**NE1010 Multistate Project**

**Breeding and Genetics of Forage Crops to Improve Productivity, Quality, and Industrial Uses**

**October 1, 2002 to September 30, 2017**

**Period Covered: October 2015 to September 2016**

**Annual Meeting Date: July 12, 2016 (Madison, WI)**

**Meeting was called to order by Maria Monteros at 8:04 am.**

**Participants:**

**Present:**

Bill Biligetu (Bill.Biligetu@usask.ca) - Univ. of Saskatchewan, Canada;

Boe, Arvid (arvid.boe@sdstate.edu) - South Dakota State University, Brookings, SD;

Brummer, Charles (ecbrummer@ucdavis.edu) – University of California, Davis, CA;

Casler, Mike (mdcasler@wisc.edu) – University of Wisconsin, Madison, WI;

Claessens, Annie (annie.claessens@agr.gc.ca) - AAFC, Quebec, QC;

Ehlke, Nancy (nancy@umn.edu) - University of Minnesota, St. Paul, MN;

Kenaley, Shawn (sck26@cornell.edu) - Cornell University, Ithaca, NY;

Monteros, Maria (mjmonteros@noble.org), Noble Foundation, Ardmore, OK;

Papadopoulos, Yousef (yousef.papadopoulos@agr.gc.ca) - AAFC, Truro, NS;

Peel, Michael (mike.peel@ars.usda.gov), - ARS, Logan, UT;

Riday, Heathcliffe (heathcliffe.riday@ars.usda.gov) - ARS, Madison, WI;

Robins, Joe (joseph.robins@ars.usda.gov) – ARS, Idaho;

Viands, Don (drv3@cornell.edu) - Cornell University, Ithaca, NY; (Administrative Advisor);

**Abbreviation of Locations**

AFCCH: Agriculture and Agri-Food Canada, Charlottetown, NS

AFCL: Agriculture and Agri-Food Canada, Lethbridge, AB

AFCSF: Agriculture and Agri-Food Canada, Ste. Foy, QC

AFCSK: Agriculture and Agri-Food Canada, Saskatoon, SK

FRRL: USDA-ARS Forage and Range Research Lab, Logan, UT

GA: University of Georgia, Athens, GA

KY: University of Kentucky, Lexington, KY

MN: University of Minnesota, St. Paul, MN

MS: Mississippi State University

NY: Cornell University, Ithaca, NY

PSRUMN: USDA-ARS Plant Science Research Unit, St. Paul, MN

PSWMRL: USDA-ARS, Pasture Systems & Watershed Management Research Lab, PA

SD: South Dakota State University, Brookings, SD

UC-Davis: University of California at Davis

USDFRC: US Dairy Forage Research Center, Madison, WI

**Updates during the meeting:**

Don: The current project is scheduled to end on Sept 30, 2017. August 26, 2016 is the deadline to get the project submitted for this year. Charlie Brummer was going to draft a proposal.

Charlie: has received the individual projects that people were working with. However, they are lacking integration and the group projects have not been fully developed. He has received information from: Ali (aluminum), Heathcliff (alfalfa germplasm in the North but not discussed in detail), Joe/Annie (grasses), Patricio (work he is doing for some projects), but not any kind of coordinated framework.

Timeframe: 5 year project starting in 2017. 15 pages maximum project and Don already wrote the first 3 pages justification. Still need to include milestones. Team is requesting a short paragraph for each one of the projects. Milestones are in a separate section (not too detailed either). State when anticipate completing the milestones.

Charlie: take the list (handout from Don Viands = 2.5 pages), talk about each of the objectives and narrow it down.

Mike: taking it down to four to five major projects that are truly collaborative capturing diverse species (grass, alfalfa, Trifolium). Alfalfa breeding systems project was a highlight a few years ago. Bill’s bromegrass project moving forward.

Don: make sure to include all the species important to a cooperative project. Stacy is already part of this project; breeding for production on marginal land in switchgrass; climate change, not a lot of marker work due to budget restrictions. Rebecca Brown from Rhode Island (turfgrass breeder) is interested in trefoil, forage for deworming sheep and goats. Both submitted what they are interested in. Brian Baldwin has an interest in a project in switchgrass. Essential to include them (need Northeastern locations = NE location). Need to have at least two projects in a region but really like to have four.

Don: Each person should go through experiment station and submit an appendix E with information. USDA and Canadians submit it to Don, who will add the info in a table and submit it for you.

Maria: talked about species vs. topics (1-4). Focus topics and consider break out groups to develop the project further.

Don: also mention any relationship with extension collaborators as well.

Yousef: identify key areas of adaptation to focus on (i.e. water, flooding and drought) in alfalfa could that be a subproject. Flooding topic is a good one: crop is flooded for 4 to 5 weeks; spring and fall waterlogging. There is a drought tolerance concept. He has an experiment for drought and flooding. Fits well with area of adaptation. Adaptation to climate change should be a theme.

Heathcliff: #4 - germplasm screen, breeding, genomics and stress components to develop tools to breed for it. Coordinated forage variety testing is important. Get to questions that we want to ask. What are the outcomes: products, cultivars or information on how to breed for them? For him in terms of germplasm, base, round of selection and get new germplasm; have some genomic things that he is interested in.

Charlie: questions of forage production, most important things to all get behind.

Mike: start with # 4, testing germplasm in different areas. Ex: trefoil trial, alfalfa trial that goes in different locations. Each location may want to test for: testing materials in broad areas could be useful.

Don: germplasm testing was a consistent objective from previous projects. We are in our location, but promising material, want to evaluate it in multiple locations. This should be an objective of the project. They place a red clover trial, ask Heathcliff to send him some materials.

Yousef: continuum of evaluating materials beyond breeding program, for example, for acid tolerance. Physiology and genetics, their focus is germplasm development. The outcome is to assess the population for traits.

Don: cooperative in nature is genomics topic but better if phenotyping is done at multiple locations. Everyone is happy to phenotype but no one is willing to commit to genotyping. Need interim report in 3 years and at the end of 5 years, need to show that accomplished what set out to do, but also need to be realistic.

Charlie: this is the issue with Hatch funds. How do Directors view projects now that States no longer have Hatch funds? Other States have committed Hatch funds for salaries. Multi-State project proposals, not guaranteed to have money at experiment stations. Use multi-state projects to gain leverage to get funding for other grant proposals. Part of the project here, is to set up to coordinate new initiatives for genomics components and write grants. Leverage to get more funding to accomplish more work. Most interested in alfalfa, ties with his program in California. Trying to select and use germplasm collections for adaptation. Put out nurseries, develop germplasm pools, output would be new populations, populations used to screen for various traits that different people want to look at (#4, coordination of what we are doing); germplasm resources at NPGS, new materials and new populations that can be used.

Heathcliff: a few markers floating around, to validate the use of markers for some of the traits. Develop assays; people are busy and funding is not available. Alfalfa and multi-state project could apply for the alfalfa RFP money.

Yousef: focus on traits, genomics for him gets a bit complicated. In Northern latitudes, drought is a big issue for them and more global. Understanding the biology of water is important for him.

Charlie: common germplasm base, develop broad populations and people screen them for other things are already doing; germplasm is a consistent thread across.

Don: alfalfa germplasm theme and trait theme. Switchgrass topic. Multi-disciplinary. Need sufficient people for themes. Not every project in 5 years needs to be completed. Have at least some deliverables.

Suggested projects on alfalfa, switchgrass, trefoil, cool season grasses.

Mike: cool season grasses, abiotic stress, quality.

Project theme ideas:

1. Alfalfa: adaptation, climate resilient alfalfa germplasm, genomics tool added on top of that. Screen germplasm for multiple diseases (collaborate with companies, but could have IP issues). After regional adaptation, include disease screening pipelines.
2. Switchgrass: Shawn: it is getting hammered with smut (no cultivar that has resistance to it yet). N-applications in smut-infected fields help with the smut issue. Julie and Jamie have an interest and Mike and Arvid could chip in.

3. Birdsfoot trefoil: climate resilient germplasm.

Attendees broke into groups to focus on writing each of the sections for the new proposal based on topic, species and interest.

Meeting location next year: Halifax, Nova Scotia (hosted by Yousef Papadopoulos). We will also tour the Nappan site. Travel on Monday and meet on Tuesday. We can either leave on Wednesday or remain an additional day for an optional tour.

New chair of NE-1010: Jose Gonzalez.

New secretary: Shawn Kenaly.

**Objective 1: Evaluate new plant characters and develop germplasm and cultivars with these characters to improve perennial forage species as livestock feed and biofuel uses to enhance rural vitality and promote more secure energy sources.**

* 1. **Alfalfa**

1.1.3 Breeding for resistance to alfalfa snout beetle in alfalfa.
 Lead: Viands, NY. Cooperating locations: MN, AFCCH, AFCL, AFCSF.

Alfalfa snout beetle (*Otiorhychus ligustica*) has caused severe productivity and stand losses on alfalfa in northern NY. Because this insect is spreading across the state, we established several field experiments since 1998 to evaluate various germplasm sources for level of resistance under natural infestations of the insect. Several years ago, we initiated recurrent phenotypic selection for resistance to alfalfa snout beetle (ASB) in several alfalfa populations.

This year, the 13th cycle of recurrent selection was completed on six alfalfa populations to increase the level of resistance to ASB under controlled greenhouse conditions. Also, new alfalfa populations were developed from plants dug from trials on alfalfa snout beetle infested fields in the fall 2014. Specifically, one population was developed from a cross of Seedway 9558 Asb cycle 12 and potato leafhopper resistant alfalfa Asb cycle 12, and more than four pounds of seed for yield trials was produced in Idaho. A second population was developed from a cross of Guardsman II and Seedway 9558 Asb9 and more than four pounds of seed for yield trials was produced in Idaho. These two populations will be planted in yield trials in spring 2016 on fields that are not infested with alfalfa snout beetle. New trials on alfalfa snout beetle infested fields are in the planning stage for spring 2017. Two population crosses were completed in 2015 and seed was sent to Idaho for caged seed increases in 2016. The crosses were MIII Asb cycle 13 crossed to Guardsman II Asb cycle 2 and Seedway 9558 Asb cycle 13 crossed to Guardsman II Asb cycle 2. Guardsman II was used in a cross because it has been the highest yielding cultivar on ASB-infested land although it has never been bred for resistance to this insect.

In a field trial with natural infestations of ASB, populations developed from nine cycles of selection for resistance to ASB had higher forage yield than the base populations in five of seven comparisons in the first production year. In another field trial, half of the replicates were inoculated with nematodes that control ASB to compare forage yield and root damage of resistant alfalfa populations with and without nematodes.

Recurrent phenotypic selection will be continued to further increase resistance levels in these populations. Maximum control of this insect is achieved by using resistant cultivars in combination with applying to the land nematodes that kill the ASB.

Resistant alfalfa cultivars will provide a more reliable source of economical feed for dairy and other livestock industries in areas where the insect is present.

This project was described to seed company representatives and seed producers in December 2015 and during a field tour July 2016.

* + 1. Developing alfalfa germplasm with potato leafhopper resistance from three diverse genetic sources.
		Lead: Viands, NY. Cooperating locations: UC Davis, SD.

The goal of this project is to develop germplasm with multiple mechanisms for more stable resistance to potato leafhopper (PLH). Seed of *Medicago falcata* SD201, which was selected for resistance to PLH in SD, subsequently was selected for resistance in NY. These selected plants were pollinated by hand as 2x X 4x crosses, using pollen from NY germplasm that had been selected for resistance to this insect. The NY germplasm originated from glandular trichome sources crossed with Peruvian germplasm that had been selected for resistance to PLH. The cross with the SD germplasm created an alfalfa population presumably with three distinct sources of resistance in one plant population. The five hybrid plants from these crosses were intercrossed by hand, followed by a second generation of intercrossing to accomplish genetic recombination. Seed was sent to the cooperators for establishing field nurseries in 2004. Each nursery was established with about 1000 plants at each cooperating location to begin recurrent phenotypic selection for resistance. Plants appearing to be resistant to PLH from NY and from IA were intercrossed in the greenhouse during the winter of 2006-07 to complete the first cycle of selection.

Since then, we have continued recurrent selection in NY through the third cycle of selection for plant vigor and potato leafhopper resistance.

Impact: Cultivars with a broader spectrum of resistance mechanisms should be more stable against PLH. The result will be more economical production of feed.

* + 1. Aluminum tolerance in tetraploid alfalfa.
		Lead: Acharya, AFCL. Cooperating locations: NY, AFCCH, Noble.

The first cycle of selection for acid tolerance in all the cooperators’ alfalfa populations had been completed in a NY field nursery in 2008. A field experiment with half-sib progenies was established in 2010 to determine the heritability of this trait. For each of three harvests, individual plants were visually scored in 2011 and in 2012 for vigor and plant color, and the half-sib rows were harvested for forage yield. Data collection on this experiment was completed in 2012. A replicated plot trial was established in NY in 2012 to determine progress from selection for acid tolerance. Third production year forage was harvested in 2015 and the data analyzed. This trial is now complete.

Impact: Naturally acid soils are very extensive in North America. Alfalfa cultivars with tolerance to these soils will provide more economical feed by eliminating or reducing the need for lime applications.

**1.2 Birdsfoot trefoil**

1.2.1 Rhizomatous birdsfoot trefoil for yield improvement.
 Lead: Viands, NY. Cooperating locations: USDFRC, SD, AFCCH.

In NY we have been selecting birdsfoot trefoil for rhizomes and plant vigor in germplasm developed in MO by crossing rhizomatous germplasm with NY germplasm (a precursor of ‘Pardee’ trefoil). We completed the fourth cycle of selection in 2010, but the vigor of this population was still low; therefore, we backcrossed the Cycle 4 plants to advanced germplasm derived from Pardee, followed by randomly intercrossing the progenies before continuing recurrent phenotypic selection for plant vigor and rhizome production. In 2013, progenies of this intercross were established in a field nursery.

Plants will be selected for vigor and rhizome production in 2016.

Impact: Cultivars with a combination of good agronomic characteristics and rhizomes might be more persistent, thus providing excellent quality and more economical feed production. This crop is especially valuable in pastures on marginal soils.

1.2.2 Plot evaluation of birdsfoot trefoil for vigor.
Lead: Peel, FRRL. Cooperating locations: MN, NY, AFCCH, USDFRC.

Data collection on this was completed in 2013 with AFCCH collecting data in 2014. The project has been completed.

**1.5 Multiple species**

* + 1. Selection of fiber digestibility and cell wall pectin.
		Lead: Viands, NY. Cooperating locations: AFCSF, USDFRC, MS.

In NY we had concentrated for several years on increasing NDSF (Neutral Detergent Soluble Fiber) concentration in alfalfa. The NDSF is mostly pectin in this crop. The cultivar N-R-Gee was released a few years ago with higher concentration of NDSF. We have noticed, however, that selection for this trait results in lower forage yield potential. Therefore, we recently have been focusing more on NDF concentration as our primary selection criterion to improve alfalfa forage quality.

Our emphasis now is to select in tandem for resistance to potato leafhopper and forage quality in alfalfa populations that have been bred for resistance to potato leafhopper. Seed from plants selected in 2015 were established in a field nursery for another cycle of selection for both traits.

Impact: Feed with higher forage quality should make milk production more economical.

* 1. **Marker-assisted selection.**
		1. **Red Clover**.

Lead: Riday, USDFRC. Cooperating locations: AFCNS, GA (and Europeans), NY(?).
A new genotyping system is being developed for red clover and alfalfa that can sequence 200, 80 bp regions at ~50X coverage for ~$5.25 (excluding DNA extraction and bioinformatics). A pilot run was run which included 200 red clover SNP 80 bp targets on 72 genotypes and 100 alfalfa SNPs on 24 genotypes. Currently a bioinformatics pipeline is being developed to rapidly evaluate the SNP data (hopefully complete by autumn 2016). Once the bioinformatics pipeline is developed, more SNP target regions will be screened to develop 200 “well behaved” red clover and alfalfa targets that are highly polymorphic, sequence in every genotype, and show appropriate haplotype segregation ratios.

* + 1. **Kura clover**: Paternity testing.
		Lead: Riday, USDFRC. Cooperating locations: FRRL

Mike Peel provided leaf tissue and seed to Heathcliff in 2014 for molecular characterization. Project manuscript was published: Riday H., MA Smith, and MD Peel. 2015. A simple model for pollen-parent fecundity distributions in bee-pollinated forage legume polycrosses. Theo. Appl. Genet. 128: 1865–1879.

* + 1. **Alfalfa**: Marker-assisted selection.
		Leads: Riday, USDFRC, and Lamb, USDA-MN.

		One goal of this component is to determine changes in half-sib progeny frequencies in a sward from establishment to 4th year production. All tissue has been collected and initial genotyping analysis has been initiated.

**1.7 Kura Clover:** Vigor and spreadability. To be developed.
Lead: Ehlke, MN. Cooperating locations: FRRL, USDFRC, others?

Mike Peel does not have any kura clover in trials at the FRRL. He produced foundation seed. This material will be pursued through commercialization after which he does not intend to have an active breeding effort on kura. Mike Peel would be willing to participate in future cooperative trials.

**Objective 2: Build on previous research to evaluate additional breeding methods for improving yield and persistence of alfalfa, red clover, orchardgrass, and other forage species to make production agriculture more economical and sustainable.**

* 1. **Alfalfa**

2.1.2 Replicated clonal selection for improving forage yield of alfalfa.
Lead: Viands, NY. Cooperating locations: MN, AFCCH, AFCL, AFCSF.

A broad-based alfalfa population was developed by two generations of random mating among Seedway 9558 (from NY), 5454 (sent by IA), and SF 9001=AC Viva (from AFCSF). For each of three harvests in each of two production years (2005 and 2006), data were recorded for the number of plants, forage yield, and disease symptoms. Cooperators sent their data to NY, and the highest yielding genotypes (10% = 20 genotypes) across all the locations were selected. A population at NY also was developed from the same germplasm using mass selection. In 2009, 200 random plants from the Cycle 1 clonal population were cloned to establish nurseries for the second cycle of selection in spring 2009. Data on the second production year were collected in 2011 from three locations, followed by selecting 20 plants that performed the best across the locations.

In 2013, Syn. 2 seed was sent to MN, AFCCH, AFCL, and AFCSF to establish a replicated plot trial at each location (in addition to NY) to determine progress from selection for forage yield. In NY, a second trial was established in 2014. Both trials are being harvested for forage yield in 2016.

At the time of this report, three trials had been harvested for two production years and three trials for one production year. The mean yield of the three parent populations was lower than the base population yield at all locations, thus the base population had hybrid vigor for yield. The Cycle 2 NY selection (1221) yielded more than the base population (0358) at three locations. The Cycle 2 population selected across locations (1222) and Cycle 2 New York mass selection (1210) averaged lower yield than did the base population at four and six trials, respectively. More comparisons will be done with the data collected in 2016 and 2017.

Impact: Identification of breeding methods that will improve forage yield potential is essential for improving the economics of forage production.

**2.2 Orchardgrass**

2.2.1 Clonal selection in orchardgrass for broad adaptation.
Lead: Phillips, KY. Cooperating locations: AFCL, AFCSF, AFCSK, FRRL, SD, Noble.

2.2.2 Non-heading orchardgrass research.
Lead: Casler, USDFRC. Cooperating locations: AFCSK, AFCL, AFCSF, AFCNS, FRRL, ID, MN, KY, WV, NY, Newfoundland.

A potential cultivar is almost ready to release.

**2.3 Red clover**

2.3.1 Selection for general adaptation in red clover.
Lead: Papadopoulos, AFCCH. Cooperating locations: NY, AFCL, AFCSF, AFCSK, SD, KY, USDFRC.

In 2012 a new replicated plot trial was established in NY as part of a multiple location evaluation of the populations selected in previous years. Harvesting of this trial was completed in 2015.

Final 4th year of biomass yield is underway. TR-121, a cross between WIxNY selections out of this study had good performance. A seed increase was initiated on this material for more variety testing. TR-121 was also included in the broader USDFRC red clover space plant evaluation system.

2.3.2 Selection for persistence in red clover using half-sib families.
Lead: Riday, USDFRC. Cooperating locations: SD, NY, AFCCH.

2.3.3 Red clover biofuels.
Lead: Papadopoulos, AFCNS. Cooperating locations: Future collaborations for new NE-1010 project.

**2.4** **Reed canarygrass:** Methods to improve reed canarygrass.
Lead: Casler, USDFRC. Cooperating locations: Future collaborations for new NE-1010 project.

**2.5** **Legume/Grass mixtures**: Compatibility of legumes with various grasses.
Lead: Peel, FRRL. Cooperating locations: AFCCH, AFCL, MN, NY, USDA-MN.

Field data collection at the FRRL was completed in 2013. The legumes were alfalfa, birdsfoot trefoil, and cicer milkvetch in binary mixes with tall fescue, meadow brome, orchard grass, timothy and perennial ryegrass. All grass-legume mixtures were equal to or higher in yield than respective grass monocultures fertilized at 134 kg N ha-1. The BFTF-TF, ALF-TF and ALF-MB mixes were the highest producing with more uniform distribution of forage across the growing season. A manuscript for the forage yield has been accepted and a second one on forage nutritive value is in review.

**Objective 3: Evaluate new experimental populations and cultivars of perennial forage species for characteristics necessary for breeders, seed companies, seed and forage producers, and crop consultants to make decisions on commercial use over large regions.**

Yield trials of various perennial forage species are established in NY annually to compare yield of experimental populations and cultivars.

3.1 **Alfalfa**

3.1.1 Evaluation of new *M. sativa* subsp. *falcata* populations.
Lead: Peel, FRRL. Cooperating locations: AFCSF, AFCL, NGPRL, SD, USDFRC.

FRRL has nothing new to report.

3.1.2 Hybrid alfalfa evaluations.
Lead: Lamb, USDA-MN. Cooperating locations: USDFRC.

 Biomass trials were completed. Awaiting analysis and manuscript preparation.

3.1.4 Evaluation of salt tolerant alfalfa.
Lead: Acharya, AFCL. Cooperating locations: FRRL.

A trial was planted in the summer of 2014 that included both spaced plants and seeded trials at our saline field location in Utah. This trial was lost due to a combination of an open winter and repeated defoliation by prairie dogs. This was replanted spring of 2016 in collaboration with Long-Xi and included as part of an AFRI grant.

**3.3 Multiple species**

3.3.1 Biomass alfalfa/grass mixture evaluation.
Lead: Lamb, USDA-MN. Cooperating locations: SD, USDFRC.

**3.4 Meadow and hybrid bromegrass:** Evaluation of meadow and hybrid bromegrass

Lead: Coulman, AFCSK. Cooperating locations: AFCSF, AFCCH, SD, USDFRC.

**Report from G. C. Bergstrom (Cornell University)**

Focus: (1) Conduct regional surveys for yielding-reducing fungal pathogens affecting switchgrass in the eastern United States to provide seed producers with resistance ratings for common pathogens and permit consumers to integrate plant resistance into their disease mitigation strategies; (2) assist in cultivar selection of perennial bioenergy grasses to best-fit regional biomass, soil, and wildlife conservation programs; and, (3) assess epidemiological factors influencing the spread and intensification of yield-reducing switchgrass pathogens.

Projects: One peer-reviewed manuscript- Kenaley et al (2016) was published to inform the science community (e.g., switchgrass breeders and growers) of our work. Four projects are in varying stages of completion: (1) field evaluation of switchgrass susceptibility to head smut (*Tilletia maclaganii*) across commercially important cultivars; (2) relationship between the incidence of head smut and soil nitrogen-loading in a switchgrass bioenergy system; (3) long-term monitoring of head smut progress and severity in artificially-inoculated plots of lowland and upland switchgrass; and, (4) the environmental factors influencing teliospore germination of *T. maclaganii*. The Bergstrom lab will look to present the results of the latter four projects at extension and professional meetings as well as prepare each study for publication in separate refereed journals germane to bioenergy and biomass communities.

In 2015, we assisted collaborator Dr. Donald Viands (Cornell - Plant Breeding) and his research program personnel to delimit and quantify the severity of foliar pathogens among upland switchgrass populations selected for increased resistance to common pests (e.g., switchgrass gall midge, *Chilophaga virgate*). The occurrence of rust fungi (*Puccinia emaculata* and *Uromyces graminicola)* and the smut fungus were also surveyed across all plantings of commercially important switchgrass cultivars (e.g., Cave-in-Rock, Kanlow, Summer, Sunburst) within the Cornell University farm system (Ithaca, NY) and the USDA-NRCS Plant Material Center in Big Flats, NY. For the latter site, the infection severity of head smut (percent panicles infected) was measured in a replicated, randomized block planting of switchgrass. These data will be utilized in a future publication (in prep) as well as disseminated to switchgrass breeders and seed producers; this work will be the first to document smut disease progress and switchgrass susceptibility by cultivar over multiple field seasons. We also documented leaf tip necrosis within two alfalfa variety trials (D. Viands, Cornell - Plant Breeding); necrosis was attributable to overhead fertilization and, based on monthly observations, was not adversely influencing crop establishment, persistence, and/or yield.

In collaboration with Ernst Conservation Seed Company (Meadville, PA), we have also begun a research program to address epidemiological questions surrounding head smut of switchgrass, particularly the germination biology of teliospores and the mode of infection in mature plants. An initial meeting to craft the trajectory of the aforementioned research program occurred on September 11, 2015 at the company’s headquarters. In May 2016, we artificially introduced smut-infected switchgrass plants into a single-field consisting of the switchgrass cultivars Cave-in-Rock and Shawnee as well as a tetraploid cross, Timber x Kanlow. Infected plant material was taken from the center of smut-infected Cave-in-Rock identified off-site in 2015. Cores were divided into thirds and included a crown area approximately 52 cm2 and a root zone 20.3 cm in length. The source material (infected plugs) were sprayed until wet with a transplant tonic solution at excision and after division. Thereafter, smut-infected plugs were interplanted amongst the aforementioned cultivars and tetraploid cross. Interplanting locations within each of the three switchgrass plots were centrally located and devoid of any evidence of agricultural traffic. Head smut surveys will be executed in August 2016 to establish the baseline of infection. Plots will be examined annually over the next five field seasons during peak flowering to determine smut disease incidence as well as spread from the inoculation foci (smut-infected interplants). Additional monitoring is anticipated over the next 10 years to examine the epidemiological factor contributing to disease spread and intensification.

We began a two-year study (Year 2015-2016) to determine the influence of soil nutrient (nitrogen-loading) and moisture regimes (drainage class) on switchgrass stand health. This project leverages plant and site resources utilized by an existing USDA-funded project (Brian Richards, Cornell - Biological and Environmental Engineering). The site consists of a replicated strip planting of the cultivar Shawnee with individual strip receiving 0, 50, or 100 lb. nitrogen/acre; wherein, soil moisture monitoring systems were established in parallel to capture a drainage catena representing three soil series of different drainage classes (Ellery, Langford, and Erie). Analysis of Year 1 (2016) data is ongoing; however, preliminary results revealed a negative correlation among nitrogen-loading and the frequency of head smut infection. To our knowledge, no study to date has demonstrated an interaction between nitrogen availability and smut disease in switchgrass. The occurrence of head smut on switchgrass has increased remarkably over the last decade in the Northeast as stands mature; thus, these data could provide growers with a necessary tool to improve switchgrass yield and plant health on marginal, smut-infected sites.

Teliospore germination testing presently is underway. Preliminary results indicated that *T. maclaganii* is capable of germinating in water (i.e., complete, free-moisture) within four hours. Moreover, percent germination often exceeds 60% within 24-h when spores of plated to solid media and incubated in complete darkness at 15-32º C. Variation in the frequency of teliospore germination has also been noted among collections and collection dates.

Goals 2016 (G.C. Bergstrom, Cornell University,)

* Complete analyses, morphologic and molecular, of switchgrass rust fungi as well as those affecting allied *Panicum*s and distantly-related species, such as *Dichanthelium* *clandestinum*
* Determine taxonomy and phylogenetic relationships of smut fungi affecting selected samples of switchgrass in the eastern U.S.
* Pursue funding avenues to establish a research program examining the biology and epidemiology of *T. maclaganii*, focusing on teliospore germination and mode(s) of infection.
* Continue 2015 collection program for rust- and smut-infected swithchgrass across USDA-NRCS Plant Material Centers in the eastern U.S.
* Utilize the latter collections (2015-2016) to assess the species and genetic diversity of rust and smut fungi on bioenergy switchgrass.
* Extend existing and foster new collaborations with Brian Richards (BEE, Cornell), Ernst Conservation Seed Co (Meadeville, PA), and the USDA-NRCS Plant Material Center in Big Flats, NY.
* Establish and validate molecular protocols for the detection of switchgrass head smut in asymptomatic plants and contaminated/infected seed.

**Summary of Accomplishments:**

Objective 1:

1. A new genotyping system is being developed for red clover and alfalfa.
2. Populations tolerant to Al based on field evaluations have been developed and continue to be evaluated.
3. The new alfalfa snout beetle cultivar, Seedway 9558 SBR, is being used in northern NY. Field experiments are indicating that this cultivar has less root damage and higher forage yield than susceptible cultivars.
4. New birdsfoot trefoil germplasm is being evaluated for potential release.
5. Research on paternity testing in kura clover has progressed to a publication.

Objective 2:

1. Comparison of selection methods for biomass yield is continuing at multiple location trials. Data so far indicate that progress from replicated clonal selection for higher yield has resulted in some progress in yield, but only at the location where selection was conducted.
2. A non-heading orchardgrass population is close to release as a potential cultivar.
3. Selection in red clover for improved persistence and general adaptation has resulted in plant populations with better adaptation.
4. Mixture trials documented the value of including legumes with grasses. All grass-legume mixtures were equal or higher in forage yield than their respective grass monocultures that were fertilized.

Objective 3:

(1) Evaluations of multiple species of cool and warm season perennial forages continue to be evaluated for forage yield, persistence, and other agronomic traits at multiple locations in North America.

**Impact Statements:**

1. The development of new grass and legume cultivars will provide a more reliable source of economical feed for dairy and other livestock industries. For example, alfalfa cultivars with resistance to alfalfa snout beetle and potato leafhopper provide protection of the crop to realize maximum forage yield and quality. A new orchardgrass cultivar that does not produce seed heads in the areas of forage production would provide higher quality grass. Foundation seed of a kura clover cultivar is available for acquisition by the seed industry for marketing this new cultivar.
2. This project improves environmental quality through the development of new cultivars of grasses and legumes with improved persistence, increased resistance to abiotic and biotic stresses, and enhanced soil-binding improvement capabilities (e.g., reduced soil erosion; improved nutrient cycling; less soil surface runoff; increased soil carbon sequestration; reduced atmospheric CO2; reduced use of agricultural chemicals/fertilizers; reduced pollution/contamination of surface and ground waters).
3. Acid soils are very extensive in North America and worldwide. Alfalfa cultivars with tolerance to these soils will provide more economical forage by eliminating or reducing the need for lime applications. New cultivars will convert such problem soils, previously unsuitable for agriculture, into areas of stable high quality forage production. Development of salt-tolerant forage species, such as ‘Bridgeview’ alfalfa, should expand the use of crops for forage production.
4. With improved forages and biomass crops, increased diversification and sustainability in agricultural ecosystems can be achieved. Identification of breeding methods that will improve forage and biomass yield and quality is essential for improving the economics of these crops in production agriculture and in conservation and wildlife habitat systems.
5. The evaluation of experimental populations is essential to ensure that all stakeholders have the agronomic information to make decisions on use of forage species and cultivars within species.
6. Development of warm season grasses for biofuel use will contribute toward sustainability of energy production. Protecting switchgrass from diseases and insects will help to provide biomass more economically.

**Relevant Publications**:

(2015 publications were in print after the 2015 NE1010 annual report)

Anower, M.R., A. Boe, D. Auger, I. W. Mott, M. D. Peel, L. Xu, P. Kanchupati, and Y. Wu. 2016. Comparative Drought Response in Eleven Diverse Alfalfa Accessions. Journal of Agronomy and Crop Science. DOI: 10.1111/jac.12156.

Cox, S., M.D. Peel, J.E. Creech, B.L. Waldron, J-S. Eun, D.R. Zobell, R.L. Miller, and D.L. Snyder. Forage production of grass-legume binary mixtures on Intermountain Western USA irrigated pastures. Crop Sci. Tentatively accepted.

Crawford, R., P. Salon, J. Crawford, J. Hansen, S. Bonos, M. Hall, and D. Viands. Fall 2014 height, vigor, quality and yield data from Cornell University NEWBio Switchgrass Nurseries. Poster presented at Northeast Wood/Warm Season Biomass Consortium 2015 Annual Meeting, NEWBio CAP Project, Morgantown, WV. 3-5 August 2015.

Crawford, R., J. Crawford, J. Hansen, and D. Viands. Development of gall midge susceptible and resistant Cave-in-Rock switchgrass populations. Poster presented at: Switchgrass III Prairie & Native Grass International Conference. Knoxville, TN 30 September – 2 October 2015.

Hansen, J., J. Crawford, C. Brummer, R. Michaud, A. Claessens, S. Acharya, Y. Papadopoulos, J. Lamb, C. Sheaffer, and D. Viands. 2016. Replicated clonal selection for improving forage yield of alfalfa – Preliminary Report. North Amer. Alfalfa Improv. Conf. 12-14 July 2016. Madison, WI. <https://www.naaic.org/>

Hansen, J.L, D.R. Viands, R. Deubler, J. Crawford, J. Schiller, and R. Crawford. 2016. New York forage legume and grass variety yield trials summary for 2016 - season totals

<http://plbrgen.cals.cornell.edu/research-extension/forage-project/ny-forage-yield-results>

Hoffman, L., E. N. Weibel, J. L. Crawford, R.V. Crawford, J. L. Hansen, M. H. Hall, D. R. Viands, and S.A. Bonos. 2015. Selection of switchgrass for reclaimed mineland. ASA, CSSA and SSSA International Ann. Meeting, 16 November 2015. Minneapolis, MN.

Kenaley, S.C., J.A. Cummings, C.N. Layton, G.C. Bergstrom. *In prep*. Multi-year field evaluation of bioenergy switchgrass (*Panicum virgatum*) susceptibility to the smut fungus *Tilletia maclaganii. Bioenergy Research* (expected submission, September 2016).

Kenaley, S.C., G.W. Hudler, G.C. Bergstrom. 2016. Detection and phylogenetic relationships of *Puccinia* *emaculata* and *Uromyces* *graminicola* (Pucciniales) on switchgrass in New York State using rDNA sequence information. *Fungal Biology* 120: 791-806.

Li, X., Y. Wei, A. Acharya, J.L. Hansen, J. L. Crawford, D. R. Viands, R. Michaud, A. Claessens, and E. C. Brummer.  2015. Genomic prediction of biomass in two selection cycles of a tetraploid alfalfa breeding populations. The Plant Genome. July Vol. 8 No. 2.

Richards, B. K., C. R. Stoof, C. Mason, R. Crawford, H. S. Mayton, S. Das, J. Hansen, J. Crawford, T. S. Steenhuis, M. T. Walter, and D. R. Viands. 2015. Sustainable Perennial Grass Bioenergy Production on Marginal Lands of the Northeast: Five Years and Counting. Invited presentation, USDA Sustainable Bioenergy Program Project Director Meeting, November 4, 2015. Denver, Colorado. DOI: 10.13140/RG.2.1.2223.0486

Richards, B. K., C. R. Stoof, C. Mason, R. Crawford, H. S. Mayton, S. Das, J. Hansen, J. Crawford, T. S. Steenhuis, M. T. Walter, and D. R. Viands. 2015.  Research Poster: Carbon sequestration and gaseous emissions in perennial grass bioenergy cropping systems in the Northeastern US. USDA Sustainable Bioenergy Program Project Director Meeting, November 3, 2015. Denver, CO. DOI: 10.13140/RG.2.1.3795.9121

Richards, B. K., C. R. Stoof, C. Mason, R. Crawford, H. S. Mayton, S. Das, J. Hansen, J. Crawford, T. S. Steenhuis, M. T. Walter, and D. R. Viands. 2015. Research Poster: Carbon sequestration and gaseous emissions in perennial grass bioenergy cropping systems in the Northeastern US. NEWBio Bioenergy Consortium Annual Meeting Poster Session, Tuesday August 4, 2015. West Virginia University, Morgantown, WV. DOI: 10.13140/RG.2.1.4799.4725

Riday, H., M.A. Smith, M.D. Peel. 2015. A simple model for pollen-parent fecundity distribution in bee-pollinated forage legume polycrosses. J. of T.A.G. 128:1865-1879.

Songsomboon K., J. Crawford, J. Cummings, G. Bergstrom, and D. Viands. Heritability and genetic gain of resistances to diseases caused by Bipolaris oryzae in switchgrass. Poster session presented at: 5th International Conference on Quantitative Genetics. 13 – 17 June 2016; Madison, WI.

Songsomboon K., J. Crawford, J. Cummings, G. Bergstrom, and D. Viands. Heritability and genetic gain from selection for resistance to Bipolaris leaf spot in switchgrass. Poster session presented at: Switchgrass III: Prairie & Native Grass International Conference. 30 September– 2 Oct 2015; Knoxville, TN.

Songsomboon K., J. Crawford, J. Cummings, G. Bergstrom, and D. Viands. Techniques for screening switchgrass for resistance to diseases caused by*Bipolaris oryzae*. Poster session presented at: 2015 Northeast Woody/Warm-season Biomass Consortium Annual Meeting. 3-5 August 2015; Morgantown, WV.

Stoof, C. R., B. K. Richards, P. B. Woodbury, E. S. Fabio, A. Brumbach, J. H. Cherney, S. Das, L. D. Geohring, J. L. Hansen, J. Hornesky, H. S. Mayton, C. Mason, G. Ruestow, L. Smart, T. A. Volk, T. S. Steenhuis. 2015. Untapped potential: Opportunities and challenges for sustainable bioenergy production from marginal lands in the Northeast USA. BioEnergy Research 8:482-501.

Viands, D.R., J. Hansen, J. Crawford, E.J. Shields, and A. Testa. 2015. Breeding alfalfa cultivars with resistance to alfalfa snout beetle. Northern NY Agric. Devel. Program Report. <http://www.nnyagdev.org/wp-content/uploads/2016/06/NNYADP15ViandsASBReportWeb.pdf>

Conference Papers and Presentations:

Kenaley, S.C. and G.C. Bergstrom. 2015. Poster: Switchgrass leaf rust in U.S. caused by two genetically and morphologically distinct, yet, closely-related fungi. Switchgrass III: Prairie and Native Grass International Conference. Sept. 30-Oct. 2, Knoxville, TN.

**Dissertations:**

None.