Alfalfa Research: Still Growing Strong After 65 Years

Deborah Samac, USDA-ARS

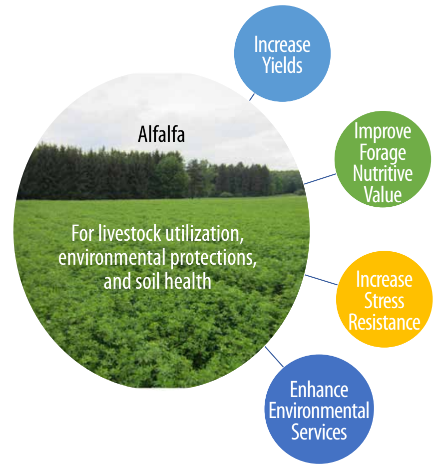
There is a long history of alfalfa research in Minnesota, starting from the development of the first winterhardy alfalfa by the German immigrant Wendelin Grimm in the 1860s. The Plant Science Research Unit (PSRU) was established 65 years ago in St. Paul, on the campus of the University of Minnesota by the U.S. Department of Agriculture. Thus, the PSRU is celebrating its blue sapphire jubilee. Over the past two years, five new scientists focusing their research on alfalfa have been hired to fill positions vacated by retirements and made possible by MFA/NAFA advocacy. This article highlights past accomplishments and current research to address regional and national priorities in agricultural and environmental research.

Recognizing diseases were a major factor reducing alfalfa yield, forage quality, and persistence, the first position hired in 1956 was a plant pathologist to facilitate cooperative research with University faculty to increase disease resistance in alfalfa. The project was augmented with a full-time alfalfa geneticist in 1965. Products of this early research were the standard tests for evaluating alfalfa germplasm for disease resistance, many of which are still in use today and have been adopted nationwide, such as those for Phytophthora root rot, Fusarium wilt, and bacterial wilt. The team released 'Agate,' the first cultivar with resistance to Phytophthora root rot and 'Ramsey,' a winterhardy disease-resistant cultivar.

With the addition of two plant physiologists to the team in 1973, research focused on improving biological nitrogen (N) fixation potential in alfalfa. Field and greenhouse assays were developed to measure N fixation, which have become standard methodologies. An important component of the research was the discovery and characterization of ineffective alfalfa mutants that cannot establish a symbiotic relationship with the N-fixing bacteria. These mutants were subsequently developed for use in remediating soil of excess N and to remove N from soil and water below the root systems of cereal crops. One large remediation project was the clean-up from a train derailment in North Dakota. In 1988, the team released 'Nitro,' the first legume cultivar selected for enhanced N fixation and N assimilation. It is a highly effective cover crop or green manure crop that grows rapidly in the seeding year and typically dies off in northern winters with gradual release of N to the following crop.

In 1982, the research capacity of the team was enhanced by the addition of a soil scientist and dairy scientist focusing on forage quality. Expertise in molecular genetics was added in 1993. A major research focus at this time was evaluating alfalfa as a bioenergy feedstock, first for generating electricity by gasification and later by fermentation to ethanol for transportation fuel. A major product of the team was the development of a high biomass non-lodging alfalfa with the potential to produce twice the ethanol than a hay-type alfalfa with fewer harvests. The team evaluated alfalfa leaf and stem fractions of alfalfa as animal feeds and measured the environmental, agronomic, and economic benefits of alfalfa rotation with corn. Cooperative research with University of Minnesota agronomists showed terminating a three-year-old alfalfa stand releases sufficient N for the subsequent corn crop and additional N does not benefit yield, even with the highest-producing corn cultivars. In many locations, no additional N is needed the second year, saving the farmer two years of fertilizer costs.

Research on environmental services provided by alfalfa was a strong research focus that continues today. The team conducted research on a landscape scale, finding almost no N escapes into tile drains from fields with alfalfa or perennial conservation reserve crops. Furthermore, alfalfa can be grown above tile lines to remove nutrients and prevent surface water contamination. Accomplishments in molecular biology included development of a rapid and efficient method of introducing new genes into alfalfa for understanding gene function and regulation, and to introduce novel traits. Among these traits are enhanced aluminum tolerance in acidic soil, increased resistance to crown rot disease organisms, tolerance to the herbicide atrazine for remediation of contaminated soil, and production of a biodegradable plastic polymer as a high-value product. Tools to measure gene expression were developed, and the first atlas of genes expressed in leaves, roots, stems, nodules, and flowers was produced.



The current PSRU alfalfa team includes two geneticists (one focusing on alfalfa breeding and one focusing on genomic resources and gene editing), a plant pathologist, a soil microbiologist, a forage biochemist, and a forage agronomist. Research to be conducted by this team builds on the foundation of previous research accomplishments. A major focus is developing genomic resources for alfalfa, which has lagged behind other crop species due to the complexity of the alfalfa genome. A reference genome sequence for alfalfa is needed to accelerate molecular breeding methods and for cataloging and understanding the function of genes and regulatory sequences. Sequencing and analysis of one genome are currently being completed with the goal of having chromosome length sequences with another 10 genomes in 'draft' form with near-complete chromosome length sequences. Additionally, 'universal' DNA markers are being developed in collaboration with Breeding Insights at Cornell University that can be used with any alfalfa population for tagging agronomic traits to accelerate selection and breeding of improved cultivars. The PSRU team will be using the markers and alfalfa germplasm developed in previous team research to identify genes linked to traits such as root architecture, improved forage digestibility, and for resistance to diseases. Research will include studies to identify and measure components of forages leading to improved animal performance, improved understanding of the role of plant stem morphology and cell wall components on forage digestibility, and development of high throughput assays for plant composition. Various breeding methodologies will be tested to identify the most successful strategies. The team will also be developing new methods for gene editing and has focused on editing genes for phosphate uptake and seed traits.

Improving disease resistance and losses from disease remains a strong research focus. DNA markers associated with resistance to Aphanomyces root rot, one of the most important diseases of alfalfa in the U.S., are being used to clarify the resistance gene-pathogen race interaction to facilitate developing resistant cultivars. New seed treatments are being tested for seedling diseases, and resistance to these diseases increased in alfalfa germplasm. Newly added expertise in soil microbiology will increase team capacity to identify pathogenic and beneficial soil organisms. A major focus will be on identifying management methods and microbial communities associated with improved soil health and carbon sequestration.

As a critical component of dairy forage rotations, alfalfa has a large impact on field carbon balances and the overall carbon footprint of dairy production. Research is underway to evaluate conventional and novel crop rotations utilizing perennial forages for their effect on greenhouse gas emissions, carbon sequestration, and nutrient cycling and to determine the impacts of dairy manure application on alfalfa productivity, forage quality, and soil health. The team will also be focusing on understanding winter persistence in alfalfa to provide management methods, develop assays to identify plants persisting under stressful winter conditions, and improve plant materials for increasing persistence of alfalfa stands. The research will be of use to public and private plant breeders who will utilize the alfalfa genome sequence, markers, and breeding strategies in developing new cultivars; alfalfa farmers who will use soil indexing methods and seed fungicides to reduce damage from plant diseases; and the dairy food industry which has increased emphasis on reducing the environmental impacts of dairy, especially greenhouse gas emissions.