**Project/Activity Number:** WERA1014

**Project/Activity Title:** Intensive Pasture Management for Sustainable Livestock Production in the Western US

**Period Covered:** 10/01/2017-09/30/2018

**Date of This Report:** 13 December 2018

**Annual Meeting Date(s):** 18-19 October 2018

**Participants**: Joe Brummer, Colorado State University

 Lynn Jaynes, Editor-Progressive Forage, Jerome, ID

 Hank Mayland, USDA-ARS Kimberly, ID (retired)

 Glenn Shewmaker, University of Idaho

 Ross Spackman, BYU Idaho and students

 Molly Hammond, Montana State University

 Pat Hatfield, Montana State University; Administrative Advisor

 Emily Meccage, Montana State University, meeting host

 Mike Schuldt, Montana State University

 Megan Van Emon, Montana State University

 Gord Pearse, Bruce Seed Farm, Townsend, MT

 Susan Tallman, USDA-NRCS Bozeman, Montana

 Mylen Bohle, Oregon State University

 Gordon Jones, Oregon State University

 Ian McGregor, Oregon State University

 Guojie Wang, Oregon State University

 Peter Ballerstedt, Barenbrug USA, Corvallis, OR

 Earl Creech, Utah State University

 Jennifer MacAdam, Utah State University

 Steve Norberg, Washington State University

 Anowar Islam, University of Wyoming

**Minutes of Annual Meeting:**

 October 18 (morning) - The meeting was held in the Animal Bioscience Building on the Montana State University campus in Bozeman, MT. Dr. Pat Hatfield, the head of the Animal and Range Sciences Department, welcomed the group and described current initiatives in beef research, teaching, and outreach. These include a 2-year internship program, a new ranch management program, the Steer-A-Year donated by producers and finished by students, registered black Angus and registered red Angus herds, a new endowed chair in Beef Science, and a new Beef Extension faculty member.

 Jennifer MacAdam (Utah State University) described an in vitro forage (whole plant and isolated fiber) fermentation study that demonstrated the rate and extent of forage digestion. Alfalfa and birdsfoot trefoil had the highest rates of whole plant fermentation, while meadow bromegrass and alfalfa were the most extensively digested. Birdsfoot trefoil and sainfoin had the greatest concentrations of non-fibrous carbohydrates, but the higher concentrations of tannin and lignin in sainfoin may have inhibited sainfoin in vitro digestion. Cicer milkvetch and birdsfoot trefoil had the greatest rates of isolated fiber digestion, while cicer milkvetch and meadow bromegrass fiber were the most extensively digested, followed by alfalfa and birdsfoot trefoil fiber. In vitro fermentation of whole plant material of the forb small burnet was initially rapid but quickly inhibited, perhaps by a significant concentration of hydrolysable tannins.

 Anowar Islam (University of Wyoming) discussed a collaborative study of potassium fertility in alfalfa that includes Kansas and Colorado. In Wyoming, Hi-Gest alfalfa appeared to respond to a higher level of potassium fertilization than conventional alfalfa. Tissue testing and stand counts will be done before the study is completed. A study of dryland and irrigated sorghum demonstrated that irrigated sorghum became chlorotic when grown on a high pH soil.

 Guojie Wang (Oregon State University) is studying water quality in relation to salmon habitat in eastern Oregon. Important factors for salmon are water temperature, flow, and water quality. The study has 20 perennial and 20 spring and fall annual forage species under four levels of irrigation (none, May 1 to June 15, May 1 to August 1 and May 1 to Sept. 15), with continuous or rotational and early- vs. late-season grazing.

 Mylen Bohle (Oregon State University) described a number of innovative and efficient center-pivot or linear move irrigation systems, including LEPA (low energy precision application).and precision manual drip irrigation (PMDI).

 Glenn Shewmaker (University of Idaho) discussed hay bale sampling. He recommends the Star Quality Probe, and normalizing forage samples for ash.

 Steve Norberg (Washington State University) is studying Struvite (crystalline magnesium ammonium phosphate) as a slow-release source of recycled phosphate for alfalfa fertilization, compared with quick-release mono-ammonium phosphate (MAP). Potassium fertility was also included in the study. Steve reported the production of metabolizable protein (55% of CP or approx. 217 lbs. metabolizable protein per ton of alfalfa hay), which is affected by forage fiber concentration. Yield is far more important than quality in the ultimate value of hay production per acre.

 Susan Tallman (NRCS Bozeman) reviewed some key points to improve soil health: minimize disturbance (e.g., no-till), keep the soil covered, keep plants growing all year, increase crop diversity to vary rooting depth and improve soil microbial diversity, and integrate livestock to return nutrients to the soil (hay mines soil nutrients). Susan described a system of interseeding annual ryegrass in silage corn to provide more soil cover and additional grazing. Shallow soil acidification caused by excessive application of ammonium fertilizers is increasingly problematic for cereal producers in Montana, and is aggravated by no-till production. Susan recommends growing RR alfalfa for 2 years to clean up weeds, then growing cereal crop to use the organic nitrogen; too much N can reduce reproductive growth in cereals.

 Joe Brummer (Colorado State University) is collaborating with Anowar on the study of potassium fertilization of alfalfa. There did not appear to be a response to potassium at the Colorado site. Potassium levels were 1, 50, 100 and 150 kg/ha, and the alfalfa was cut on a 28- or 35-day schedule. There *was* higher production with earlier cutting.

 October 18 (afternoon) After lunch, we visited with Dr. Perry Miller at the MSU Fort Ellis research plots about a long-term organic cropping systems project. The project has evolved over time, and Dr. Miller told us about problematic weeds (Canada thistle) and high-value annuals (chickpeas). Our second stop was at the Droge family potato seed farm that collaborates with MSU in the development of new potato varieties. After visiting the farm, we toured a potato packing facility and learned about storing, sorting and boxing fresh potatoes for shipment. We also learned that the perfect baking potato weighs 7 oz. A new Droge family enterprise is the Dry Hills Distillery, where Jeff Droge explained the process of establishing the distillery, developing a range of products in addition to vodka, distilling grains for other producers to increase income, and the challenges associated with distilling ethanol from fresh potatoes rather than from potato flakes. We had a catered dinner at the tasting room.

 October 19 (morning) – Dr. Tim DelCurto, the Nancy Cameron Chair and Professor at Montana State University, discussed his research program which aims to optimize the use of western rangelands. Montana has 1.5 million mother cows (20% of the US cow-calf inventory) but no feedlot or packing industry. The growing season is 90-100 days, so ranchers need to provide 1.5 to 3 tons of harvested forage per cow. DelCurto’s program focuses on extended, ecologically sustainable grazing to reduce the need for hay. Native grasses evolved to be grazed every 2-3 years and supplementation is needed to optimize fetal programming. Some specific proposed approaches are precision-supplementation with alfalfa hay, limiting the salt ingested in supplements, and delivering individual protein supplementation and salts at feeding stations that use EID ear tags. A weaning weight ratio study demonstrated that smaller cows (1100-1200 lbs.) consumed more feed and were no more efficient than larger cows (1300-1400 lbs.).

 Dr. Kevin Wanner, MSU entomologist, discussed a western regional alfalfa weevil project seeking to improve degree-day models to improve management.

 Earl Creech (Utah State University) has studied the impact of Roundup on Roundup Ready alfalfa to increase yield. Application rates were 22 and 44 oz/ac, and there were hand-weeded and herbicide (Gramoxone + Sencor) controls. Roundup treatments were applied at 2, 4, 6 or 8 inches (March 22, April 16, April 31 and May 4, respectively), and the study was carried out for 2 years. Based on results, spray the lower rate of Roundup as early in the spring as possible for better weed control and minimal yield reduction.

 Gordon Jones (Oregon State University) from the Southern Oregon Research & Extension Center is working with small-scale producers in a Mediterranean climate with 16-18 inches of annual precipitation. An orchardgrass study in which vegetative regrowth was cut 3 time per year at 2, 4, 6, or 8 inches demonstrated a linear relationship of dry matter per tiller with log10 tiller density; tiller weight decreased as tiller density increased in response to decreasing cutting height.

 Ian McGregor (new faculty at Montana State University) is sampling forages to determine the need for mineral supplementation and was interested in input from the group. Suggestions included tissue testing and tips on working with the forage testing lab to reduce the cost per sample.

 Emily Meccage (Montana State University) reported on studies of boron-irrigation interactions, sulfur fertility, and a new sainfoin variety x maturity trial. Emily will sample sainfoin at 10, 50 and 100% bloom for condensed tannin concentrations and effectiveness against internal parasites. Emily also updated the group on the nitrate strip test as a replacement for the nitrate quick test. The strip test was 73% accurate and less subjective than the quick test. There is a new Montana Extension fact sheet comparing methods for nitrate testing. Emily also reported on production trials of annuals alone and in complex mixtures. Radish, canola, turnip were higher in nitrates than oats; millet, soybean and chickpea were also high in nitrate. Emily will continue in her position at Montana State University, but is relocating to Miles City as of January 1, 2019.

 Peter Ballerstedt from Barenbrug, a family-owned seed company founded in the Netherlands, talked about new products, including Rangeshield, a seed coating for rangeland species that improves germination and establishment; a stoloniferous perennial ryegrass; rhizomatous tall fescue that can spread 1 foot in a year; and beneficial endophytes for tall fescue, perennial ryegrass and meadow fescue. Barenbrug will be marketing the successor to Cache meadow bromegrass, called Arsenal. Peter also discussed the benefits of a diet high in meat and saturated fat compared with a carbohydrate-centered diet.

 Business meeting: Pat Hatfield has agreed to serve as our new administrative advisor (yay!). Tentative plans are for the University of Idaho to host our 2019 meeting in Salmon, ID and for Washington State University to host our 2020 meeting. Joe Brummer will continue to serve as chair and Jennifer MacAdam will continue to serve as secretary for the next year.

**ACCOMPLISHMENTS AND IMPACTS**

**Colorado Accomplishments and Impacts**

Completed the second year of data collection on a study looking at the effects of increasing rates of potassium fertilizer on yield and nutritive content of 2 varieties of alfalfa (conventional and low lignin) harvested on 2 different schedules (normal 10% bloom and delayed when the plants reach 25 to 50% BLOOM). This is a cooperative project between the University of Wyoming, Colorado State University, and Kansas State University. Results from Colorado indicate that total seasonal yields are higher when the alfalfa is harvested on the normal schedule. When harvested on the delayed schedule, the last cutting is taken in late September which is too late for the plants to be able to replenish carbohydrate reserves before winter dormancy. This has resulted in lower vigor, disease issues, and loss of stand in the alfalfa harvested on the delayed schedule which has contributed to the lower total seasonal yields measured in those plots. If harvesting on the delayed schedule (i.e. about every 35 to 38 days), then producers should consider only cutting 3 times instead of the normal 4 to avoid impacts of that late season harvest.

Completed the first full year of data collection on an irrigated pasture study looking at the response of 4 different grass and grass-legume mixtures to management intensive grazing. A wide array of soils data is being collected as this field transitions from agronomic crops to perennial pasture. One of the biggest changes associated with the soil measured in the first year has been a doubling of the microbial biomass and activity. This has major implications for nutrient cycling, building organic matter, and contributing to soil aggregate stability. This is a long-term project in which we will continue to quantify changes in numerous soil variables as well as forage yield, nutritive content, species composition, and ground cover.

A 2-day irrigated pasture field day and workshop was held the first of October 2018. There were about 65 in attendance on the first day in which we toured the irrigated pasture project and discussed research findings to date as well as management issues that arose during the grazing season. The second day was more of a hands-on workshop with about 20 in attendance in which participants built a small section of high-tensile fence and learned different methods to collect yield data and how to use that information to calculate stocking rates and densities. The workshop was well received by those in attendance and more in-depth workshops are planned for the future that will span several days.

**Idaho Accomplishments and Impacts**

Organized educational programs for Idaho Hay and Forage Conference (100 participants) and Western Alfalfa and Forage Symposium (400 participants). Organized and trained 20 participants in 4-day Lost Rivers Grazing Academy.

**Montana Accomplishments and Impacts**

The goals of the forage research program at MSU are to develop and improve best forage management practices to optimize overall forage production, which in turn will optimize livestock production in a sustainable and productive manner. Several current projects are evaluating methods of integrating livestock grazing into cropping systems, and how this can impact soil health as well as overall productivity.

Other projects are looking at optimal forage species to grow in different environments found throughout the state of Montana, including both annual and perennial forages. We are also evaluating methods of pest control, particularly targeting the alfalfa weevil and methods of scouting and control. Additionally, we are looking at current management practices such as winter grazing of alfalfa or spring tillage, and how this can impact production.

Several other projects are aimed at evaluating fertilization practices, and creating recommendations for our specific management practices and environment. Boron was the first nutrient that was evaluated in alfalfa, and now we are working on evaluating sulfur fertilization in tame cool-season perennial forages. Information from this project will be provided to producers in order to optimize fertilization that better targets plant needs, while improving nutrient availability to animals.

**Oregon Accomplishments and Impacts**

Overall: Oregon State University extension office initiated “Grazing and Forage” working group. The mission of this working group is to plan, coordinate, and collaborate among different county, region, and discipline research and outreach professionals working together with a priority list. With this effort, Oregon State will have a single and centralized website about “Grazing and Forage” topics. It will simplify producer’s information search and build a better connection between research and outreach efforts. OSU Extension Service decided we needed to reconstruct our Websites. Dr. Wang revised some forage content. Work is continuing, but it is currently somewhat difficult to navigate and lacks the necessary content to be effective for faculty and clientele. See <https://extension.oregonstate.edu/crop-production/pastures-forages>

Research: 1) Research on novel forage species, especially legumes to diversify forage production bases as well as research on renovated grazing systems such as sequential grazing by Dr. Serkan Ates and his group lead to increased livestock gain, extended grazing season, and increased farm/ranch profitability. 2) Research on Se deficiency and fodder beets by Dr. Shelby Filley advocate Se fertilization to forage and adoption of fodder beets as fall/winter grazing forages. 3) Research on modeling forage species ecoregion adaptation and matching the right forage species with specific pasture situations by Dr. David Hannaway and his group has an international impact as well as Oregon impact. With the on-line tool development, producers could make a scientific based decision and foster all the novel species and management practices adoption rates. 4) Research on N, P, K, Se, and Ag lime management and clipping intensity by Mylen Bohle and his group lead to fine-tuning practical forage management recommendations and increased forage production and quality. 5) Research on forage production with limited irrigation water by Dr. Guojie Wang and his group finds a balance between agricultural production and ecosystems services including wildlife and fish habitats.

Outreach: 1) Multiple locations outreach on Forage Production and Management coupled with new technology such as Box and other online forms by Dr. Shelby Filley continued to deliver profession help to regional producers. 2) Diverse activities including Forage Seminar, Hay King Contest, Field Days, and Grazing Class by Mylen Bohle keep communicating and educating producers and stakeholders with newly developed knowledge and information. 3) Field survey about trace mineral levels related to livestock supplements by Ian McGregor will renew supplemental requirement recommendations and save money for producers.

**Utah Accomplishments and Impacts**

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. The significance of this study 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.

**Washington Accomplishments and Impacts**

Optimum P alfalfa tissue phosphorus content based on the first year of the experiment should be between 0.24-0.28 and 0.25-0.29% when the price of alfalfa hay is $150 and $200 per ton, respectively.

First year data show that struvite can be used alone or in combination with monoammonium phosphate (MAP) when put on prior to planting and incorporated without a yield loss even on a soil averaging 8.1 ppm P (Olson Method).

Excessive phosphorus or potassium has a negative effect on hay quality and can affect aNDF, lignin, RFV, RFQ, and the nutrient value of the hay ($/ton).

**Wyoming Accomplishments and Impacts**

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

Demand for new and suitable plant materials is a long-term issue and is increasing continuously especially in the Intermountain West regions. The objective of this study is to evaluate different advanced lines of C3 grasses with the inclusion of some local checks in relation to their growth, yield, and quality response to irrigation, drought, and planting time. Species used in this study include tall fescue (seven lines), tall wheatgrass (three lines), western wheatgrass (five lines), and wildrye (two lines). Data collected on different growth parameters, persistence, and forage quality from 2009 - 2018 seems to be different among species and lines. Long-term data collection will help select and develop superior and well-adapted cultivars.

**PRESENTATIONS**

**Colorado Presentations**

Brummer, J.E. Colorado Forage Research Overview: From Dryland Cover Crops to Irrigated Pastures. Field Research Center Seminar, Lincoln University, Lincoln, NZ, March 21, 2018.

Brummer, J.E. Cover Crops for Forage: Importance, Establishment, Management, and Utilization. Wyoming Forage Field Day, Lingle, WY, June 12, 2018.

Brummer, J.E. Alfalfa: Importance and Uses. Colorado Ag. Water Alliance Summer Tour, Sterling, CO, July 12, 2018.

Brummer, J.E. Management-intensive Grazing: Grazier’s Math. CSU Beef Cattle Field Day & Pasture School, Fort Collins, CO, October 4-5, 2018.

Brummer, J.E., L. Jones, P. Cabot, C. Pearson, and A. Berrada. Agronomic Responses of Grass and Alfalfa Hayfields to No or Partial-Season Irrigation as Part of a Potential Colorado Western Slope Water Bank. CSU Ag. Exp. Station Water Research Update, Steamboat Springs, CO, October 16, 2018.

**Idaho Presentations**

Sagers, J.; Findlay, J.R.; Shewmaker, G.E.; Roemer, R.; and Jensen, K. Idaho grass trials—Tetonia, Proceedings Idaho Hay and Forage Conference — March/2018

Shewmaker, G.E. Hay Quality Loss during Storage, American Forage & Grassland Council Annual Meeting, 16 January 2018, Louisville, KY

Shewmaker, G.E. Balancing Rations on Pasture using NIRS, NIRS Consortium Workshop, 16 January 2018, Louisville, KY

Shewmaker, G.E. Hay Quality: Sampling, Analyzing, and Interpretation, Wyoming Forage Field Day, 12 June 2018, Lingle, WY

Shewmaker, G.E. The Hay Quality-Yield Tradeoff, Arizona Alfalfa & Forage Workshop, 28 March 2018, Maricopa, AZ

Shewmaker, G.E. Idaho Forage Report, Northwest Forage Workers Conference, 30 November 2017, Reno, NV

Shewmaker, G.E. Definitions and Range of Variability for Hay Test Parameters, Western Alfalfa & Forage Symposium, 28 November 2017, Reno, NV

Shewmaker, G.E. Agronomic Influences on Forage Quality, Western Alfalfa & Forage Symposium, 28 November 2017, Reno, NV

Shewmaker, G.E. Interpreting Hay Test Results, Western Alfalfa & Forage Symposium, 28 November 2017, Reno, NV

Shewmaker, G.E. Forage Pesticide Management during Drought, North Idaho Forage & Grazing School, 30 Oct. 2018, Naples, ID

Shewmaker, G.E. Alfalfa Variety Trials, NMCREEC Twilight Open House, 6 September 2018, Carmen, ID

Shewmaker, G.E. Forages of Southern Idaho, Ecology of Grazing Lands Class, 23 July 2018, Jerome Co., ID

Shewmaker, G.E. Forage Industry and Research, Ag in the Classroom, Kimberly R&E 2017

Shewmaker, G.E. Forages, Twilight Tour, 18 July 2018, Kimberly R&E Center

Shewmaker, G.E. Idaho Forage Trends and Survey, Idaho Hay & Forage Conference, 2 March 2018, Burley, ID

Shewmaker, G.E. Hay Storage Losses and Costs, Idaho Hay & Forage Conference, 1 March 2018, Burley, ID

Shewmaker, G.E. Idaho forage Outlook, Cooper-Norman Ag Outlook Seminar, Twin Falls

Shewmaker, G.E. IPM for Controlling Rodents in Hay and Pasture, N ID Forage School, 6 November 2017, Bonners Ferry

Shewmaker, G.E. Hay Sampling & Testing, N ID Forage School, 6 November 2017, Bonners Ferry

**Montana Presentations**

Meccage, E. June 21, 2018. **Hay Field Evaluation.** Musselshell County**.** Methods of assessing hay fields, and how to determine productivity or need to renovate.50 attendees.

Meccage, E. June 21, 2018. **Annual forages for drought.** Hill County**.** Options for annual forage production in drought situations, including what species to use and when, and what are some anti-quality factors to consider.100 attendees.

Meccage, E. June 19, 2018. **Hay Storage and Forage Options.** Deer Lodge County**.** Dealer Awards Event for CHS dealers across the Western part of the state.46 attendees.

Meccage, E. May 17, 2018. **Forage Management: Nitrates and Hay Storage.** Blackfeet Reservation**.** Importance of hay storage and nitrates in animal performance and forage management. 28 attendees.

Meccage, E. October 4, 2018. **Annual forages for MT.** Yellowstone County**.**100 attendees.

Meccage, E. September 26, 2018. **Forage quality interpretation and analysis.** Gallatin County**.**10 attendees.

Meccage, E. August 23, 2018. **Optimizing alfalfa production.** Yellowstone County**.** Methods of optimizing alfalfa production, from fertilization through harvesting and fall management: How can you optimize your forage production?74 attendees.

Meccage, E. July 24, 2018. **Pasture Management Workshop Series.** Wibaux County**.** Different methods of pasture management, as well as hands-on assessment of stand health, how to make management decisions, etc. Hands-on activity in producer's pasture.15 attendees.

Meccage, E. July 17, 2018. **Pasture Management Workshop Series.** Ravalli County**.** Different methods of pasture management, as well as hands-on assessment of stand health, how to make management decisions, etc. Hands-on activity in producer's pasture.30 attendees.

Meccage, E. July 13, 2018. **Annual forages for drought.** Gallatin County**.** Annual forage options in drought situations**.**120 attendees.

Meccage, E. June 28, 2018. **Reduced-lignin technology: Where is it taking us?** Yellowstone County**.** Recent research into the new-reduced lignin alfalfa technology and how it can work for MT producers.16 attendees.

Meccage, E. April 17, 2018. **Alternative Forages: Quality and Management.** 130 attendees.

Meccage, E. April 12, 2018. **Equine Nutrition II.** 6 attendees.

Meccage, E. April 10, 2018. **Equine Nutrition I.** 6 attendees.

Meccage, E. April 5, 2018. **Forage Testing and Interpretation.** Cascade County**.** 6 attendees.

Meccage, E. April 5, 2018. **Forage Testing and Interpretation.** Judith Basin County**.** 40 attendees.

Meccage, E. April 5, 2018. **Hay Storage Techniques.** Cascade County**.** 6 attendees.

Meccage, E. April 5, 2018. **Hay Storage Techniques.** Judith Basin County**.** 40 attendees.

Meccage, E. March 28, 2018. **Nitrate Toxicity and Forage Quality Analysis.** Gallatin County**. N**itrate toxicity and testing your forages for quality analysis with students of the beef practicum course.35 attendees.

Meccage, E. March 15, 2018. **Optimizing Hay Quality.** Rocky Boy Reservation**.**12 attendees.

Meccage, E. March 6, 2018. **Interseeding legumes into irrigated pastures.** Ravalli County**.** Ways to interseed and incorporate legumes into an existing grass stand**.** 28 attendees.

Meccage, E. February 27, 2018. **Equine Nutrition Basics II.** 30 attendees.

Meccage, E. February 26, 2018. **Equine Nutrition Basics.** 30 attendees.

Meccage, E. February 21, 2018. **Making the right decisions for your forage seeding mix.** Gallatin County**.** 110 attendees.

Meccage, E. February 16, 2018. **Alfalfa Weevil Control in MT.** Stillwater County**.** 30 attendees.

Meccage, E. February 6, 2018. **Optimizing Hay Quality.** Stillwater County**.** Discussed methods of improving overall forage quality for livestock. 23 attendees.

Meccage, E. January 25, 2018. **Cover crops for forage: quality and management.** Cascade County**. H**ow cover crops/ annual forages can be used in an integrated livestock cropping system**.** 45 attendees.

Meccage, E. January 24, 2018. **Cover crops for forage: an option for drought.** Phillips County**.** Presented at the annual Jim Schumacher Memorial Day**.** 27 attendees.

Meccage, E. January 18, 2018. **Feeding Alfalfa to Horses.** 80 attendees.

Meccage, E. January 17, 2018. **Boron fertilization under irrigation.** Invited speaker to discuss research evaluating boron impacts on alfalfa production**.** 35 attendees.

Meccage, E. January 10, 2018. **Maximizing herd nutrition: forages first.** Deer Lodge County**.** 16 attendees.

Meccage, E. January 9, 2018. **Factors affecting alfalfa forage quality.** Flathead County**.** 100 attendees.

Meccage, E. January 4, 2018. **Alfalfa as a Rotation Crop. How** alfalfa can be used in cropping system rotations- benefits, disadvantages, and things to look out for.115 attendees.

**Oregon Presentations**

Ates, S., Cicek, H., Ozcan G., and M. Tezel (2018) Effect of nurse crop and seeding rate on the productivity and persistence of sainfoin in Central Anatolia ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD

Ates, S., Louhaichi, M., Hassan, H., Cicek, H., Kassam, S., Qudratullah, S., Farhang, A.H. and Esmati, H. (2018) Effect of seeding rate on the yield of legume-cereal bi-crops in rainfed production systems of Afghanistan 5th International Conference on Sustainable Agriculture and Environment October 08-10, Hammamet, Tunisia.

Ates, S., Keles, G., Demirci, U., Dogan, S., Ozcan, G. and Filley, S. (2018) The effects of forage-based and a concentrate feeding system on lamb production 12th World Conference on Animal Production July 5-8, Vancouver, Canada.

Blair, S., Pirelli, G., Filley, S., Bohle, M., Davis, Z., Hall, J. and Wang G. (2018) Selenium and NPKS fertilization effects on alfalfa and grass production and quality in eastern Oregon. ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD

Fan, Q., Blair, S., Hannaway, D. and Wang, G. (2018) Spring seeded annual forages differ in response to partial-season irrigation. ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD

Fan, Q., Blair, S., Hannaway, D. and Wang, G. (2018) Summer seeded annual forages differ in response to partial-season irrigation. ASA and CSSA Meeting, Nov. 4-7, Baltimore, MD

Filley, S.J., Wang, G., Hall, J., Pirelli, G., Bohle, M., Ates, S. and Davis, T.Z. (2018) Selenium and fertiliser application schemes in hay fields, 27th European Grassland Federation General Meeting, 17th - 21st June Cork, Ireland

Hannaway, D.B., Brewer, L.J., Ates, S., Anderson, N.P., Wang, G. Filley, S. Daly, C. Halbleib, M.D., Ringo, C., Monk, S., Moot, D.J., Yang, X., Chapman, D.F., and Sohn, P. (2018) MatchClover: web-based tool for matching clovers to climates, soils, and intended Uses, 27th European Grassland Federation General Meeting, 17th - 21st June Cork, Ireland

Hannaway, David B. 2018. Forage Production & Management lectures. Sichuan Agricultural University. “Foreign Expert” Program. Oct 7–30. Chengdu, Sichuan Province, China.

Hannaway, David B. 2018. Forage Production & Management lectures. Northwest Agriculture & Forestry University. “Foreign Expert” Program. Aug. 28–Sep. 6 and Nov. 4-9. Yangling, Shaanxi Province, China.

Hannaway, David. 2018. MatchClover – Web Based Tools for Matching Clovers to Climates, Soils and Intended Uses. Invited Presentation to Tasmanian Institute of Agriculture, Launceston, Tasmania, Australia. May 9.

Hannaway, David. 2018. MatchClover – Web Based Tools for Matching Clovers to Climates, Soils and Intended Uses. Plenary paper presented to Dairy NZ Workshop, Christchurch, New Zealand. Feb. 28.

Slim, S., Harbeg, L., Hassan, S., Moyo, H.P., Ates, S. and Louhaichi, M. (2018) Yield and nutritive quality of *Hedysarum coronarium* across three different agro-climatic zones of northern Tunisia, 71st Annual Meeting of The Society for Range Management, Jan. 28 to Feb. 2, Reno, Nevada, US.

**Utah Presentations**

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.

**Washington Presentations**

Norberg, O.S., L. Yu, D.K. Combs, G.E. Shewmaker, G.J. Wang, D. A. Llewellyn, S.C. Fransen and E. van Santen. 2018. Determining Genetic Factors That Influence Forage Quality In Alfalfa. International Invited Abstract. North American Alfalfa Improvement Conference. June 4-6, 2018 Logan, Utah.

Norberg, O.S., Valuing Alfalfa for Dairy Cattle from a Nutrient Perspective. 2018. North American Alfalfa Improvement Conference. Poster, 2018 North American Alfalfa Improvement Conference. June 4-6, 2018 Logan, Utah.

Norberg, S. 2018. *Alfalfa Quality Results from Washington State Alfalfa Variety Trials at WERA-1014*. Bozeman, MT.

Norberg, S. 2018. *Developing Calibration for SPAD Meter and Tissue Test for In-Season Nitrogen Assessment in Timothy Hay.* NC 1182 Annual Meeting - Management and Environmental Factors Affecting Nitrogen Cycling and Use Efficiency in Forage-Based Livestock Production Systems. Pasco, WA.

Norberg, S. 2018. *In-Season Timothy Nitrogen Management Using the SPAD Meter.* 2018 FWAA December Winter Conference. Far West Agribusiness Association. Kennewick, WA Invited Presentation.

Norberg, S. 2018. *Diagnosing Pest Problems in Alfalfa and Timothy*. 2018 FWAA December Winter Conference. Far West Agribusiness Association. Kennewick, WA Invited Presentation.

Norberg, S. 2018. Comparing Hi-Gest Alfalfa to other Alfalfa. NW Hay Expo. Kennewick, WA

Norberg, S. 2018. 2017 Results from WSHGA and WSU Variety Trials NW Hay Expo. Kennewick, WA

Norberg, O.S. 2018. Valuing Alfalfa from a Nutrient Perspective. 2018. Fall Forage Conference Oregon American Forage and Grasslands Assoc. Nov. 16, 2018 Corvallis, OR. Invited Presentation.

Norberg, O.S. 2018. Valuing Alfalfa from a Nutrient Perspective. 2018. 2018 Washington dairy Conference. Grand Mound, WA Invited Presentation.

Norberg, S. 2018. Valuing Alfalfa from a Nutrient Perspective. Mid-Columbia Hay Growers Assn. Annual Meeting. Moses Lake, WA.

Norberg, S. 2018. 2018. WSU/WSHGA Variety Testing Results. Mid-Columbia Hay Growers Assn. Annual Meeting. Moses Lake, WA.

**Wyoming Presentations**

Khatiwada1, B., Acharya, S.N., Larney, F., Lupwayi, N.Z., Smith, E., and Islam, M.A. 2018. Ability of sainfoin and cicer milkvetch populations to rejuvenate existing pastures in western Canada. The Western Society of Crop Science Annual Meetings June 20, 2018. Laramie, WY. Attendance: 35

Islam, M.A. 2018. The silent decline in soil potassium levels and its effect on alfalfa productivity in the Central and Western U.S. The North American Alfalfa Improvement Conference Annual Meetings June 6, 2018. Logan, UT. Attendance: 95.

Islam, M.A. 2018. Organic Forage Production: Options and Considerations. The 5th Annual High Plains Organic Farming Conference, February 28, 2018. Laramie County Community College, Cheyenne, WY. Attendance: 35.

Islam, MA. 2018. Agronomy in Alfalfa. Alfalfa U – Loveland CO High Plains Journal, February 6, 2018. Loveland, CO. (*Two breakout presentations*) Attendance: 68.

Islam, MA. 2017. Alternative Forage Crop Options (forage sorghums, sainfoin, nitrate (prussic acid) poising of hybrid forage sorghum). High Plains Crop Convention, November 21, 2017. UWE Goshen County, Torrington, WY. Attendance: 21

Islam, M.A. 2017. Organic Forage Production: Can Alfalfa be Grazed Without Fear of Bloat? The 3rd Annual High Plains Organic Farming Conference, February 22, 2017. Laramie County Community College, Cheyenne, WY. Attendance: 45.

Islam, M.A. 2017. Plant Diversity and Physiology for Efficient and Sustainable Agricultural Production: USA, Japan, and Global Perspectives. The 2nd Japan-US Science Forum International Conference November 18, 2017. Harvard University, Boston, MA. (*Invited presentation*) Attendance: 75.

Ashilenje, D.S. and Islam, M.A. 2017. Profiling canopy light interception and growth forms to predict forage yield and nutritive value for meadow bromegrass-alfalfa mixtures. ASA-CSSA-SSSA International Meetings. October 23, Tampa, FL. (*Oral PhD Student Competition*) Attendance: 53.

Islam, M.A. 2017. Evaluation of birdsfoot trefoil: Planting method, harvesting frequency, and cultivar. W2012 - Enhancing management, production, and sustainability of grazing ruminants in extensive landscapes Meetings, August 7-10, 2017. Eastern Oregon Agricultural Research Center, Oregon State University, Burns, OR. Attendance: 22.

Islam, M.A. 2017. Forage Research at UW, USA: Germplasm Search, Evaluation, and Cultivar Development. Department Seminar, The University of Sydney, Sydney Institute of Agriculture, Australia. July 28, 2017 Australian Technology Park, Sydney, Australia. (*Invited presentation*) Attendance: 35.

Islam, M.A. 2017. Legume adoption practices in the central great plains of USA for sustainable agricultural production in the face of climate change. The 2nd International Conference on Plant Science and Physiology June 27, 2017 Bangkok, Thailand (Conference Series Limited, UK). (*Invited presentation*) Attendance: 45.

Islam, M.A. 2017. Understanding Plant Diversity and Physiology for Resilient Production Systems and Environmental Benefits. The 2nd International Conference on Plant Science and Physiology June 26, 2017 Bangkok, Thailand (Conference Series Limited, UK). (*Invited Keynote Speaker*) Attendance: 45.

Islam, M.A. 2017. Wyoming NCCC-31 Report-Ecophysiological Aspects of Forage Management. University of Lincoln, Nebraska, June 20-22 2017. Lincoln, NE. Attendance: 27.

Islam, MA. 2017. Alternative Forage Crop Options (forage sorghums, sainfoin, nitrate (prussic acid) poising of hybrid forage sorghum). High Plains Crop Convention, November 21, 2017. UWE Goshen County, Torrington, WY. Attendance: 21

Islam, M.A. 2017. Organic Forage Production: Can Alfalfa be Grazed Without Fear of Bloat? The 3rd Annual High Plains Organic Farming Conference, February 22, 2017. Laramie County Community College, Cheyenne, WY. Attendance: 45.

**PUBLICATIONS**

**Idaho Publications**

Cherney, J.H., K.A. Albrecht, M.T. Berti, M. Bohle, S.C. Bosworth, K.A. Cassida, W.J. Cox, E. Creech, S.C. Fransen, M.H. Hall, D.B. Hannaway, M.A. Islam, K.D. Johnson, J.W. MacAdam, E.C. Meccage, D.H. Putnam, E.B. Rayburn, C.C. Sheaffer, G. Shewmaker, J. Solomon, and R.M. Sulc. 2018. Forage crops don’t get no respect! *Progressive Forage*  1 September 2018. (8):14-16.

Hannaway, D., L. Brewer, S. Fransen, G. Shewmaker, S. Williams, and S. Baker. 2018. CH 10: Planning and sowing grasslands. pp. 1-46. In Marshall, A. and Collins, R. (ed.), Improving grassland and pasture management in temperate agriculture, Burleigh Dodds Science Publishing, Cambridge, UK, 2018, (ISBN: 978 1 78676 200 9; www.bdspublishing.com)

Sagers, J., J.R. Findlay, G.E. Shewmaker, R. Roemer, and K. Jensen. 2018. Idaho grass trials—Tetonia 2017. P. 33-37 In Proceedings Idaho Hay and Forage Conference, 1-2 March 2018, Burley, ID, University of Idaho Extension.

Shewmaker, G.E. 2018. The quest for nutritive value. *Progressive Forage* 1 February 2018. (2):36-38.

Shewmaker, G.E. 2018. Hay storage losses. P. 1-11 In Proceedings Idaho Hay and Forage Conference, 1-2 March 2018, Burley, ID, University of Idaho Extension.

**Montana Publications**

Meccage, E.C.G., D.M. Peterson. 2018. Seeding Date Impact on Production of Four Perennial Cool- Season Forage Species. NRCS Tech Note MT-15-008.

Meccage, E.C., P. Carr, M. Bourgault, K. McVay, D. Boss. “Potential of Annual Forages in the Northern Great Plains”. Submitted. *Crops and Soils Magazine.* Accepted, pending publication.

Meccage, E.C. “Alfalfa fields: be prepared for 2018”. AgWeek. February, 2018.

Meccage, E.C. “Seeding decisions- the importance of variety trials”. AgWeek. February, 2018.

Meccage, E.C. “Know your forage quality to be better prepared for winter”. AgWeek. November 22, 2017.

Meccage, E.C. April 18, 2018. “Drought still a possibility in 2018”. Lane Nordlund for Northern Ag Network.

Meccage, E.C. December 8, 2017. “Alfalfa leaf retention during harvest”. Jeff Caldwell for FarmLife Magazine.

Meccage, E.C. April 19, 2018. “MT Forage Production Update”. Interview with Lane Nordlund. Northern Ag Network.

Miller, P.R., E.C. Glunk, J.A. Holmes, and R.E. Engel. Pea and barley hay as fallow replacement for dryland wheat. *J Agronomy.* Accepted December 22, 2017.

Peterson, D.M., J.G.P. Bowman, R.L. Endecott, A.L. Mack, E.C.G. Meccage\*. The effects of feeding reduced-lignin alfalfa on growing beef cattle performance: a preliminary study. *J. Ag. Studies.*

Sapkota, A., E.C. Meccage*†,* R.N. Stougaard, J.P. Tanner, D.M. Peterson, J.A. Torrion. 2018. Boron Fertilization of Alfalfa in Montana. *Crop, Forage, and Turfgrass Mgmgt. Accepted pending revision.*

Staudenmeyer, D.M., D. Fuga, E.C. Glunk\*. 2016. Preference and forage quality of 13 cultivars of forage barley and 2 cultivars of oats when grazed by sheep. *Am. J. Exp. Agric.*15:2.1-7.

**Oregon Publications**

Ates, S., Cicek, H., Gultekin, I., Yigezu, Y. A., Keser M., & Filley, S. (2018) Bio-economic analysis of dual-purpose management of winter cereals in high and low input production systems. Field Crops Research, 227: 56-66.

Daly, C., Halbleib, M., Hannaway, D.B., Eaton, L.M. 2018. Environmental Limitation Mapping of Potential Biomass Resources across the Conterminous United States. Global Change Biology: Bioenergy DOI: 10.1111/gcbb.12496.

Fery, Melissa, Maud Powell, and David B. Hannaway. 201X. Pasture and Grazing Management. Professional and Continuing Education Course. Oregon State Univ.

Hannaway, David B., Linda Brewer, Steve Fransen, Glenn Shewmaker, Shannon Williams, and Sarah Baker. 2018. Planning and Sowing Grasslands. Chapter 5, pp. 125-170. In: Improving Grassland and Pasture Management in Agriculture. Athole Marshall and Rosemary Collins, Eds. http://dx.doi.org/10.19103/AS.2017.0024.10

Hannaway, D.B.\*, L.J. Brewer, S. Ates, N.P. Anderson, G. Wang, S. Filley, C. Daly, M.D. Halbleib, C. Ringo, S. Monk, D.J. Moot, X. Yang, D.F. Chapman, and P. Sohn. 2018. Match Clover: Optimal selection of clover species. European Grassland Federation Conf., Cork, Ireland. 18-21 June.

Hannaway, D., He, F., Moot, D., Yang, X., Mills, A., Smith, R., Teixeira, E., Shewmaker, G., Islam, A., Wang, G. *2018*. Improving Alfalfa (*Medicago* *sativa* L.) Cultivar Selection by GIS Mapping of Fall Dormancy and Winter Survival Index Classes and Modeling Seasonal and Annual Yield. 2nd World Alfalfa Congress, Cordoba, Argentina. 11-14 Nov. Abstract.

He, Feng, Kun Wang, Xianglin Li, and David B. Hannaway. 2018. Effects of precipitation and clipping intensity on net primary productivity and composition of *Leymus chinensis* in temperate grasslands. PLoSONE PONE-D-17-14028R3.

Misra, A. K. Kumar, S., Kumar, T.K., Ahmed, S., Palsaniya, D. R., Ghosh, P. K., Louhaichi, M., Sarker, A., Hassan, S. & Ates, S (2018). Nutrient intake and utilization in sheep fed opuntia [Opuntia ficus-indica (L.) Mill.] in combination with conventional green and dry fodders. Range Management and Agroforestry, 39: 97-102

Roseberg, R.J., S. Norberg, and B.A. Charlton. 2018. Teff grass for forage: Nitrogen and irrigation requirements. PNW 709, Oregon State Univ. Extension Service.

Revised Pasture Fertilizer Guide (FG63; submitted to OSU Extension and Experiment Station Communications, EESC). Grass Tetany article is on the OSU website (<https://extension.oregonstate.edu/crop-production/pastures-forages/grass-tetany-fast-growing-grass-can-mean-problems>). Will submit for publication through EESC.

Yang, X., Moot, D., Brown, H., Teixeira, E., Hung, T. Hannaway, D. 2018. Modelling Alfalfa (Medicago sativa L.) Phenological Development. 2nd World Alfalfa Congress, Cordoba, Argentina. 11-14 Nov. Abstract.

**Utah Publications**

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.

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.

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.

**Washington Publications**

Roseberg, R., S. Norberg, and Brian Charlton. 2018. Teff Grass for Forage. Pacific Northwest Extension Publication PNW709, June 2018.

Norberg, S. 2018. 2017 Washington State Hay Growers Association and Washington State University Alfalfa Variety Trials. *Northwest Hay Expo.* Kennewick, WA. Jan. 17-18, 2017.

**Wyoming Publications**

*Peer-Reviewed Journal Articles*

Islam, M.A. and Ashilenje, D. 2018. Diversified forage cropping systems and their implications on resilience and productivity. *Sustainability*. 10, 3920; doi:10.3390/su10113920.

Nilahyane, A., Islam, M.A., Mesbah, A.O., and Garcia y Garcia, A. 2018. Effect of irrigation and nitrogen fertilization strategies on silage corn grown in semi-arid conditions. *Agronomy*. 8, 208; doi:10.3390/agronomy8100208.

Dhakal, D. and Islam, M.A. 2018. Grass-legume mixtures for improved soil health in cultivated agroecosystem. *Sustainability*. 10, 2718; doi:10.3390/su10082718.

Nilahyane, A., Islam, M.A., Mesbah, A.O., and Garcia y Garcia, A. 2018. Evaluation of silage corn yield gap: An approach for sustainable production in the semi-arid region of USA. *Sustainability*. 10, 2523; doi:10.3390/su10072523.

Tracy, B.F., Foster, J.L., Butler, T.J., Islam, M.A., Toledo, D., and Vendramini, J.M.B. 2018. Resilience in Forage and Grazinglands. *Crop Science (in press)*.

Adjesiwor, A.T., Islam, M.A., Zheljazkov, V.D., Ritten, J.P., and Garcia y Garcia, A. 2017. Grass-legume seed mass ratios and nitrogen rates affect forage accumulation, nutritive value, and profitability. *Crop Science*. 57:1-13. doi: 10.2135/cropsci2016.09.0776.

Islam, M.A., Obour, A.K., Rule, D., Bandara, M., and Acharya, S. 2017. Forage and seed production potential, nutritive value, and fatty acid profile of fenugreek. *Crop Science*. 57:1764–1772. doi: 10.2135/cropsci2016.08.0685.

*Book Chapter (Refereed)*

Islam, M.A. and Ashilenje, D. 2018. Understanding species traits and biodiversity indices to solve problems associated with legume persistence in cropping systems. In: Plant Competition in Cropping Systems, (D. Dunea, Ed.). InTechOpen, Rijeka, Croatia (*in press*).

Islam, M.A. and Adjesiwor, A.T. 2018. Nitrogen fixation and transfer in agricultural production systems. In: Nitrogen in Agriculture - Updates, (Amanullah and S. Fahad. Eds), pp. 95-110. InTechOpen, Rijeka, Croatia. DOI: 10.5772/intechopen.71766. Available at: <https://www.intechopen.com/books/nitrogen-in-agriculture-updates/nitrogen-fixation-and-transfer-in-agricultural-production-systems>.

*Reviewed Proceedings*

Islam, M.A. 2018. Effects of potassium, cultivar, and harvest time on sustainable alfalfa production. Proceedings of the 2nd World Alfalfa Congress, November 11‐14, 2018, Cordoba, Argentina.

*Abstracts*

Baidoo, M. and Islam, M.A. 2018. Effect of Potassium and Harvest Time on Forage Accumulation and Potassium Uptake of Alfalfa. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).

Baidoo, M. and Islam, M.A. 2018. Potassium and Harvest Time Affect Production and Nutritive Value of Alfalfa. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).

Ashilenje, D.S. and Islam, M.A. 2018. Plant community structure and nitrogen dynamics underlie sustained productivity of grass-legume forage mixtures in Wyoming. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).

Ashilenje, D.S. and Islam, M.A. 2018. Benefits of grass-legume mixture extend to nitrogen gains and alleviation of greenhouse gas emissions in Wyoming. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).

Khatiwada1, B., Acharya, S.N., Larney, F., Lupwayi, N.Z., Smith, E., and Islam, M.A. 2018. Ability of sainfoin and cicer milkvetch populations to rejuvenate existing pastures in western Canada. Proceedings of the Western Society of Crop Science Annual Meetings June 19-20, 2018. Laramie, WY (Western Society of Crop Science).

Islam, M.A. 2018. The silent decline in soil potassium levels and its effect on alfalfa productivity in the Central and Western U.S. Proceedings of the North American Alfalfa Improvement Conference Annual Meetings June 4-6, 2018. Logan, UT (NAAIC, Trifolium, & Grass Breeders).

Ashilenje, D.S. and Islam, M.A. 2017. Profiling canopy light interception and growth forms to predict forage yield and nutritive value for meadow bromegrass-alfalfa mixtures. Proceedings of the ASA-CSSA-SSSA International Annual Meetings October 22-25 2017. Tampa, FL (American Society of Agronomy, Crop Science Society of America, Soil Science Society of America).

Islam, M.A. 2017. Legume adoption practices in the central great plains of USA for sustainable agricultural production in the face of climate change. Proceedings of the 2nd International Conference on Plant Science and Physiology June 26-29, 2017 Bangkok, Thailand (Conference Series Limited, UK).

Islam, M.A. 2017. Understanding Plant Diversity and Physiology for Resilient Production Systems and Environmental Benefits. Proceedings of the 2nd International Conference on Plant Science and Physiology June 26-29, 2017 Bangkok, Thailand (Conference Series Limited, UK).

Islam, M.A. 2017. Silent Decline in Soil Potassium May Influence Sustainable Production of Alfalfa. Proceedings of the International - Conference Frontiers of Potassium January 25-27, 2017 Rome, Italy (International Plant Nutrient Institute).

*Extension publications*

Adjesiwor, A. and Islam, M.A. 2018. Birdsfoot Trefoil: Establishment and Management as Monocultures and Mixtures in Wyoming. University of Wyoming Extension Bulletin B-1321, Ed. S.L. Miller, pp.1-7, May 2018. University of Wyoming, Laramie. Available at: <http://www.wyoextension.org/agpubs/pubs/b-1321.pdf> (verified July 12, 2018).

Aryal, P. and Islam, M.A. 2018. Forage Kochia Establishment: Effects of Planting Time and Grass Mixtures. University of Wyoming Extension Bulletin B-1318, Ed. S.L. Miller, pp.1-4, April 2018. University of Wyoming, Laramie. Available at: <http://www.wyoextension.org/agpubs/pubs/B-1318.pdf> (verified July 12, 2018).

Dhakal, D. and Islam, M.A. 2017. Grass-legume mixtures improve forage yield, quality, stand persistence. University of Wyoming Extension Bulletin B-1309.1, Ed. S.L. Miller, pp.1-4, August 2017. University of Wyoming, Laramie. Available at: <http://www.wyoextension.org/agpubs/pubs/B1309-1.pdf> (verified July 12, 2018).

Islam, M.A. 2018. Legume inoculation – an important factor for sustainable forage production-Part II. *Wyoming Livestock Roundup*, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, May 26, 2018.

Islam, M.A. 2018. Legume inoculation – an important factor for sustainable forage production-Part I. *Wyoming Livestock Roundup*, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, March 3, 2018.

Islam, M.A. 2017. Varieties of birdsfoot trefoil – a non-bloating forage legume. Wyoming Livestock Roundup, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, November 18, 2017.

Dhakal, D. and Islam, M.A. 2017. Grass-legume mixtures improve forage yield, quality, stand persistence. University of Wyoming Extension Bulletin **B-1309.1**, Ed. S.L. Miller, pp.1-4, August 2017. University of Wyoming, Laramie. Available at: <http://www.wyoextension.org/publications/Search_Details.php?pubid=1937&pub=B-1309.1> (verified October 27, 2017).

Sarkar, S. and Islam, M.A. 2017. On-farm performance of bird’s-foot trefoil cultivars. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 146-147. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Ashilenje, D. and Islam, M.A. 2017. Changes in plant community structure influence forage yield and quality of irrigated meadow bromegrass-legume mixtures in Wyoming. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 126-127. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Horn, B.E., Islam, M.A., Smith, D., Jeliazkov, V., and Garcia y Garcia, A. 2017. Perennial cool-season grasses for hay production and fall grazing under full and limited irrigation. 2016 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 124-125. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Dhekney, S., Jabbour, R., and Islam, M.A. 2017. Engineering alfalfa cultivars for alfalfa weevil resistance. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 121. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Sarkar, S. and Islam, M.A. 2017. Effect of planting method, harvesting frequency, and cultivars on yield of bird’s-foot trefoil. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 104-105. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Baskota, S. and Islam, M.A. 2017. Evaluation of forage nutritive value of different fenugreek entries in Wyoming. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 102-103. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Nilahyane, A. and Islam, M.A. 2017. Evaluation of irrigation water and nitrogen management for silage corn production in Wyoming. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 58-59. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Nilahyane, A. and Islam, M.A. 2017. Effect of water stress on yield and water use of corn for silage grown in a semiarid environment of Wyoming. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 56-57. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Nilahyane, A. and Islam, M.A. 2017. Response of silage corn to irrigation water and nitrogen under on-surface and sub-surface drip irrigation. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 54-55. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Ashilenje, D. and Islam, M.A. 2017. Meadow bromegrass in mixture with alfalfa affects light and nitrogen acquisition, forage yield, and nutritive value. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 20-21. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Baskota, S. and Islam, M.A. 2017. Evaluation of forage nutritive value of quinoa cultivars. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 18-19. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Baskota, S. and Islam, M.A. 2017. Effect of planting time on dry matter and seed yield of fenugreek. 2017 Field Days Bulletin, University of Wyoming Agricultural Experiment Station, pp. 16-17. Available at <http://www.uwyo.edu/uwexpstn/_files/docs/2017-field-days-bulletin.pdf> (verified October 26, 2017).

Islam, M.A. 2017. Grass-legume Mixtures Have Benefits Over Monoculture Systems. Wyoming Livestock Roundup, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, August 26, 2017.

Islam, M.A. 2017. Establishment of birdsfoot trefoil – a non-bloating forage legume. Wyoming Livestock Roundup, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, June 24, 2017.

Islam, M.A. 2017. Inoculation of Legumes. Wyoming Livestock Roundup, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, April 8, 2017.

Islam, M.A. 2017. Silage: Production and Feeding – Part VI. Wyoming Livestock Roundup, the Weekly News Source for Wyoming’s Ranchers, Farmers, and Agribusiness Community, February 11, 2017.

**GRANTS**

**Colorado Grants**

Brummer, J.E. The Silent Decline in Soil Potassium Levels and its Effect on Alfalfa Productivity in the Central and Western US. USDA-NIFA Alfalfa and Forage Research Program, 9/1/2016 to 8/31/2019, $63,928.

Rhoades, R., J. Brummer, J. Ippolito, and J. Ahola. A Long-term Integrated Evaluation of the ARDEC Irrigated Forage System. CSU Ag. Exp. Station, 1/1/2017 to 12/31/2018, $89,933.

Schipanski, M.E. et al. Demonstrating the Potential of Cover Crop and Forage Mixtures to Improve Soil Health, Productivity, and Profitability in Water-Limited Regions. USDA-NRCS Conservation Innovation Grant, 11/12/2015 to 9/29/2019, $995,451.

**Montana Grants**

Wanner, K., S. Schell, R. Ramirez, J. Vardijman, E. Meccage. Protecting alfalfa yield from weevil damage in the Intermountain West Region. USDA NIFA. 09/01/18-09/31/2021

Carr, P., A. Bekkerman, J. Eberly, K. Fuller, B. Menalled, E. Meccage, F. Menalled, P. Miller, Z. Miller, T. Murphy, T. Seipel.Creep Stop: Integrating biological, cultural, and mechanical/ physical tools for long-term suppression of creeping perennial weeds in Northern Great Plains and Pacific Northwest Cropping Systems. USDA NIFA.

Meccage, E. Impact of Sulfur fertilization rate and timing on forage quality, yield, and persistence in cool-season perennial grass stands. MT Fertilizer Tax Assessment Committee. 05/1/2018-4/30/2020.

Meccage, E. Do different methods of outdoor round bale hay storage impact dry matter and forage quality losses in Montana? BAIR Ranch Foundation. 8/1/17-7/31/18

Wanner, K. and E. Meccage. Increasing the adoption of alfalfa weevil integrated pest management in the Western region. WRIPM. 3/1/17-2/1/18.

Olson, B. and J. Berardinelli. Winter Grazaing in Montana. NIFA MONB. 10/1/16-9/30/2021

Delcurto, T., M. VanEmon, L. McNew, T. Murphy, B. Sowell, J. Mosely, C. Carr, E. Glunk, C. Parsons, J. Dafoe. Beef production strategies that optimize use of western rangelands. NIFA MONB. 07/2/18-06/30/2023

Carr, P. Intensifying and diversifying dryland cropping systems using full and warm-season crops and crop mixtures in central Montana. Hatch Project. 07/1/17-06/30/2020

Seipel, T., A. Bekkerman, P. Carr, T. Murphy, E. Burns, F. Menalled. Integrating little hammers: using crop variety, crop diversification, cover crops, and targeted grazing to chip away at multiple herbicide resistant weeds. USDA NIFA. 09/01/17- 08/31/2020

Jabbour, R., F. Peairs, J. Ritten, M. Islam, T. Rand, B. Lee. Integration of early harvest with biological control for sustainable alfalfa production. USDA NIFA. 09/01/18-08/31/2022

**Oregon Grants**

Ates, S. Evaluation of seasonal yield, forage quality, and persistence of cool-season grass and legume species for sheep production systems in non-irrigated western Oregon pastures (ARF Grant)

Ates, S. Milk and Forage Production from Mixed or Spatially Separated Simple and Diverse Pastures (ARF Grant)

Ates, S. Milk Yield and Composition of Dairy Cows from Diversified Grass, Herb or Legume-based Summer Pastures (ODFA Grant)

Ates, S. Fodder Beets as winter forage for cattle in eastern Oregon (W. SARE farmer rancher/researcher)

Filley, S. Prepared and received funding for a proposal for updating and improving the Forage Information System for the Forage-Livestock Systems Working Group. $10,000.

Filley, S. “Evaluation of seasonal yield, forage quality, and persistence of cool-season grass and legume species for sheep production systems in non-irrigated western Oregon pastures.” Funded for $12,500 by the Agricultural Research Foundation, Oregon State University. PI: Serkan Ates; Cooperators: David Hannaway, Mary Smallman, Claudia Ingham, Shelby Filley, Gene Pirelli, and Jerry Hall.

Wang, G. Cover crops after forage spring triticale in eastern Oregon. $12,500 from ARF.

Wang, G. Developing a fall-winter grazing system by using fodder beets. $12,500 from ARF.

Wang, G. Irrigation and seeding date effects on winter grasses and forbs forage production and quality in eastern Oregon. $17,434 from OBC.

**Utah 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.

**Washington Grants**

Alfalfa Variety Trials. Washington Hay Growers Association $20,000. P.I.: S. Norberg. (03/18-4/19)

Developing Practical Phosphorus and Potassium Tissue Test Recommendations and Utilizing Struvite in Modern Alfalfa Systems, National Alfalfa and Forage Alliance $50,000. P.I.: S. Norberg, Co-P.I.: D. Llewellyn, S. Fransen, J. Harrison and L. Whitefield. (11/18-11/19)

Phenotypic Response of the Soil Microbiome to Environmental Perturbations, Subcontract of DOE Grant Received by PNNL (PI J.K. Jansson,) $148,671 (10/17 – 9/20) S. Fransen, S. Norberg.

Determining Genetic Factors that Influence Forage Quality in Alfalfa, The National Institute of Food and Agriculture (NIFA), Alfalfa and Forage Program, $250,000. PD. S. Norberg, L. Yu, D. Combs, G. Shewmaker, G. Wang, D. Llewellyn, S. Fransen 9/17- 8/19.

Developing Practical Phosphorus and Potassium Tissue Test Recommendations and Utilizing Struvite in Modern Alfalfa Systems, National Alfalfa and Forage Alliance $40,000. P.I.: S. Norberg, Co-P.I.: D. Llewellyn, S. Fransen, J. Harrison and L. Whitefield. (11/17-11/18)

Capturing and Managing Phosphorus for Environmental Stewardship and a Sustainable Dairy Industry/ Evaluating Struvite Efficacy in Alfalfa, Subcontract with Joe Harrison $20,000. P.I.: S. Norberg, S. Fransen (8/17-07/18).

Influence of Premier’s Arbuscular Mycorrhizae on Forage Yield and Quality of Alfalfa. Premier Tech Technologies Ltd. $5,147 P.I.: S. Norberg (8/1/17 – 7/31/19).

**Wyoming Grants**

Energy GA Fellowships, UW. 2018-2020. Islam, M.A. Reclamation of disturbed areas used by gas industries in Wyoming by using some promising grass and legume genotypes. $55,008.

Y Cross Ranch Tuition and Fee Award, COANR, UW. 2018-2019. Islam, M.A. Developing a potassium fertility management program on alfalfa. $9,000

Edward H. and Susan King Lloyd Graduate Research Award, UW. 2018-2019. Islam, M.A and Baidoo, M. Potassium and harvest management in alfalfa. $3,000.

UW School of Energy Resources. 2018-2019. Stahl, P.D., Eberle, C.A., Norton, J.B., Islam, M.A., and Coupal, R.H. Use of Coal Residues as a Soil Amendment. $83,000.

Specialty Crop Block Grant Program – Farm Bill (SCBGP-FB), USDA Wyoming Department of Agriculture. 2017-2019. Islam, M.A. Evaluation of chickpeas in Wyoming Environments. $24,500.

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

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