FY 2009 Annual Report for National Program 215
Rangeland, Pasture, and Forage Systems

Public and private range, pasture, forage and turf lands contribute significantly to the Nation's agricultural, environmental, economic, and social well-being by providing a rich variety of goods and services. Range, pasture, forage, and turf lands are found in all 50 states and comprise about 55% of the total land area of the United States. Reliance on the production, maintenance and use of perennial grasses, legumes and other herbaceous vegetation within sustainable ecosystems is the common foundation of these land types. These lands are grazed by more than 60 million cattle and 8 million sheep and support a livestock industry contributing over $80 billion in farm sales annually. The estimated value of hay production alone is around $13 billion, making hay the third most valuable crop in U.S. agriculture. Another 30 million acres is in turf that directly affects the citizenry through home and commercial landscaping, school grounds, right-of-ways, parks and other recreational facilities. The Nation's highly diverse grass, forage and shrub lands also provide an important habitat for many wildlife species, including 20 million deer, 500,000 pronghorn antelope, 400,000 elk, and 55,000 feral horses and burros. Other important environmental services include water resources, open space, and recreational opportunities. The benefits derived from these lands will increase dramatically as grasses and forage legumes become significant bioenergy feedstocks.

Although vast in area and rich in resources, these lands are being stressed in order to meet the rapidly expanding demands of a growing population and world economy. Research must provide land owners with new science-based management systems and practices that identify, quantify and balance the trade-offs between resource uses in ways that are economically viable, environmentally sustainable and socially acceptable. These needs will be met through research that results in scientific and technological advances that are integrated within an ecosystem framework based on the principles of ecology, agronomy, economics and the earth sciences.

Component I. Rangeland Management Systems to Increase Economic Viability and Enhance the Environment

Problem Area A: *Need for economically viable and environmentally sustainable rangeland management practices, germplasm, technologies and strategies to conserve rangelands ecosystems.*

Selected Accomplishments

Recovery—a new grass cultivar to improve rangeland restoration. Western wheatgrass is an important native grass in many rangeland ecosystems, but its low rate of seed production and poor seedling vigor limit its use when quick establishment is needed to stabilize and restore degraded rangelands. ARS scientists at Logan, UT worked with the U.S. Army Corps of Engineers and the NRCS to develop and jointly release "Recovery," a superior and more easily established western wheatgrass. Developed and tested over 10 years, Recovery was designed for reseeding rangelands following severe disturbance, frequent wildfires, and soil erosion. With a 20% increase in the rate of successful establishment, Recovery allows land managers to use a

native grass species to help limit weed infestation and soil erosion in systems where reestablishment of wheatgrass is inhibited by frequent disturbances. Recovery is being recommended by the NRCS and the U.S. Army Corps of Engineers for reseeding private, public, and military training lands throughout the northern Plains and Intermountain West.

Carbon sequestration on rangelands. The impact of managing pinyon-juniper woodlands in the intermountain Western U.S. on carbon storage is not known, especially below-ground. ARS scientists at Reno, NV found that prescribed burning caused immediate increases in surface soil C and N concentrations, but over intermediate to longer time periods no statistically detectable change in soil C or N content occurred. Proposed fuel load reduction treatments in the pinyon-juniper woodlands should have no impact on long-term carbon sequestration while reducing the risks of catastrophic wildfires.

North American rangelands as carbon dioxide sinks. In a collaborative regional experiment, ARS scientists used Bowen ratio micrometeorological tower methodology to measure carbon flows under different management conditions in four rangelands of the Great Plains, two of the desert Southwest, and two Northwest sagebrush steppe sites. Both sagebrush steppe sites functioned as carbon sinks capturing carbon dioxide from the air through plan activity. Three of the four Great Plains grasslands were sinks, but the two Southwest hot desert sites showed a net release carbon into the atmosphere on an annual basis. These results clarify the role of rangelands in the global carbon cycle, and provide information on how land management can affect carbon sequestration.

New subspecies of bottlebrush squirreltail for rangeland restoration. Bottlebrush squirreltail (Elymus elymoides) is widely used for rangeland restoration in the Intermountain Region, but information was lacking about subspecies adaptation in this highly genetically diverse grass species. ARS scientists in Logan, UT used DNA technology to show that one of bottlebrush squirreltail's three major subspecies should be divided into two subspecies, one centered in the Rocky Mountains, and a newly recognized subspecies centered in the northern Intermountain Region of Oregon and adjacent states. For this new subspecies, two new plant materials (Antelope Creek Germplasm and Pleasant Valley Germplasm) are being released to provide seed adapted respectively to the western Blue Mountains of central Oregon and the eastern Blue Mountains of eastern Oregon and adjacent portions of Idaho and Washington.

Manipulating nitrogen reduces weed invasion. Diffuse knapweed and Dalmatian toadflax are damaging invasive weeds. ARS scientists at Ft. Collins, CO found that high levels of nitrogen resulting from nitrogen deposition or soil disturbance, contribute to their invasiveness on rangelands where water, rather than nitrogen, often limits plant growth. They found that experimental reductions in nitrogen reduced invasion of diffuse knapweed by 95%, and completely prevented invasion by Dalmatian toadflax. These results show that reducing nitrogen can help control invasive weeds even in relatively dry rangeland ecosystems. The challenge now is to determine how management practices such as controlled burns to reduce fuel loads, adjusting stocking rates, and reseeding can be modified to reduce N release and deposition.

Potential for using warm-season grasses for bioenergy production. ARS scientists at Logan, UT investigated producing warm-season grasses for bioenergy under various irrigation options.

They found that in the Intermountain West warm-season grasses produce substantially less biomass than cool-season grasses. While warm-season grasses such as switchgrass appear to be the best option, this is not true for all parts of the country. Consequently, more attention needs to be given to evaluating cool-season grass and forage legume varieties and their bioenergy-feedstocks production systems for those parts of the country dominated by cool-season species.

Effects of prescribed fire on soil and water. ARS scientists in Boise, Idaho studied the hydrologic impacts of using prescribed fire to reduce fuel loads on mountainous sagebrush rangelands. Prescribed fire caused increased runoff and erosion until groundcover was above 60% and this typically took two growing seasons. This information contributes to improving hydrology and erosion modeling of burned rangelands so land managers can make better decisions on the impact of prescribe burning and wildfires to control the risks of runoff and erosion following fire.

Monitoring shrubland conversion using Very Large Scale Aerial (VLSA) imagery. VLSA imagery, a low altitude, small aircraft-based method, can be used for measuring bare ground and total plant cover, but has not been validated for measuring shrub cover. ARS scientists at Dubois, ID determined that estimates of image- and ground-measured shrub cover were similar, and that VLSA imagery could be used to accurately measure the cover of 3 species (mountain big sagebrush, bitterbrush, and horsebrush) common to mountain big sagebrush communities. Rapid and accurate assessment of shrub cover will help in identifying and maintaining sage grouse and other rangeland habitat.

Importance of landscape connections in successful restoration. ARS scientists at Las Cruces, NM found that landscape context and connections between adjoining rangeland sites need to be better understood to increase restoration success. They found that reducing barriers to improve interactions between sites can increase resource retention and plant establishment at plant and patch scales in different parts of the landscape, but the magnitude of the effect varied with landscape location. Land managers can use this information to identify landscape locations where modification of soil and vegetation is more likely to improve soil and water resource retention.

Problem Area B: *Need for improved livestock production systems for rangelands that provide and use forages in ways that are economically viable and environmentally sustainable.*

Selected Accomplishments

A quantitative method for measuring toxic compounds in rayless goldenrod and white snakeroot. White snakeroot (*Ageratina altissima*) and rayless goldenrod (*Isocoma pluriflora*) can cause "trembles" in livestock and "milk sickness" in humans. Managing this problem has been difficult because injuries from plant toxicity have historically been both sporadic and unpredictable. ARS scientists at Logan, UT have developed a quantitative method for measuring the toxic components (benzofuran ketones) in these plants. They found that toxicity varied considerably among the different white snakeroot and rayless goldenrod plant collections. This new quantitative method will be used to measure toxicity of plants growing in different locations

and environmental conditions to assess risks to livestock and to humans consuming milk from pastures containing these plants.

Vegetation and livestock responses to prescribed fire in shortgrass steppe. Livestock producers in the Great Plains have expressed concerns about the impact of prescribed burning on forage production. ARS scientists at Cheyenne, WY, and Fort Collins, CO, studied the effects of late-winter prescribed burns on forage production, forage nitrogen content, and plant species composition of shortgrass steppe in northeastern Colorado. Burns conducted under a wide range of precipitation conditions during 1997–2001 did not negatively affect forage production in either the first or the second postburn growing season. Burning followed by a severe drought in 2002 reduced production by 19% in the second postburn growing season. Except following severe drought, prescribed burns conducted in late winter to enhance wildlife habitat, control unpalatable plant species, and restore historic disturbance, have a neutral or positive impact on livestock production. This information will aid producers in overall management of their rangelands for multiple ecosystem services including livestock production.

High intensity grazing systems force cattle to graze lupine. ARS scientists at Logan, UT found that increasing grazing pressure in intensive grazing systems can force cattle to graze lupine when it is most toxic and during the critical period of livestock gestation. Three, 10-day grazing trials were conducted over two years with forage restricted to only enough to last for 10 days. Increasing grazing pressure forced cattle to graze lupine towards the end of the 10-day trial in May, and in the middle of the trial in June. In July, lupine was the most palatable forage available and cattle selected it at the beginning of the trial. Lupine is relatively palatable in July and August, but mush less so at other times. But even when palatability is low, cattle can be forced to consume it when intensive grazing systems are used earlier in the season. Increased consumption carries the risk of poisoning.

Clearance times of larkspur alkaloids in Angus cattle. Intoxication of cattle by larkspur alkaloids is highly related to dose and to rate of elimination of individual alkaloids. ARS scientists in Logan, UT have shown that in Angus cattle, larkspur toxins reach maximum serum concentrations by 10 hours after dosing and the most toxic of these compounds has a half life of elimination (20.5 hours). This clearance suggests that a withdrawal time of 7 days be used to allow poisoned animals to clear these toxins. Clearance times for natural toxins are important for food safety considerations and for recommendations for treating intoxicated animals.

Grazing reduces fire impacts. ARS scientists from Burns, OR completed a long-term study with treatments applied in 1937 (grazing exclusion) and 1993 (prescribed fire). Vegetation measurements were taken 12, 13, and 17 years after the fire. They found grazing exclusion on sagebrush rangeland can result in more frequent fires in native grasses because of fuel buildup. More frequent fires can increase invasive weeds and reduce desirable forages for livestock and wildlife.

Impact of grazing and gaps between plants and soil erosion. Gaps in plant cover that exposed bare soil to erosion are an important indicator of rangeland health. In cooperation with the University of Wyoming, ARS researchers in Cheyenne, WY examined vegetative gaps in rangeland that had been in a long-term stocking rate (25 years) study in the northern mixed-grass

prairie. They found that heavy stocking rates resulted in a bunchgrass-dominated community with a higher number of gaps but these gaps were smaller than those in a rhizomatous-dominated community under no grazing. As a result less of the soil surface was exposed in the heavily grazed area (68%) than the ungrazed area (87%), but this difference was offset by greater litter cover in the ungrazed area. Alteration of the size and distribution of gaps between plants by livestock grazing can be mitigated by management practices that increase litter cover in these gaps to reduce wind and water erosion.

Biochemistry of juniper diet selection by livestock. Juniper is a widely available plant but not typically used by livestock. ARS scientists at Las Cruces studied supplementation options to see if juniper consumption could be increased. Sheep and goats were fed one-seeded juniper branches following basal diets with either a rumen degradable protein supplement, undegradable protein supplement, or a control with no additional protein. Goats had higher juniper intake than sheep, and intake of juniper was greater for both species with protein supplements compared to controls. Juniper intake was lowest when the juniper secondary chemical compounds were greatest. Land managers can use these results to modify livestock foraging habits to increase juniper consumption by varying the type of supplement used. Increasing juniper consumption when other rangeland forages are in short supply will reduce the need to feed hay or reduce livestock numbers.

Comparative effects of Locoweed in sheep and cattle. Locoweed was fed to pregnant western white face ewes (wool sheep), St. Croix ewes (hair sheep), and Spanish goats to compare its effects on pregnancy. Spanish goats were most sensitive exhibiting relatively early abortions while in hair sheep and wool sheep the abortions occurred much later or not at all. Managers should avoid grazing pregnant Spanish goats in locoweed-invested pastures and exercise considerable care when grazing wool and hair sheep. If veterinarians notice an increase in abortions, they should check for outbreaks of locoweed in the area.

Problem Area C: *Need for improved rangeland restoration, rehabilitation and mitigation practices, germplasm, tools and strategies to restore rangeland health in a manner that is economically feasible and environmentally acceptable.*

Selected Accomplishments

Post-fire grazing management. Livestock producers in the Great Basin are frequently not allowed to graze livestock on public rangeland for at least two years after a wildfire, adversely affecting profitability. ARS scientists at Burns OR found that livestock grazing the year after a fire need not damage sagebrush rangeland. A 5-year study showed that moderate grazing either one or two years after a fire was not different from deferring the rangeland for two full years. The research was conducted on sagebrush rangeland in a good condition. Results could vary depending on rangeland type and condition prior to the fire. These findings show that deferring grazing for two-years is not always necessary. Consequently, grazing deferral decisions after fire should based on local conditions.

Prescribed burning reduces emergence of invasive weeds. In the Northern Great Plains, common weed control methods rarely prevent weed seeds already on the ground from reestablishing weed population. ARS scientists at Miles City, MT evaluated using fire management to reduce seed viability. Seeds of Japanese brome, spotted knapweed, Russian knapweed, and leafy spurge were deposited on the soil surface, subjected to fire at six fuel loads common to grasslands, and results compared to a non-burned control. Seedling emergence was reduced 79-88%; with fuel loads common to the north-central Great Plains, emergence was reduced by at least 97%; with fuel loads typical of the northeastern Great Plains, emergence probabilities were less than 1% for all species except spotted knapweed. Results indicate the high potential for using fire to disrupt the life cycle of invasive species across the northern Great Plains.

Simulation modeling of species composition over time. ARS scientists at Las Cruces, NM developed a soil-water dynamics simulation model to integrate knowledge on factors affecting historic shifts in plant composition to predict future dynamics. The establishment of black grama, an important native grass, under historic (1850s) and current vegetation and soil conditions was compared to explain the shifts in vegetation dominance from grass to shrubs. Plant establishment appeared to be affected more by changes in soil properties than by changes in the vegetation present. These results can be used to help identify landscape locations where soils favor restoration efforts.

New herbicide for rangeland invasive weeds. ARS Scientists at Logan, UT completed a 3-year study using the herbicide *imazapic* to achieve weed control without injuring species seeded for revegetation. This work was on big sagebrush and salt desert shrublands invaded by cheatgrass. Exceeding the 6 oz per acre herbicide rate significantly hindered recently seeded plants even though higher herbicide rates could improve invasive plant control. When adequate weed control cannot be achieved at the 6 oz per acre rate, managers should not simultaneously reseed and apply herbicide at rates higher than 6 ounce rate.

Component II. Pasture Management Systems to Improve Economic Viability and Enhance the Environment

Problem Area D: *Need for appropriate plant materials to improve the economic viability and environmental sustainability of pasture and livestock grazing systems.*

Selected Accomplishments

Sabine—a new grass cultivar to improve southeastern cattle production. Cattle producers have long needed a more productive forage grass adapted to the hot, humid climate of the southeastern U.S. In collaboration with Texas AgriLife Research and the Louisiana State University AgCenter, ARS scientists at College Station, TX developed a new dallisgrass cultivar called "Sabine," that produces significantly more forage than common dallisgrass while being more tolerant of heavy grazing pressure and maintaining good nutritional value into the late summer. In the short time since Sabine was released, many forage researchers and producers have requested seed. At least one commercial seed company plans to distribute Sabine.

Screening Texas bluegrass for host suitability to greenbug. Greenbug biotype E is the predominant biotype in the southern Great Plains that infests winter wheat and sorghum while biotype F infests some bluegrass species. ARS scientists in Woodward, OK determined that at least some native cool-season Texas bluegrass genotypes collected from northwest Oklahoma are capable of supporting the growth and reproduction of both greenbug biotype E and F. Results indicate that Texas bluegrass can be an alternate host for greenbug biotype evolution. Consequently, breeding programs should screen for greenbug resistance when developing improved forage and turf featuring Texas bluegrass.

Genetic regions regulating bioherbicide production. Commercial production of sufficient quantities of a naturally occurring herbicide produced by soil bacteria depends on developing a chemical process for manufacturing the herbicide, or by causing cultured bacteria to produce large quantities. With collaborators at Oregon State University, ARS scientists in Corvallis, OR identified the genetic regions that regulate the natural production of this herbicide by soil bacteria. Now scientists can produce sufficient quantities of this herbicide so its chemical structure can be described and chemical processes developed and tested for production. This will accelerate the development of a commercial natural product for controlling weeds in grass and cereal crops.

Generation of tall fescue clone pairs with and without endophyte. To test the effects of seed-transmissible endophyte in tall fescue, clone pairs are needed to compare a clone with the endophyte to one that lacks it. ARS scientists at Lexington, KY developed methods that generated 29 endophyte-infected and endophyte-free tall fescue clone pairs. The clone pairs are now being used to test endophyte effects on tall fescue physiology and gene expression under various conditions such as water deficit stress, grazing, nematode parasitism or insect feeding.

Problem Area E: *Need for profitable and environmentally sustainable pasture-livestock systems for the Mid-South*

Selected Accomplishments

Controlling gastrointestinal parasites in sheep and goats in the southeast. Gastrointestinal parasites are a major health challenge in small ruminants. Widespread resistance of gastrointestinal worms to chemical dewormers, and the desire to control these parasites without risk of chemical residue have resulted in a need for alternative parasite management strategies. Rotational grazing of pastures as a means to control internal parasites has been suggested by the U.S. National Organic Program, but has never been examined without the use of chemical dewormers. Working with Louisiana State University and Fort Valley State University, ARS scientists at Booneville, Arkansas determined that rotational grazing of lambs on bermudagrass led to fewer deworming treatments than animals not rotated. Along with scientists at Auburn University, they also determined that diets containing 50 to 75% of dried sericea lespedeza can reduce worm problems in small ruminants while providing nutrients for the animals when compared to diets lacking lespedeza component. Using lespedeza and rotational grazing as part of an integrated control system can increase economic viability for both conventional and

organic sheep and goat production in the southeast.

Gamagrass as an alternative warm-season forage. ARS scientists at Raleigh, NC Research evaluated gamagrass production and quality to determine if this grass could be grown in the Mid-Atlantic Region and used for pasture, hay and silage, as well as biomass. Gamagrass is a native grass that requires lower inputs of nitrogen per unit of production than many of the commonly used introduced pasture grasses. Gamagrass pastures were grazed to obtain estimates of steer daily performance and potential pasture production and cut and preserved as both hay and silage to determine its nutritive value and quality. Gamagrass was found to be a viable lower-input alternative warm-season grass in regional ruminant production systems. In wet soils, gamagrass yields are better than switchgrass. Gamagrass should be considered when designing production systems for forages and bioenergy feedstocks on poorly drained soils in the Mid-Atlantic Region.

Effect of tall fescue endophyte on bluebird reproduction. Tall fescue is one of the most common pasture grasses in the southeastern US. This grass is often infected with a fungus that makes the plant more tolerant to drought and pests but can lead to problems in animals consuming it. With the University of Arkansas scientists, ARS scientists at Booneville, AR determined that Eastern bluebirds (*Sialia sialis*) laid smaller eggs, nestlings tended to be in poorer condition, and weight of nestlings at the time of first flight was lower in endophyte-infected tall fescue pastures compared with endophyte-free pastures even though arthropod numbers were greater so there was more food. While the specific factors adversely affecting bluebird performance are not clear, preservation efforts for the birds should avoid endophyte-infected tall fescue pastures.

Problem Area F: *Need for profitable and environmentally sustainable pasture-livestock systems in the Great Plains.*

Selected Accomplishments

Grazing impacts on soil properties under intermediate wheatgrass. Intermediate wheatgrass has been proposed as a good pasture grass to use in crop-pasture rotations because it provides high-quality perennial forage but only persists a few years under grazing pressure. However, producers were concerned that having livestock in the rotation would in serious soil compaction that would adversely affect follow-on crop rotations. A study by ARS scientists at Mandan, ND evaluated the effects of three grazing periods on soil bulk density, pH, and organic carbon content under pasture planted in intermediate wheatgrass. Treatment effects on the three soil attributes were negligible implying that grazing time did not negatively impact critical soil functions. Intermediate grass pasture can be part of sustainable crop rotation systems because the grass does not persist and grazing does not result in soil compaction that adversely affects follow-on crop production.

Forage height is a key determinant of cattle performance. ARS scientists at Woodward, OK evaluated three tillage systems to establish wheat pastures with canopies differing in height to evaluate effects on short-term forage intake rate and dynamics by beef steers. Forage intake rate increased as sward surface height increased resulting in steers that grazed the tallest pastures

being the most efficient since cattle were able to reach the same forage intake level in less time. This information is useful in designing pasture grazing systems and cattle rotation schedules in the Southern Great Plains. Managers can increase grazing efficiency by allowing swards to grow taller before turning in livestock and by adjusting pasture size and the time animals are allowed to graze to balance nutritional needs with grass height. (Similar results were found for dairy cattle in the North Atlantic states and are discussed in the next section.)

Problem Area G: *Need for profitable and environmentally sustainable pasture-livestock systems in the Northeast and North Central States*
Selected Accomplishments

Assess grazing behavior of cattle in biodiverse pastures. Dairy pastures have traditionally been planted in one variety of grass. In recent years, ARS scientists at University Park, PA have evaluated planting pastures in a mix of grasses and other forage species. They found such mixtures can increase forage productivity and maintain production more consistently during seasonal and yearly climatic variations. The scientists then determined if this greater diversity of plants changes the grazing behavior of cattle and affects animal performance. They offered four grass species to cattle in short-term intake trials and found that plant height had the largest and most consistent effect on cattle grazing behavior. They found that cattle grazing was more efficient on taller plants because the animals were able to take more and larger bites from taller plants. (Similar results were found for beef cattle in the Southern Great Plains as discussed in the previous section.) Producers can influence grazing efficiency by managing forage height by regulating grazing schedules and intensity in established pastures. In establishing and rehabilitating pastures, they can select forage mixtures that favor taller plants that still meet nutritional and seasonal requirements and are adapted to local conditions.

Pasture is "easier" to chew in the evening. Cud chewing is an important part of the digestion process in cattle and things that make forage difficult to chew and digest can reduce cattle performance. ARS scientists at University Park, PA evaluated changes in the "toughness" of pasture forage in relation to its chemical composition throughout the day. An indirect measure of how hard forage is to chew, toughness decreased late in the day and this corresponds to a decrease in fiber and protein with an increase in sugar content. These results help explain why cattle graze longer and more intensely in the evening. Dairy farmers can adjust their pasture rotation systems and milking schedules to maximize evening grazing to improved animal performance.

Anthelmintic effects of orange oils in small ruminants. Major losses to small ruminant producers worldwide are resulting from resistance of *Haemonchus contortus* (barber pole worm) to commercial dewormers. Collaborators at Virginia Tech and ARS scientists at Beaver, WV treated infected sheep with emulsions containing orange terpene oil and orange Valencia oil. Treated animals had significantly fewer worms than untreated controls. Results show that orange oil emulsions have promise as an alternative to commercial dewormers for sheep and goats.

Anthelmintic effects of chicory in small ruminants. Previously, ARS scientists at Beaver, WV found that forage chicory is both nutritious and contains sesquiterpene lactones that can reduce

gastrointestinal parasites in sheep and goats. Further research has found that sesquiterpene lactone concentrations, but not chemical composition, vary over the growing season. Based on the analysis of three chicory cultivars collected throughout West Virginia and Pennsylvania over two growing seasons, concentrations of sesquiterpene lactones are highest in late spring and summer, and lowest in fall, for all cultivars. This information lets producers who using chicory as part of the parasite control program know that they will need to use additional control measures in fall when lactone levels are lowest.

Component III. Sustainable Harvested Forage Systems for Livestock, Bioenergy and Bioproducts

Problem Area H: *Need for improved plant materials to improve the profitability and environmental sustainability of using harvested grasses and forage legumes for livestock, bioenergy and byproducts production.*

Selected Accomplishments

Improving alfalfa as a bioenergy crop. ARS scientists at St. Paul, MN identified genes controlling cell wall composition and content of alfalfa stems using the GeneChip developed for barrel medic, a close relative of alfalfa. (No GeneChip is available for alfalfa.) Gene expression in alfalfa stems selected for cell wall polymers important in converting lignocellulosic biomass to ethanol was investigated. Numerous genes were identified for the first time that regulate polymer biosynthesis in alfalfa. This research demonstrated that the barrel medic GeneChip could be used successfully to identify genes useful for improving alfalfa as a bioenergy crop.

Problem Area J: *Need for economically viable, energy efficient and environmentally sustainable production systems for establishing, growing, maintaining, harvesting, treating, storing and transporting forages for livestock, bioenergy, byproducts and conservation objectives.*

Selected Accomplishments

Near-infrared Reflectance Spectrometry (NIRS) calibrations to predict switchgrass ethanol yields. Conventional wet chemistry analysis of biomass for composition and conversion to ethanol is time-consuming and expensive. A team of ARS scientists from Lincoln, NE, Peoria, IL, St. Paul, MN, and Madison, WI developed NIRS calibrations that, along with biomass yield data, enable the following switchgrass bioenergy traits to be rapidly and accurately determined: theoretical ethanol yield from hexose sugars, theoretical ethanol yield from pentose sugars, total ethanol yield per Mg (ton) from pre-treated biomass, total ethanol yield per acre, total theoretical ethanol yield per ton, total theoretical ethanol yield per acre, and conversion ratio of actual to theoretical on a liter to liter basis. These calibrations will have multiple uses in breeding, genetics, and management research and could be used by biorefineries to determine ethanol yield of switchgrass biomass.

Developing switchgrass for multiple uses. Switchgrass has great potential as a bioenergy feedstock but producers are reluctant to grow this difficult-to-establish perennial grass because of the current lack of suitable conversion facilities. Growing switchgrass as an animal feed could help expand switchgrass production until conversion facilities come on line, but many animal owners are concerned about saponins, a class of toxic compounds found in switchgrass. Saponins can cause photosensitization and liver damage in sheep and horses. Identifying the presence of saponins in switchgrass is easy, but quantifying how much is present is difficult. ARS scientists at Lincoln, NE and Logan, UT developed a method to quantify saponins in switchgrass at different maturity stages and under different management conditions. As these testing methods become commercially available, sheep and horse owners can feed switchgrass safely. Expanded use of switchgrass hay would give grass farmers more opportunities to gain experience in switchgrass production while suitable bioenergy conversion plants are being built.

Spontaneous heating in large forage and bioenergy feedstock bales. Spontaneous heating in grass and forage legume hay, generally caused by too much moisture at the time of baling, costs livestock producers by reducing dry matter (less hay to feed) and forage quality. Similar losses can be expected when baling these plant materials as bioenergy feedstocks. In conventional small rectangular bales (80 to 100 pounds), a linear relationship has been found between moisture content and heating. The higher the moisture content, the higher the spontaneous heating. Currently, producers typically use much larger round or square bales to reduce labor costs, but these larger hay packages have not been studied extensively for spontaneous heating. ARS scientists at Madison, WI found that large bales (3-, 4-, or 5-foot diameter) were more likely to exhibit spontaneous heating at relatively lower moisture contents (<20%) than smaller bales. As with small bales, the amount of feed lost increased linearly with the amount of spontaneous heating; forage digestibility decreased at low to moderate levels of heating, but then stabilized thereafter. Producers can improve profitability by reducing spontaneous heating and dry matter losses by putting more emphasis on measuring and managing moisture levels when harvesting larger bales for livestock and bioenergy.

Rapid screening of plant fiber for energy conversion efficiency. Lignin is key to cell wall development, but it is indigestible and hinders the utilization of carbohydrates for livestock and bioenergy production. Combining a cell wall "solubilization" method they developed with nuclear magnetic resonance (NMR) spectroscopy, ARS scientists in Madison, WI, developed a rapid processing method to characterize large numbers of forage samples for specific wall components including lignin, carbohydrates and cell-wall structure. The screening of a specific biomass crop indicates its potential digestibility for ruminants or energy conversion efficiency. This information will be used by breeders in developing improved varieties and by producers when they are selecting the appropriate biomass crop and varieties for their location and management goals.

Potential biomass production from Conservation Reserve Program (CRP) land. ARS scientists at El Reno, OK, showed that Old World bluestem produced an average of 3380 lbs/acre, and a native mix produced 1710 lbs/acre of dry biomass feedstock on Oklahoma CRP land evaluated across all years, locations, and harvest dates. Maximum yields were obtained at the October harvest for both Old World bluestem (3720 lbs/acre) and the native mixed species (1950 lbs/acre). At the native mixed species sites, there was no observed change in species

composition. Three years of annual harvest did not alter soil characteristics, but biomass production consistently declined at all sites and for all harvest dates over the period. Maintaining sustainable production will require some form of nutrient replacement such as chemical fertilizers, manure, or conversion-process byproducts. Adding a legume component to the grasslands could also help. Without nutrient replacement, several years between each harvesting will be required to let soil fertility recover naturally.

Forage sorghum and sorghum/sudan hybrids excel at biomass production. Special sorghum hybrids have been developed with impressive biomass yields and tolerance to environmental stress. ARS scientists at El Reno, OK found that average yield for a single late-season harvest was 12 tons per acre of dry matter per year. Average yield for a first harvest plus a ratoon crop was 11.4 tons per acre of dry matter per year. The best-performing cultivar yielded almost 18 tons per acre of dry matter for a single late season harvest. Results demonstrate that sorghum cultivars offer management options for maximizing biomass production for combinations of livestock forage or bioenergy feedstock production at the same time.

Reducing protein degradation in silage. ARS scientists at Madison, WI found that ensiling forages with polyphenol oxidase activity decreases protein degradation and improves the nutrient value of the silage. Red clover has high protein levels and requires little effort to preserve its protein (>85%) during the ensiling process. Red clover has polyphenol oxidase (PPO) and appropriate o-diphenols that together inhibit protein degradation. Many important forage grasses also contain PPO activity, but have much higher levels of protein degradation during ensiling because they lack appropriate o-diphenol substrates. When chlorogenic acid (an o-diphenol found in many common plants including coffee, dried plums, and the forage tall fescue) is added during the ensiling process, protein degradation is inhibited. This indicates that adding extracts with chlorogenic acid or co-ensiling two forages that complement each other (one with PPO activity and the other with chlorogenic acid) would produce superior silage. This would increase profitability and reduce nitrogen waste in the environment by decreasing the use of protein supplements.

Reducing Brown Root Rot of Alfalfa. Brown root rot is a fungal disease in the northern U.S. that causes winter kill and significantly reduces stand life and forage yield. Because chemical control is not possible, management strategies are needed to reduce damage. Collaborative research between ARS scientists in St. Paul, MN and the University of Minnesota, found that corn and soybean residues increased pathogen populations while spring wheat, oat, and canola residues decreased pathogen populations. Multi-year field trials also identified alfalfa varieties that persist in locations with high amounts of the brown root rot fungus and have high forage yield potential. Losses from brown root rot can be reduced by rotating crops with a spring-seeded small grain crop and by planting brown root rot tolerant varieties.

Characterization of leaf spot disease in alfalfa. Leaf spot diseases in alfalfa are caused by fungi. A high degree of genetic variability in these fungi exists within species and strains that attack different crops worldwide. ARS scientists at Beltsville, MD developed methods to characterize molecular variation and the genetic structure of fungal populations. Individual fungi were isolated and their relatedness to similar fungi that attack vegetable and fruit tree crops was determined. Several new species of fungi were identified and characterized. The research will

help scientists, breeders, and managers identify specific species and populations causing leaf spot and lead to improved control strategies.

Identification of nematodes in ornamentals that affect forages. Root-knot nematodes are destructive to the roots of many kinds of plants, including alfalfa, grasses, and other forage crops. ARS scientists at Beltsville, MD described the anatomical and molecular characteristics of an unusual population of root-knot nematode (*Meloidogyne arenaria*) isolated from a diseased palm-like ornamental tree (traveler's tree). They characterized the wide range of morphological and molecular variation seen in this common nematode species. Because *M. arenaria* infect a wide range of forage legumes and grasses worldwide, this research will help scientists, regulators, and extension agencies to accurately identify and improve control this nematode on a variety of crops.

Component IV. Turf Plant Materials

Problem Area K: *Need for improved germplasm that is adapted to biotic and abiotic stresses to reduce economic and increase environmental sustainability while meeting the objectives of turf producers and users.*

Selected Accomplishments

Genetic variation in creeping bentgrass. Creeping bentgrass, a member of the *Agrostis* genus, is the premier golf turfgrass species. Breeding programs to improve this grass have been slow because of limitations in identifying parental lines. Not knowing the identity of parental lines limits the ability to select parents to produce offspring with desired qualities. Like many grasses, creeping bentgrass can cross with other grass species within and outside its genus and produce fertile hybrids. These hybrids typically have multiple chromosomes sets. For example, the hybrid can have a complete set of chromosomes from each parent and these can be passed on to the next generation. Creeping bentgrass improvement is being slowed because of limited knowledge about the chromosome sets of many of the *Agrostis* populations maintained in the National Plant Germplasm System (NPGS). Using flow cytometry and 1,309 DNA markers, ARS scientists at Beltsville, MD, analyzed 75 Agrostis populations representing 15 distinct species along with two Apera and four Polypogon populations. Cluster analysis clearly separated the common turf-type Agrostis species into distinct groups. Finding previously understudied species within these groups offers insights into the genetic origins of creeping bentgrass that will be useful in future breeding efforts. In addition, the data suggest a narrowing of the genetic diversity within cultivated creeping bentgrass varieties that could affect its climate change adaptability. The identification of different parental lines will help identify which populations to use to increase genetic diversity.