APPENDIX D
SAES-422
Format for Multistate Research Activity
Accomplishments Report

Project/Activity Number: NCCC-31
Project/Activity Title: Ecophysiological Aspects of Forage Management
Period Covered: June 2017 to May 2018
Date of This Report: August 2, 2018
Annual Meeting Date(s): The meeting was held in Fayetteville, AR, June 26th and 27th, 2018.

Brief summary of minutes of annual meeting:
Participants:

State	Attending Members	UA Students-Postdocs attending	Admin attending	Reported remotely	Not attending
WI	Valentin Picasso	Taylor Adams	James Kells	Jamie Foster	Marisol Berti
TX	Chuck West	Mohan Acharya		John Guretzky	Marvin Hall
AR	Amanda Ashworth	Jamie Hess		Jeff Steiner	Scott Wells
AR	Dirk Philipp	Sonia Tsau			Mark Sulc
VA	Ben Tracy	Lillian Meadors			John Grabber
UT	Jennifer MacAdam				Tom Griggs
KY	Rebecca McCulley				William Lamp
OH	David Barker				Jeff Volenec
MI	Kim Cassidy				
WY	Anowar Islam				
MO	Craig Roberts				

Activities and comments:
Tuesday, June 26th

- Started with welcoming remarks by Dirk Philipp and roll-call by attendees
- Reports were given by the respective state representatives in alphabetical order
- John Guretzky (NE) and Jamie Foster (TX) reported via a Zoom link setup
- Jeffrey Steiner reported as the NIFA liaison (Division Director for Plant Production and Sustainability)
    - Jeff gave a general update on NIFA activities:
        - Travel budgets have been "reinstated" within NIFA for better planning when travelling to PI meetings
        - AFRI budget released for 2019 and submitted for 2020
        - AFRI budget went up; foundational programs were financially improved

        - "NIFA explanatory notes 2019" can be found on NIFA-AFRI website
    - Recommendations/comments to committee:
        - Committee has good history of working together
        - Reports should be turned into impact statements
        - Tangible results should be shown
        - Try to do more formal cooperation among committee members and states
- After the lunch break, Jim Kells (committee administrator) reported and gave recommendations:
    - Committee as a whole does very good things!
    - Project was reviewed last winter and passed
    - Project was approved for second half for project duration
    - On annual reports:
        - Highlight interstate collaboration
        - Reports due within 60 days of meeting
    - Committee will need to think about submission of new project by fall of 2019
        - Current project expires Sep 30, 2020
        - Sep 15, 2019 is deadline for "issues/justification" (similar for a "letter of intent")
        - October 15, 2019 upload project objectives
        - Nov 15, 2019 identification of participants
        - December 1, 2019 proposal due!
        - Identify area(s) of focus and make case for it in new proposal
    - Committee should focus on attendance in 2019 and bring number of attendees up if possible
    - Will suggest the committee for official recognition
- The first day concluded at 5 pm after which some participants toured the Ozark Botanical Garden followed by a joint dinner in downtown Fayetteville

June 27th

- The second day was started with a tour of local farms and research projects
    - Ozark Pasture Beef
    - Coyote Creek Dorper
    - Univ. of Arkansas North Farm
        - Collaborative research USDA-ARS, Univ. of Arkansas
        - Speakers were Amanda Ashworth, Phillip Owens, and Ben Runkle
- Business meeting:
    - Meeting location for 2019 will be Wisconsin
    - Meeting location for 2020 will be Wyoming
    - Meeting location for 2021 will be Missouri
    - Dirk:
        - will send current project proposal to Kim Cassida who volunteered to take the lead on drafting the new proposal
        - will contact Marisol Berti to coordinate reporting and project proposal work
    - Amanda Ashworth was elected incoming secretary
        - Will be secretary for 2019 meeting

        - Will be chair for 2020 meeting
    - The group discussed joint NIFA etc. proposals:
        - Ecosystems services, in particular pollinator-related projects and experiments
        - Guidance perhaps through CEAP programs
    - Discussion about symposium at ASA/CSSA meeting
        - Symposium on ecosystems services
        - Less difficult to organize than a special issues publication
            - If symposium will materialize, still opportunity for symposium papers
- The meeting concluded at 2:30 pm
- Some participants visited Crystal Bridges Museum in Bentonville with the AR host

State Reports

Arkansas

USDA-ARS, Poultry Production and Product Safety Research Unit
Fayetteville, AR
Year 2017-2018

1. Impact Nugget

The USDA-ARS, Poultry Production and Product Safety Research Unit, located at the University of Arkansas, conducts research and technology transfer on practices that reduce negative environmental impacts of poultry litter on air, soil, and water resources, while improving the agronomic value of this resource in pasture agroecosystems.

2. New Facilities and Equipment

MinION (Oxford Nanopore Technologies)
WinRHIZO Root Scanner (Regent Instruments)
Pressure Plate Extractor (Soil Moisture)
Muffle Furnace
Forced Air Oven

3. Unique Project-Related Findings

Poultry litter is a low-cost fertilizer; however, land applications can result in excessive nitrogen runoff. A 14-yr study was conducted on 15 small watersheds using five management practices: continuous grazing, hayed, rotational grazing, rotational grazing with an unfertilized buffer strip, and rotational grazing with a fenced unfertilized riparian buffer. Rotational grazing resulted in the highest concentrations and loads of all forms of nitrogen in runoff compared to other treatments, including continuous grazing. Total organic carbon concentrations and loads in runoff were also higher from rotationally grazed watersheds than other treatments. These results were unexpected since rotational grazing is considered a best management practice, which typically reduces soil erosion and increases soil organic carbon. Nitrogen runoff from rotationally grazed pastures were reduced 44% with unfertilized buffer strips and by 54% with fenced unfertilized riparian buffers and by 52% by converting pastures to hayfields.

We conducted a meta-analysis on 2,753 studies published over the last 53 years to test: if biological N_2 fixation (BNF) supplies adequate nitrogen for plant growth relative to synthetic fertilizers and how crop physiological traits affect legume-grass symbiosis over a range of soils and climates overtime. Globally, net primary productivity (NPP; total aboveground production response of grass and legume in higher-diversity treatments) increased 44% via legume associations relative to sole grass controls (including both with and without N fertilizer). These historical trends suggest potential for legume intercrops to displace inorganic-N fertilizer and sustainably intensify global NPP. Results to this study provide a framework for improving crop diversification systems and heightening BNF capacities in agro-grasslands.

One of the biggest environmental issues associated with the poultry industry is ammonia emissions from poultry houses, which causes 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), 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 considerable, 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.

4. Accomplishment Summaries

During 2017-2017, Arkansas (USDA-ARS, Ashworth et al.) published data on BMPs for reducing nutrient losses and antibiotic resistance, while improving forage production and soil health in pasture systems at the soil-plant-water nexus. Outreach activities included the delivery of our findings during in-service training sessions, field days, and through technology transfer. A summary of all publications and funding procured from 2017-2018 is included at the end of this document. Selected project summaries are listed below in detail.

Pasture Management Impacts on Water Quality

a) Grazing management and buffer strip impact on nitrogen runoff from pastures fertilized with poultry litter

Nitrogen runoff from pastures can result in accelerated eutrophication. Poultry litter is a low-cost fertilizer for nutrients; however, applications to pastures can result in excessive nitrogen runoff. The objective of this study was to evaluate long-term effects of grazing management and buffer strips on nitrogen runoff from pastures fertilized with poultry litter. A 14-yr study was conducted on 15 small watersheds using five management practices: continuous grazing, hayed, rotational grazing, rotational grazing with an unfertilized buffer strip, and rotational grazing with a fenced unfertilized riparian buffer. Poultry litter was applied annually at a rate of 5.6 Mg ha^{-1}. Concentrations and loads of total N (TN), NO_3^-N, NH_4^-N, organic nitrogen and total organic carbon in runoff varied intra and inter-annually and coincided with precipitation trends. Overall, the greatest component of TN in runoff was organic N. Rotational grazing resulted in the highest concentrations and loads of all forms of N in runoff compared to other treatments, including continuous grazing. Total organic carbon concentrations and loads in runoff were also higher from rotationally grazed watersheds than other treatments. These results were unexpected considering rotational grazing is considered a best management, which typically reduces soil erosion and increases soil organic carbon. Nitrogen runoff losses from rotationally grazed pastures were reduced by 44% with unfertilized buffer strips and by 54% with fenced unfertilized riparian buffers and by 52% by converting pastures to hayfields (Pilon et al., *In Press*).

b) 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 14 yrs 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 (RUSLE) 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 over-predicted 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 appears to be effective options for reducing soil erosion and runoff to waterways from pasture soils (Pilon et al., 2017).

Integrating Legumes into Grasslands for the Reduction of Nitrogen Inputs

a) Global meta-analysis reveals agro-grassland productivity varies based on species diversity over time

Ecological research suggests increased diversity may improve ecosystem services, as well as yield stability; however, such theories are sometimes disproven by agronomic research, particularly at higher diversity levels. We conducted a meta-analysis on 2,753 studies in 48 articles published over the last 53 years to test: if biological N_2 fixation (BNF) supplies adequate nitrogen (N) for plant growth relative to synthetic fertilizers; how crop physiological traits affect legume-grass symbiosis; and, how cultural practices affect BNF over a range of soils and climates overtime (in polycultures versus sole grasslands). Globally, net primary productivity (NPP; total aboveground production response of grass and legume in higher-diversity treatments) increased 44% via legume associations relative to sole grass controls (including both with and without N fertilizer). Several moderating variables affected NPP including: (i) plant photosynthetic pathway (mixtures of C_3 grasses resulted in a 57% increase in NPP, whereas mixtures of C_4 grasses resulted in a 31% increase; similarly cool-season legumes increased NPP 52% compared to a 27% increase for warm-season legumes relative to grasslands without diversity); (ii) legume life cycle [NPP response for perennial legume mixtures was 50% greater than sole grass controls, followed by a 28% increase for biennial, and a 0% increase for annual legumes)]; and, (iii) species richness (one leguminous species in a grassland agroecosystem resulted in 52% increase in NPP, whereas >2 legumes resulted in only 6% increases). Temporal and spatial effect sizes also influenced facilitation, considering facilitation was greatest (114% change) in Mediterranean climates followed by oceanic (84%), and tropical savanna (65%) environments; conversely, semi-arid and sub-artic systems had lowest Rhizobium-induced changes (5 and 0% change, respectively). Facilitation of grass production by legumes was also affected by soil texture. For example, a 122% NPP increase was observed in silt clay soils compared to 14% for silt loam soils. Niche complementarity effects were greatest prior to 1971 (61% change), compared to recent studies (2011-2016; -7% change), likely owing to reduced global sulfur deposition and increased ambient temperatures overtime. These historical trends suggest potential for legume intercrops to displace inorganic-N fertilizer and sustainably intensify global NPP. Results herein provide a framework for ecologists and agronomists to improve crop diversification systems, refine research goals, and heighten BNF capacities in agro-grasslands (Ashworth et al., 2018).

How Spatially Variable Landscape Attributes Influence Soil Function

a) <u>Topographic Controls on Soil Nutrient Variations in a Silvopasture System</u>

Topography plays a crucial role in spatial distribution of nutrients in soils; however, studies to quantify topographic influence on soil nutrient distribution from a silvopasture system are mostly lacking. To address this question, a 4.3-ha silvopasture site in northwest Arkansas was selected and a total of 51 topsoil (0–15 cm thickness) samples were collected and analyzed for primary (total N [TN], P, K), secondary (Ca, Mg, S), and micronutrients (Fe, Zn, Cu, Mn, B, Na).

Topographic information was acquired from 12 terrain attributes derived from a 1-m digital elevation model. The prediction model was based on random forest. Results showed TN, S, and P were best predicted, whereas Cu, Ca, and Mn had the lowest prediction performance. Levels of S, Ca, Zn, Fe, and TN increased with SAGA wetness index, valley depth, flow accumulation, and multi-resolution valley bottom flatness index. Normalized height and slope height were positively related to Na but negatively to B and Cu distribution. Aspect had a positive influence on P and Mg concentrations. Based on terrain attributes, the study site could be divided into four topographic functional units (TFU), namely A, B, C, and D; TFU A had the highest nutrients present, whereas TFU B had the lowest P, K, Zn, Cu, Fe, and Ca but highest Na content. However, Mn, Mg, and B did not vary among TFUs. This study affirmed topographic influences on soil nutrient distribution, and the resulting continuous soil nutrient maps are useful for fine-tuning production systems through optimum nutrient and pasture management (Adhikari et al., 2018).

5. Impact Statements

A long-term (14 year) study was conducted utilizing 15 small watersheds to determine the impacts of pasture management strategies (over grazing, rotational grazing, buffer strips, riparian buffer strips and haying) on pasture hydrology, erosion and nutrient, and pathogen runoff. Runoff volumes, sediment, metal concentration, and loads were lowest for hayed and rotationally grazed systems with a fenced riparian buffer and highest for continuously overgrazed pastures.

We conducted a meta-analysis on 2,753 studies published over the last 53 years. Overall: mixtures of C_3 grasses resulted in a 57% increase in NPP, whereas mixtures of C_4 grasses had a 31% increase; cool-season legumes increased NPP 52% compared to a 27% increase for warm-season legumes; NPP for perennial legume mixtures was 50% greater than sole grass controls, followed by a 28% increase for biennial legumes; and, one leguminous species in a grassland agroecosystem resulted in 52% increase in NPP, whereas >2 legumes resulted in only 6% increases. Historical trends suggest potential for legume intercrops to displace inorganic-N fertilizer and sustainably intensify global NPP. Results herein provide a framework for improving crop diversification systems and heightening BNF capacities in agro-grasslands.

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.

Contact:

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Cooperators: Philip Moore

6. Published Written Works

Refereed Journal Articles

Pilon, C., P.A. Moore, Jr., D.H. Pote, J.W. Martin, P.R. Owens, A.J. Ashworth, D.M. Miller, and P.B. DeLaune. *In press*. Grazing management and buffer strip impact on nitrogen runoff from pastures fertilized with poultry litter. Journal of Environmental Quality.

Popp, M., A.J. Ashworth, P.A. Moore, Jr., P.R. Owens, J.L. Douglas, D.H. Pote, A.A. Jacobs, K.R. Lindsay, and B. Dixon. *In press*. Fertilizer recommendations for switchgrass: quantifying economic effects on quality and yield. Agronomy Journal. doi: 10.2134/agronj2018.04.0273

Ashworth, A.J., H.D. Toler, R.M. Augé, and F.L. Allen. 2018. Global meta-analysis reveals agro-grassland productivity varies based on species diversity over time. PLOS ONE. 13(7): e0200274. https://doi.org/10.1371/journal.pone.0200274

Adhikari, K., P.R. Owens, A.J. Ashworth, T.J. Sauer, Z. Libohova, and D.M. Miller. 2018. Topographic controls on soil nutrient variations in a silvopasture system. Agrosystems, Geosciences & Environment. 1:180008. doi:10.2134/age2018.04.0008

Ashworth, A.J., F.L. Allen, J. DeBruyn, P.R. Owens, and C. Sams. 2018. Crop rotations and poultry litter impact dynamic soil chemical properties and soil biota long-term. Journal of Environmental Quality. Special Section: Soil Chemistry and the One Health Initiative. doi:10.2134/jeq2017.12.0465

Martin, J.W., P.A. Moore, Jr., H. Li, A.J. Ashworth, and D.M. Miles. 2018. Effects of land-applied ammonia scrubber solutions on yield, nitrogen uptake, phosphorus runoff, and soil test phosphorus. Journal of Environmental Quality. 47: 263-269.

Burner, D.M., A.J. Ashworth, K.F. Laughlin, and M.E. Boyer. 2018. Using Google SketchUp to simulate tree row azimuth effects on alley shading. Agronomy Journal. 110: 1-6.

Lindsay, K., M. Popp, C. West, A.J Ashworth, A. Rocateli, R. Farris, G. Kakani, F. Fritschi, S. Green, M.W. Alison, and M. Maw. 2018. Predicted harvest time effects on switchgrass moisture content, nutrient concentration, yield, and profitability. Biomass and Bioenergy. 108: 74-89.

Ashworth, A.J., F.L. Allen, J.L. Bacon, C.E. Sams, W.E. Hart, J.F. Grant, P.A. Moore Jr., and D.H. Pote. 2017. Switchgrass cultivar, yield, and nutrient removal responses to harvest timing. Agronomy Journal. 109: 1-8.

Ashworth, A.J., F.L. Allen, K. Goddard, K.S. Warwick, D. Yeaman, and D.H. Pote. 2017. Switchgrass compositional variations arising from spatial distribution and legume intercropping. Communications in Soil Science and Plant Analysis. 1532-2416. doi: 10.1080/00103624.2017.1373796

Burner, D.M., A.L. Hale, R.P. Viator, D.P. Belesky, J.H. Houx, III, A.J. Ashworth, and F.B.

Fritschi. 2017. Ratoon cold tolerance of Pennisetum, Erianthus, and Saccharum bioenergy feedstocks. Industrial Crops and Products. 109: 327-334.

Ashworth, A.J., J. DeBruyn, F.L. Allen, M.A. Radiosevich, and P.R. Owens. 2017. Microbial community structure is affected by cropping sequences and poultry litter under long-term no-tillage. Soil Biology and Biochemistry. 114: 210-219.

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

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

Book Chapters

Sauer, T.J., C. Dold, **A.J. Ashworth**, A. Thomas, Y.G. Chendev, D. Philipp, A Gennadiev, and G.H. Ramirez. *In press.* Agroforestry Practices for Soil Conservation and Resilient Agriculture. *In* R. Udawatta and S. Jose (*Eds*.) *Ecosystems Services of Agroforestry*.

7. Scientific Outreach and Oral Presentations

Acharya, M. A.J. Ashworth, D.M. Burner, D. Pote, J., Burke, and J.P. Muir. 2018. Evaluation of yield and nutritive value of three browse species for feeding small ruminants during summer. Southern Pasture & Forage Crop Improvement Conference. Fayetteville, AR.

Lindsay, K., M. Popp, P.R. Owens, and A.J Ashworth. 2018. Decision support for economic and environmental impact of tractor guidance on small crop and livestock farms. Southern Agricultural Economics Association. Jacksonville, FL.

Ashworth, A.J., P.R. Owens, M. Popp, and K.R Lindsay. 2018. Economic and environmental assessment of tractor guidance technologies. International Commission of Agricultural and Biosystems. Antalya, Turkey.

Owens, P.R., A.J. Ashworth, and Z. Libohova. 2018. A pattern recognition approach combined with Fuzzy Logic for predicting soil properties and function. International Commission of Agricultural and Biosystems. Antalya, Turkey.

Ashworth, A.J., A.W. Lepore, F.L. Allen, R.M. Connaster, P. Kim, and N. Labbé. 2018. Use of red mud as a pyrolysis catalyst and a carbonated soil amendment. Food and Agriculture Organization of the United Nations. Global Symposium on Soil Pollution. Rome, Italy.

Adhikari, K., P.R. Owens, L. West, A.J. Ashworth, M.A. Wilson, D.M. Miller. 2018. Geostatistical mapping of metal elements distribution across conterminous USA. Food and Agriculture Organization of the United Nations. Global Symposium on Soil Pollution. Rome, Italy.

Zechiel, K., J. Rhinehart, G. Bates, A.J. Ashworth, and C. Boyer. 2018. Evaluation of five warm-season forages for beef cattle production. American Forage and Grassland Council. Annual Conference, Louisville, KY.

Ashworth, A.J., J.M. DeBruyn, F.L. Allen, M. Radosevich, and Phillip R. Owens. 2017. Cropping sequence, cover crops, and poultry litter applications impact soil microbial community structure. [CD-ROM]. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America (ASA, CSSA, and SSSA), International Meetings, Madison, WI.

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, VA.

Popular Articles

Dold, C., A.L., T.J. Sauer, A.J. Ashworth, D. Philipp, and T.C. Adams. 2018. Carbon budget calculation for silvopastoral systems. Association for Temperate Agroforestry Newsletter. Vol. 24.

Ashworth, A.J., F.L. Allen, J.L. Bacon, C.E. Sams, W.E. Hart, J.F. Grant, P.A. Moore Jr., and D.H. Pote. 2017. Nutrient Cycling and Yield Vary in Response to Switchgrass Genotype. Crop, Soils, Agronomy News. November, 2017 Issue; pg. 12.

Ashworth, A.J., A.C. Rocateli, C.P. West, K.R. Brye, and M. Popp. 2017. Quantifying Intra-Seasonal Switchgrass Changes Allows for Simulating Productivity Trade-offs. Crop, Soils, Agronomy News. August, 2017 Issue; pg. 12.

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.

8. Funding Leveraging

2018 USDA-Office of Technology Transfer, Innovation Fund, "Quantifying Air and Water Quality Benefits of Improved Poultry Manure Management Practices" $25,000 for 2018-2019 with Amanda Ashworth, Phillip Owens, and Michael Popp.

2018 USDA-Agricultural Research Service funding Opportunity in Antimicrobial Resistance, Evaluating Mitigation Strategies for the Reduction of Antimicrobial Resistance Gene Transfer from Animal Hosts to the Environment" $79,000 for 2019-2022 with Amanda Ashworth, Annie Donoghue, Yichao Yang, Yong Wang, Cammy Willett, Abhi Upadhyay, Michael Rothrock, and Kim Cook.

2017 USDA-Agricultural Research Service Postdoctoral Research Associate Program, "Bridging ARS Analytics: Improved Visualization and Decision Support Tools for Big Data in Systems Research" $140,000 for 2018-2020 with Amanda Ashworth.

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" $100,000 for 2017-2019 with Amanda Ashworth, Cammy Willet, Philip Moore, Phillip Owens, and Dan Pote.

2017 USDA-Natural Resources Conservation Service, 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 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.

9. Other Activities

A decision support tool for economic and environmental impact assessment of tractor guidance technology in grasslands was developed and released March, 2018: https://agribusiness.uark.edu/decision-support-software.php#TGA

Arkansas

University of Arkansas, Animal Science
Year 2017-2018

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 have also extending our activities into the areas of determining N fluxes in pastures and measuring N-use efficiencies across the soil-plant-animal interface. Generated data and knowledge is published in peer-reviewed journals and summarized in extension publications such as newsletter articles and factsheets.

New Facilities and Equipment

None

Unique Project-Related Findings

An glyphosate-resistant alfalfa inter-seeding project that was started 2 years ago is nearing its end. The objectives were to evaluate forages that can be planted into existing alfalfa stands to complement dry matter (DM) production, close gaps in soil cover, and balance forage nutritive value.

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.

During spring and summer of 2018, limitations for interseeding forages into alfalfa stands became evident. Italian ryegrass ceases growth during the hot summer months, thereby opening up gaps in the canopy that will become populated with undesirable plants during late summer and fall. It is possible that inter-seeding alfalfa may only serve as a short-term strategy as competition among the different forages are difficult to control

Accomplishment Summaries

During 2017-2018, 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 2017-2018 is included at the end of

this document.

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.

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. It appears that over-seeding alfalfa should follow a specific strategy and should be short-term. If practiced longer than 1-2 growing seasons, alfalfa stands may be weakened further due to the competition of inter-seeded forages.

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Cooperators: Robert Rhein, Barenbrug Seed Co.

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

Published Written Works

Journal articles:

Wood, E., J. M. Burke, D. Philipp, M. Acharya, J. E. Miller, K. P. Coffey. 20XX. Finishing light weight Katahdin lambs on pasture without or with minimal supplement. Submitted (Livestock Science).

Dold, C., Thomas, Andrew. L., Ashworth A. J., Philipp, D., Sauer, T.J.; 20XX. Calculating tree growth rates in agroforestry systems: a silvopastoral example. Submitted (Agroforestry System).

Clark, J. K, K. P. Coffey, W. K. Coblentz, B. C. Shanks, J. D. Caldwell, R. E. Muck, D. Philipp, M. A. Borchardt, R. T. Rhein, W. E. Jokela, E. A. Backes, M. G. Bertram, and W. B. Smith. 2018. Voluntary intake and digestibility by sheep of alfalfa ensiled at different moisture concentrations following fertilization with dairy slurry. J. Anim. Sci. 96:964-974

W. B. Smith, K. P. Coffey, R. T. Rhein, E. B. Kegley, D. Philipp, J. G. Powell, J. D. Caldwell and A. N. Young. 2017**.** Feeding distillers' grains, soybean hulls, or a mixture of both to cows as a forage replacement: Effects on intake, digestibility, and ruminal fermentation characteristics. doi:10.2527/jas.2017.1379. J. Anim.Sci. 95:3666-3675.

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

Abstracts:

Niyigena, V., K. P. Coffey, W. K. Coblentz, D. Philipp, A. N. Young, and R. T. Rhein. 2017. Effect of delayed wrapping and wrapping source on nitrogen balance and blood urea nitrogen in gestating sheep offered alfalfa silage.

Philipp, D., R. Rhein, V. Niyigena, D. Bignar, and A. Selman. 2017. Interseeding options for thinning alfalfa stands. Southern Pasture and Forage Crop Improvement Conference (SPFCIC), Knoxville, TN.

Jennings, J. A., K. Simon, S. Gadberry, P. Beck, D. Philipp, and D. Hubbell. 2017. Arkansas 300 Days Grazing Program "It's About Time". *In* 2017 Proceedings of the American Forage and Grassland Council Conference. AFGC Berea, KY

Simon, K.J., D. Philipp, J. A. Jennings, and R. Rhein. 2017 Influence of planting date on late fall dry matter yield of spring oat, winter oat, and winter wheat. *In* 2017 Proceedings of the American Forage and Grassland Council Conference. AFGC Berea, KY.

Extension publications:

Philipp, D., K. Jogan, and M. Russell. 2018. Forages for horse grazing in Arkansas. FS

Scientific Outreach and Oral Presentations
Philipp, D. 2018. Research update at NCCC-31 meeting. Annual committee meeting, Fayetteville, AR.

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.

NCCC-31 Report Kentucky
2017-2018

1. Impact Nugget

The forage group at the University of Kentucky conducts research on how symbioses between forage species and microbes affects forage production, nutritive value, secondary plant metabolites, resilience to climate change, and mitigation potential.

2. New Facilities and Equipment

3. Unique Project-Related Findings

Human alteration of symbiont genetics among aboveground endophytic *Epichloë coenophiala* strains within tall fescue (*Schedonorus arundinaceus*) has led to widespread deployment of novel grass-endophyte combinations, yet little is known about their ecological consequences. In this study, clone pairs (endophyte-infected, endophyte-free) of two tall fescue genotypes received factorial combinations of increased temperature (+3^{o}C) and precipitation (+30% long-term annual mean) for 2 yr. We measured root arbuscular mycorrhizal fungi (AMF), dark septate endophyte (DSE) colonization, and soil AMF extraradical hyphae (ERH) length. We hypothesized that genetically distinct grass-*E. coenophiala* associations would differentially affect belowground fungi, and that these relationships would be climate-sensitive. Tall fescue genotype, endophyte presence, and climate treatment interactions affected AMF arbuscules, vesicles, and ERH. DSE decreased with *E. coenophiala* presence but increased with warming. Genetically distinct tall fescue-*E. coenophiala* associations may have divergent long-term impacts on other host-symbiont interactions, potentially impacting ecosystem function and response to climate change.

4. Accomplishment Summaries

Plant-microbe symbioses can be important in governing ecosystem response to climate change. They are also increasingly being explored for novel agricultural management applications aimed at improving production resilience and sustainability. One
example occurs with tall fescue (*Schedonorus arundinaceus*), a predominant cool season forage in managed grasslands of the eastern U.S., and its leaf fungal endophyte (*Epichloë coenophiala).* Infection with the common toxic strain of Epichloë improves fescue's ability to resist environmental stressors, including drought and other likely impacts of climate change, and endophyte infection can increase soil C sequestration, modify greenhouse gas (GHG) fluxes, and alter soil microbial community composition and function (i.e., modify soil health). However, toxic alkaloids produced by this strain of the endophyte negatively
affect animal production and have led to the inoculation of fescue with "non-mammal-toxic" strains. Whether these non-toxic endophytes confer a similar level of environmental stress resistance is unknown, as are their effects on soil health. To address
this knowledge gap, we are leveraging two existing field projects to accomplish the following objectives: (i) Quantify how farmer adoption of different fescue-endophyte symbiotic material will affect fescue root fungal symbionts and overall pasture production

resilience and forage quality under warmer and drier conditions; and (ii) Determine whether increasing fescue-endophyte symbiotic diversity alters pasture soil health. The proposed work will allow us to assess whether grass-endophyte technology can be utilized to improve the resilience and soil health of fescue pastures, the base of animal production for much of the eastern US.

5. Impact Statements

"Utilizing grass-endophyte technology to improve pasture soil health and resilience to climate change stressors"

Issue: Agronomists and the grass seed industry have long recognized the value in manipulating plant-endophyte symbioses to improve pasture sustainability. Significant resources have been devoted to the ongoing discovery and deployment of novel endophyte technology, where the production of 'good' alkaloids is maintained but the 'bad' ergots are not. However, to date, the development of these 'symbiotically modified organisms' has focused primarily on maintaining fescue stand persistence and insect resistance, while improving animal performance, under current climatic conditions. The primary tenet
of this proposal is that manipulation of these plant-microbe associations can also improve forage production resilience and forage quality under future warmer and potentially drier conditions. Furthermore, adoption of new grass-endophyte technology may have repercussions for a variety of soil health parameters, which may also affect pasture resilience and feedbacks to climate change.

Action: We are entering the third year of our manipulative warming and altered precipitation regime field project, where we are evaluating a suite of grass-endophyte combinations for their ability to tolerate these stressful conditions. We have collected two full years of soil-to-atmosphere trace gas fluxes, which we are in the process of analyzing. We have also evaluated rates of endophyte seed transmission to see if the climate treatments produce a disconnect between the grass host and fungus. We are also analyzing plant production and alkaloid data, and have sampled some of the material for a full leaf
and root microbiome analysis. This data has just come in and is interesting, as it shows our site to have more responsive plant microbial communities to warming, in both leaf and roots, than the two other sites measured (both long-term warming sites: Kessler in OK and Rocky Mountain Biological Lab in CO).

Impact: Overall, we observe that some grass-endophyte combinations are considerably better able to withstand the environmental stress produced by the climate treatments than others - illustrating the need to evaluate stress responses for novel combinations entering the market. It is important to thoroughly evaluate the resilience of new agricultural plant material to stressors such as climate change.

"Biodiversity effects on grassland response to nutrients and herbivory"

Issue: Human land use is driving biodiversity loss world-wide, including increasingly homogenizing plant communities. As species and their interactions are important in determining the function of ecosystem, e.g. nutrient retention or resilience to climate variability, loss of

biodiversity may have major effects on the provisioning of ecosystem services.

Action: Research conducted at the University of Kentucky and a global network of grassland sites (NutNet) assessed the relationship between plant diversity and ecosystem multifunctionality at local and landscape scales. We measured plant diversity and ecosystem functions, including aboveground live biomass, resource capture aboveground (light interception), resource pools belowground (% total soil nitrogen and extractable soil phosphorus and potassium), soil carbon storage, litter decomposition, and invasion resistance, at 65 grassland sites located on five continents.

Impact: Our results provide robust evidence that plant diversity at the local and landscape scale is associated with more reliable functioning of grassland ecosystems. Human activities that simplify ecosystems through the loss of plant diversity are likely to diminish the capacity of systems to supply essential ecosystem functions. The maintenance and restoration of plant diversity at local and landscape scales should help ensure the reliable provision of ecosystem services.

6. Published Written Works

Refereed Journal Articles

Hodapp, D., E. Borer, S.W. Harpole, E. Lind, E. Seabloom, P. Adler, J. Alberti, C. Arnillas, J. Bakker, L. Biederman, M. Cadotte, E. Cleland, S. Collins, P. Fay, J. Firn, N. Hagenah, Y. Hautier, O. Iribarne, J. Knops, R.L. McCulley, A. MacDougall, J. Moore, J. Morgan, B. Mortensen, K. La Pierre, A. Risch, M. Schuetz, P. Peri, C. Stevens, J. Wright, and H. Hellbrand. **2018**. Spatial heterogeneity in species composition constrains plant community responses to herbivory and fertilization. Ecology Letters. Doi: 10.1111/ele.13102

Derner, J.D., A.J. Smart, T.P. Toombs, D. Larsen, R.L. McCulley, J. Goodwin, S. Sims, and L.M. Roche. **2018**. Soil health as a transformation change agent for U.S. grazing lands management. Rangeland Ecology & Management 71:403-408.

Rounsaville, T.J., C.C. Baskin, E.A. Roualdes, R.L. McCulley, and M.A. Arthur. **2018**. Seed dynamics of the liana *Euonymus fortune* and implications for invasibility. Journal of the Torrey Botanical Society 145:225-236.

Kalosa-Kenyon, E. , L.C. Slaughter, J.A. Rudgers, and R.L. McCulley. **2018**. Asexual *Epichloë* endophytes do not consistently alter arbuscular mycorrhizal fungi colonization in three grasses. American Midland Naturalist 179:157-165.

Anderson, T.M., D. Griffith, J. Grace, E. Lind, P. Adler, L. Biederman, D. Blumenthal, P. Daleo, J. Firn, N. Hagenah, A. MacDougall, R. McCulley, S. Prober, A. Risch, M. Sankaran, M. Schutz, E. Seabloom, C. Stevens, L. Sullivan, P. Wragg, and E. Borer. **2018**. Herbivory and eutrophication mediate grassland plant nutrient responses across a global climatic gradient. Ecology 99: 822-831.

Shelton, R.E., K.L. Jacobsen, and R.L. McCulley. **2018**. Cover crops and fertilization alter nitrogen loss in organic and conventional conservation agriculture systems. Frontiers in Plant Science 8: 2260.

Slaughter, L.C., J.A. Nelson, E. Carlisle, M. Bourguignon, R.D. Dinkins, T.D. Phillips, and R.L. McCulley. **2018**. Climate change and *Epichloë coenophiala* association modify belowground fungal symbioses of tall fescue host. Fungal Ecology 31: 37-46.

Hautier, Y., I. Forest, E.T. Borer, E.W. Seabloom, W.S. Harpole, E.M. Lind, A.S. MacDougall, C.J. Stevens, P.B. Adler, J. Alberti, J.D. Bakker, L.A. Brudvig, Y.M. Buckley, M. Cadotte, M.C. Caldeira, E.J. Chaneton, C. Chu, P. Daleo, C.R. Dickman, J.M. Dwyer, A. Eskelinen, P.A. Fay, J. Firn, N. Hagenah, H. Hillebrand, O. Iribarne, K.P. Kirkham, J.M.H. Knops, K.J. La Pierre, R.L. McCulley, J.W. Morgan, M. Partel, J. Pascual, J.N. Price, S.M. Prober, A.C. Risch, M. Sankaran, M. Schuetz, R.J. Standish, R. Virtanen, G.M. Wardle, L. Yahdjian, and A. Hector. **2017**. Local loss and spatial homogenization of plant diversity reduce ecosystem multifunctionality. Nature Ecology & Evolution https://doi.org/10.1038/s41559-017-0395-0

Biederman, L.A., B. Mortensen, P.A. Fay, N. Hagenah, J. Knops, K. La Pierre, R. Laungani, E. Lind, R.L. McCulley, S. Power, E.W. Seabloom, P. Tognetti. **2017.** Nutrient addition shifts plant community composition towards earlier flowering species in some prairie ecoregions in the U.S. Central Plains. PLOS ONE. https://doi.org/10.1371/journal.pone.0178440

Other Peer Reviewed Publications

Biederman, L.A., B. Mortensen, P. Fay, N. Hagenah, J. Knops, K. La Pierre, R. Laungani, E. Lind, R. McCulley, S. Power, E. Seabloom, and P. Tognetti. **2017**. How do nutrients change flowering in prairies? Environmental Science Journal for Teens. September issue.

7. Scientific and Outreach Oral Presentations

McCulley, R.L. **2017**. Can grass-fungal endophyte technology be utilized to build soil health in pastures? FFAR sponsored workshop entitled, 'Assessing and Managing Soil Health on Rangelands and Pasture Lands,' November 6-9, 2017, Noble Research Institute, Ardmore, OK.
McCulley, R.L. **2017**. Can grass-endophyte technology be utilized to build soil organic matter and improve pasture soil function? ASA-CSSA-SSSA Annual Meeting, Tampa, FL.
McCulley, R.L., J.A. Nelson, K. Predick, E.M. Levi, P.W. Barnes, H.L. Throop, and S.R. Archer. **2017**. UV radiation stimulates but soil-litter mixing reduces fungal role in dryland litter decomposition. Ecological Society of America Annual Meeting, Portland, OR.

8. Fund leveraging

McCulley, R.L. (PI), K. Saikkonen, and I. Zabalgogeazcoa (Co-PIs). "Manipulating Grass-Fungal Endophyte Symbioses to Reduce Greenhouse Gas Emissions and Increase Soil Carbon Sequestration in Grasslands of Finland, Spain, and the United States." ***FACCE-JPI***. 2014 – 2017. **$1,000,000**

McCulley, R.L. (PI). "Utilizing grass-endophyte technology to improve pasture soil health and resilience to climate change stressors and soil health." ***NIFA-AFRI-Foundational – Agricultural Production Systems***. 2017-2021. **$500,000**

McCulley, R.L. (PI), J. White, and C.A. Young (Co-PIs). "Can manipulation of fungal endophyte diversity positively influence tall fescue pasture sustainability and ecosystem functioning?" ***NIFA-AFRI-Foundational – Agroecosystem Biodiversity***. 2016 – 2018. **$150,000**

R.L. McCulley (PI). Determining tall fescue genotype interactions with both fungal endophyte presence/genotype and changes in climate to alter tall fescue production, secondary metabolite concentrations, and overall fescue forage quality. ***USDA-FAPRU- Specific Cooperative Agreement***, 2013-2017. **$152,896**

R. Hirsch (PI), C. Schardl, P. Calie, R.L. McCulley, J. White (Co-PI's). KY EPSCoR: Integrating collegiate ecological and molecular research into the K-12 STEM curriculum. ***KY NSF EPSCoR***, 2016-2017. **$9,860**

9. Other relevant accomplishments and activities

The UK Forage Climate Change and Symbiotic Diversity field experiments were part of the Spring 2018 Novel Fescue Renovation Workshop, held in Lexington, KY, and hosted by the Alliance for Grassland Renewal. Approximately 50 producers and industry specialists participated.

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10. Impact Nugget

None.

11. **New Facilities and Equipment** None

12. Unique Project-Related Findings

- Harvesting cover crops for forage after winter wheat harvest in Michigan can give harvestable forage and acceptable nutritive value without negatively affecting subsequent corn grain yields.
- Genetically modified reduced lignin alfalfa varieties have improved forage quality and similar yield to standard varieties.
- Biomass yield of annual clovers are relatively low as harvested forage but suitable as a cover crop or for grazing in Michigan.
- Beef cattle finish on brassica-based pastures with acceptable rates of gain, carcass merit, and meat sensory acceptability.
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13. Accomplishment Summaries

Using Cover Crops after Wheat to Improve Soil Health. Harvesting red clover, oat/pea mix, sudangrass, and sudex cover crops as Soft red winter wheat ('Hopewell' and 'Red Dragon') was planted in October of 2013 and 2014 and harvested in July 2014 and 2015. Cover crops included: frost-seeded red clover, and summer-seeded alfalfa, cowpea, sunn hemp, radish, oat/field pea mixture, sudangrass, sorghum x sudangrass, and teffgrass. Half of each CC plot was mechanically harvested eight weeks after planting. Harvested forage dry matter yield was greatest for red clover (4.3 Mg ha^{-1}); oat-pea mix (2.5 Mg ha^{-1}), sudangrass/sudex (1.8 Mg ha^{-1}) and radish (1.2 Mg ha^{-1}) ($P < 0.01$) yielded less. Corn grain yield harvested in October averaged 13.7 Mg ha^{-1} and did not differ across CC species or forage harvest treatment ($P > 0.05$). Harvesting forage reduced total N removal (TNR) in subsequent corn for red clover only; harvesting forage did not affect TNR after any other CC (CC x harvest interaction, $P < 0.05$). In the harvested system, TNR did not differ ($P > 0.05$) between for any CC, but unharvested RCL (374 kg N ha^{-1}) had greater ($P < 0.01$) TNR than oat-pea mix (338 kg N ha^{-1}). There were no differences among treatments for soil permanganate oxidizable carbon POXC ($P > 0.05$). Harvesting cover crops for forage after winter wheat harvest in Michigan can give harvestable forage and acceptable nutritive value without negatively affecting subsequent corn grain yields.

Increasing Legume Grazing for Higher Beef Gain on Pastures: An Improved High-Tannin Birdsfoot Trefoil Cultivar with Trans- Regional Potential. Winter survival, vigor, flowering date, and seed pod rating were recorded for surviving individual trefoil plants in a selection nursery (Obj 2). Trefoil/tall fescue mixtures were grazed only once in 2017

because of drought (Obj 1). We evaluated yield and quality, condensed tannin (CT) concentration, soil microbial activity, and root morphology of pasture mixtures containing eight birdsfoot trefoil (BFT) cultivars with a range of CT concentrations and four tall fescue cultivars varying in endophyte infection status. The BFT proportion of forage mixtures declined from > 95% to < 10% from 2015-2016 due to reduced stand density of BFT. Mixtures with Oberhaunstädter BFT expressed greater CT concentrations, with levels from 7.5 to 31.7 g kg-1, and 70% greater stand density in 2016 than all other mixtures. Nutritive value and pregrazing forage yield was always adequate for pastured sheep, regardless of CT concentration or endophyte type. Therefore, high-tannin Oberhaunstädter in mixtures with endophyte-free tall fescue proves most suitable for forage production in south-central Michigan. Belowground processes were influenced more by variability between grazing seasons than by CT or endophyte type; cumulative C mineralization was greater in 2015 while root traits associated with superior resource acquisition (root length density, specific root length, root surface area density, root diameter) were greater in 2016.

Multi-site Performance of Reduced Lignin Alfalfa. Plots were established in 2014 as part of a six-state (MI, WI, KS, OH, CA, PA) industry- funded trial to evaluate the relationship of harvest maturity to forage quality in new reduced-lignin alfalfa (RLA) varieties. Data was collected in 2016 and 2017. In 2017, a new 4-year trial was established in six states (MI, WI, KS, OH, CA, UT) to examine the impact of the next generation of reduced lignin genetics, harvest schedule, and fungicide treatment on alfalfa yield, quality, and persistence. First phase genetics for RLA contains about 15% less lignin than ordinary alfalfa with slightly less yield potential on the same cutting schedule. However, extended cutting intervals reduce the yield gap while providing forage of similar quality. Preliminary results suggest RLA will do as advertised by providing similar yield and quality in fewer cuttings.

Yield and Nutritive Value of Annual Legumes in Michigan Forage Systems. Plots were established at four sites across Michigan in 2016 and three sites in 2017 to test suitability of annual forage legumes forages and cover crops. Nitrogen replacement value of the legumes was determined in 2017 for the 2016 sites, and will be determined in 2018 for the 2017 sites. Wet conditions followed by drought negatively affected yields in both years. Summer seedings were more successful than spring seedings in 2016, and no seedings performed well in 2017. Total annual dry matter yields were generally less than 2 tons/acre across the board. Biomass yield of annual clovers are relatively low as harvested forage but suitable as a cover crop or for grazing.

Identifying factors to optimize establishment of alfalfa interseeded in corn. A four-state experiment (Wisconsin, Michigan, Pennsylvania, and Idaho) was initiated in 2018 to evaluate management option to improve establishment of alfalfa in silage corn. Summary statistics and discussion of results: Data collection is ongoing and results will be evaluated at the end of the growing season. Key Outcomes and other accomplishments realized: This preliminary data helped the team obtain funding from NIFA AFRP in 2017 for an expanded project to

investigate potential of this management system.

High energy pastures for Grass Finished Beef. Michigan State University completed a three-year study on use of perennial cool season pasture, and simple or complex annual mixtures for the last eight weeks of finishing for grass-fed beef. Beef cattle grazing complex brassica-based annual pasture mixtures yielded more meat than cattle grazing perennial grass-legume mixtures, with acceptable carcass quality and no sensory off-flavors.

Commercial Variety Testing. Michigan State University conducted variety trials on alfalfa, red clover, orchardgrass, fescues, perennial and Italian ryegrass, timothy, Kentucky bluegrass, and cover crops n 2017-2018. These data are distributed to farmers, industry and made available to other researchers for "big data" analysis.

14. Impact Statements

- Harvesting cover crops for forage after winter wheat harvest in Michigan can give harvestable forage and acceptable nutritive value without negatively affecting subsequent corn grain yields.
- Genetically modified reduced lignin alfalfa varieties have improved forage quality and similar yield to standard varieties.
- Biomass yield of annual clovers are relatively low as harvested forage but suitable as a cover crop or for grazing in Michigan.
- Beef cattle finish on brassica-based pastures with acceptable rates of gain, carcass merit, and meat sensory acceptability.

15. Published Written Works

Referred Journal Articles:

Turner, K.E., K.A. Cassida, A.M. Zajac, and M.A. Brown. 2017. Performance and gastrointestinal nematode control when meat-goat kids grazed chicory, birdsfoot trefoil, or red clover pastures. Sheep Goat Res. J. 32:1-12. Available at: http://www.sheepusa.org/ResearchEducation_ResearchJournal_Volume32

Abstracts and Posters:

1. Renz, M.J., W.R. Osterholz, J.H. Grabber, K.A. Cassida, E.E. Burns, J.A. Williamson, and D.L. Bjornberg. 2018. Identifying factors to optimize establishment of alfalfa interseeded in corn. 2018 Joint Conference of NAAIC, Trifolium, and Grass Breeders, June 4-6, 2018. Logan Utah. https://www.naaic.org/Meetingsa/National/2018meeting/13 Grabber Abstract.pdf

2. Rojas -Downing, M.M., A.P. Nejadhashemi, B. Elahi, K.A. Cassida, F. Aneshvar, J. S. Hernandez-Suarez, M. Abouali, M.R. Herman, S.A. Al Masraf, and T. Harrigan. 2017. A systems approach to address sustainability in dairy production. The National Systems Conference. December 1-3, 2017, Agra, India.

3. Cassida, K.A. 2017. Potential of alternative legumes in Michigan forage and cover crop systems. Annual Meeting of ASA/CSSA/SSSA, Tampa, FL, Oct. 22-25,2017. https://scisoc.confex.com/scisoc/2017am/webprogram/Paper109156.html

4. MacAdam, J.W., K. Cassida, and E. van Santen. 2017. Location of growth influenced birdsfoot trefoil tannin accumulation, but few accessions differed in tannin concentration. Annual Meeting of ASA/CSSA/SSSA, Tampa, FL, Oct. 22-25,2017. https://scisoc.confex.com/scisoc/2017am/webprogram/Paper106779.html

Extension/Outreach:

1. Cassida, K., J. Paling, and C. Kapp. 2018. *2017 Michigan Forage Variety Test Report.* MSU Forage Factsheet 18-01, 37 pages. Published Feb. 1, 2018. https://forage.msu.edu/publications/ (Online.) https://forage.msu.edu/wp-content/uploads/2018/02/149374-MSU-Forage-Varieties-Printed-Bulletin-January-2018-corrected_v4.pdf

2. Cassida, K., and J. Lindquist. 2018. *Frost-Seeding – an Effective Forage Establishment Practice for Michigan*. MSUE #E2125. https://forage.msu.edu/wp-content/uploads/2018/08/E2185-FrostSeedingAnEffectiveForage EstablishmentPracticeForMichigan-2018.pdf

3. Cassida, K. 2017. Grass-finished beef need high-energy forages. *Hay & Forage Grower*, April/May pp. 8-9.

5. Cassida, K.A. (webmaster). *MSU Forage Connection*. http://forage.msu.edu/ (website)

6. Sulc, M., A. Parker, K. Albrecht, K. Cassida, M. Hall, D.H. Min, S. Orloff, D. Undersander, X. Xu, and E. van Santen. 2017. Reduced lignin alfalfa: research update & implications to harvest management. Western Alfalfa & Forage Symposium, Nov. 28-30, 2017, Reno, NV.

Other Creative Works:

1. Gerdes, S. 2017. *Using Cover Crops in Wheat-Corn Rotations to Provide Forage While Improving Soil.* M.S. Thesis. Michigan State University, East Lansing, MI. ProQuest, Ann Arbor, MI.

2. Kreykes, M.S. 2017. *Forage Quality, Yield, Condensed Tannin Concentration, Soil Respiration, And Root Morphology Of Birdsfoot Trefoil-Tall Fescue Mixtures*. M.S. Thesis, Michigan State University. ProQuest, Ann Arbor, MI.

16. Scientific Outreach and Oral Presentations

1. Cassida, K.A. 2018. NCCC-31 Annual Report. Fayetteville, AR. June 23-24, 2018.

2. Cassida, K.A., R.M. Martin, J.E. Rowntree, and J. Schweihofer. 2018. Finishing forages for grass-fed beef. Online. In: Proc. American Forage & Grassland Council, Jan. 14-16, 2018, Louisville, KY. AFGC, Berea, KY. http://www.afgc.org/proceedings/2018/Kim_Cassida_CassidaK_018_POST.pdf

3. Cassida, K.A., R.M. Sulc, A. Parker, K. Albrecht, M. Hall, D. Min, S. Orloff, and D. Undersander. 2018. Yield and quality of reduced lignin alfalfa across six states. In: Proc. American Forage & Grassland Council, Jan. 14-16, 2018, Louisville, KY. AFGC, Berea, KY.

4. Funding Leveraging (collaborative grants) (NCCC31 members bolded)

1. **Cassida, K.,** D. Undersander, **K. Albrecht, M. Hall,** D.H. Min, **M. Sulc**, and S. Orloff. 2017-2018. Low lignin alfalfa trials. Forage Genetics International. $27,027. (FUNDED)

2. Renz, M., W.R. Osterholz, **J.H. Grabber**, **K. Cassida**, E. Burns, J. Williamson, and D. Bjorneberg. 2017. Identifying factors to optimize establishment of alfalfa interseeded in corn. NIFA Alfalfa & Forage Research Program. $250,000. (FUNDED)

5. Other Activities

Extension presentations (K.A. Cassida)

1. Sept. 27-28, 2018. Beginner Grazing School, Hickory Corners and Lake City, Michigan.
2. Aug. 21, 2018 – Michigan Forage Council Bus Tour, Michigan Thumb area.
3. July 26, 2018. Forage Genetics International Alfalfa Field Day, East Lansing, MI.
4. June 27, 2018 – MSU Weeds Day, East Lansing, MI.
5. **June 13, 2018 – Forage Walk**, Upper Peninsula Research & Extension Center, Chatham, Michigan. (Audience: 36)
6. May 17, 2018 Alfalfa Harvest Scheduling – MSUE Field Crops Virtual Breakfast Meeting, 6:30-7:00 am.
7. May 8, 2018 - Doubling Up: Forages as Cover Crops, St. Joseph County 2018 Breakfast Meeting,

8. Mar. 27, 2018. “Alfalfa & Grass Mixes for Higher Income & Quality” at MSU Winter Forage Meetings – Optimizing Forage Profitability in 2018. Coldwater, Michigan.
9. Mar. 22, 2018. “Alfalfa & Grass Mixes for Higher Income & Quality” at MSU Winter Forage Meetings – Optimizing Forage Profitability in 2018. Shepherd, Michigan.
10. Mar. 13, 2018. “Alfalfa & Grass Mixes for Higher Income & Quality” at MSU Winter Forage Meetings – Optimizing Forage Profitability in 2018. Bad Axe, Michigan.
11. Mar. 9, 2018. “Managing Horse Pastures.” Michigan Horse Expo, East Lansing, MI.
12. Mar. 8, 2018. “Evaluating Hay” at Feeding Your Horse for Optimal Nutrition Workshop. East Lansing, MI.
13. Mar. 7, 2018. “Forage Research Update.” Great Lakes Forage and Grazing Conference. St. Johns, MI.
14. Mar. 5. 2018. “Interseeding Alfalfa into Corn” MSUE Field Crops Webinar Series.
15. Feb. 27, 2018. “Forage Species for Grassfed Beef Systems.” Grass-fed Beef School. Audience: 45. (Invited)
16. Jan. 10, 2018. “Meeting Forage Demand.” MABA Conference, Lansing, MI. Audience: 14 (Invited)
17. Jan. 26, 2018. “Managing Horse Pastures.” Ag Action Conference Audience: 12. (invited).
18. Dec. 30, 2017. “Grazing Cover Crops.” Cover Crop Services, LLC. Shipshewana, IN. Audience: ~25 (Invited)
19. Dec. 20, 2017. “Forage Research Update.” Agronomy Update. East Lansing, MI. Audience: 150.
20. Nov. 14-16, 2017. “Alfalfa Establishment,” “Soil Fertility,” and “Value of alfalfa in crop rotations.” Alfalfa Intensive Training Seminar, Boise, ID. Audience: 25 (Invited)
21. Nov. 3, 2017. “Grazing cover crops.” KBS Cover Crop Field Day. Audience: 150.

North Dakota

North Dakota State University
NCCC-31 Report
Ecophysiological Aspects of Forage Management

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

3. Unique Project Related Findings: alfalfa-corn intercropping to establish alfalfa during the corn year works quite well in North Dakota without the need of a growth regulator to enhance alfalfa survival. This practice has a lot of potential to increase the use of alfalfa in rotation with corn silage.

4. Accomplishment Summaries:

Forage management and production research

In 2017, activities included testing alfalfa varieties. Results are published in the forages website (http://www.ag.ndsu.edu/plantsci/forage/index.html).
In 2017, the forages experiments included:
a) *Silage corn-alfalfa intercropping:* The objective of this research was to evaluate the productivity and profitability of corn-alfalfa intercropping system. Corn grain yield decreases in about 30 bu/acre, but alfalfa forage yield in the next year increases in 2.5 ton/acre skipping the seeding year and benefiting of a full season of growth. This system can provide a head start for alfalfa skipping the typical low productivity of the seeding year. In 2017, the experiment was repeated at four locations, Forman and Prosper, ND, Rosemount, MN, and Ames, IA as part of the CAP project. The experiments will continue in 2018.

Bioenergy crops management research

a) Forage sorghum cold tolerance. Forage sorghum was identified as the most promising bioenergy crop for North Dakota. Forage sorghum has great potential because of 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. In 2017, 74 forage sorghum commercial cultivars and 10 check cultivars with cold tolerance were evaluated at 12 and 24°C. Screening identified eight promising cold-tolerant cultivars which were planted in the field on two seeding dates 10 May and 26 May. Cultivar by date was significant for biomass yield indicating some of the identified cultivars had greater yield when planted early in May.
b) *Life cycle assessment of double- and relay-cropping systems.* I continue to work on LCA. One article was published in 2017 in Agricultural Systems and one article has been submitted to Bioenergy Research.
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.

Cover crops

The CropSys CAP grant activities in 2017 included several experiment in cover crops:

a) *Cover crops variety and seeding date trial*: The experiment was established in 2017 in Fargo on two seeding dates, July 27 and August 23. All results of biomass yield, and N accumulation of cover crops are available in the forages web page.

b) *Interseeding of cover crops in standing soybean:* The objective of this study was to determine the effect of interseeding cover crops into soybean on yield, cover crop establishment, soil cover, and soil nitrate depletion in the inter-row. Four cover crop treatments were interseeded, Austrian winter pea, forage radish cv. Daikon winter camelina cv. Joelle winter rye cv. Rymin, a mixture of all four cover crops, and a check treatment with no cover crops. Cover crops were interseeded at the R4 and R6 reproductive stages of soybean in Fargo and Prosper in 2016 and 2017. Soybean grain test weight and yield were not affected by interseeding cover crops at any of the cover crops seeding dates or locations in 2016 or 2017. Soil NO3 in the inter row decreased significantly in plots with cover crops compared with the plot with no cover crop. This was observed in 2016 but not in 2017 due to the scarce growth of the cover crops due to drought. Wheat was planted in 2017 on the 2016 experiment to determine if any of the N on the cover crop cycle back to the wheat, but no significant differences were observed on grain yield nor in protein content.

c) Interseeding of camelina and pennycress into standing corn and soybean
Several experiments were designed by different researchers in the CAP project and their students to determine best cover crop adapted to grow under corn or soybean shade, best interseeding date, and other variables as row spacing and hybrid maturity. In general cover crops established well and did not reduce soybean or corn yield. Experiments started in 2016 and continued in 2017. Experiments locations, include, Forman and Prosper, ND, Waseca and Morris, MN and Ames, IA.

d) Interseeding of legumes into standing corn
The experiment was planted at Hickson and Prosper, ND. Five different cover crops, faba bean, forage pea, rye, balansa and red clover, were interseeded in two corn at two growth stages V8 and R4. Only faba bean and rye established well and reduced the available soil nitrate in the inter row of corn protecting it from potential leaching and runoff.

e) *Cover crop interseeder development*; members of the CAP project developed a pilot interseeder. The planter belongs to the project and 200 acres of corn were interseeded with rye and radish at V8 stage of corn at two locations in ND. No corn yield was observed

f) *N credits of cover crops to corn & sugarbeet*: Several studies were established to determine nitrogen credits of cover crops to corn and sugarbeet. Experiments will be continued next year. These studies are part of the CAP grant.

g) *Biostrips, polycultures*: Strips of several flower and grasses mixtures were planted with the objective to increase pollen sources for bees while improving soil health.

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, without including CRP or native rangeland, was 2,876,816 acres in 2016. **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 management and fertility conducted by this project have demonstrated forage yield can be easily increased on average at least by 0.3 ton/acre/yr. Pure alfalfa acreage in ND in 2016 was 419,756 acres and alfalfa-grass mixtures 948,883 acres. An increase in forage yield of 0.3 tons/acre/year x 1,368,639 acres @ $100/ton of hay equals an economic impact of **$41,059,170/yr.** Alfalfa-corn intercropping allows alfalfa to get established in the corn year. This system increases alfalfa yield in Year 2 in 2.5 tons/acre compared with a spring-seeded alfalfa. Corn yield decreases in 30 bu/acre due to competition with alfalfa. But in two years the gain of the system is about $160/acre in two years (2.5 tons/acre x $100/ton – 30 bu/acre x $3/bu corn) or $80/acre/yr. The acres of corn silage-alfalfa rotation in ND are about 150,000 acres x $80= $**1,200,000** in monetary impact.

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. In 2017, forage sorghum acreage was 28,418 acres at $50/ton value as feed the economic impact equals **$1,420,900/yr.**

Legume cover crops planted after wheat in one of our studies reduced the need of fertilizing in corn in 100 lbs N/acre but this is not usual. With a N credit of only 30 lbs/acre, the economic value of reducing the fertilization in corn in 3,376,026 acres x 30 lbs N/acre saving x $0.3 lb N, is **$30,384,234/yr.** Cover crops forage value can add $30-$50/acre revenue by grazing. If only 10% of the wheat acreage (7,438,535 acres) was planted to cover crops for grazing after harvest, the economic impact would be **$22,456,050**.

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 potential economic impact= **$96,484,354**

5. Published Written Works

Refereed publications None in forages

Proceedings publication

Ciria, C.S., **M.T. Berti**, M. Kazula, and A. Peterson. Perennial grasses: biomass quality and yield comparison of 12 different species in the northern Great Plains of the United States. In 25th European Biomass Conference and Exhibition.11-14 June, 2017, Stockholm, Sweden. Available at http://www.etaflorence.it/proceedings/index.asp (verified 10 June 2017).

Bulletins and Extension Factsheets

1. **Berti, M.T**., 2017. Alfalfa-corn intercropping may increase forage and improve soil health. North Dakota Research Report. Forage Focus, December 2017, p. 17.
2. Franzen, D.W. and **M.T. Berti**. 2017. Alfalfa soil fertility requirements in North Dakota soils. Bull. SF1863. North Dakota State University Extension Service.
3. Franzen, D.W. and **M.T. Berti**. 2017. Fertilizing alsike clover, birdsfoot trefoil, red clover, and sweetclover in North Dakota. Bull. SF1865. North Dakota State Univ. Ext. Service.
4. **Berti, M.T.** 2017. Managing alfalfa under drought stress. Forage Focus, August 2017, Midwest Forage Assoc., St. Paul, MN.
5. **Berti, M.T.**, and D. Undersander. 2017. Do seeding rates increase yield and quality in the seeding year? Forage Focus, March 2017 p. 4 Midwest Forage Assoc., St. Paul, MN.

6. Building Soil Health 2017. Booklet. NDSU extension. Compiled by Abbey Wick among authors **M. Berti**.
7. Incorporating Cover Crops. 2017. Booklet. NDSU Extension. Compiled by Abbey Wick among authors, **M. Berti**
8. Alfalfa Corn-Intercropping- Preliminary Research Results. FactSheet. NDSU extension. **M. Berti**

6. Scientific and Outreach Presentations

1. **Berti, M.T.** 2017. Cover crops: why and hat to seed. Central Dakota Ag Day. Carrington Research Extension Center, Carrington, ND. December 19, 2017. ***Invited speaker.***
2. **Berti, M.T.,** 2017. Role of cover crops roots. North Dakota Chapter of Soil and Water Conservation Annual Conference, Bismarck, ND, 21 November 2017. ***Invited speaker.***
3. Podder, S. **M.T. Berti**, A. Peterson, S. Cabello, B. Andersen, D. Samarappuli, and J. Anderson. 2017. Screening forage sorghum [*Sorghum bicolor* (L.) Moench] genotypes for cold tolerance. 29th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC), Ames, IA, 10-13, September, 2017.
4. **Berti M.T. 2017.** Use of cover crops to benefit soil health. Soil Health Workshop (Organic Systems) Carrington, ND. 18 July 2017. ***Invited speaker***
5. **Berti, M.T. 2017**. Forage, biomass, and cover crops production research in North Dakota. Annual meeting of the NCCC-31 committee. 19-20 June, Lincoln, NE.
6. **Berti, M.T**., and D. Samarappuli. 2017. Nutrient cycling potential of *Camelina sativa* as a cover crop in the northern Great Plains, USA. European Geosciences Union Conference, Vienna, Austria, 22-27 April, 2017.
7. **Berti, M.T**. 2017. Nutrient uptake by cover crops. How Far North Can We Grow? 49th Parallel Cover Crop Project. Innovation Working Group Meeting, Devils Lake, ND, 5 April, 2017. ***Invited speaker.***
8. **Berti, M**.T. and D. Toussaint. Interseeding cover crops into standing, corn, soybean, and sunflowers. 2017. Midwest Cover Crop Council Annual Conference. Grand Rapids, Michigan, 12-14 March, 2017.
9. **Berti, M.T.** 2017**.** Interseeding cover crops into standing corn and soybean: what, when, and how. Production Agriculture Symposium Univ. of Minnesota. Minneapolis, MN. 22 February 2017 ***Keynote speaker***
10. **Berti, M.T.,** 2017. What, when, and how to plant cover crops in the northern Great Plains. Annual Symposium Seed sales representatives. Agassiz Seed, Mapleton, ND. 9 February 2017 ***Invited speaker.***
11. **Berti, M.T.** 2017. Cover crops use in the Upper Midwest: What, when, and how. National Crop Insurance Services Annual Meeting. Fargo, ND, 5 January 2017. ***Invited speaker***
12. **Berti, M.T**., M. Kazula, D. Samarappuli, O. Teuber, J. Luckacheswsky, A. Aponte, A. Peterson, W. Yang and C. Ciria. 2017. Validating prediction models for on-farm alfalfa forage yields. Midwest Forage Assoc. Annual Symposium, Wisconsin Dells, WI, 23-25 January, 2017.

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)*

Ohio

The Ohio State University
NCCC-31 Report
Ecophysiological Aspects of Forage Management
Fayetteville AR
26-27 June 2018

1. Impact Nugget:
   Ohio is collaborating with multi-state projects to evaluate new forage production technologies and management practices that will be used to providing training to forage growers and advisors on how to enhance the sustainability of their production systems.

2. New Facilities and Equipment: None

3. Unique Project Related Findings:

4. Accomplishment Summaries:

   1. One of the most destructive insect pests of alfalfa is the potato leafhopper, *Empoasca fabae* Harris (Hemiptera: Cicadellidae). Loss estimates from this pest range from $32-66/ha. There is evidence that climate change is associated with earlier appearance of the leafhopper by migration in alfalfa fields each year and that the severity of potato leafhopper damage increases with rising temperatures. Scientists at The Ohio State University, University of Maryland, and University of Wisconsin are collaborating in research that will be the basis for revising the economic action threshold for insecticide treatment of potato leafhopper in alfalfa in light of changes in cultivars (i.e. host resistance to this pest), and the potential tolerance by grass-alfalfa mixtures. In Maryland, scientists will also relate leafhopper injury to rates of nitrogen fixation, providing a test of whether resistant cultivars and alfalfa-grass mixtures are an effective means to reduce damage to nitrogen fixation of alfalfa. This is important because an insecticide application late in the growth cycle is not practical nor would it be perceived as necessary by producers since it would have limited to no effect on yield of the current growth cycle. Ohio experienced heavy potato leafhopper pressure in the trial in 2016. Mean number of leafhoppers (adults+nymphs) per sweep in unsprayed plots in three summer growth cycles ranged from 10 to 26 in the resistant cultivar, 39 to 118 in the susceptible cultivar, and 42 to 156 in the susceptible alfalfa cultivar and grass mixture. Data will be summarized once the study is completed in 2018. In addition to providing new guidelines to forage producers and consultants, the research will demonstrate the value of leafhopper resistant alfalfa and grass-alfalfa mixtures, which will increase adoption of those practices, leading to more sustainable approaches to protect alfalfa from this key pest. The project is funded by the USDA-AFRI Alfalfa and Forage Research Program.

   2. The Ohio State University is part of a six state collaboration (OH, PA, MI, WI, KS, CA) to evaluate a new transgenic alfalfa cultivar with reduced lignin (RL) content developed by scientists at Forage Genetics International, The Samuel Robert Noble Foundation and the U.S. Dairy Forage Research Center and released in commercially with Monsanto Co. under

the brand of HarvXtra^{TM} alfalfa. The purpose of this research was to 1) compare forage nutritive value and yield of a RL cultivar to non-RL cultivars and 2) to determine if a recalibration of the predictive equations for alfalfa quality (PEAQ) were necessary for adequate neutral detergent fiber (NDF) predictions for RL alfalfa. For Obj. 1, the overall linear model for cultivar response to harvest intervals was significant and all cultivars responded similarly across harvest intervals and events. 'HarvXtra-008' was always higher in nutritive value than non-RL cultivars. The NDF digestibility (NDFD) for 'HarvXtra-008' was greater ($P<0.05$) by 4.0% to 10.4% than non-RL cultivars. NDF was lower ($P<0.05$) for 'HarvXtra-008' by 5.4 to 8.3% than '54R02' and numerically lower but not significantly different than 'WL 355RR'. Differences in yield at individual harvests among cultivars and across harvest intervals were non-significant; however, 'HarvXtra-008' was significantly lower ($P<0.05$) in annual total dry matter yield than non-RL cultivars. For Obj. 2, The PEAQ NDF prediction was calculated from the stage of the most mature stem (MAX) and the height of the tallest stem in each sample (MAXHT) during each regrowth period. The observed NIRS values were regressed on the estimated PEAQ values. Across both states and all cuttings, root mean square error (RMSE) for all three alfalfa cultivars ranged from 25.2 to 31.8. g kg-1 for NDF and the coefficient of determination (r2) ranged from 0.60 to 0.71. When regressions were conducted on cultivar means across four replicates, RMSE ranged from 17.2 to 27.5 g kg-1; the coefficient of determination also improved ranging from 0.69 to 0.83. The slopes and intercepts were tested and were not significantly different among cultivars, but the Wisconsin regressions differed from Ohio regressions. Based on the results from these studies, 'HarvXtra-008' was always higher in nutritive value within any given harvest interval and yield within harvest interval was not different from non-RL alfalfa. Furthermore, it can be harvested 5-10 d later and still have similar to better nutritive value and similar yield as non-RL cultivars harvested earlier, suggesting that alfalfa producers have more flexibility with RL alfalfa when making harvest timing decisions. The original PEAQ equations were acceptable for predicting forage NDF in the RL alfalfa cultivar we tested. The project is funded in part by Forage Genetics.

3. The Ohio State University is part of a three state (TN, NC, OH) collaborative study to characterize nutritive value and forage yield of alfalfa grown in monoculture and in mixtures with tall fescue and bermudagrass under four harvest frequencies (21, 28, 35, and 42-day cutting intervals). The study was established in TN and OH in 2015 and data was collected in and is being collected in 2017. Plots were established at NC in 2016. In Ohio in 2016, there was no species treatment x cutting interval interaction. Pure stands of alfalfa yielded 4.7 and 5.6 Mg ha^{-1} more ($P < 0.05$) than alfalfa with bermudagrass and tall fescue, respectively, over the 2016 growing season. The 21-day interval had the lowest seasonal forage (8.8 Mg ha^{-1}), the 35-day interval was had the highest forage yield (12.5 Mg ha^{-1}) and while the 28-day (11.6 Mg ha^{-1}) and 42-day (11.1 Mg ha^{-1}) were intermediate. The data collected will serve as a basis for grazing and harvest management recommendations that can optimize forage availability and forage nutritive value, according to region and livestock requirements. Extension programming will be developed to share results and train producers and advisors about alfalfa production and management alternatives. The project is funded by the USDA-AFRI Alfalfa and Forage Research Program.

4. The Ohio State University has collaborated with the Ohio Department of Natural Resources (ODNR), US Fish and Wildlife Service (USFWS), and Great Parks of Hamilton

County (City of Cincinnati) to collect and propagate running buffalo clover (RBC) (*Trifolium stoloniferum*) plants from natural sites in Ohio. Running buffalo clover is a federally protected, endangered legume species. Studies to date have found RBC has high shade tolerance, readily propagates by stolons, and has excellent nutritive value. Its potential as a forage species in native pastures is not known, however, insufficient plant material is available for the conduct of research studies. During 2017, we procured 20-25 RBC stolons from each of three sites in Ohio, and successfully cloned 914 plantlets from these stolons. Some of these plants (628) were replanted back to the original sites from which the germplasm was obtained. The experimental design for the replanting included the effects: i) season (fall-17 vs spring-18), ii) plant size (small vs large), iii) fertilizer (+ vs none), iv) genotype, and v) location, and the associated interactions. In a second study, 131 plants from the three Ohio populations were stratified over winter, and during spring were placed adjacent to three beehives, and seed harvested. Plants produced 14-20 flowers per plant, and an average of 16 seed/flower. In a third study, 156 plants for Ohio were used to characterize three Ohio populations, and 5 accessions originated from Kentucky.

5. A new study by PhD student Georgia Bascherotto Kleina, aims to provide insight to farmers in developing best management practices for a rye winter cover crop (WCC) in continuous soybeans. The objectives are to investigate the effect of different rye WCC planting and termination dates on the soil water content during the subsequent growing season, N uptake and release by the rye WCC, and subsequent soybean plant stress, N status, and yield under no-tillage soil management. The associated hypotheses are:

i. a rye WCC will decrease excessive soil moisture during the spring and increase soil N during the summer compared with a continuous soybean system with no cover crop;
ii. a late terminated rye WCC will reduce excessive soil water content in the spring more than the early terminated rye; but soil water storage during summer might be reduced to the point of causing soybean water stress if soil water is not replenished by sufficient rainfall. Therefore, a late terminated rye WCC will have positive impacts on soybean establishment and early growth but will cause negative impacts on soybean plant stress and yield in dry years;
iii. a higher N concentration and lower C:N ratio of the early terminated rye WCC will result in a faster N release in the soil. Therefore, it will increase N availability for soybean uptake, soybean plant N status, grain protein content, and grain yield.

5. Impact Statements

Results of a six-state collaborative study evaluating alfalfa with reduced lignin concentrations demonstrated that this trait improves the fiber digestibility of the harvested forage compared with standard cultivars, which will lead to improved ruminant livestock productivity. The reduced lignin trait will widen the period of time when it is possible to harvest the crop with adequate nutritive value to support high animal productivity, thus reducing losses in animal gains due to poor forage quality and potentially improving the economic sustainability of alfalfa-based forage systems.

5. Published Written Works

Refereed Journal Articles

Schuster MZ; Pelissari A; de Vioraes A; Harrison SK; Sulc RM; Lustosa SBC; Anghinoni I; Carvalho PCF. (2016). Grazing intensities affect weed seedling emergence and the seed bank in an integrated crop-livestock system. Agriculture Ecosystems & Environment, 232:232-239, doi: 10.1016/j.agee.2016.08.005

Lindsey, A.J., P.R. Thomison, D.J. Barker, and J.D. Metzger. 2017. Evaluating water exclusion using plastic ground cover in maize at two population densities. Agron J. 109:1-9.

R. Tirado-Corbala, B.K. Slater, W. Dick, D. Barker. (2017) Alfalfa Responses to Gypsum Application Measured Using Undisturbed Soil Columns. Plants. doi:10.3390/plants6030029 http://www.mdpi.com/2223-7747/6/3/29/pdf

Chapters

R. Mark Sulc, David J. Barker and Kelley Tilmon. 2017. Chapter 7 Forage Production. *In* Ohio Agronomy Guide, 15th Edition. Bulletin 472 The Ohio State University Extension. Pp 86-113.

R. Mark Sulc and David J. Barker. 2017. Chapter 9 Pasture and Grazing Management. *In* Ohio Agronomy Guide, 15th Edition. Bulletin 472 The Ohio State University Extension. Pp 118-127.

A. Lindsey, David J. Barker and R. Mark Sulc. 2017. Chapter 11 Conducting On-Farm Research. Agronomy Guide Ohio Agronomy Guide, 15th Edition. Bulletin 472 The Ohio State University Extension. Pp 131-139.

Bulletins and Extension Factsheets
J.S. McCormick, R.M. Sulc, D. J. Barker. 2017 Ohio Forage Performance Trials. (Dec 2017). (Published).
Popular Articles
1. Sulc, R.M. (2017). How often should you cut alfalfa? [Popular press]. Farm & Dairy Magazine. Farm & Dairy Magazine, 2017-12-14

2 Sulc, RM. (2017). Dangers of harvesting and grazing certain forages following frost. C.O.R.N. Newsletter, edn: 2017-34

3. Hay & Forage Grower, (2017). When frost and grazing don't mix [Article]. Hay & Forage Grower Online. Hay & Forage Grower Online, Start date: 2017-10-24,
4. Lewandowski, R.; Sulc, M. (2017). Last alfalfa cutting and risk management. Ohio's Country Journal

5. Lindsey, A.J.; Sulc, R.M.; Watters, H. (2017) Cover crops following wheat harvest in

grain rotations. [Newsletter]. Columbus, United States: Ohio State University Extension. CORN Newsletter, vol.: 2017-25

6. Lewandowski, R.; Sulc, M. (2017). August establishment of perennial forages. [Newsletter]. Columbus, United States: Ohio State University Extension. CORN Newsletter, vol.: 2017-25

7. Lindsey, A.; Sulc, M.,; Thomison, P. (2017) Crops under water – crop stage is critical for recovery. [Newsletter article]. OSU Extension. C.O.R.N. Newsletter, ed.: 2017-22
Hartschuh, J.; Sulc, R.M.; Noggle, S.; Dugan, D. (2017). Hay and straw barn fires a real danger [Newsletter article]. OSU Extension.

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Agronomy Abstracts. J. Craft, A. Lindsey, L. Lindsey, D. Barker. (2017) Quantifying Foliar Nitrogen Effects on Soybean Relative Maturity, Grain Yield, and Grain Quality. ASA Tampa FL. Nov 2017

Alt, D.S.; Lindsey, L.E.; Lindsey, A.J.; Sulc, R.M. (2017). Quantifying Spring Freeze

Damage to Field Acclimated Winter Wheat and Potential Yield Impacts. [Abstract]. ASA, CSSA, and SSSA Annual Meeting Abstract.

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6. Scientific and Outreach Presentations

7. Collaborative Grants

Nave, R., Bates, G., Mulliniks, J., Barker, D., Sulc, M., Johnson, J. Nutritive value and forage accumulation of alfalfa and alfalfa-mixtures as influenced by forage management. Univ. of Tennessee Sub award 850042854 through USDA-NIFA prime award 2014-70005-22538. September 2014 – June 2017. $33,150.

Lamp, W.P., Sulc, R.M., Albrecht, K.A. Potato leafhopper threshold revised for alfalfa host resistance and alfalfa-grass mixture. USDA-NIFA subcontract through Univ. of Maryland ($58,527). Award 2015-70005-24078 (full award $215,000). 9/1/2015 – 7/31/2018.

Richard L. Gardner, David Barker & Marleen Kromer “Determining genetic diversity of running buffalo clover (*Trifolium stoloniferum*) populations in Ohio. USFWS (Section 6): July 2018-2019

Texas

NCCC-31 Report Texas A&M AgriLife Research Report
Year 2017-2018
Jamie L. Foster, State Representative to Committee

1. 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.

2. New Facilities and Equipment
Texas A&M AgriLife Research at Amarillo (J. Bell) acquired a used silage chopper (John Deere 3800 drag-type chopper with a 2-row gathering header).

3. Unique Project Related Findings
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.

4. Accomplishment Summaries
During 2017-2018, Texas A&M AgriLife Research (Bell, Foster, Kimura, Malinowski, Muir, Olson, Redmon, and Rouquette) 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 2017-2018 is included at the end of this document.

5. Impact Statements
Issue: There are no perennial cool-season grasses which are adapted, and persistent in Texas.
Action: Texas A&M AgriLife has developed a summer-dormant tall fescue line TAL-02 that will be commercialized by Grasslands Innivation, NZ, and we are in the final stage of developing 2 cultivars of orchardgrass, and 2 cultivars of perennial ryegrass.

Issue: Sorghum is more drought tolerant than corn; therefore, sorghum is a more efficient crop in semi-arid regions. There is a paucity of information on the nutritive value of sorghum silage, compared to corn silage.
Action: 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.

Issue: Fallow periods in row-cropping agriculture leave the soil prone to erosion and reduced organic matter and water holding capacity.
Action: Cotton and sorghum production is not reduced by use of cool-season legume cover crops when incorporated into strip-till cotton-sorghum rotations, water footprint is still under long-term evaluation.

Issue: Improvement in livestock production can only occur by improvements to the quantity and quality of forages in the diet. Warm-season perennial grasses are the mainstay of livestock production in Texas; however, these are typically lesser in quality than cool-season grasses.
Action: We have generated data on relatively new warm-season annual forage, teff, for the forage producers in the Rolling Plains of Texas.

Contact:
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Cooperators: Bell, Kimura, Malinowski, Muir, Olson, Redmon, and Rouquette

6. Published Written Works

Book Chapters

Bell, J.M., R.C. Schwartz, K.J. McInnes, Q. Xue, and D. Porter. 2017. Improving Water Management in Sorghum Cultivation. In W. Rooney ed. Achieving Sustainable Cultivation of Sorghum Volume 1. ISBN-13: 9781786761200

Refereed Journal Articles

Aiosa, M., C.L. Morgan, V. Corriher-Olson, R.W. Jessup, A.C. Somenahally, G.R. Smith, C.B. Neely, and F.M. Rouquette. In preparation. A Double Cropping System Evaluating Cowpea as a Cover Crop and N Transfer to Forage Rye. Forage and Grazinglands.

Apolinário, V.X.O., J.C.B. Dubeux, Jr., M.A. Lira, A.C.L. Mello, M.V.F. Santos, J. P. Muir and S. Oliveira de Amorim. 2017. Nitrogen and grazing affect napier grass leaf litter biomass and decomposition. Agron. J. 109:2982-2987.

Belesky, D.P., and D.P. Malinowski. 2016. Grassland communities in the USA and expected trends associated with climate change. Acta Agrobot. 9(2). DOI: http://dx. doi. org/10. 5586/aa. 1673.

DeMilto, A.M., M. Rouquette, Jr., U.G. Mueller, K. Kellner, and J.N. Seal. 2017. Effects of substrate, ant and fungal species on plant fiber degradation in a fungus-gardening ant symbiosis. J. Insect Physiol. 98:301-308. doi: 10.1016/j.jinsphys.2017.02.001.

Dubeux, J.C.B., Jr., J.P. Muir, V.X.O. Apolinário, P.K. Ramachandran Nair, M.A. Lira, and L.E. Sollenberger. 2017. Tree legumes: an underexploited resource in warm-climate silvopastures. Revista Brasileira de Zootecnia 46:689-703.

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Foster, J.L., J.P. Muir, R. Bow, and E. Valencia. 2017. Biomass and nitrogen content of fifteen annual warm-season legumes grown in a semi-arid environment. Biomass & Bioenergy. 106:38-42.

Garcia, E.M., N. Cherry, B.D. Lambert, J.P. Muir, M.A. Nazareno, and J.I. Arroquy. 2017. Exploring the biological activity of condensed tannins and nutritional value of native tree and shrub leaves of the Argentinean Dry Chaco. J. Sci. Food Agric. 97:5021-5027.

Javed, S., S. Rauf, J. Paderewski, D.P. Malinowski, U. Saleem, M. Shahzad. 2016. Evaluation of Egyptian clover (Trifolium alexandrinum L.) germplasm through redundancy analysis for forage yield and its components. Crop Sci. 56:1179–1188.

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Jessup, R.W., R.R. Klein, B.L. Burson, S.C. Murray, J.D. Washburn, J.J. Heiholt, and J.L. Foster. 2017. Registration of perennial Sorghum bicolor × S. propinquum line 'PSH12TX09'. J. Plant Reg. 11:76-79.

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Season progression, ontogenesis and environment affect *Lespedeza cuneata* herbage condensed tannin, fiber and crude protein content. Crop Science 57:515-524.

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dos Santos, M.V.F., Cunha, M.V., Dubeux Jr., J.C.B., Muir, J. P., Souza, R.T.A., Lira, M. de Andrade, Teixeira, V.I., Melo, A.C.L. 2017. Leguminosas nativas. In: IV International Congress of Sciences, Technology, Innovation and Entrepreneurship. Guaranda, Ecuador. Proc. IV International Congress of Sciences, Technology, Innovation and Entrepreneurship. pp. 277-278. Universidad Estatal de Bolívar UEB.

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Brown, M.W., L.A. Redmon, J. Zoller, and C.J. Huseman. 2017. The Lone Star Healthy Streams Program: Bacterial Runoff Associated with Horses. Annual Meeting of the American Society of Agronomy. 22-25 Oct, Tampa, FL.

Carabajal, L., M.J. Starek, J.L. Foster, and M. Clayton. 2017. Evaluation of UAS-based remote sensing for measuring forage properties at an experimental rangeland. 2017 Texas UAS Summit, Dallas, TX, May 9-10. (Abstr.)

Clayton, M.K., A.M. Young, L.A. Redmon, and F.S. Smith. 2017. Using Goals and Profitability to Determine What to Plant in Pastures. National Wildlife Federation - America's Grassland Conference. 14-16 Nov, Fort Worth, TX.

DeLaune, P., P. Mubvumba, K. Lewis, and J.L. Foster. 2017. Improving soil health and water dynamics in deficit-irrigated agriculture. Conservation Innovation Grants (CIG) Showcase at the SWCS Annual Conference, Madison, WI, Jul. 31. (Abstr.).

Hilaire, S., B. Bellow, J. Brady, J.P. Muir, J. Speshock. 2017. Impact of Antibiotics and Manure on Uptake and Fate in Greenhouse grown Bermuda grass (Tifton85). Poster session presented at The National council for Science and the Environment's 17th National Conference and Global Forum on Science, Policy, and the Environment: Integrating Environment and Health, Washington, D.C., 24-26 January 2017. Poster 13.

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Maeda, A., J.L. Foster, and K.L. Lewis. 2017. Quantifying sustainability using the Fieldprint® Calculator. ASA-CSSA-SSSA 2017 International Meetings, Tampa, FL, Oct. 22-25. (Abstr.)

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cultivars. 2017 ASAS-CSAS Annual Meeting, Baltimore, MD, Jul. 8-12. J. Anim. Sci. 95(4): 138-138. (Abstr.)

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Extension Publications

Clayton, Megan, K., A. Mac Young, Larry A. Redmon, and Forrest S. Smith. 2017. Using Goals and Profitability to Determine What to Plant in the Pasture. ERM-033

Clayton, M.K., J.L. Foster, K.C. McCuistion, T.W. Teinert, and M.M. Lesak. 2017. Introduced bluestem grasses: Management on Native Lands. Texas A&M AgriLife Extension, ERM-036.
Kimura, E., J. Bell, C. Trostle, and C. Neely. 2017. Winter Wheat Management Calendar for the Rolling Plains and High Plains of Texas. ESC-048.

Popular Articles

Bechtel, W., and V. Corriher Olson. 2017. Annual forages help extend winter grazing, especially for hurricane flooded pasture. Drovers. Oct. 11.Gresham, L., J. Bell, and K. Ledbetter. 2017. Sorghum silage field day adds nutritional education to crop production. 9/19/2017

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Russell, A., and V. Corriher-Olson. 2017. Options to address ryegrass for warm-season forage production. AgriLife Today. Feb. 4.

Smith, W. B., and M. Rouquette, Jr. 2017. Supplement evaluation for stockers grazing bermudagrass. Progressive Cattleman. Vol. 7. Iss. 4. p. 23-25. Progressive Publishing, Jerome, ID.

7. Scientific Outreach Presentations

Bell, J., T. McCollum, E. Bynum, R. Schnell, D. Pietsch, P. Sirmon, B. Finch and C. Naylor. 2018. 2017 Texas Panhandle Forage Sorghum Silage Trial.

Bell, J., T. McCollum, E. Bynum, R. Schnell, D. Pietsch, P. Sirmon and C. Naylor. 2017. 2016 Texas Panhandle Forage Sorghum Silage Trial.

Clayton, M., Foster, J.L., and M. Starek. 2017. 47th Annual Vegetation Management Conference. Drones and Managing Pesticide Applications. Houston, TX. Jan. 19-20, 2017.

Foster, J.L. 2017 Field-to-Market: Overview and Demonstration. Texas/Oklahoma Cotton Physiology Meeting. College Station, TX. Jan. 31-Feb. 2, 2017.

Foster, J.L. 2017. KR and Kleberg Bluestem Management. Texas Standard. Statewide syndicated radio show. Recorded Dec. 7.

Foster, J.L., and M. Clayton. Remote Sensor Applications to Forages and Rangelands. Texas A&M UAS Working Group Annual Meeting. Jan. 12, 2017.

Foster, J.L. 2017. Forages of South Texas Update. Texas Pasture and Forage Work Group. College Station, TX, Jan. 10.

Foster, J.L. 2017. Remote Sensor Applications for Forage and Rangeland Management. Seminar Series at Texas A&M AgriLife Research-Corpus Christi. Corpus Christi, TX, Jun. 12.

Foster, J.L. 2017. Legume Haying and Grazing in South Texas. Grass Growers Continuing Education Unit Event. Texas A&M AgriLife Extension of Nueces and San Patricio Counties. Robstown, TX, Mar. 14.

Kimura, E. 2017. Annual forage management. Red River Crops Conference. Jan 25, 2017.

Kimura, E. 2017. Soil compaction in pasture system. Comanche soil program. Feb. 23, 2017.

Kimura, E. 2017. How much forage do I have? ESSM Webinar. Apr 6, 2017.

Kimura, E. 2017. Wheat variety and trial update at Haskell co. Apr 7, 2017.

Kimura, E. 2017. Wheat variety and trial update at Baylor co. Apr 28, 2017.

Kimura, E. 2017. Wheat variety and trial update at Taylor co. May 5, 2017.

Kimura, E. 2017. Wheat variety and trial update at Foard co. May 10, 2017.

Kimura, E. 2017. Wheat variety and trial update at Wilbarger co. May 11, 2017.

Kimura, E. 2017. CEA training on forage management. Jun 28, 2017.

Kimura, E. 2017. CEA training on forage management. Jul 31, 2017.

Kimura, E. 2017. Wheat management update. Wilbarger co program. Aug 8, 2017.
Kimura, E. 2017. How much forage do I have? Cooke co. program. Oct 12, 2017.

8. Collaborative Grants between Stations and Members Awarded in 2017

Adams, C., B. Pinchack, **E. Kimura**, J. Bell, A. Somenahally, and S. Park. Introducing organic to producers of grain-only and pasture-grain wheat cropping systems of northern Texas. 2018-2021.

Bell, J., J. Jennings, and T. McCollum. 2017. Optimizing Starch Availability in Forage Sorghum Silages - Hybrid Selection Based, Harvest Stage, Kernal Processing, and Duration of Ensiling. (Bell, $60,400)

Bell, N.L., J. Foster, V. Olson and J. Banta. 2017. TExAS Scholar Program: Teaching with Experiential learning in Animal Science. USDA/NIFA/AFRI ELI. (Collaborator). $299,856.

Bellows, B., J.P. Muir, and J. Brady. 2017. NLGCA-NIFA. Capacity Building for Soil-Plant-Animal Interaction Research and Education. 2018-2020. Total awarded: $300,000.

Bynum, E. and J. Bell. 2018. Sugarcane Aphid Damage Potential to Yield and Silage Quality from Different Infestation Levels on Forage Sorghum for the Texas High Plains, Texas Grain Sorghum Board. ($20,000)

Corriher-Olson, V. and Banta, J.P. 2017. Natural Resource Management for Sustainable Agriculture in East Texas. Southern Region SARE Professional Development Program. (PI). $42,773.

Foster, J.L., G. Morgan, K. Lewis, J. McGinty, P. DeLaune, J. Bell, A. Maeda, and J. Landivar. 2017. Texas Field to Market Project. Texas A&M AgriLife Research. Primary Investigator. $10,000.Malinowski, D.P., Butler, T.J. et al. 2017. Agronomic evaluation of small grains mixtures. Co-PI. Grantor: Noble Research Institute. Amount: $17,000.

Foster, J.L., G. Morgan, K. Lewis, J. McGinty, P. DeLaune, J. Bell, A. Maeda, and J. Landivar. 2017. Texas Field to Market Project. Cotton Incorporated. Primary Investigator. $10,000.

Kimura, E. and P.B. DeLaune. 2017-2018. Support of Texas Wheat Extension Program in the Rolling Plains. $11,000. Texas Wheat Producers Board.

Lewis, K, J.L. Foster, H. Neely, A. Somenahally, M. Maeda, P. DeLaune, J. Jung, C. Neely, and M. Welch. 2017. A novel approach for evaluating the impact of cropping systems on crop productivity and the soil microbiome by linking UAS-data to soil health indicators. Texas A&M AgriLife Research Cropping Systems Program. Co-Investigator.

$200,000; $8,250 for program.

Muir, J.P., J.L. Foster & L.O. Tedeschi. 2017. Texas A&M AgriLife Research Livestock initiative. Mitigating methane emission from beef operations. Total awarded: $90,000.

Neely, H., C. Neely, K. Lewis, and J.L. Foster. 2017. Improving soil health with novel wheat double-cropping rotations under reduced tillage. Texas NRCS. Co-Investigator. $30,000; $8,729 for program.

Utah

NCCC-31 Ecophysiological Aspects of Forage Management
26-27 June 2018, Fayetteville Arkansas
Utah Report

Impacts:
There are significant concerns regarding the global environmental costs associated with livestock production such as methane and nitrogen losses to the environment. Consumers seek grass-finished beef that does not employ hormones and antibiotics, but the extra time required for grass-finishing increases negative environmental impacts and beef gains on grass are slow and result in less juicy, less tender meat. The significance of the present study of legume-finished beef to US beef producers is that alternative bioactive tannin-containing hays have the potential to increase average daily gain of cattle finished on pastures to a feedlot-finished timeframe while reducing methane and nitrogen emissions to the environment. The resulting meat has the beneficial fatty acids of grass-finished beef but is as juicy and tender as grain-finished beef. The increased rate of gain results in improved profitability for ranchers finishing beef locally on perennial legume pastures.

Accomplishments:
In a project titled "***Optimizing Inputs for Forages and Field Crops In Utah"*** led by Earl Creech, dryland wheat yields averaged 1062 to 2165 kg ha^{-1} in plots treated with 0 and 50 Mg ha^{-1} compost, respectively. Cover crops used as a source of organic matter did not influence wheat yield in any way. Understanding differences in crop response to compost among sites will allow the economic viability of compost application to be determined.

In a project titled "***Scaling Up Soil Quality Assessment and Sustainable Production at Local, Landscape and Regional Levels***" led by Dr. Jennifer Reeve, compost applications increased soil carbon while manure increased soil nitrogen. In an orchard floor experiment, alleyways planted to birdsfoot trefoil significantly increased soil carbon and nitrogen and increased nutrient cycling potential in the tree-rows compared to tilled soil or other cover crops. The tillage treatment had the lowest measured soil health indicators.

Projects titled "***Employing Forage Legumes to Improve the Sustainability of Ruminant Production,***" led by Dr. Jennifer MacAdam and two related projects led by Dr. Juan Villalba, ***Legume-Finished Beef: Achieving Current Production with Greater Environmental, Economic and Social Sustainability*** and ***"Tannin-Containing Legumes in Pasturelands and their Ecological Services"*** are leading to the development of a transformative beef production system in which cattle are fed and finished on tannin-containing legumes. For the finishing phase, calves finished on tannin-containing legumes or choices among tannin-containing legumes have greater liveweight gains and lower methane and nitrogen losses than calves finished on grass monocultures. In a study of cows and heifers fed tannin-containing hays, the concentrations of condensed tannins were lower than values observed in fresh forages of the same species. However, these hays maintained their bioactive properties. Methane (CH4) emissions from cows and heifers were lower for cattle fed small burnet, which contains hydrolysable tannins than for other treatments, although digestibility was reduced for animals

consuming this hay. Cows and heifers fed condensed tannin-containing hays showed lower urine and blood urea nitrogen (N) than animals fed non-tannin containing hays and there was a significant increase in the excretion of fecal N with the increase in concentration of CT in feces. Feeding the tannin-containing hays sainfoin and birdsfoot trefoil, as well as the non-tannin containing legume cicer milkvetch, resulted in greater efficiencies of N utilization than for cattle fed alfalfa, small burnet or grass hays. A literature review of willingness-to-pay studies demonstrated that consumers are willing to pay a price premium to obtain locally-grown, grass-fed, eco-friendly, and animal welfare certified beef. Consumers rate freshness, taste/flavor, and tenderness as extremely important when they purchase beef. Thus, legume-finished beef should be marketed as locally-raised, econ-friendly, equally as healthy as grass-finished but tasting like grain-finished beef, based on consumer taste panel results published in 2016.

2017 Book Chapter:

MacAdam, J.W. and C.J. Nelson. 2017. Physiology of forage plants. pp. 51-70 *In* M. Collins, C.J. Nelson, K.J. Moore, and R.F. Barnes (ed.) Forages, Vol. 1: An Introduction to Grassland Agriculture, 7th Ed., Wiley Blackwell, Hoboken, NJ.

2017 Refereed Journal Articles:

Chail, A., J.F. Legako, S. Martini, and J.W. MacAdam. 2017. Consumer sensory evaluation and chemical composition of forage and conventional feedlot finished beef *Gluteus medius* and *Triceps brachii* steaks. Journal of Animal Science 95: 1553–1564.

Christensen, R., J.-S. Eun, S.-Y. Yang, B.-R. Min, and J.W. MacAdam. 2017. In vitro effects of birdsfoot trefoil (*Lotus corniculatus* L.) pasture on ruminal fermentation, microbial population, and methane production. Professional Animal Scientist 33: 451-460.

Cox, S., M.D. Peel, J.E. Creech, B.L. Waldron, J.-S. Eun, D. Zobell, R.L. Miller, D.L. Snyder. 2017. Forage production of grass-legume binary mixtures on Intermountain Western USA irrigated pastures. Crop Science 57: 1742-1753.

Creech, J. E., B.L. Waldron, M.D. Peel, S.R. Larson, I.W. Mott. 2017. Tall fescue forage mass in a grass-legume mixture: Predicted efficiency of indirect selection. Euphytica 213: 67.

Sagers, J. K., B.L. Waldron, J.E. Creech, I.W. Mott, B.G. Bugbee. (2017). Salinity tolerance of three competing rangeland pant species: Studies in hydroponic culture. Ecology and Evolution 7: 10916-10929.

Stettler, J.M., D.A. Johnson, B.S. Bushman, K.J. Connors, T.A. Jones, J.W. MacAdam, and D.J. Hole. 2017. Utah *Lotus*: North American legume for rangeland revegetation in the southern Great Basin and Colorado Plateau. Rangeland Ecology and Management 70: 691-699.

2017 Published Abstracts:

Lagrange, S., K.A. Beauchemin, J.W. MacAdam, and J.J. Villalba. 2017. Effects of grazing diverse combinations of sainfoin, birdsfoot trefoil and alfalfa on beef cow performance and environmental impacts Journal of Animal Science 95:143-144.

MacAdam, J.W., K.A. Cassida and E. van Santen. 2017. Location of growth influenced birdsfoot trefoil tannin accumulation, but few accessions differed in tannin concentration. *In* Annual Meetings Abstracts. ASA, CSSA, and SSSA, Madison, WI.

Roca-Fernández, A.I., S.L. Dillard, C.J. Dell, J. MacAdam, and K.J. Soder. 2017. Effect of oilseed source on ruminal fermentation and methane production of a grass-legume diet in continuous culture. Journal of Animal Science 95: 133-134.

Roca-Fernández, A.I., S.L. Dillard, M.D. Rubano, M. Baldin, C.J. Dell, J. MacAdam. and K.J. Soder. 2017. Modification of ruminal fermentation and methane production by adding legumes containing condensed tannins to an orchardgrass diet in continuous culture. American Dairy Science Association Annual Meeting, June 25-28, 2017, Pittsburgh, PA.
Stewart, E.K., K.A. Beauchemin, J.W. MacAdam, and J.J. Villalba. 2017. Environmental impacts from cattle consuming tannin-containing hays. Journal of Animal Science 95:133-134.

2017 Active Grants:

Utah Native Plant Society. 07/01/16-06/30/18. Developing a restoration strategy for *Eriogonum mitophyllum* Reveal. $500. MacAdam, P.I.
USDA NIFA AFRI Agroecosystem Management Program. 06/01/16-05/031/20. Tannin-containing legumes in pasturelands and their ecological services. Grant #2016-67019-25086. $499,884. MacAdam Co-P.I.
USDA NIFA AFRI Food Security Program. 02/15/16-02/14/18. Legume-finished beef: Achieving current production with greater environmental, economic and social sustainability. Grant #2016-69004-24855. $150,000. MacAdam Co-P.I.
USDA NIFA AFRI Climate and Microbial Processes in Agroecosystems program. 02/15/16-02/14/19. Microbial carbon-use efficiency in agroecosystems: The effect of drought and N availability on soil microbial production and respiration. Grant# 2016-67004-24920. $714,080. MacAdam Co-P.I.
USU Office of Research and Graduate Studies, Research Catalyst Grant. Understanding the increased omega-3 fatty acid concentration in legume-fed beef. 05/01/18-04/30/20. $20,000. MacAdam P.I.

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