanski (CSU, Lead PI) and 12 co-PDs including C.P. West. USDA-NIFA-AFRI CAP. $10,000,000. My share $294,638 over 4 years. Funding runs 2016-2020.

9. Other relevant accomplishments and activities.

West, C.P. is principal investigator of the Texas Alliance for Water Conservation project, which is an outreach effort to educate and demonstrate to producers how to reduce use of the Ogallala Aquifer for irrigating crops while minimizing loss of income.

Penn State

Completed Research

- Quality of Reduced and Low Lignin Alfalfas with maturity
- Yield of Reduced and Low Lignin Alfalfas with maturity
- Evaluating the efficacy if Silo-Guard® on alfalfa/grass baleage at three moisture levels

Research in Progress

- Efficacy of the BioAg® seed treatment on alfalfa establishment and yield
- Efficacy of the adding pelletized Mycorrhizae to alfalfa seed at time planting.
- Biomass (switchgrass, willow, Miscanthus) production on marginal lands
- Switchgrass ecotype screening for productivity on marginal lands

Publications

- Ben Tracy, Ken Albrecht, Joao Flores, Marvin Hall, Anowarul Islam, Gordon Jones, Bill Lamp, Jennifer MacAdam, Howard Skinner, and Chris Teutsch. 2016. Evaluation of Alfalfa-Tall Fescue Mixtures across Multiple Environments. Crop Sci. 56:2026-2034. doi:10.2135/cropsci2015.09.0553.
- Neu, A.E., C.C. Sheaffer, D.J. Undersander, M.H. Hall, D.M. Kniffen, M.S. Wells, D.N. Catalano, and K.L. Martinson. 2017. Hay-rake type affects ash content of alfalfa hay. J. Equine Vet. Sci. 52:105–106. doi:10.1016/j.jevs.2017.03.164.
- Neu, Abby E., Craig C. Sheaffer, Daniel J. Undersander, Marvin H. Hall, Daniel M. Kniffen, M. Scott Wells, Devan N. Catalano, Krishona L. Martinson. 2017. Hay Rake-Type Effect on Ash and Forage Nutritive Values of Alfalfa Hay. Agron. J. (in press)
- Hall, M.H. and M. Collins. Forage Establishment. Chapter 11. *In* J. Nelson, K. Moore and M. Collins (eds). Forages: The Science of Grassland Agriculture (7th Edition). Blackwell Press. (in press)
- Hristov, A.N. A.T. Degaetano, C.A. Rotz, E. Hoberg, R.H. Skinner, T. Felix, H. Li, P.H. Patterson, G. Roth,1 M.H. Hall, T.L. Ott, L. Baumgard, W. Staniar, R.M. Hulet, C. Dell, A.F. Brito and D.Y. Hollinger. 2016. Climate Change Effects on Livestock in the Northeast US and Strategies for Adaptation. (in press)

Extension Publications and Popular Press

- Boone, W., S.D. Harkcom and M.H. Hall. 2016. Forage Trials Report.

Recent Developments at Penn State

Jessica Williamson was hired to serve as the Forage Extension Specialist and do forage research. Dr. Williamson did her Ph.D. research under the direction of Glenn Akin at the USDA-ARS in Lexington, KY. Marvin Hall has transitioned over to doing more teaching and will continue his research efforts.

North Dakota State University

1. Impact Nugget:
   Forages research in North Dakota has its main focus in alfalfa and cover crops for grazing. Integration of forages researcher into cropping systems has allowed us to get funding to continue research
2. New Facilities and Equipment: NIR-XDS analyzer, 2 ceptometers

3. Unique Project Related Findings:

4. Accomplishment Summaries:

Forage management and production research

In 2016, activities included testing of private and public alfalfa (*Medicago sativa* L.) 2016 results are published in the forages website (http://www.ag.ndsu.edu/plantsci/forage/index.html).
In 2016, the forages experiments included: a) alfalfa seeding rate and plant density (last year), b) Validating prediction models for on-farm alfalfa forage yields - farmer's survey; c) corn -alfalfa rotational system, and e) slow P-releasing fertilizers on regrowth after harvest (last year).
a) *Alfalfa seeding rate and plant density:* 2016 was the last year of this multi-location and year experiment. The results from the combined analysis across locations for each year of alfalfa indicated maximum forage yield in the seeding year, Year 1, Year 2, and Year 3 was reached with 73, 52, 36, and 36 plants/m^2 and 583,497,433 and 428 stems/m^2, respectively. Alfalfa plants compensate yield as stand density decreases.
b) *Validating prediction models for on-farm alfalfa forage yields*: In 2016, with the collaboration of ND county agents and farmers, 24 alfalfa fields were evaluated for forage yield, plants/m^2 and stems/m^2 in 1-3 cuts over the season. Predictive models generated with the controlled experiments from 2013-2016 indicated that stems/m^2 predicts yields slightly better (r^2=0.30) than plants/m^2 (r^2=0.0002), although the high variability in the data collected on-farm made difficult to generate one-fit-all models. Fields varied in age of alfalfa, plant height and growth stage at harvest plus the variation on seasonal rainfall. What was interesting is that both the models developed with controlled experiments from 2013-2016 and the models from on-farm samples in 2016 predicted that forage yield is maximized above 350 stems/m^2.
c) *Silage corn-alfalfa intercropping:* The objective of this research was to evaluate the productivity and profitability of corn-alfalfa intercropping system, with the aim to increase alfalfa productivity in the first year of production. This experiment was conducted in 2014, 2015, and 2016. Corn biomass yield in monoculture was not different than the biomass yield in corn intercropped with alfalfa. Alfalfa intercropped with corn in 2014 and 2015 accumulated more than twice the biomass of alfalfa seeded in the spring of 2016. This system can provide a head start for alfalfa skipping the typical low productivity of the seeding year.
d) *P fertilizer in alfalfa:* Slow release fertilizers applied after the first cut in the first year of production increased regrowth and forage yield in the second harvest. In 2016, plots were not fertilized to assess if the Crystal Green fertilizer had a residual effect on the year after. A slight residual activity was observed. Experiment was terminated.

Bioenergy crops management research

a) *Forage sorghum cold tolerance. F*orage sorghum was identified as the most promising bioenergy crop for North Dakota. Forage sorghum has great potential because its high productivity even with limited water. Forage sorghum's limitation is its low cold tolerance which doesn't allow for an earlier seeding date. A project on forage sorghum cold tolerance was submitted to Sungrant and awarded. The project started in Sept. 1, 2016
b) *Life cycle assessment of double and relay cropping systems.* As indicated in my goals for this year, I learned to use the Simapro software for Life cycle assessment analysis (LCA). One publications was submitted to the Agricultural Systems journal in September 2016 (under review).
c) *Perennial forage grasses:* The objective of this study was to determine the yield potential and biomass quality of 12 different species of perennial grasses, eight cool-season and four warm-season grasses under rain-fed conditions, in the Northern Great Plains. Grasses were established in August of 2015. The species with the highest yield was tall wheatgrass (TWG) [*Thinopyrum ponticum* (Podp.) Z.-W.Liu & R.-C. Wang] (11.3 Mg DM/ha) significantly higher than all other species except for red canarygrass (RCG) (*Phalaris arundinaceae* L.) (10.15 Mg DM/ha). Biomass quality varied among grasses and harvest date. Ash content was higher in the second harvest compared with the first harvest, in most grasses. Lignin content was higher in western wheatgrass (WWG) [*Pascopyrum smit*hii (Rydb.) A.] in the first harvest compared with the second harvest, while lignin content was similar between harvests in all other grasses. Cellulose content was in general higher in the second harvest in all crops. Nitrogen uptake was similar among all grasses in the first harvest, but significantly lower in the second harvest. The gross calorific value (GCV) of the biomass was higher in the first harvest in IWG, MB, and TWG. Oppositely, the GCV in RCG and OG was higher in the second harvest. Slender wheatgrass [*Elymus trachycaulus* (Link) Gould ex Shinners] had the highest GCV value (138.8 MJ/ha). Cool-season grasses such as TWG and RCG have great potential to become biomass feedstocks for bioenergy or biofuels.

Cover crops

The CropSys CAP grant activities in 2016 included several experiment in cover crops:

a) *Cover crops variety and seeding date trial*: The experiment was established in 2016 in Fargo on two seeding dates, July 28 and August 20. All results of biomass yield, and N uptake are available in the forages web page.

4. Impact Statements

The forage program at NDSU **is the only program that provides non-biased information** to farmers on the performance of forages in ND. Forages acreage in North Dakota, without including CRP or native rangeland, was 2,876,816 acres in 2015. **Forages are the third most important crop in acreage in ND** after wheat and soybean. Alfalfa alone had more acres planted than each one of the following crops: oat, pea, lentil, flax, sugarbeet, and potato.
The optimization of alfalfa management greatly impacts forage productivity. Diverse studies in alfalfa conducted by the NDSU forage project have demonstrated forage yield can be increased on average at least 0.3 ton/acre/yr. Pure alfalfa acreage in ND in 2015 was 405,409 acres and alfalfa-grass mixtures 965,585 acres. An increase in forage yield of 0.3 tons/acre x 1,370,994 acres at a price of $100/ton of hay equals an economic impact of **$41,129,820/yr.**

The impact of bioenergy crops research it is hard to value monetarily, since there is not commercial production of energy crops in ND yet. But forage sorghum can yield up to 10 tons of dry matter/acre at $30-50/ton for biomass feedstock gross income will be $300-500/acre. Legume cover crops planted after wheat in one of our studies reduced the need of fertilizing in corn in 100 lbs N/acre. With a N credit of only 50 lbs/acre, the economic value of reducing the fertilization in corn in 2,655,334 acres x 50 lbs N/acre saving x $0.3 lb N, is **$39,830,010/year**. Also, recent results indicate that radish planted as a cover crop in the fall increase corn yield as much as 15%. Yield difference was 34 bu/acre at a $3.0/bu. This is a gain of $102/acre, planting cost (seed + planting approx. $30/acre). An increased revenue of $72/acre in 2,655,334 acres could amount **$191,184,048.** Cover crops forage value can add $30-$50/acre revenue by grazing. If only 10% of the wheat acreage (7,793,275) was planted to cover crops for grazing after harvest, the economic impact would be **$23,798,250**.
In summary the forages, biomass, and cover crops project at NDSU impacts the state's economy by: - a) increasing alfalfa and other forages yield, b) decreasing N fertilizer rates in corn, c) increasing corn yield in the long term, and d) providing additional forage for grazing in the fall. Total economic impact= $295,942,128.

5. Published Written Works
Refereed publications
None in forages

Proceedings publication
Berti, M.T., A. Aponte, B.L. Johnson, and D. Ripplinger. 2016. Environmental sustainability of double and relay cropping of food, feed, and fuel crops in the northern Great Plains, USA. In 24th European Biomass Conference and Exhibition.5-9 June, 2016, Amsterdam, The Netherlands Available at http://www.etaflorence.it/proceedings/index.asp (verified 10 December 2016).
Bulletins and Extension Factsheets
Berti, M.T., 2016. Frost damage in alfalfa: what to do after it? Crop and Pest Report No. 3, p-6-7. North Dakota State Univ. Ext. Serv. 19 May 2016. Available at http://www.ag.ndsu.edu/cpr
Berti, M.T., 2016. Has your alfalfa been winter-killed or winter-injured? Forage Focus, March 2016 p. 4 Midwest Forage Assoc., St. Paul, MN.
Berti, M.T., 2016. Cover crops in corn silage production provide many benefits Clippings. Midwest Forage Assoc. February 2016. Available at http://www.midwestforage.org/newsletter/160225clippings.htm

6. Scientific and Outreach Presentations

Berti., M.T., B.L. Johnson, R.W. Gesch, J. Ransom, H.H. Kandel, M. Kazula, M.S. Wells, and A. Lenssen. 2016 Integrating camelina into corn and soybean cropping systems. p. 9 *In* Berti, M.T and E. Alexopoulou (Eds.) 28th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC), Rochester, NY, 14-19 September, 2016.
Berti, M.T., J. Luckaschewsky, and M. Kazula. 2016. Alfalfa silage corn interseeding in North Dakota. North American Alfalfa Improvement Conference, Trifolium Conference and Grass Breeders Conference. Madison, WI. 12-14 July, 2016.

Maharlooei, M., S.A. Mireei, A. Shirzadifar, S. Sivarajan, S.G. Bajwa, **M.T. Berti**, and J. Nowatzki. 2016. Feasibility study of employing Vis/NIR Spectroscopy to estimate crude protein (CP) in alfalfa crop. ICPA 2016 conference.

7. Collaborative Grants
SUNGRANT, 10/2016-09/2018. $187,496. Improving cold tolerance in sorghum: a promising feedstock for biofuels and biobased products in the northern Great Plains
Midwest Forage Association, 05/2016-04/2017. $2,100. Validating prediction models for on-farm alfalfa forage yields
USDA-NIFA- 01/2016-12/2020, $3,739,199. CropSys-CAP- A novel management approach to increase productivity, resilience, and long-term sustainability of cropping systems in the northern Great Plains *(Includes alfalfa-corn intercropping research)*

University of Missouri –Craig Roberts and Harley Naumann
Graduate students: Brett Jones, Sarah Kenyon, Isaac Lepcha

1. Impact Nugget:
Tall fescue supports most grazing systems in Missouri. But it is semidormant in the summer, requiring other forages to complement the grazing system. Also, tall fescue is infected with *Epichlo coenophiala*, a fungal endophyte that produces ergot alkaloids and devastates livestock production. Missouri research focuses in three areas: 1) management systems that integrate other species into tall fescue based systems, 2) evaluating production in cattle with known genotypes for SNPs thought important to withstand the effects of the endophyte in tall fescue, and 3) exploration of complementary forages.

2. New Facilities and Equipment.
N/A

3. Unique Project Related Findings.
1) Ensiling characteristics of Sunn hemp, not the nutritive value, contributed to reduced animal performance compared to tall fescue, likely due to an unfavorable environment for rumen microbes.
2) Interseeding Sunn hemp can be managed in Tall fescue pasture for improved DM yield and nutritive value during the summer.
3) Nutritive value of an experimental striate lespedeza (MU 3993) and Korean lespedeza may be more desirable than Legend lespedeza based on greater dNDF and lesser concentrations of biologically active polyphenolic compounds. However, Legend is superior if the objective is to exploit condensed tannins and their protein binding ability for potential benefits of rumen bypass protein
4) Coastal bermudagrass produced the greatest amount of total fat and unsaturated fatty acids in a comparison of bermudagrass varieties adapted to northern climates.
5) In 'Kentucky 31' pastures highly infected with toxic endophyte, lactating beef cows with the beneficial genotype at DRD2 locus raised calves with higher 205 day adjusted weaning mass than those with the unfavorable genotype. Forage accumulation in Kentucky 31 and 'Baroptima

Plus E34' did not differ (p=0.06) but hay balance and animal grazing days were lower (p<0.01) for BarOptima plus E34 compared to Kentucky 31.
6) The DRD2 genotype could be useful to mitigate tall fescue toxicosis, but other genes may also be involved. It is more important to eliminate toxins from the diet by replacing Kentucky 31 tall fescue.
7) Animal genotype at DRD2 locus has very little to no effect on the rumen microbial community but some variation exists depending on tall fescue cultivar.
8) To minimize ergot alkaloids in the diet of livestock, pasture management should consider maintaining a tall fescue canopy height above 5 cm while implementing other practices that reduce animal exposure to or ingestion of these toxins.
9) Limestone application did not increase ergovaline concentrations. Other soil amendments, such as N and poultry litter, increase ergovaline concentrations and therefore create a sort of penalty for the producer
10) In a low pressure grazing system, 'BarOptima' plus E34 tall fescue was grazed more frequently than other tall fescue cultivars, whether they were endophyte-free or infected with a novel or toxic endophyte.

4. Accomplishment Summaries.

Nutritive Value and Ensiling Characteristics of Sunn Hemp (Crotolaria juncea L.) Baleage Impact Animal Response

In fescue-based forage-livestock systems, tall fescue (TF; *Lolium arundinaceum*

(Schreb.) S.J. Darbyshire) is commonly harvested for stored forage at later stages of maturity when its nutritive value is less than optimum. Sunn hemp (SH; *Crotalaria juncea* L.) is a high yielding and high nutritive value warm-season legume that may be used as a suitable alternative stored forage. Our objectives were to compare ensiling characteristics and nutritive values of SH and TF, as well as animal performance when fed over winter. SH and TF baleage were analyzed for ammonia and total VFA, as well as nutritive value (CP, NDF, ADF, IVTD) in each bale during feedout. Stored forage was allocated to weaned steers at 3.5% of body weight to ensure no limit-feeding occurred. Forage refusals were weighed and removed daily. Cattle were weighed every 20 days for a 80-d period to determine ADG. Total VFA and ammonia concentrations for SH were 51.5 and 27.1 g/kg DM, respectively; those of TF were 19.8 and 11.3 g/kg DM. We observed a species x period interaction ($P \leq 0.05$) for NDF and CP. NDF was greater in TF compared to SH for all feeding periods. Crude protein was greater in SH than TF through all periods except for period 1. Compounded average daily gain were greater ($P<0.05$) in TF (0.71 kg/d) compared to SH (0.27 kg/d). However, a species by period interaction ($P<0.05$) was observed such that ADG was greatest for TF during period 2 (0.83 kg/d) and least for SH in period 3 and 4 (0.12 and -0.27 kg/d, respectively). Animal performance was greater for TF but the nutritive value of SH was greater or equal to TF. Our results suggest that the ensiling characteristics of SH, not the nutritive value, contributed to reduced animal performance, likely due to an unfavorable environment for rumen microbes.

Interseeding Sunn Hemp (*Crotalaria juncea* L.) into Tall Fescue Pasture for Summer Forage Production

Warm-season legumes in tall fescue (TF) pasture can improve productivity and nutritive value when TF becomes dormant and less productive during summer. Our objectives were to evaluate *Crotalaria juncea* L. (Sunnhemp; SH) as potential species for interseeding into TF pasture with different interseeding systems (Mow-drill: MD, Strip-kill drill: SKD, TF, SH) and nitrogen (N) rates (0 and 50 lbs. /acre) on forage yield and nutritive values during summer. Yield and nutritive values were determined on data collected at 45, 55 and 65 days after planting (DAP) during the summer of 2016. Forage yield for SKD (3.1 Mg ha^{-1}) and MD (2.7 Mg ha^{-1}) were similar but SKD yielded greater (P<0.05) than TF (2.5 Mg ha^{-1}) and SH (2.0 Mg ha^{-1}) at 65 DAP. Forage yield increased with maturity and N rates (P<0.05). Crude protein concentrations were similar between SKD, MD and SH (153, 157, 155 g kg^{-1} respectively) but greater (P<0.05) than TF (135 g kg^{-1}) at 45 DAP. Crude protein was greater for MD than TF but similar to SH, and SKD at both N rates. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were greatest (P<0.05) for TF (600, 320 g kg^{-1} respectively) followed by SKD, MD and SH (503, 494 and 384 g kg^{-1} NDF, and 299, 296 and 288 g kg^{-1} ADF respectively). Interseeding systems produced lower NDF than TF but similar ADF at both N rates. In vitro true digestibility was greatest (P<0.05) for SH (856 g kg^{-1}) followed by MD and SKD (833 and 824 g kg^{-1} respectively) and lowest (P<0.05) for TF (806 g kg^{-1}) at 45 DAP. Digestibility was greater for MD than TF at both N rates (P<0.05). Our results suggest that both MD and SKD systems of interseeding SH can be managed in TF pasture for improved DM yield and nutritive value during the summer.

Yield, Nutritive Value and Condensed Tannins are Affected by Cultivar of Annual Lespedeza

'Marion' lespedeza was once the predominant summer-annual legume in Missouri and other parts of the Southeast due to its persistence in low fertility acidic soils. It is now virtually unavailable. Other varieties have not been widely evaluated in replicated trials.

An experimental cultivar of annual lespedeza, *Kummerowia striata* (Thunb.) Schindl., (MU 3993) has been selected for its characteristic tolerance to heat- and water-stress. MU 3993 may prove to be a valuable resource during the summer months in cool-season forage-livestock systems.

We evaluated the annual DM yield, nutritive value, and polyphenolic characteristics (condensed tannins, CT; protein-precipitable phenolics, PPP; total phenolics, TP; and protein bound by protein-precipitable phenolics, PB) of an experimental striate cultivar of annual lespedeza (MU 3993) compared with 'Legend', a striate type, and with a Korean type.

Nutritive value of MU 3993 and Korean lespedeza may be more desirable than Legend lespedeza based on greater dNDF and lesser concentrations of biologically active polyphenolic compounds. However, Legend is superior if the objective is to exploit condensed tannins and their protein binding ability for potential benefits of rumen bypass protein.

Fatty Acid Concentration in Bermudagrass Cultivars

Cynodon dactylon (Bermudagrass) is a warm-season perennial grass commonly used as a forage in the southern United States. Currently, there are only a select number of cold tolerant cultivars available for use as a summer forage in the central United States. Little is known about the concentration of fatty acids (FA) in forage bermudagrass and its function in thermal acclimation. The objective was to analyze the concentrations of saturated and unsaturated FA in cultivars adapted to both northern and southern latitudes to determine the relationship between fatty acid concentrations and thermal acclimation. Total fat and unsaturated fatty acids increased from less temperate to more temperate latitudes. Of the cultivars evaluated, Coastal bermudagrass produced the greatest amount of total fat and unsaturated fatty acids.

Response of Genotyped Cows and Calves Grazing BarOptima Plus E34 or Kentucky 31 Tall Fescue Pasture

Cattle and toxic endophyte infected tall fescue are common throughout the United States. Tall fescue toxicosis is a common problem and causes decreased animal performance and reproduction. This research evaluated the effects of cow-calf pairs grazing toxic Kentucky 31 or novel BarOptima plus E34. Cows were evaluated for tolerance to tall fescue toxicosis using a single nucleotide polymorphism at the DRD2 gene. Cow weights throughout the year were significantly different between the tall fescue types ($p<0.01$). Cow pre-calving mass was significantly higher for tolerant cows compared to susceptible cows on toxic Kentucky 31. Calves from tolerant cows grazing Kentucky 31 had significantly higher 205 day adjusted

weaning mass compared to the susceptible animals on Kentucky 31. Forage accumulation was not significantly different ($p=0.06$) but hay balance and animal grazing days were significantly different ($p<0.01$) when comparing BarOptima plus E34 and Kentucky 31.

Response of Genotyped Heifers Fed Baroptima Plus E34 or Kentucky 31 Tall Fescue Silage in the Growsafe™

The purpose of this study was to determine the intake and average daily gain of heifers, genotyped using the DRD2 gene, fed either BarOptima plus E34 or Kentucky 31 in the GrowSafe feeding system. There was a significant difference in the average daily gain between BarOptima plus E34 and Kentucky 31 but no separation based on genotype. When evaluating dry matter intake as a percent of body weight the tolerant heifers consuming Kentucky 31 were not significantly different from the same genotype heifers fed BarOptima plus E34. These results suggest the DRD2 genotype could be useful to mitigate tall fescue toxicosis, but other genes may also be involved, and tall fescue type has a greater effect.

Effects of Novel or Toxic Tall Fescue Rations and Animal DRD2 Genotype in the Continuous Culture System

The rumen is a diverse environment with microbial communities that are continually changing. The recently discovered DRD2 genotype has the ability to show tolerance to tall fescue toxicosis in beef cattle. This research was conducted to determine if any differences in rumen characteristics could be seen between animals of different genotypes being fed either BarOptima plus E34 or Kentucky 31. Research shows differences in organic matter digestibility, ammonia, and acetic acid ($p<0.05$) when comparing BarOptima plus E34 and Kentucky 31. True crude protein digestibility was the only rumen characteristics where a slight difference was seen based on animal genotype. The susceptible animals fed Kentucky 31 showed a tendency for lower values ($p=0.08$). These results would suggest that animal genotype has very little to no effect on the rumen microbial community and tall fescue type results in some variations.

Vertical Distribution of Ergovaline and Total Ergot Alkaloids in the Vegetative Tall Fescue Canopy

Issue: Ergot alkaloids are toxins produced by *Epichloë coenophiala* [(Morgan-Jones & W. Gams) C.W. Bacon & Schardl, comb. nov.], a fungal endophyte that infects tall fescue (*Lolium arundinaceum* (Schreb.) Darbysh.) and causes fescue toxicosis in livestock. Previous studies have reported the distribution of ergovaline among anatomical parts during reproductive development. This study was conducted to determine the vertical distribution of ergovaline and total ergot alkaloids throughout the vegetative canopy of tall fescue. Research could reveal that certain portions of the vegetative canopy contain high concentrations of ergot alkaloids, much like seedheads during reproductive development, which should be avoided to minimize livestock toxicosis.

Action: Between October 2012 and April 2014, whole tillers were harvested four times from a stand of *Epichloë*-infected 'Kentucky 31' tall fescue near Alton, MO. Harvests occurred in April

before boot stage and in October before killing frost. Tillers were sliced into four segments: 0-5, 5-10, 10-15, and > 15 cm, where 0 cm = soil level, and > 15 cm = top of the canopy. Segments were analyzed for ergovaline and total ergot alkaloids.

Impact: Vegetative Kentucky 31 tall fescue canopy segments had the highest ergovaline and total ergot alkaloid concentration in the 0-5 cm canopy segments; above that height, toxin concentrations decreased or remained steady near or below current thresholds for grazing cattle. To minimize ergot alkaloids in the diet of livestock, pasture management should consider maintaining a tall fescue canopy height above 5 cm while implementing other practices that reduce animal exposure to or ingestion of these toxins.

Ergovaline Concentration of Tall Fescue as Affected by Limestone Application

Issue: Tall fescue [*Lolium arundinaceum* (Schreb.) Darbysh.] infected with *Epichloë coenophiala* [(Morgan-Jones & W. Gams) C.W. Bacon & Schardl, comb. nov.] produces ergovaline and other alkaloids responsible for fescue toxicosis, a devastating livestock disorder. Limestone application can alter plant growth and nutrient access, which may in turn affect ergovaline production in pastures. The effect of limestone on ergovaline levels in tall fescue has not been documented.

Action: Limestone was surface applied to treatment plots in December 2011 to a field of endophyte-infected tall fescue near Alton, MO. Whole tillers were harvested spring and autumn from 2012 to 2014 and analyzed for ergovaline concentrations.

Impact: Limestone application reduced ergovaline concentrations by 20 μg kg^{-1} DM compared to non-treated control plots. This slight reduction in ergovaline concentrations is not enough to affect toxicosis, but may aid in the overall reduction of fescue toxicosis by causing a slight reduction in ergovaline concentrations. In addition, limestone application may affect toxicosis by improving the growing conditions for legumes, a practice that can decrease fescue toxicosis symptoms by diluting the amount of ergovaline in the diet of the livestock.

An important conclusion is that limestone application did not increase ergovaline concentrations. Other soil amendments, such as N and poultry litter, increase ergovaline concentrations and therefore create a sort of penalty for the producer.

Comparison and Diet Preference of Novel Endophyte-Infected Tall Fescue Cultivars

Issue: Tall fescue is naturally infected with a fungal endophyte that produces toxic ergot alkaloids which cause fescue toxicosis in livestock. Endophyte-free cultivars have been used to eliminate toxicosis; however, endophyte-free cultivars do not persist in stress environments. Tall fescue has been re-infected with fungal strains called “novel endophytes”, which are nontoxic strains of the fungus. This study was conducted to determine if cattle would preferentially select novel tall fescue cultivars in a low pressure grazing system.

Action: Six cultivars of novel tall fescue and controls of toxic, endophyte-infected and endophyte-free tall fescue were evaluated for animal preference, dry matter (DM) yield, DM disappearance, forage quality, and ground cover during a two-year grazing trial at Linneus, MO. Tall fescue cultivars were established in 9- x 12-m plots in a randomized complete block design

replicated four times. Plots were grazed nine times by beef cattle (*Bos* spp.) during the two-year study, and some animals were fitted with GPS collars to reveal which cultivar was grazed first and most often.

Impact: In a low pressure grazing system, 'BarOptima' tall fescue was grazed more frequently than other tall fescue cultivars, whether they were endophyte-free or infected with a novel or toxic endophyte. Cultivars did not differ in crude protein, ADF or NDF, which was expected as forage was maintained in a vegetative state. Further differences in cultivar selection may have been detected with a grazing strategy that included long rotations or continuous defoliation. In addition, rust (*Puccinia* spp.) susceptibility differed among cultivars.

5. Impact Statements.

Sunn hemp produces large amounts of forage with potential to be high quality when well managed. It is relatively new to the Midwest and is the subject of several investigations to determine its fit within tall fescue based systems.

We continue to learn and refine simple practices to help producers manage fescue toxicosis. Grazing management is key to mitigating the amount of alkaloids ingested by grazing animals; techniques differ with respect to season and physiological state of the forage. Elimination of toxins by renovation to a novel endophyte is the best approach; but other factors can play a role in producer's decisions to renovate. Some geography is not acceptable for renovation.

Genetic variation within cattle provides an opportunity to lessen the effects of the endophyte from the animal side of the equation when agronomic changes cannot be made.

6. Published Written Works.

Refereed Journal Articles

Kallenbach, R.L., C.A. Roberts, J.A. Lory, and S.A. Hamilton. 2017. Nitrogen Fertilization Rates Influence Stockpiled Tall Fescue Forage through Winter. Crop Sci. 57:1732-1741. DOI:10.2135/cropsci2016.02.0097

Yuan, Z.Y., F. Jiao, Y.H. Li, and R.L. Kallenbach. 2016. Anthropogenic disturbances are key to maintaining the biodiversity of grasslands. Scientific Rpts. 6:22132.

Harmoney, K.R., D.K. Lee, R.L. Kallenbach, and E.Z. Aberle. 2016. Species composition changes in conservation reserve program (CRP) grassland when managed for biomass feedstock production. BioEnergy Res. 9:1180 doi: 10.1007/s12155-016-9764-9

Chen, L., X. Mu, Z. Yuan, Q. Deng, Y. Chen, L.Y. Yuan, T.R. Lock, and R.L. Kallenbach. 2016. Soil nutrients and water affect the age-related fine root biomass but not production in two plantation forests on the Loess Plateau, China. J. Arid Environ. 135:173-180.

Anderson, E.K., E.Z. Aberle, C. Chen., J. Egenolf, K.R. Harmoney, G. Kakani, R.L. Kallenbach, M. Khanna, W. Wang, and D.K. Lee. 2016. Impacts of management practices on

bioenergy feedstock yield and economic feasibility on conservation reserve program (CRP) grasslands. GCB Bioenergy. doi: 10.1111/gcbb.12328.

Stewart, W.C., Whitney, T.R., Scholljegerdes, E.J., Hallford, D.M., Walker, J.W., Adams, R.P., and Naumann, H.D. Accepted 7/2017. Effects of feeding ground redberry juniper (Juniperus pinchotii) to gestating ewes on pre- and postpartum performance, serum metabolites and hormones, milk fatty acid composition and progeny preweaning performance. Journal of Animal Science.

Cash, K.A., Caldwell, J.D., Naumann, H.D. Bax, A.L., Wilbers, L.S., McKnelly, A.T., Drane, T.N., Basinger, K.L., Clark, J.K. and Bartimus, H.L. The use of organic Pinot Noir grape extract as a natural anthelmintic in Katahdin lambs. Sheep & Goat Research Journal. 31:38-44.

Johnson, N., Naumann, H.D., Kenny, A., Kerley, M. 2016. Black rhinoceros (Diceros bicornis) and domestic horse (Equus caballus) hindgut microflora demonstrate similar fermentation responses to grape seed extract supplementation in continuous culture. Journal of Animal Physiology and Nutrition. At Press. http://onlinelibrary.wiley.com/doi/10.1111/jpn.12587/full

Naumann, H.D., Cooper, C.E., and Muir, J.P. 2016. Seasonality affects leaf nutrient and condensed tannin concentration in southern African savanna browse. African Journal of Ecology. 55:168-175.

Naumann, H.D., Kallenbach, R.L. and Lock, T.R. Yield, nutritive value and condensed tannins are affected by cultivar of annual lespedeza. Proc. International Annual Meetings of the ASA, CSSA, and SSSA. 2016 Nov 6-9. Phoenix, AZ.

Masiero, M. M., Roberts, C. A., Kerley, M. S., & Kallenbach, R. L. (2016). 347 Evaluation of a commercial genetic test to determine tolerance to fescue toxicity in beef cattle. Journal of Animal Science, 94(supplement2), 163-163.

Other Creative Works

Kallenbach, R.L. and M. Collins. 2017. Grazing management systems. In M. Collins, C.J. Nelson, K.J. Moore, and R.F Barnes (ed.) Forages: An introduction to grassland agriculture, Vol. I, 7th ed. John Wiley and Sons, Ltd., Hoboken, N.J. In Press.

Kallenbach, R.L., D.J. Patterson, R.R. Broz, C.A. Roberts, C.A. Payne, D.S. Brown, and H.E. Stelzer. 2016. The role and responsibilities of state specialists in agriculture and natural resources extension at the University of Missouri. MU publ. UED1184. Univ. Missouri Ext. Pubs., Columbia, MO

Kallenbach, R.L. 2016. The TigerTooth Forage Plot Yield Monitor. Proprietary program to measure plant growth and quality from multiple plots simultaneously using ultrasound and neural networking. LabView and C# languages. University of Missouri, Columbia, MO.

Poster and Oral Presentations

Invited Speaker. Naumann, H.D. Predicting ruminal methane inhibition by condensed tannins. Proceedings of the 1st International Meeting of Advances in Animal Science. 2016 Jun 8-10. Jaboticabal, Sao Paulo, Brazil.
Invited Speaker. Roberts, C.A. T-Snip: a test for tolerance to toxicosis. 2016. Jan 26. Blackstone, VA.
Invited Speaker. Roberts, C.A. T-Snip: a test for tolerance to toxicosis. 2016. Jan 27. Wytheville, VA.
Invited Speaker. Roberts, C.A. T-Snip: a test for tolerance to toxicosis. 2016. Jan 28. Weyers Cave, VA.
Invited Speaker. Roberts, C.A. T-Snip: a test for tolerance to toxicosis. 2016. Jan 29. Brandy Station, VA.
Invited Speaker. Roberts, C.A. NIR analysis of forage crops. 2016. Eastern Analytical Symposium, Nov 13-15, Somerset, NJ.

Popular Articles
None

7. Outreach Oral Presentations (Scientific presentations are listed above)

Two major outreach efforts continued in the 2016 year. Fescue toxicosis presentations occurred through the Alliance for Grassland Renewal, an Extension-led organization and addressed toxicosis, management, and novel endophytes. In 2016, presentations occurred in Oklahoma and Kansas.

The other major effort occurred through grazing schools, which are 3-day workshops with presentations on plant physiology and growth, animal nutrition, soil science, and economics. In 2016, 26 workshops were held between April 1 and October 31 across the state of Missouri.

8. Fund leveraging, specifically, collaborative grants between stations and members.
N/A
9. Other relevant accomplishments and activities.
N/A