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A History of Plant Improvement by the USDA-ARS Forage and Range Research Laboratory for Rehabilitation of Degraded Western U.S. Rangelands

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On the Ground

- Climate change models for the western United States predict warmer winters in the Great Basin and hotter, drier summers in the Mojave Desert, increasing the already high rate of rangeland and pasture degradation, which in turn will increase annual grass invasion, escalate wildfire frequency, and reduce forage production.
- These changes in western U.S. rangelands will continue to result in the emergence of novel ecosystems that will require different and/or improved plant materials for successful revegetation.
- Traditional plant improvement of native and non-native rangeland plant species by the USDA, ARS Forage and Range Research Laboratory (FRRL, Logan, Utah) has been accomplished through rigorous evaluation of seed collections followed by recurrent selection and hybridization of unique plant types within selected populations to identify plants with superior establishment and performance characteristics. After such plant types have been selected, they are further evaluated in multiple ecologically diverse locations to identify broadly adapted superior germplasm for public release.
- Plant improvement of perennial grasses, legumes, and forbs by the FRRL has provided and will continue to deliver plant materials that support sustainable rangeland management efforts to service productive and functionally diverse rangelands.

Keywords: plant materials, restoration, novel ecosystems, plant breeding, abiotic stress tolerance, resilience.

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The semi-arid and arid rangelands of the western United States provide a broad array of ecosystem services, including wildlife/livestock forage, a diversity of native plants, pollinators, wildlife, and recreational activities.[1] However, disturbances by wildfire, livestock, wildlife (e.g., undomesticated mammals), and humans (including recreational activities) have contributed to degraded conditions on much of America's 800 million acres of rangeland.[2] Many of these regions have been classified as severely disturbed and non-productive,[3] resulting in the emergence of novel ecosystems (i.e., the emergence of species that occur in combinations and relative abundances that have not occurred previously within a given biome).[4] Moreover, based on predicted climate change models for semi-arid regions, seasonal weather patterns of several environments in the western United States will likely change (e.g., warmer winters in the Great Basin and hotter, drier summers in the Mojave Desert), increasing the already high rate of rangeland and pasture degradation and resulting in the spread and dominance of invasive annual grass species, more frequent wildfires, and reduced forage productivity.[5] In fact, currently available plant materials do not often display the degree/type of traits required to persist in novel ecosystems.[6,7] Thus, in water-limited environments of the western United States, there is a need to develop grasses, legumes, and forbs that will establish under drought, compete with invasive weeds, and persist with adequate productivity and quality to meet the needs of wildlife populations and livestock throughout the year.

The U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), Forage and Range Research Laboratory (FRRL[i]) in Logan, Utah[ii] has historically provided improved

[i] For more information on the FRRL, see http://www.ars.usda.gov/main/site_main.htm?modecode=20-80-10-00.

[ii] The 70th Annual Society of Range Management Annual Meeting will be held in St. George, Utah 29 January–2 February 2017. This article highlights Utah range science and management. For more information on SRM Red Rock & Rangelands 2017 see http://rangelands.org/srm17/.

plant materials and management alternatives for sustainable stewardship of rangelands and pastures in the western United States. Research by the FRRL is performed at 38 field locations in the greater Intermountain West from the Mojave Desert north to the Scablands of Washington state, west to central Nevada, and east to the western edge of the short grass prairie of the United States. Through evaluation and breeding of native and non-native species, the FRRL has developed over 50 plant materials that are used broadly on western rangelands and pastures. The development of these improved grass, legume, and forb plant materials as pre-variety germplasms and cultivars has been accomplished through a multidisciplinary team of geneticists (breeding and genomics) and ecologists/plant physiologists (ecological applications). When combined with best-management practices, these plant materials have and will continue to provide rangeland practitioners with flexible strategies for sustainable rangeland stewardship. What follows describes the evolution of the FRRL as an international research organization, its germplasm collection contributions, ecological research to improve rangeland rehabilitation strategies, and future prospects. Research efforts by the FRRL have resulted in plant materials that improve the resilience of rangelands and pastures to environmental and anthropogenic stresses.[8]

Rangeland Management in the Great Basin of the Intermountain West

There were historic interactions between ranchers and federal and state governments that led to the emergence of strategies for rangeland improvement in the Great Basin and the concomitant creation of the FRRL. During the early 1900s, many citizens shared concerns about the degradation of public lands in the western United States. Private producers and public institutions (e.g., U.S. government, universities) concluded that concerted and sustained efforts were necessary to improve plant cover and reduce soil erosion. Through the efforts of Gifford Pinchot (U.S. forester and politician) and Albert F. Potter (Chief of Grazing-Division of Forestry), President Theodore Roosevelt traveled to Salt Lake City in 1903 to create the Logan Forest Reserve in Utah. Subsequently, cooperative studies among the USDA (established in 1862), the Bureau of Plant Industry (established in 1901), and the U.S. Forest Service (established in 1905) were initiated in 1907 with the goal of improving range and forestland conditions. These and other actions in 1912 led to the creation of the USDA Utah Experiment Station located near Ephraim in Sanpete County (central Utah) to conduct research on Great Basin rangelands. In 1930, the Intermountain Forest and Range Experimental Station was created in Ogden, UT to re-establish native grasses found on U.S. rangelands during its early settlement by explorers and pioneers. However, early revegetation efforts using native plants to seed arid and semiarid rangelands frequently failed. Non-native crested wheatgrass (*Agropyron cristatum* [L.] Gaertn.) and Russian wildrye grass (*Psathyrostachys juncea* [Fisch.] Nevski) nevertheless proved to establish well, especially in revegetation efforts during 1930 to 1950.[7,8]

Research Relationships Between the USDA, ARS, and Utah State University in Logan, Utah

Cooperative relationships between the U.S. government and Utah State University (named in 1957) had their origins very early in the history of the university, which was first established as the Agricultural College of Utah in 1888 through Hatch Act appropriations. In fact, several USDA employees (e.g., William M. Jardine, P.V. Cardon, and Gerald Thorne) were associated with the Agricultural College of Utah (UAC) shortly after the college was established. In the 1920s, the USDA and UAC began collaborative efforts to reduce soil erosion, which continue to the present. Subsequently, in the middle 1930s cooperative work commenced on rangelands and forage grasses as a complement to ongoing research in water, irrigation, and soils. A key cooperative relationship between the Utah Agricultural Experiment Station and the U.S. government during that time up to the present involved the Intermountain Herbarium (established in 1931) at USU. By 1938, there were 17 USDA collaborators (e.g., John W. Carlson, Dean F. Ferdinand, A.C. Hull, and Wesley Keller) associated with the college. Research focused on drought resistance and mineral nutrition of cereals, vegetables, sugar beets, and legume seed production, as well as soils and irrigation-related problems.

In 1960, ARS completed construction of a research complex on the USU campus named the USDA, ARS Crops Research Laboratory, which was renamed the FRRL in 1987. Through the late 1970s and early 1980s, increasing emphasis at FRRL was placed on forage breeding and genetics research, which was led initially by Douglas R. Dewey. This work focused on the cytogenetics and reproductive mechanisms of range grasses. Since the late 1980s, substantial emphasis has been placed on improving rangeland, pasture, and turf grass species for drought, heat, and salinity tolerance, with emphasis placed on seedling establishment (germination and emergence) and plant persistence. More recently, efforts have been made to characterize the genetic nature of economically important traits using DNA technologies.

Historic, Current, and Future Research at the FRRL

Historically, plant improvement at the FRRL involved the collection of unique domestic (native) and foreign (non-native) germplasm followed by the evaluation of their potential for rangeland rehabilitation of degraded western landscapes (Figure 1). If domestic germplasm is deemed to have immediate economic potential, it typically is released as pre-variety germplasm with (manipulated track) or without (natural track) trait selection.[9] In addition to morphological evaluation, recent FRRL pre-variety germplasm releases have been described using DNA-based technologies that define their genetic identity and relationships to other accessions of the same species. If native or non-native germplasm has potential (e.g., possesses drought, heat, and/or salinity tolerances), but is lacking in important agronomic attributes (e.g., adequate seed production, seedling establishment, or