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Cold Regions Research
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Report on the Workshop on New Grass Germplasms and Invasive Weed Control

30 April–1 May 2002

Fort Carson and the United States Air Force Academy
Colorado Springs, Colorado

Susan E. Hardy and Antonio J. Palazzo

October 2002



Abstract: A two-day workshop provided information on new introduced- and native-grass germplasms adapted to the western United States and presented methods for fighting invasive weeds. The intent of the workshop was to help land managers choose native herbaceous plants to rehabilitate sites, reduce soil erosion, and increase training opportunities. Western rangelands are typically dry, with annual precipitation from 4 to 12 inches. Participants presented the land-management problems they face on their installations. Military facilities, which must balance training mission needs with environmental concerns, are seeking natives that are resistant to training activities and can germinate quickly in a semi-arid environment. ERDC-CRREL and the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) in Logan, Utah, have developed new cultivars and germplasms of native and introduced grasses that establish rapidly, compete with invasive weeds, and are resistant to land disturbances caused by military training activities. These plants were developed by improving the native and introduced grasses

already growing on military ranges in the western United States. The new germplasms are also appropriate for other federal, state, or local agencies; highway right-of-ways; mine spoils; and other disturbed areas; they also will help managers satisfy the Presidential Order on native plants. Three germplasms have been released to date and eight more will be available. Related establishment studies have shown that seed mixtures using the native grasses along with rapidly establishing introduced species can quickly form a grass cover that inhibits invasion of noxious weeds and prevents erosion, and that, over time, will develop into a stand of predominantly native grasses. Other methods to control areas of noxious weeds include use of chemicals, introduction of insects that feed on specific weed species, and judicious use of mechanical methods such as mowing, pulling, or controlled burns. Biocontrol research has shown successful control using insects targeting knapweed and musk thistle. Often, a combination of tools, taking into account the proper timing for each, provides the best results in controlling weeds.

COVER: Workshop participants examine a drill-seeded area on the grounds of the United States Air Force Academy.

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Special Report
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Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

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PREFACE

This report was prepared by Susan E. Hardy, Research Program Specialist, and Antonio J. Palazzo, Research Agronomist, Environmental Sciences Branch, U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire.

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The authors thank Dr. Robert Holst for managing this project. They also thank Wayne Fordham of Tyndall Air Force Base, Jeff Linn and Rusty Savoy of Fort Carson, Brian Muhlbachler of the United States Air Force Academy, and Timothy Cary and Dr. J.-C. Tatinclaux of CRREL for assistance in planning and running the workshop.

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1 INTRODUCTION

This report summarizes presentations given at a two-day workshop, 30 April to 1 May 2002, which provided information on our new introduced- and native-grass germplasms and presented methods for fighting invasive weeds. The intent of the workshop was to help land managers choose native herbaceous plants to rehabilitate sites, reduce soil erosion, and increase training opportunities.

The new plant materials, which are adapted to the western United States, were developed in a breeding program to improve native and introduced plant cultivars that establish rapidly, compete with invasive weeds, and are resistant to land disturbances caused by military training activities. These plants will also be helpful on other federal lands where managers need to satisfy the Presidential Order on native plants. The breeding program is a cooperative effort between the U.S. Army Corps of Engineers Engineer Research and Development Center–Cold Regions Research and Engineering Laboratory (ERDC–CRREL) and the U.S. Department of Agriculture–Agricultural Research Service (USDA–ARS) in Logan, Utah. The Strategic Environmental Research and Development Program (SERDP) funded the project under the work unit “Identify resilient plant characteristics and develop a wear-resistant plant cultivar for use on military training lands (CS-1103).”

The format of the workshop included classroom presentations and field trips to demonstrate our new germplasms, successful seeding techniques for native plant establishment, and biological control methods for invasive weeds. The first day at Fort Carson, located south of Colorado Springs, Colorado, included morning presentations on new grass germplasms followed by an afternoon field

trip to plot sites on the base. The second day at the United States Air Force Academy, located northwest of Colorado Springs, included presentations on invasive weed control followed by a tour of erosion and weed-control sites on the Academy grounds.

We had participants from the Army, Navy, Air Force, National Guard Bureau, U.S. Department of Agriculture, Department of Interior, the National Park Service, regional and state organizations, and seed companies (see Appendices A and B).

2 CONCERNS AND PROBLEMS ON FACILITIES

On the first day of the workshop, Bob Stack and Jeff Linn discussed the training activities at Fort Carson and the environmental and rangeland management problems on the base. Representatives of each federal agency also spoke briefly on the land use and specific problems at their facilities. At the beginning of the second day, Brian Milhbachler discussed the problems faced by the United States Air Force Academy. These presentations are summarized below.

Fort Carson

Welcome. Bob Stack, Range Control

Fort Carson has about 340 thousand acres of maneuver ranges at two different locations; Fort Carson itself is 138 thousand acres and Piñon Canyon, located 150 miles to the south, consists of 235 thousand acres. A wide range of training involving various types of equipment is conducted on these installations. Many of the ranges are being reconfigured to streamline the training mission.

The training lands are **monitored** through the Land Condition Trend Analysis (LCTA) program. Monitoring plots are identified with geographic positioning system (GPS) technology and digital photography. The monitoring plots are allocated according to the various vegetation types in the training areas. At Fort Carson, one monitoring plot is allocated for every 150 maneuverable acres for a total of 356 plots; at Piñon Canyon, one monitoring plot is allocated for every 450 acres for a total of 332 plots. Data collection includes ground cover, biodiversity, and measurements of erosion and maneuver disturbances. The majority of the training areas monitored last year were in average or improved condition; only two areas were found in conditions below average, one each with moderate and severe disturbance.

Challenges addressed by the Land Rehabilitation and Maintenance (LRAM) program at Fort Carson include reducing wind and water erosion on firebreaks, trails, and other heavily used areas, and decreasing training downtime as a result of fires that are exacerbated by the prevalence of invasive weeds in the small impact areas.

A long-term goal for the LRAM program is to develop maneuver-impact-resistant grass stands on the ranges and training areas at Fort Carson and Piñon Canyon. This should reduce erosion potential while building a more realistic training environment.

To demonstrate the beneficial effects of land management on Fort Carson, the LCTA program is working to implement a program similar to that used by the Idaho National Guard. In Idaho, Dana Quinney has stated that the comparison of off- and on-post monitoring plots has been helpful. We believe this will be beneficial at Fort Carson, as grazing is no longer permitted on post, but does occur nearby.

Land management procedures at Fort Carson. Jeff Linn, Directorate of Environmental Compliance and Management (DECAM)

The Directorate of Environmental Compliance and Management is charged with managing the natural and cultural resources at Fort Carson and the Piñon Canyon Maneuver Site. It is also required to support its primary customer, the soldier. It is through a variety of land-management practices that we are able to provide the soldier with high-quality realistic training lands. We strive to improve our management by reevaluating our practices. One such effort is to improve our seed mixes to use more native plant materials that are resistant to training activities and that can germinate quickly in a semi-arid environment. It is through a partnership with CRREL and the USDA Agricultural Research Station in Logan, Utah, that this progressive advancement is possible.

Both Fort Carson and Piñon Canyon support a variety of training exercises using tactical vehicles such as Abrams tanks, aircraft, howitzers, and humvees. Activities include large-scale training exercises, digging anti-tank trenches and hull defilades, using woodlands for concealment, live firing, bivouacking, and dismounted training. While these activities are essential to prepare our soldiers for war, they do have an impact on the natural resources. The challenge is to restore the land for future training activities. Fort Carson approaches this challenge in several ways.

Education. Soldiers are instructed not to damage or destroy trees. The piñon pines and junipers are slow-growing and suitable replacements can take up to 60 years to provide adequate concealment.

Revegetation. Areas disturbed by training are reseeded annually. As many as 5,000 acres are reseeded annually, with most of the work being performed by contract managed and funded by the Integrated Training and Management (ITAM) program. Drill seeding is used primarily, with broadcast seeding in areas where maneuvering of equipment is difficult. "Critical-area seeding" is used on drastically disturbed areas: the area is first drill seeded and then native grass hay is blown on and crimped into the soil.

Watershed management and erosion control. Soil loss and deposition are concerns on Fort Carson. Impacted areas are identified at the watershed level. Each year measures are taken to control erosion and trap sediment. These include the construction of erosion-control dams, check dams, hardened crossings, bank-sloped gullies, turnouts, diversions, and terraces, as well as the reclamation of redundant roads and trails. Erosion-control dams are now constructed with broader tops to allow vehicular traffic to cross, and the older dams are being reworked to allow safe crossing.

Deferment areas. Highly disturbed areas at Fort Carson and Piñon Canyon are identified and, in coordination with DPTM, are rested for up to three years. The areas are identified with signs that limit training to dismounted exercises and passing through on designated roads and trails. The rested sites are assessed for the type of treatment required to improve the site. This may include seeding or the construction of erosion control structures. Each year, the sites are evaluated to determine if they have recovered and are ready for opening to full training use.

Monitoring. The Land Condition Trend Analysis of ITAM performs annual data collection and analysis of the vegetation at Fort Carson and Piñon Canyon. Analyzed data can be used to assess the condition and trend of the training lands.

Research. Several research projects are conducted to improve our understanding of our resources and to improve our management strategies. Research includes understanding the erosion and sediment processes in a watershed, gaining understanding on the little-known gullying processes, detecting soil moisture levels from satellite imagery, determining the effectiveness of biological controls on several species of noxious weeds, and studying plant materials to improve seed performance and seed mixes.

Question and answer topics included the following:

- There is some erosion by wind, but the main problem is from water.
- We do use mulch on drastically disturbed areas. We call this critical-area seeding. The process is to drill seed, then blow on native grass hay, and finally crimp it into the soil. We require that native grass hay be used because it crimps in better than straw and carries with it additional seed. We have experimented with seeding annuals, such as oats, and have found it works well as a substitute to blowing and crimping hay.
- We have a good relationship with the Corps of Engineers at Pueblo, Colorado. We worked with them in the development of a programmatic agreement for the 404 permitting process.

- Early succession plants, such as weeds, dominate newly seeded bank-sloped sites the first few years, but we have observed that the seeded perennials are coming in and gradually dominating the site. We do not use chemicals downrange for such species. Such a practice on the early succession plants would be costly and, in many instances, unnecessary. If necessary, we will mow.
- We have not observed there being a problem with seed predation with drill seeding. Obviously, there will be seed predation with broadcast seeding, but to reduce this we require that an attachment such as a harrow be used to incorporate the seed into the soil.

Yakima Training Center (part of Fort Lewis, Washington)

Clark Reames

Yakima Training Center is on the dry, eastern side of the Cascades and it hosts a wide spectrum of training, from the 3rd Brigade out of Fort Lewis and the National Guard Bureau (NGB) to the Japanese ground defense force. It receives six to nine inches of precipitation per year, and sagebrush and bunchgrasses are the predominant vegetation. Current issues include water quality impacts on the salmon in the Columbia and Yakima Rivers; rerouting of roads and the associated control of drainage and siltation; control of noxious weeds using spray and biological controls; and wildfires and the problem of re-establishing sagebrush after such fires. There is currently some tracked vehicle traffic, but the training activities are transitioning to rubber-tired light armored vehicles (LAVs), and it is not known what type of damage the tires will cause.

National Guard Bureau

Dana Quinney, Orchard Training Area, Idaho

The Orchard Training Area in Idaho serves as a multi-purpose training range for four states. All of this area is within the Snake River Birds of Prey National Conservation Area, which is Bureau of Land Management (BLM) land. The entire training area is heavily grazed. The area receives 4 to 12 inches of rain per year. About a third of the training area was burned many years ago and there are severe exotic weed problems. We plant mostly tough, low natives, such as squirreltail, sagebrush, and rabbit brush. We don't plant high grasses, such as bluebunch wheatgrasses, because of the high grazing pressure.

Danny Moss, Wyoming National Guard

Problems here are similar to those at the Orchard Training Area in Idaho. \$15 to \$20K per year is spent on seed.

Army Corps of Engineers

Bill Casale, Sacramento District

The Corps of Engineers does both military and civil works projects. On the military side, the Corps is a reimbursable agency that does tasks for other organizations. In this capacity we do not manage lands, we act as advisors, mostly for the Army but also for the Air Force and Navy. On the civil works side, the Corps does manage lands around lakes, reservoirs, flood control projects, and multi-use lands. On the lands managed by the Corps we do have problems with invasive species, such as cheatgrass and star thistle. Urbanization is also a problem, creating conflicts between multi-use management and heavy recreation use.

Army Environmental Center

David Lorenz, USDA-NRSC liaison to AEC

The Army Environmental Center, located at Aberdeen Proving Ground, Maryland, provides installation support concerning the environment including but not limited to reclamation, acquisition, compliance, restoration, range and munitions, conservation, human resources, pollution prevention, cleanup, unexploded ordnance (UXO), and technology demonstration and transfer.

National Park Service

Pamela Benjamin, Intermountain Region

The National Park Service (NPS) currently is composed of 389 park units nationwide, encompassing 83 million acres of land.

Major issues. Disturbed lands restoration and exotic plant management are major issues for the National Park Service (NPS). Both of these issues are identified as reportable Performance Management Category 1 Mission Goals for the NPS in accordance with the Government Performance and Results Act. Close to three million acres are currently identified service-wide as “targeted”

(of higher priority) under the NPS 2001–2005 Strategic Plan for either restoration or exotic-plant management actions.

The Intermountain Region of the NPS consists of 89 park units (10 million acres) within eight states: Montana, Wyoming, Utah, Colorado, New Mexico, Arizona, Oklahoma, and Texas. Acreage within the Intermountain Region “targeted” for restoration and weed management activities is equal to nearly 800,000 acres under the 2001–2005 Strategic Plan.

Policies and guidelines. Because the NPS is a Congressionally mandated preservation agency, it is required by some very specific policies and guidelines to maintain biological and genetic diversity within the parks. NPS “Management Policies” (2001) and Vegetation Management Guidelines (NPS-77, currently under revision) are the main documents that provide parks with direction and formal policy guidance in addressing vegetation and weed management and disturbed-land restoration issues. The newly revised “Management Policies” (2001) for the first time contains a section especially directed at “Restoration of Natural Systems.” This section specifically states that “The NPS will strive to protect the full range of genetic types of native plant and animal populations in the parks by perpetuating natural evolutionary processes *and minimizing human interference with evolving genetic diversity.*”

Sources of native materials. The guidance further specifies a process for considering the *sources* for native vegetation materials to be used in restoration or revegetation activities. Plants should be taken from populations as closely related as possible both genetically and ecologically to the area to be restored, using the following priority:

- Same site
- Adjacent site
- Within park
- Local (external to park)
- Regional (within same eco-region).

Use of cultivars of native species is not currently restricted by NPS policy, but is more or less discouraged and considered as a “last resort” and may become restricted in the future.

NPS concerns on the use of cultivars are related to potential impacts to biodiversity at both the genetic and species levels. At the *genetic level*, the NPS wants to avoid the potential of diluting or possibly eliminating historic native genotypes within the parks. At the *species level*, cultivars are often selected for

traits that allow for quicker establishment or that are more aggressive, or both. This can lead to the formation on monocultures of the cultivar similar to some weed species, reducing the presence of other native species within a site.

The NPS is not trying to condemn research on or use of most native plant cultivars, but it hopes

- 1) To encourage additional research on the long-term impacts of native cultivars on natural populations, especially at the genetic level; and
- 2) To continue to *increase communications* with its neighbors so that all are more aware of each other's resource management issues, concerns, and needs, with the ultimate goal being to ensure that what may solve one problem is not creating another.

Air Force

Wayne Fordham, Agronomist, HQ AFCESA/CESM, Tyndall Air Force Base

The Air Force manages about 9.9 million acres of land. Land use is different from the Army or NGB because we do not have heavy military equipment on the land. The typical Air Force base is relatively small in size. Many bases have only 4,000 to 4,500 acres. However, there are several larger bases with bombing and range-firing missions. Missile sites are generally small and have little soil disruption. A few bases have agricultural out-leases for grazing or other agricultural purposes.

United States Air Force Academy

Brian Milhbachler, Natural Resources Program

The Natural Resources Program at the United States Air Force Academy encompasses 18,455 acres on the Academy grounds plus 655 acres on the Farish Recreation Area. There is high plant and animal diversity throughout. Rangeland management goals include sustaining healthy rangeland plant communities that promote soil conservation and watershed protection, provide wildlife habitat, and discourage the invasion of noxious weeds; preventing the introduction of new noxious weed species; and implementing an integrated weed management program to control the existing noxious weed populations. Native seed mixes and recommended revegetation techniques are used on all restoration projects. Management issues include encroachment, threatened and endangered species, wild-

land fires, forest pests and disease, noxious weeds, game and fisheries management, nuisance wildlife, and erosion and sedimentation.

Encroachment. Along with security problems and noise issues, encroachment of suburban development creates a loss of biological diversity and contributes to some erosion and sedimentation problems. Residential and industrial development, particularly along the eastern and northern boundaries of the base, will likely increase the problem of bird and wildlife strike hazards (BASH) as more wildlife will be forced onto the base as natural habitats are disturbed and additional wildlife, including waterfowl, may be attracted by landscaping and recreational facilities associated with developments.

Threatened and endangered species. Two federally listed species occur on the base: Preble's Meadow Jumping Mouse (PMJM) and Greenback Cutthroat Trout (GBCT). Field surveys by the Colorado Natural Heritage Program in 1993–1995 identified 10 rare or imperiled vertebrates, five rare or imperiled invertebrates, and six rare or imperiled plants on Academy property, including Farish Recreation Area.

The Academy property supports the largest population of Preble's Meadow Jumping Mouse in the Arkansas Basin and one of the larger populations range-wide for the species. It occurs in Monument Creek and all of its major tributaries, and its habitat is disturbed by erosion and sedimentation. The base is implementing a Conservation Agreement and Conservation Plan with the U.S. Fish and Wildlife Service to protect the habitat.

Greenback Cutthroat Trout were introduced in the 1990s to non-potable reservoirs as experimental populations for assessing their compatibility with a catch-and-release recreational fishing program, but the population has declined in both reservoirs as a result of problems with high pH and periodic low reservoir levels.

Wildland fire. The Academy uses controlled burns for weed control and to maintain open spaces for security. Prescribed burns in the fall, winter, and spring are used on weed-infested rangeland to stimulate native vegetation and reduce the weed seed bank. The plan is to burn about 1,000 acres per year, but typically, approximately 100 acres are actually burned annually. A range-management goal calls for increased use of prescribed burning in grassland and shrubland habitats to facilitate healthy plant communities, quality wildlife habitat, and fire protection.

Forest pests and diseases include the mountain pine beetle and dwarf mistletoe. Some pine mortality has also occurred from the use of road deicers.

Noxious weeds. There are six species of noxious weeds known to occur on base that are listed by the state of Colorado as a priority for control: diffuse knapweed, spotted knapweed, yellow toadflax, leafy spurge, Canada thistle, and musk thistle. The Texas Agricultural Experiment Station has been working on base since 2000 to introduce biological control agents for these weed species. This is part of a regional biological weed control effort that also includes Monument Fire Center and Fort Carson. The Colorado Natural Heritage Program has been contracted to conduct a base-wide noxious weed inventory in 2002. The data will be put into the GIS database and will form the basis for developing an integrated weed management plan in 2003.

Future weed-control efforts will include chemical, biological, burning, and mechanical measures that are implemented in a systematic and ecologically prioritized manner. Release of biological control agents that have been proven effective and host-specific for controlling noxious weeds will continue. Native seed mixes and revegetation techniques that are adapted to the local area have been developed in conjunction with the Natural Resources Conservation Service. Permanent range transects have been surveyed since 1991 to document trends in species composition, cover, production, and invasive species. Certified weed-free hay is used at the base stables and weed-free mulch and native seed are used in revegetation and erosion control projects.

Game and fisheries management includes deer, elk, bass, and Canada geese and stocking for recreational fishing. The loss of wildlife habitat due to off-base development puts greater pressure on the base to sustain and manage a healthy wildlife population. However, as more animals reside on base, the need for effective habitat and population management increases.

In 2001, Natural Resources personnel observed approximately 70 elk on base, and a January 2002 aerial survey by the Colorado Division of Wildlife (CDOW) estimated that there are approximately 700 deer on base. In conjunction with the CDOW, the Natural Resources office determined that it will manage for a deer population of 500–700 animals and an elk population of 25–30 animals. Hunting is viewed as the most effective, efficient, and economical means of controlling deer and elk numbers on base. Natural Resources coordinates with the Forestry program to plan prescribed burns and clearing to improve habitat for elk, deer, bighorn sheep, turkey, and other wildlife. In cooperation with CDOW, turkeys are trapped on base and transplanted for off-base populations.

Five lakes at the Academy are stocked by Natural Resources between March and September with catchable-size rainbow trout, brook trout, and channel catfish, and occasionally with German brown trout or Snake River cutthroat trout. Annual and one-day fishing permits can be purchased; 6000 one-day permits are

available between Farish (4000) and the Academy (2000). In 2003, the Air Force Academy will comply with new state regulations that mandate stocking of whirling-disease-free fish in all waters connected to streams that support wild, reproducing salmonid populations. Disease-free fish are already stocked on base.

Nuisance wildlife includes bears, coyotes, and mountain lions, along with smaller mammals, such as mice, squirrels, bats, skunks, foxes, and raccoons. The management approach is to educate people and implement practices that do not attract these animals to the more populated areas. Coyotes and bears in trashcans are the most common complaints. Nuisance bear calls should decline in base housing because Pine Valley was outfitted with bearproof dumpsters in 2001 and Douglas Valley will be bearproofed by late 2002. Additional bearproofing will be needed elsewhere on base as the bears discover that food is no longer available in the housing areas. Persistent bears may be harassed with spot-lighting, fireworks, paintballs, or rubber buckshot to teach them to avoid certain areas on base, particularly the housing areas. Occasional sightings of mountain lions are reported to Natural Resources. The base public is educated on safety in lion country through various articles, signs, and CDOW brochures.

Erosion and sedimentation, both from on- and off-base sources, are degrading wetland, riparian, and upland habitats, including areas occupied by the federally protected Preble's Meadow Jumping Mouse. The permanent loss of soil resources exacerbates the difficulties and cost associated with conducting successful revegetation projects. Natural Resources is coordinating with on- and off-base entities to prevent erosion, sedimentation, and excessive runoff into wetland and riparian areas. Conservation Agreement mitigation projects and erosion control projects to enhance wetland and riparian habitat include willow planting, tree planting, soil stabilization measures, and native revegetation. Construction projects are coordinated to minimize the amount of time that bare ground is exposed. Native seed mixes and NRCS-recommended site preparation and seeding guidelines are used for all revegetation projects to promote the establishment of vegetation cover. Any new development of impacts within the 100-year floodplain of Monument Creek and its tributaries is discouraged.

3 NEW GRASS GERMPASMS: ESTABLISHING NATIVE PLANTS AND DEVELOPING RESILIENT GERMPASMS

Current techniques and problems for native plant establishment

Larry Holzworth, Plant Materials Specialist, USDA-NRCS, Bozeman, Montana

Reclamation objectives include

- Stabilizing soils
- Minimizing environmental impacts
- Creating a favorable plant growth media
- Species selection and appropriate establishment techniques
- Plant protection during establishment
- Maintaining a desirable plant community.

The key to establishing natives on a site is to know the site: its soils, climate, and other limitations on what can grow there. Timing of the seeding is important. Soil is a good seed storage bank; seeds can persist for a long time waiting for favorable germination conditions.

If the disturbance has not already occurred, preplanning can be valuable. Things to consider are

- Biological inventory, such as climate, vegetation, etc.
- Soil physical and chemical characteristics
- Land form
- Topsoil and subsoil preservation: topsoil is the most precious commodity; do what you can to preserve or stockpile it so it can be replaced after the disturbance
- Toxic material remediation
- Reclamation construction and soil replacement
- Site preparation techniques.

Steps for revegetation are

- Eliminating competition

- Matching species to site conditions
- Preparing the seedbed
- Planting: broadcasting vs. drilling
- Protecting the area appropriately from problems such as grazing and weed competition.

Examples of disturbed areas and revegetation efforts

- **Hard Rock Gold Mine in western Montana.** The site receives 10 to 12 inches of precipitation per year. It has 1:1 slopes and no topsoil. Seeding was accomplished on coarse-textured overburden with bluebunch wheatgrass, slender wheatgrass, and thickspike wheatgrass using a modified snowmobile.
- **Snake River highway project** used a native species seed mixture and straw fiber mats along roadsides. Hydromulching and wood fiber cost about \$1000/acre plus mobilization fees. A native grass seed mixture costs about \$65/acre. Straw mesh erosion control fabric costs about \$0.20 to 0.50/sq. yd. plus installation.
- **Hell Creek landslide, west of Glacier National Park.** This site also had 1:1 slopes. Restoration included a combination of shrubs, jute net, and a sterile hybrid wheatgrass as a nurse crop. The hybrid lasted only two to three years and helped prevent erosion until the perennial grasses became established.
- **ARCO, “C Hill,” Anaconda, Montana.** The C Hill is a 60% slope site that was originally timbered. Tons of soil had been lost, some stump roots were 3 to 4 feet above ground, and sediment was washing into city streets and sewers. The surface 3–4 inches of soil material was highly acidic (pH 3.7 to 4.2) from smelter stack emissions, with calcium carbonate below. A gouging machine (Hodder Gouger) towed by a tractor was used to make pits (4 feet long by 2 feet wide by 4 inches deep) to hold water and get down to the Ca layer. Broadcast seeding of thickspike wheatgrass, slender wheatgrass, and basin wildrye established well in the pits. The area was also limed—although the liming was probably not necessary—and mulched with cereal straw, but the mulch blew away. The pits provided microsites for successful plant establishment. Five years later, shrubs that had come from adjacent lands and that had been grown in a nursery were transplanted onto the site.

Seeding practices	Cost/acre (1987 \$)
Seed	203
Pitting and seeding	55
Fertilizer	32
Lime	286
Lime application	55
Straw mulch	242
Total	873

Shrub establishment	Cost/acre (1989 \$)
Transplants	476
Planting	476
Fertilizer	54
Total	1006

Another steep slope above and below a cemetery was reshaped, broadcast seeded with the same species mixture as above, and covered with an excelsior erosion control blanket, which is very expensive but which was needed in this small critical erosion situation.

- **Birch Creek water diversion dikes.** Bulldozer basins were made on the faces of 1:1 slopes. A native seed mixture was broadcast prior to dozer tracking. The dozer tracks helped promote growth by providing contour catchments and a firm seedbed for seed germination.
- **Stillwater Mine.** Rows of hay bales and some snow fence cut wind and erosion until the plants established on silica oxide mine tailings.
- **Rising Sun Road reconstruction, Glacier National Park.** The topsoil was stripped and stored before the construction, and then brought back after the work. The area was hydromulched with an indigenous native diverse seed mixture. Diversity is important for stabilization. Mowing has become a problem as it harms the desired plants and allows weed encroachment.
- **Bucksnot wildfire seeding near Helena, Montana.** Seeding with native species of slender, thickspike, and bluebunch wheatgrass on snow in February proved successful. Orchardgrass has been used in the past

and is a good cheap choice for broadcasting on snow from helicopters. Helicopter seeding costs are estimated at \$50/acre.

Summary

- Conditions are seldom perfect for seeding.
- Work with nature.
- Timing is everything.
- Accommodate biological systems.
- Plan ahead. Preserve the topsoil!
- Use common sense and patience.

The most successful seedings are those that are planted just before a rain event. If that does not happen, the safest thing with native species is to get the seed into the ground. Once it rains, the plants will grow, even if the rain is three to four years late. Seed persists well in the soil.

Demonstrating resilient plant species at Fort Carson: Overview of SERDP Research Program

Antonio J. Palazzo, Research Agronomist, ERDC-CRREL

The new germplasms demonstrated at this workshop were developed under the Strategic Environmental Research and Development Program (SERDP) project, CS-1103, “Identify Resilient Plant Characteristics and Develop Wear-Resistant Plant Cultivars for Use on Military Training Lands.”

Mr. Palazzo, at the Cold Regions Research and Engineering Laboratory, is the lead researcher for the project. Other participants are

- U.S. Department of Agriculture–Agriculture Research Service: Dr. K.B. Jensen, Dr. B.L. Waldron, and Dr. S. Larson, plant breeding specialists
- Construction Engineering Research Laboratory: Mr. A. Anderson and Dr. Richard Gebhart, land capability models specialists
- Pennsylvania State University: Dr. D. Huff, plant genetics and root growth specialist

The goal of the project is to increase availability of training lands by enhancing plant resiliency through improved selective breeding programs to develop new germplasms. The Army has 11 million acres of training lands under the Integrated Training Area Management (ITAM) program, and the Land Repair

and Maintenance (LRAM) is the greatest expense in ITAM's budget. Today's training needs create Army-unique impacts on vegetation and soil conditions, driving the need for resilient species. The demand for the resilient plants will depend on market availability and genetic diversity. The primary reason for this workshop is to demonstrate the genetic diversity of the new germplasms and to promote them for commercial availability.

The technical objectives for the project are to (1) breed improved native and naturalized plant cultivars to control erosion and provide stable plant ecosystems on military training lands and (2) enhance existing land-management models to include effects of training on soil compaction, plant injury, and regrowth and to provide methods for mitigation and rehabilitation. The project began with basic research on genetic markers associated with desired traits for resiliency on low-maintenance, high-use military training areas. The applied research aim is to use the genetic markers to improve the selective breeding process by ensuring that selected plants carry the desired traits. In the demonstration phase of the project, the resiliency of new plant materials is being evaluated through controlled tests on military training lands at Yakima Training Center, Washington, and Fort Carson, Colorado. This year, the demonstrations are being expanded to include Camp Guernsey, Wyoming.

The technical approach covers four areas: (1) For plant breeding and germplasm development, we surveyed existing native plants on military facilities and selected the most promising existing species. The most promising populations were bred for improved seed germination, seedling vigor, rhizome development, persistence, drought tolerance, and weed control. Similar surveys were also conducted on military facilities for introduced species, which were bred with additional off-base collections. Final steps in this part of the approach are to test and release the new germplasms. To date three germplasms have been released (see Appendix D) and we expect to release an additional eight germplasms in the next two years (see Kevin Jensen's presentation on the new germplasms, below). (2) For plant root growth and tracking, we established tracking studies on existing grasses as well as new germplasms. We are completing a report on this phase of the project. (3) To improve establishment and inhibit invasive weeds, we are evaluating the use of seed mixtures at three locations and in the greenhouse (see Blair Waldron's presentation on establishing native plants, below). (4) This workshop is our first major effort for marketing and technology transfer.

Within the adapted area for the new germplasms (Fig. 1), we have identified 42 military facilities, which include 1.3 million acres of Army lands. The new germplasms are also appropriate for other federal, state, or local agencies, highway right-of-ways, mine spoils, rangelands, and other disturbed areas.



Figure 1. Adapted area for SERDP-select germplasms. All plant materials were collected within this area.

While our current emphasis is on improving the resilience of native species present on training lands, the research program began by looking primarily at introduced or naturalized species. Our first three releases are naturalized species; in-progress program reviewers were concerned about the effects of introducing these cultivars in native ecosystems. To address this concern, we invited a panel of independent reviewers from the U.S. Environmental Protection Agency, The Nature Conservancy, USDA-NRCS, and another USDA-ARS office to review the materials we were developing at Yakima Training Center (Palazzo et al. 1999). This group met in May 1999 and evaluated a research site of mature plants, examined several previously sown sites of naturalized grasses, and reviewed our data. The naturalized species we are working with are limited to bunch-type or moderately rhizomatous species that are already present on military training lands, and the review panel found that the plants were not encroaching into other plant communities and were not establishing monocultures.

An interim product of our research is the recommended seed mixtures that have been used at Fort Carson, Yakima Training Center, and Fort Drum, New York. At Fort Drum we have planted mixed seedings of weeping lovegrass and fescues with the desired native switchgrass. The weeping lovegrass establishes

quickly, protecting the soil and moisture; however, as a warm-climate annual, it quickly dies back, allowing the fescues to come in. After two to four years, switchgrass dominates the stand.

A description of our program was published in *Diversity* (Palazzo and Hardy 1998). Appendix C lists all publications related to this research project.

New germplasms

Kevin Jensen, Research Geneticist, USDA-ARS, Logan, Utah

The goal of the breeding program is to breed improved native and introduced plant germplasms to control erosion and provide stable plant ecosystems on military training lands. The characters of interest are

- Increased tillering rate
- Rhizome development
- Increased rate of seed germination and better seedling vigor
- Resistance to drought and temperature extremes
- Salinity tolerance.

At the beginning of the program, many more species were examined and eventually dropped as the most promising species became apparent. Seedling vigor was identified as the most important of the above desired characters.

At Yakima Training Center, 134 collections were made in 1994 and 1995, including the natives bluebunch wheatgrass, Sandberg bluegrass, basin wildrye, and western yarrow. At Fort Carson, 166 collections were made, including the native species western wheatgrass, blue grama, sideoats grama, and Indian ricegrass.

Evaluation trials were established at both Yakima Training Center and Fort Carson during the fall of 1994 and 1996. The plots are 5 feet by 75 feet, with four replications. Visual percent stand and vigor ratings were taken throughout 1995–1998. Over 60 cultivars, breeding lines, and material directly from the training sites were included in the Yakima trials. Over 40 cultivars, breeding lines, and material indigenous to the training sites were included at Fort Carson.

Based on the evaluation trials (see Tables 1 and 2), the following species were selected for improvement:

Introduced

Crested wheatgrass	(SERDP-selected 'RoadCrest' & 'CD-II' commercial releases)
Siberian wheatgrass	(SERDP selected)
Russian wildrye	(SERDP-selected Tetra-1 commercial release and Syn A)

Native

Bluebunch wheatgrass	('P-7' Multi-line & SERDP selected)
Snake River wheatgrass	(SERDP selected)
Basin wildrye	(SERDP selected)
Western wheatgrass	(SERDP selected)
Slender wheatgrass	(two SERDP-selected populations)
Sandberg bluegrass	(SERDP multi-line)
Western yarrow	(SERDP multi-line)

Native germplasms

Following is information about natives selected for improvement. Table 3 compares traits from original populations with those of the selected populations.

Bluebunch wheatgrass is difficult to establish and sensitive to grazing. The SERDP-select bluebunch population originated from collections near Yakima, Washington. This particular population has had two cycles of selection for seed germination, seedling vigor, and plant vigor. A Selected Class Germplasm release is expected in 2004. Within the selected population, the seedling emergence rate from a deep seeding was double that of the original population (see Table 3). Bluebunch wheatgrass 'P7' is a multi-origin germplasm bringing together 25 ecotypic lines from Utah, Idaho, Washington, Oregon, Nevada, Montana, and British Columbia. With its broader genetic base it is adapted to a wider range of environments. Foundation seed was produced in 1999 and commercial seed is now available.

Western wheatgrass is a strongly rhizomatous grass. SERDP-select populations originated from collections near and on Fort Carson, Colorado, and from already existing cultivars. In the first cycle, collections were selected for plant vigor and persistence; in the second cycle, plant vigor and seedling vigor; and in the third cycle, plant vigor, seed weight, seed yield, and seedling vigor (see Table

3). We are testing and increasing these populations and will release them as a Selected Class Germplasm in 2003.

	% Stand		
	Exit 11	Snake A	Snake B
Introduced species			
Crested wheatgrass	74	72	
Russian wildrye	47	60	
Siberian wheatgrass	84	94	
Forage kochia	70	25	
Intermediate wheatgrass	49	81	
Hard fescue	11		
Alfalfa		35	
Native species			
Snake River wheatgrass	66		90
Bluebunch wheatgrass	45		63
Thickspike wheatgrass	38		58
Basin wildrye	4	60	
Western wheatgrass	21	40	
Indian ricegrass	1	6	
Thurbers needlegrass	0		
Idaho fescue	13		
Globemallow	0		
Needle and thread grass	3	10	
Sandberg bluegrass	0	35	
Squirreltail	2	10	
Yarrow	24	28	
Forbs	1	3	

The SERDP-select **Snake River wheatgrass** population originated from ‘Secar’ and two native collections near Yakima, Washington. This grass is difficult to establish and sensitive to grazing. The SERDP-select population exhibits increased seedling vigor and seed yield compared to the original population (see Table 3). We expect to release a Selected Class Germplasm in 2004.

Table 2. Percent stand at Fort Carson evaluation plots in 1998.		
	% Stand	
	Turkey Creek	South Boundary
Introduced species		
Crested wheatgrass	95	78
Intermediate wheatgrass		32
Russian wildrye	48	65
Siberian wheatgrass	85	81
Native species		
Squirreltail		31
Sand lovegrass		31
Blue grama	0	0
Slender wheatgrass		71
Thickspike wheatgrass	54	26
Western wheatgrass	54	55
Indian ricegrass	19	
Needle and thread grass	5	
Sideoats grama	0	

Table 3. Mean values of desired traits for SERDP-select germplasm compared to the original populations.

	Seedling emergence rate/day (mean)		Total seedling emergence (mean)		Seed weight (mean g/50 seeds)		Total seed yield (mean g/plant)	
	Original	Selected	Original	Selected	Original	Selected	Original	Selected
Bluebunch wheatgrass	1.24	2.58			0.23	0.30	5.91	8.32
Western wheatgrass	2.3	3.9	31.6	52.9				
Snake River wheatgrass	2.3	3.9					11.75	16.25
Basin wildrye	0.85	1.32						

The SERDP-select **Basin wildrye** was collected near Yakima, Washington. Historically this species is known for its poor seed germination and seedling vigor. Two cycles of selection for improved seed germination and seedling vigor resulted in significant increases to both traits (see Table 3). We expect to release a Selected Class Germplasm in 2004.

The major limitation with **slender wheatgrass** is its lack of persistence. We are working with two SERDP-select populations. Collections from Fort Carson were selected for emergence from a deep planting depth with concurrent phenotypic selection for improved plant vigor. A large-scale seed increase field was established in 2000. Several hundred pounds of this germplasm are available for demonstration. A formal pre-variety germplasm release is expected in 2003.

A second population of **slender wheatgrass** from the Pikes Peak area of Colorado has undergone two cycles of selection for emergence from a deep planting depth with concurrent phenotypic selection for improved plant vigor and rhizome development. Breeder seed increase fields of cycle-2 were established in 2002. This is an excellent-looking population with good seedling and plant vigor. Cycle-2 seed will be available for demonstrations in the fall of 2003.

SERDP-multi-line **Western yarrow** comprises 28 collections within Yakima Training Center. It is a broad-based population with no selection pressure having been applied. This germplasm is in the seed-increase phase and a formal release as a Selected Class Germplasm is expected by 2004.

Sandburg bluegrass is one of the first grasses to establish after a disturbance. SERDP-multi-line Sandberg bluegrass germplasm originated from 28 different ecotypes within Yakima Training Center. By combining the different ecotypes, this broad-based germplasm should be better adapted to a wider range of environments. No genetic manipulation was done. Seed is being increased in 2002 and 2003 and a Selected Class Germplasm release is expected in 2004.

Introduced germplasms

'Vavilov' **Siberian wheatgrass** is available commercially and is an excellent grass for dry sandy soils with 8 to 12 inches of annual precipitation. SERDP-select Siberian wheatgrass was selected out of Vavilov and germplasm collected in Kazakhstan (former Soviet Union). After two cycles of selection for plant color, vegetative vigor, seedling vigor, and seed yield, the selected population is more drought-tolerant than Fairway or Standard-type crested wheatgrass and it greens up earlier in the spring. Release is planned for 2004.

SERDP-select **crested wheatgrass** cultivars commercially available are CD-II (Reg. No. CV-24, PI 594024, Asay et al. 1997) and RoadCrest (Reg. No. CV-25, PI 606546, Asay et al. 1999). CD-II crested wheatgrass is excellent on dry sites receiving 10 to 12 inches of precipitation. It is derived from the cultivar Hycrest, which is a hybrid between induced tetraploid *Agropyron cristatum* and natural tetraploid *Agropyron desertorum*. This cultivar is more resilient to training because it has improved drought resistance and increased growth under

cold temperatures, and it is easier to establish than other crested wheatgrass cultivars.

RoadCrest crested wheatgrass is recommended as a low-maintenance turf with moderate rhizome development and is often used on roadsides to prevent erosion. RoadCrest is a long-lived perennial and is significantly more rhizomatous than 'Ephraim' crested wheatgrass. RoadCrest produces less biomass and is 15 to 25% shorter than forage-type crested wheatgrass cultivars, making it suitable in areas where mowing is necessary, such as gunnery ranges and roadside plantings. Seedling vigor and drought resistance of RoadCrest compares favorably with other crested wheatgrasses, and RoadCrest initiates growth earlier in the spring than other turf and low-maintenance grasses.

The cultivar Bozoisky-select **Russian wildrye** is an excellent dryland bunchgrass that is drought resistant with excellent winter forage quality. However, the use of Russian wildrye is often limited by its poor establishment characteristics. SERDP-select lines Tetra-1 and Syn A Russian wildrye have improved seed germination and seedling vigor. Tetra-1 germplasm of Russian wildrye was released as a Selected Class Germplasm. It has increased plant height, longer and wider leaves, increased seedling emergence, heavier seeds, and improved water-use efficiency (Reg. no. GP-75, PI 599302; Jensen et al. 1998). A large-scale seed increase field of Syn A was established in 2000. We currently have several hundred pounds of this germplasm. We plan to release it in 2002 and continue seed harvest in 2002, 2003, and 2004.

Tracking study

The cumulative effect of two years after light to heavy training activity—consisting of 0, 1, 2, and 4 passes—were evaluated on over 25 species by measuring percent target species, other species, weedy species, litter, and bare ground on and off the tracked area. Preliminary data suggest that in most cases the introduced or naturalized species were more tolerant or recovered more rapidly under repeated tracking. However, native grasses western and Snake River wheatgrass showed promise as stabilization species. In addition, significant differences between on and off tracks were not apparent in passes 1 and 2.

Questions

Several questions concerned batched ecotypes and the problem with seeds maturing at different times. There is a possibility of losing some seed depending on when the seeds are harvested. By using a seed stripper instead of a combine,

seeds can be harvested at various times to overcome this problem. If the grasses are self pollinating, however, there will be little mixing.

The seed dormancy mechanism is not known. For this work, we are just trying to “break” it.

4 INVASIVE WEED CONTROL

DoD perspective on invasive weed control

*Captain Gary Breeden, USN, Executive Director,
Armed Forces Pest Management Board*

The Armed Forces Pest Management Board got its start during World War II when Marines became ill at Guadalcanal. After living under various umbrellas, it eventually found its current home with the Department of Defense (DoD). The Board is concerned with environmental compliance within the DoD. A major role is to bring rational, science-based information to the decision-making process, providing the needed counterpoint to the political and emotional aspects of decisions.

Current issues include dealing with range encroachment (urbanization near facilities) and acting as good stewards of the environment.

Chemical control of invasive weeds

Lisa Moore, DuPont Chemical Company

There are many reasons to control undesirable vegetation. In addition to displacing native ecosystems, undesirable plants create roadside hazards, provide fuel for wildfires, and become nuisances in recreation areas and around our homes. Two Executive Orders on invasive species and the use of native plants direct Federal agencies to control and monitor invasive species, prevent the introduction of invasive species to new areas, and restore native species.

The toolbox of control methods includes biological controls, such as insects; cultural controls, such as making the site strong enough to resist weed invasion; mechanical controls, such as mowing, pulling, cutting, burning; education to prevent poor vegetation management practices; and chemical controls.

Toxicity of chemicals

When using chemicals, it is important to understand how to use them properly as well as be aware of their toxicity. Relative acute toxicity may be compared using the LD50 measure (the dose required to kill half of a rat population), which is the federal standard in determining pesticide toxicity. Common herbicides vary from almost non-toxic to highly toxic (Table 4). By

comparison, nicotine, gasoline, and caffeine are moderately toxic, and table salt and baking soda are very slightly toxic.

Table 4. Toxicity of some herbicides and other common items.		
Toxicity	LD50 (mg/kg)	
Almost non-toxic	greater than 5,000	OUST XP ESCORT XP KRENITE S Glyphosate Clopyralid picloram
Very slightly toxic	about 3,500	table salt baking soda
Slightly toxic	from 2,000 to 3,000	KROVAR I DF TELAR DF dicamba Sahara diuron
Moderately toxic	from 53 to 200	nicotine gasoline caffeine
Highly toxic	40 mg/kg	paraquat

Labels and Material Safety Data Sheets (MSDS) provide all necessary information for a particular chemical.

Some chemicals are restricted for use only by certified agents. Federal restrictions are based on EPA toxicity classifications. States differ in their restrictions on chemicals based on many aspects. In Colorado, for example, chemicals are restricted depending on bird or fish toxicity, leaching, groundwater concerns, residual effects, or off-target concerns in dry conditions. Chemicals restricted in Colorado include bromacil (Krovar, Hyvar), diuron (Karmex), prometon (Pramitol), tebuthiuron (Spike), monuron, sodium chlorate, and sodium metaborate.

Performance of chemicals

In choosing the appropriate chemical, you must consider type of plant, soil texture, rainfall, application, temperature, and herbicide type. Timing is important especially for annuals: winter annuals germinate in the fall and mature in the spring, while summer annuals germinate in the spring and mature in the fall. It is better to spray plants when they are young or before the seed head matures. The

higher the organic content of soil, the higher the application rate that should be used because the greater number of microbes in high-organic soil will break down the chemical faster. Rainfall helps plants grow and can wash contact herbicides off the plant and carry residuals into the soil and plant roots. Mixing order, agitation, calibration of equipment, weather, and wind are all important considerations for successfully applying chemicals. Temperature affects the rate of plant growth and the absorption of residuals from the soil; high temperatures speed up the degradation of chemicals.

Modes of action

Herbicides may be selective—affecting only certain plants, such as only broadleaf weeds or annual grasses—or non-selective. Herbicides primarily affect plant growth either systemically—by translocation within the plant—or by direct contact with a specific part of the plant, such as foliage or roots. Some herbicides have a residual effect in that they will persist for some time after application instead of breaking down and becoming inert soon after application.

- Growth regulator herbicides include
 - 2,4-D (phenoxy acetic acid)
 - 2,4-DP (phenoxy propionic acid)
 - dicamba
 - picolinic acid (picloram or triclopyr)
- Photosynthetic inhibitors are
 - atrazine (Aatrex)
 - simazine (Princep)
 - prometon (Pramitol)
 - hexazinone (Velpar)
 - substituted urea (karmex/diuron)
 - substituted uracil (Hyvar XL)
- Aromatic amino acid synthesis is inhibited by glyphosates (Roundup, Rodeo, Accord, Dupont Glyphosate VMF).
- Bud development is inhibited by fosamine (Krenite S).

- Branch chain amino acid synthesis is inhibited by imidazolinone (Arsenal)
sulfonyl ureas (Oust *XP*, Telar DF, Escort *XP*)
- The modes of action are not clear for organic arsenicals (cacodylic acid, MSMA).

Final observations

The use of a quality surfactant is required to obtain the maximum performance of most herbicides. A good surfactant will provide enhanced spreading and coverage of the herbicide with no antagonism to the active ingredient. Also, it will not disrupt the active transport within the plant to allow the herbicide to penetrate the leaves and shoots of the plants.

A unique attribute of Escort and Telar is their ability to inhibit seed formation and the production of viable seed. The impact of these two herbicides on weed seed is so detrimental to weeds such as Canada thistle, musk thistle, Dyer's woad, and houndstongue, that you may not find any production of viable seed.

Leafy spurge, which is a major problem in the west, is actually stimulated by mowing, pulling, or burning. Tordon and, recently, another herbicide, Plateau, have shown excellent control of this highly invasive weed.

Chemicals are an essential component in a toolbox against weeds.

Techniques for establishing native plants on weed-infested lands

Blair Waldron, Research Geneticist, USDA-ARS, Logan, Utah

This research was performed by Blair L. Waldron, Research Geneticist, Kevin B. Jensen, Research Geneticist, W. Howard Horton, Rangeland Scientist, and R. Deane Harrison, Rangeland Specialist, all from the USDA-ARS, Forage and Range Research Lab, Logan, Utah, working with cooperators Antonio J. Palazzo and Tim Cary from CRREL, James Kulbeth and Jeff Linn from Fort Carson, and Pete Nissan and Clark Reames from Yakima Training Center.

Some general tips from Howard Horton for establishing plants on weed-infested lands are

- Remove competition.

- Disturb lands as little as possible to maintain soil structure, surface organic material, and soil moisture. This might involve use of herbicides, fire, or light cultivation.
- When preparing a seed bed, it should be firm, but not compact, to allow good soil-to-seed contact.
- Always plant just prior to the season with the highest chance of precipitation.
- Plant the most competitive plant material available for the given objective.
- Know proper depth of seeding for different species. For example, shrubs need to be at the surface, bluebunch and western wheatgrass should be less than 3/4 inch deep, and Indian ricegrass needs to be 2 to 3 inches deep to break down the seed coat.
- Use good common sense, scientific expertise, and past experience.

When choosing plant materials, use the best material for the given situation and objective. If the objective is to provide a quick hardy ground cover in a frequently disturbed site or to prevent erosion and stop or slow the spread of invasive weeds, then choose competitive plant materials with fast establishment. If the objective is restoration to native grass species, then ask the following questions during the planning stage:

- What activities are present, such as military training, livestock and wildlife management, fire control, recreation, or soil erosion? Keep in mind that some activities may limit the use of materials that are slow to establish, whereas many grasses will die if not “used” by grazing, burning, or other activity.
- Are there invasive weeds on the site?
- What is the soil condition? Are there climatic changes?
- Is nature ever static? Is restoration feasible?
- What intermediate steps may be necessary?

These are important questions. Because of the current multiple uses on the land, restoration may not be feasible, or intermediate steps may be necessary because of conditions such as erosion, invasive weeds, and repeated fires.

Perennial native triticeae grasses are usually more difficult to establish than introduced counterparts. This is caused by seed dormancy, poor seedling vigor, and a reduced tolerance of natives to defoliation, grazing, and traffic. These

problems are pronounced in areas that are weed infested, have degraded soils, or are prone to repeated fires. Another problem for natives is the limited supplies of seeds, making them more expensive.

Commonly used introduced grasses have been criticized because early seedlings were often monocultures, they may displace native species, they reduce biodiversity, and they can disrupt the ecology and aesthetics of the plant community. However, studies have shown that introduced grasses are seldom invasive, can occur in diverse ecosystems in native habitats, and often co-exist with natives.

Introduced grasses can act as an “ecological bridge” to the establishment of native grasses. An example of using an ecological bridge is demonstrated in strategies to reduce cheatgrass infestations. Cheatgrass was accidentally introduced in the late 1800s, and virtually all sagebrush and bunchgrass ranges are infested with it to some degree today. Cheatgrass is a major threat to ecological balance, resource conservation, and productivity. It forms a closed system and fuels recurrent fires, thereby perpetuating cheatgrass dominance. A logical means of controlling cheatgrass is to replace it with a perennial grass, but there has been limited success with native grasses being able to replace cheatgrass. The introduced crested and Siberian wheatgrasses have shown potential in inhibiting cheatgrass growth and may be used as a “bridge” to establish natives. The new varieties developed on the SERDP research program are particularly promising.

‘Vavilov’ Siberian crested wheatgrass seeded into a cheatgrass stand is able to do quite well without the use of herbicides. It may provide a possible “bridge” to the establishment of perennial native grasses. However, recruitment of natives from indigenous seed sources into crested wheatgrass seedings can be a slow process. We recently completed two evaluations of using different methods to seed native and introduced grasses together.

Bluebunch wheatgrass establishment through Siberian wheatgrass bridge

In the first study, we examined the establishment of the native bluebunch wheatgrass using a Siberian wheatgrass bridge. The study was seeded at Yakima Training Center in November 1998. We used four-row plots with 25- or 38-cm row spacings. The seeding rate was 100 PLS per linear meter. The experiment used Snake River wheatgrass (native), bluebunch wheatgrass (native), and Vavilov Siberian wheatgrass (introduced) in the following treatments:

- A monoculture of each of the above three grasses
- A binary seed mixture of Vavilov with each native grass
- Alternating rows of Vavilov with each native grass.

Table 5 shows percent of cheatgrass in each plot in 2000. These results show that plots with Vavilov had lower amounts of cheatgrass. For instance, significant reductions in cheatgrass occurred when Vavilov was planted in alternating rows with bluebunch or Snake River wheatgrass as compared with each of those natives planted alone. In the Vavilov and bluebunch combinations, Vavilov allowed bluebunch to get established. The next step is to see if Vavilov will allow bluebunch to persist, especially through drought.

Grasses	Row spacing		Mean
	25 cm	35 cm	
Bluebunch wheatgrass	53	65	59
Snake River wheatgrass	35	78	57
Vavilov Siberian wheatgrass	7	30	19
Bluebunch/Snake River mix	57	70	64
Bluebunch/Snake River alternating rows	30	52	41
Bluebunch/Vavilov mix	17	47	32
Bluebunch/Vavilov alternating rows	30	52	41
Snake River/Vavilov mix	25	48	36
Snake River/Vavilov alternating rows	25	48	36
Bluebunch/Snake River/Vavilov mix	16	50	33
Mean	32	56	44
LSD (0.05)	23	19	15

Turkey Creek mixed native and introduced seeding

In the second study, we compared species and varieties when seeding mixtures of native and introduced grasses at Turkey Creek on Fort Carson, Colorado. This study was dormant-seeded in the fall of 1997. The treatments involved a core native-grass mix plus one of five additional introduced grasses. The core native mix is shown in Table 6; the introduced add-on species were Bozoisky Russian wildrye, Tetra-1 Russian wildrye, RoadCrest crested wheatgrass, Vavilov Siberian wheatgrass, and CD-II crested wheatgrass. For comparison, the Fort Carson standard mix (see Table 7) was also seeded at increased rates to match the above treatments. The plots were evaluated in 1999, 2000, and 2001 for species composition, percent ground cover, percent annual and biennial weeds, percent introduced grasses, and percent natives.

Table 6. Core native mix plus introduced add-on.		
Species	Lb/acre	% of mix
Core native mix		
'Barton' western wheatgrass	4	26
'Pryor' slender wheatgrass	2	14
'Nezpar' Indian wheatgrass	1	6
'Vaughan' sideoats grama	1	6
'Critana' thickspike wheatgrass	2	13
Lovegrass	0.5	3
Blue grama	1	6
Introduced grass add-on	4	26
Total	15.5	100

Table 7. Fort Carson standard mix at seeding rate increased to match the core-mix-plus-add-on treatment.	
Species	Lb/acre
'Barton' western wheatgrass	7.9
'Vaughan' sideoats grama	4.4
Alkali sacaton	0.4
Sand dropseed	0.3
'Nordan' crested wheatgrass	1.8
'Ladak' alfalfa	0.7
Total	15.5

Overall, the mixes with the crested or Siberian wheatgrasses had the fewest weeds (Fig. 2). After three years, the plots with Fort Carson mix and the core mix with the Russian wildrye add-ons had native grasses predominating, while the core mix with the crested or Siberian wheatgrass add-ons yielded more introduced grasses. The Fort Carson mix allowed the greatest percentage of natives after three years, but there was less diversity among the native species than with the mixes with Russian wildrye (Fig. 3).

From the Turkey Creek mixed-seeding study, there appear to be several options depending upon the objective. If the objective is rapid control of soil erosion and weeds in areas with frequent disturbance, then the core mix plus crested wheatgrass is the best choice. If there are four or more years between disturbances, or if disturbances are light and erosion and weeds are not problems, then the military mix with western wheatgrass predominating is the optimum

choice. For control of soil erosion and weeds while allowing general buildup of diverse native grasses, then the best choice is the core mix plus Russian wildrye.

This study took place in an area that normally receives 38.3 cm (15 inches) of annual precipitation; the results may be different at a drier location.

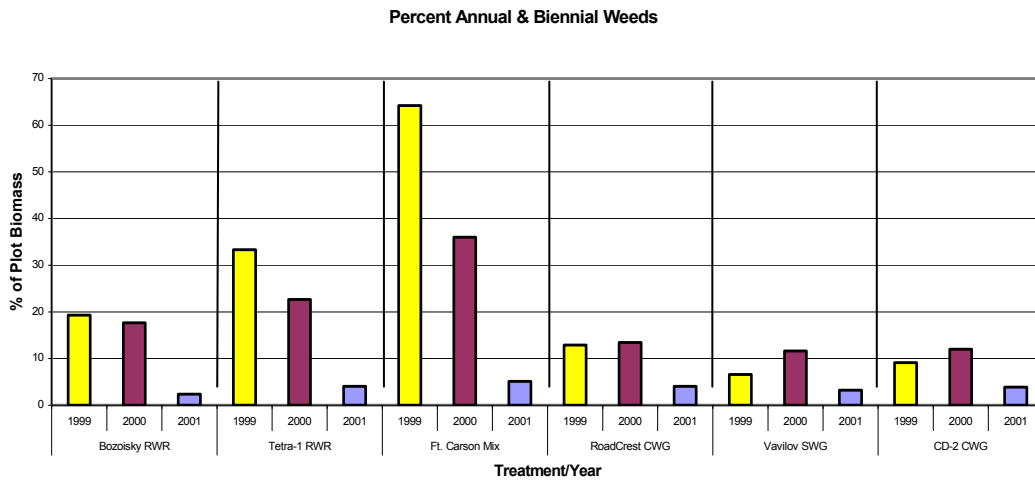


Figure 2. Percent annual and biennial weeds in Turkey Creek plots planted with the standard Fort Carson mix or with a core native mix plus an introduced-grass add-on (as named on the treatment axis).

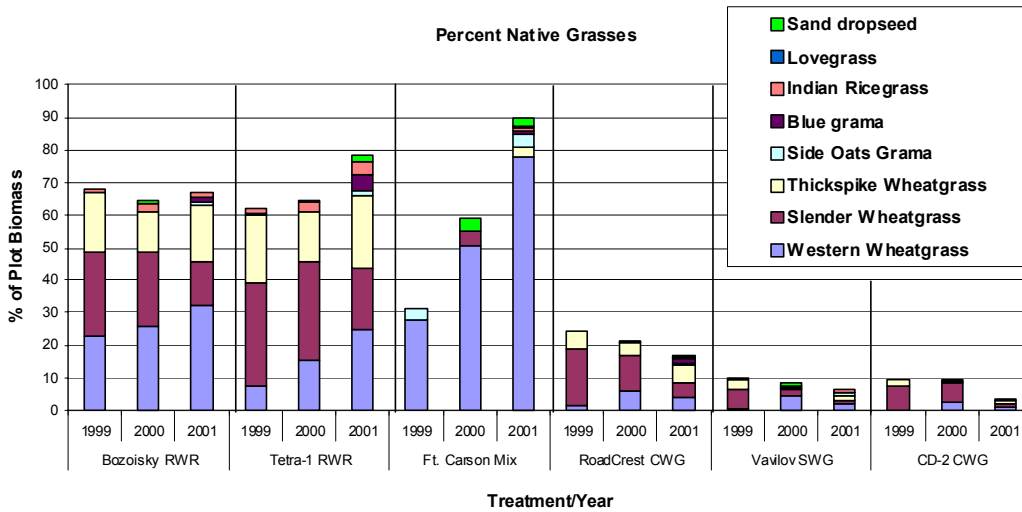


Figure 3. Percent native grasses in Turkey Creek plots planted with the standard Fort Carson mix or with a core native mix plus an introduced-grass add-on (as named on the treatment axis).

Forage kochia as an ecological bridge

Forage kochia may act as an ecological bridge by stopping the fire cycle. The introduced species forage kochia can be used in “green strips” to contain wildfires and is competitive enough to help stop the spread of invasive weeds such as cheatgrass. Forage kochia seeded at 1 lb/acre with a mix of grasses provides good forage and habitat for wildlife and livestock; however, forage kochia seeded as a monoculture at 6 lb/acre can rapidly provide a good firebreak. Firebreaks can be established using lower rates, such as 1 lb/acre, but it may take six or more years before it is fully established to the point where it can stop fires. Although it is an introduced species, forage kochia is good for wildlife such as insects, sage grouse and other birds, and deer and elk, whereas cheatgrass is relatively barren. Studies have shown that forage kochia will not invade perennial communities, but even if it were to become more invasive in the future, it is still the better choice over cheatgrass. Soil is the most important commodity and its loss through erosion is an irreplaceable tragedy; therefore, it may be beneficial to use a less-than-ideal plant to preserve the soil for future restoration.

Overall conclusions

Choose the best plant materials to meet the objectives. Restoration to native grasses may require intermediate steps to build up soil organic matter and structure, control weeds, and reduce the fire cycle. Introduced plant materials may provide an “ecological bridge” to establish native grasses. What you choose to do depends on your objective. Do you need a rapid cover for erosion control or can you afford to wait for desired cover to establish? What you decide to do is also very site-specific. In very dry conditions, an “ecological bridge” may not help failure rate.

Biological control of noxious weeds along the Colorado Front Range

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G.J. Michels and D.A. Owings of the Texas Agricultural Experiment Station performed this research in cooperation with the Fort Carson Military Reserve (DECAM), the U.S. Air Force Academy, the U.S. Department of Energy’s (DOE) Rocky Flats Environmental Technology Site, and the U.S. Forest Service’s Monument Fire Center. Collaborators are the Colorado Department of Agriculture, Colorado College (Department of Biology), Montana State University, Oregon Forestry Services Laboratory, the Pennsylvania Department of Agriculture, and the USDA APHIS (Bozeman, Montana, and Mission, Texas).

The existing sites are still in either Phase One—collection and release of biocontrol agents and sampling for establishment—or Phase Two—increasing the populations of the biocontrol agents by redistributing those that are established in Phase One into areas where they are not yet established. We do not yet have any sites in Phase Three, which is the ecological and economic analysis of the program in terms of how the biocontrol program impacted the pest and how the benefits compare to standard control practices. In general, each phase covers three years.

Current biological control release sites are at Rocky Flats, the U.S. Air Force Academy, and Fort Carson. The program began at Fort Carson with weed surveys and releases in the spring of 1997. Noxious weeds on Fort Carson include Canada thistle, spotted knapweed, musk thistle, and field bindweed. On Fort Carson, the following biological agents have been released:

To control Canada thistle	<i>Urophora cardui</i>
	<i>Larinus planus</i>
	<i>Cassida rubiginosa</i>
	<i>Ceutorhynchus litura</i>
To control spotted knapweed	<i>Cyphocleonus achates</i>
	<i>Urophora affinis</i>
	<i>Larinus minutus</i>
	<i>Agapeta zoegana</i>
	<i>Chaetorellia acrolophi</i>
	<i>Metzneria paucipunctella</i>
	<i>Sphenoptera jugoslavica</i>
	<i>Urophora quadrifasciata</i>
To control musk thistle	<i>Trichosirocalus horridus</i>
	<i>Rhinocyllus conicus</i>
To control field bindweed	<i>Aceria malherbae</i>

The biological control program expanded to the Air Force Academy in 2000; that program includes the U.S. Forest Service Monument Fire Center. Noxious weeds include Canada thistle, spotted knapweed, musk thistle, field bindweed, and leafy spurge. Biological agents released, respectively, for Canada thistle and spotted knapweed are *L. planus* near Ice Lake Road and *L. minutus* along

Monument Creek. Agents released for leafy spurge are *Aphthona lacertosa*, *A. nigriscutis*, and *A. czwalinae*. At the Monument Fire Center site, noxious weeds include Canada thistle, diffuse knapweed, leafy spurge, musk thistle, and Dalmatian toadflax. Releases there include *Brachyterolus pulicarius*.

Releases at the Department of Energy's Rocky Flats Environmental Technology Site began in the spring of 2001. The program is integrated into an ongoing weed integrated pest management (IPM) program. Noxious weeds at this site include Canada thistle, diffuse knapweed, musk thistle, field bindweed, and Dalmatian toadflax. At this site, *Mecinus janthinus* was released to control Dalmatian toadflax.

Successes

Knapweed control at Fort Carson has been highly successful. Four of six insects have been recovered. *L. minutus* is present in sufficient densities to begin redistribution. *C. achates* is prevalent and significant damage is evident. *U. affinis* is present, but there may be competition with *U. quad.* *C. acrolophi* has also been recovered, but its impact is unknown.

R. conicus was previously established at Fort Carson on musk thistle, and is easily recovered. *T. horridus* was released in 1999 and has had a synergistic effect. This combination is reducing musk thistle density at three sites at Fort Carson.

Although the program at the Air Force Academy is not as advanced as at Fort Carson, it is proceeding rapidly. Knapweed and spurge insects are well established. We have recovered *Cassida rubiginosa* and *Larinus planus* on Canada thistle—a first for this area. Mapping weed and insect densities continues, and new releases will be made in 2002.

Disappointments

Canada thistle has been the most difficult target to address. Although *C. rubiginosa* and *L. planus* have been recovered, impact is slight at present. Competition from ants tending aphids and leafhoppers may be one of the reasons why the biocontrol agents are not effective. We noticed this effect when sites at Fort Carson, which had a lot of ants, differed from sites at the Academy, which had few ants, in *C. rubiginosa* and *L. planus* establishment.

A problem with Canada thistle is that insects such as *L. planus* and *C. rubiginosa* are targeted at the seed head and upper leaves, and they do little to limit spread because of the thistle's extensive root systems. Commonwealth Agricultural Biology International (CABI) is conducting surveys in Russia and

Asia for additional species that attack the stems and roots. Candidate species include

Aceria anthocoptes: an eriophyid mite, inflicts severe damage

Thamnurgus spp: a scolytid beetle (taxonomic status uncertain)

Euhagena palarifformis: a sessid moth, very specific

Altica carduorum: a chrysomelid beetle, non-target damage?

Unexpected or unintended events have had an impact on the research. Some sites have been destroyed due to construction. Also there have been problems trying to integrate different phases of the IPM program. A few of our sites were sprayed with herbicides long after the chemicals had any chance of being effective and after signs had been posted! Some overlapping research projects were permitted, and some unusual requests were made for access to our sites. As an example, a new housing development is going in at our Gate 5 release site.

Directions for 2002

We now have a series of sites in different temporal states allowing the program to “feed upon itself.”

- Fort Carson is in the second stage of a typical biocontrol program, where redistribution and monitoring weed reduction is the major focus.
- The United States Air Force Academy is in the second year of the first phase, releasing and establishing biocontrol agents.
- Rocky Flats is just starting as far as our involvement is concerned; however, from earlier efforts, they seem to be in the latter stages of Phase One.

In 2002, we will redistribute biocontrol agents at Fort Carson and use Fort Carson sites as source material for the Air Force Academy, Monument Fire Center, and Rocky Flats programs. We will collect extensive plant mapping, density, and distribution data at all four sites. Remediation efforts will occur at Fort Carson. More insects will be released for leafy spurge control at the Air Force Academy and toadflax control at Rocky Flats. Experiments will be conducted on potential competition from ants in Canada and musk thistle patches.

The program has a well-trained, experienced team in place and strong contacts with other weed biocontrol researchers around the country. The program received a “Pulling Together Initiative” grant for our work at the Air Force Academy and Monument Fire Center. We actively seek further cooperation from

any organizations interested in furthering biological control of noxious weeds along the Front Range.

Environmental concerns

Another aspect of our program is the potential impact on native thistle species. These species are important to the Colorado ecosystem, and must be taken into account when biocontrol agents are released.

Platte thistle is a native found at the Air Force Academy. It has definite phenological differences compared to the weed musk thistle. Can an insect such as *R. conicus* attack both? If so, what damage is the native subjected to? What damage can be tolerated?

Our program has developed impact statements for native thistles, we track the occurrence of natives at all sites, and we are conducting long-term research on the impact to natives. We believe that the answer is not 0% impact. We must take care so that natives are not destroyed, but the risk of doing nothing or using alternative controls (herbicidal or mechanical) must also be assessed.

Future directions

In 2002, we intend to continue expanding the program to other Federal sites. With continued help from our cooperators, we hope to begin a program this summer at Warren Air Force Base in Cheyenne, Wyoming, for control of Dalmatian toadflax in an environmentally sensitive area where we will be dealing with an endangered plant species, the Colorado butterfly plant.

Integrating weed management strategies: How to tie it all together

Cindy Lair, Boulder County Weed Supervisor, Boulder, Colorado

Timing is key to the control of weeds. We have a variety of tools, which in addition to chemical or biological controls, include mapping, monitoring, burning, and grazing. The right tool must be used at the right time so that it has its desired effect.

Often a combination of tools provides the best results, taking into account the proper timing. For example, biocontrols may be your main method of control, but it can help to use herbicides or mowing along the edges to contain the weeds while the biocontrol does its job. A good analogy is wildfire management: fight the edges and prevent spread.

When choosing appropriate control methods, you need a picture of the whole landscape. At one site, for example, elk came in and destroyed other grasses after knapweed had been controlled. Or, when mowing, some undesired species might survive below the mower level and live to produce seeds.

Biocontrols may never provide complete eradication, so it is often good to combine such controls with herbicide application.

The overall goal is not necessarily total eradication, which is probably impossible, but to keep the invasiveness under control. To obtain that goal, you must also be prepared to fill the niche with desirable species that can help keep the weeds from re-invading.

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APPENDIX C. PUBLICATIONS FROM SERDP PROJECT

The following publications relate to research funded by the Strategic Environmental Research and Development Program (SERDP) project, CS-1103, “Identify Resilient Plant Characteristics and Develop Wear-Resistant Plant Cultivars for Use on Military Training Lands.”

Peer-reviewed journals or papers

Asay, K.H., N.J. Chatterton, K.B. Jensen, R.R-C. Wang, D.A. Johnson, W.H. Horton, A.J. Palazzo, and S.A. Young (1997) Registration of ‘CD-II’ crested wheatgrass. *Crop Science*, **37**: 1023.

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APPENDIX D. GERMPLASM RELEASES

Registration of 'CD-II' crested wheatgrass

Published in *Crop Science*, **37**: 1023 (1997).

K.H. Asay, N.J. Chatterton, K.B. Jensen, R.R-C. Wang, D.A. Johnson, W.H. Horton, A.J. Palazzo, and S.A. Young

'CD-II' (Reg. no. CV-24, PI 594024) crested wheatgrass is derived from the cultivar Hycrest, which is a hybrid between induced tetraploid *Agropyron cristatum* (L.) Gaertner and natural tetraploid *Agropyron desertorum* (Fisch. ex Link) Schultes. CD-II was developed by a research team at the USDA-ARS Forage and Range Research Laboratory, Utah State University, Logan, Utah, and released in cooperation with the Utah Agricultural Experiment Station and the USDA Natural Resources Conservation Service. This was partially funded under the SERDP Program.

This new plant is more resilient to training because it has better drought resistance, has greater growth under cold temperatures, and is easier to establish than the crested wheatgrass cultivars that are currently on the market. We are using the germplasm of this new cultivar to identify the genetic markers in plants with these resilient characteristics. The genetic markers will be used in further breeding studies.

Registration of RWR-Tetra-1 tetraploid

Published in *Crop Science*, **38**: 1403 (1998).

K.B. Jensen, K.H. Asay, D.A. Johnson, W.H. Horton, A.J. Palazzo, and N.J. Chatterton

RWR-Tetra-1 Russian wildrye (*Psathyrostachys juncea* [Fisch.] Nevski) germplasm (Reg. no. GP-75, PI 599302) was partially funded under the SERDP Program and developed and released by the USDA-ARS Forage and Range Research Laboratory in cooperation with the Utah Agricultural Experiment Station at Utah State University (USU). RWR-Tetra-1 is the first release of tetraploid Russian wildrye germplasm that includes naturally occurring tetraploid plants in its parentage.

This germplasm was found to have a rapid rate of emergence, which was significantly greater than for the other named cultivars tested. This rapid emergence will reduce downtime when reseeding training lands. In environments with 450 to 500 mm of annual precipitation, dry matter production was equal to cur-

rent cultivars. When evaluated on harsh sites (250 to 350 mm of annual precipitation) and under close row spacings (0.5 vs. 1.0 m), yields were equal to or less than current cultivars.

Seed stocks of RWR-Tetra-1 are maintained by the USDA-ARS, Forage and Range Research Laboratory, Utah State University, Logan, Utah 84322-6300, and genetic material of this release will be deposited in the National Plant Germplasm System, where it will also be available for research purposes, including development and commercialization of new cultivars.

Registration of 'RoadCrest' crested wheatgrass

Published in *Crop Science*, **39**: 1535 (1999)

Asay, K.H., K.B. Jensen, W.H. Horton, D.A. Johnson, N.J. Chatterton, and S.A. Young

'RoadCrest' crested wheatgrass (*Agropyron crestatum* [L.] Gaertn.) (Reg. No. CV-25, PI 606546), a rhizomatous cultivar, was developed by the USDA-ARS Forage and Range Research Laboratory, Utah State University, Logan, Utah. This research was partially funded under the SERDP Program.

RoadCrest is a long-lived perennial and is significantly more rhizomatous than the only other released rhizomatous crested wheatgrass, Ephraim. RoadCrest produces less biomass and is 15 to 25% shorter than forage-type crested wheatgrass cultivars, making it suitable in areas where mowing is necessary, such as gunnery ranges and roadside plantings. Seedling vigor and drought resistance of RoadCrest compares favorably with other crested wheatgrasses, and RoadCrest initiates growth earlier in the spring than other turf and low-maintenance grasses.

Genetic material of this release will be deposited in the National Plant Germplasm System, where it will also be available for research purposes, including development and commercialization of new cultivars.

REPORT DOCUMENTATION PAGE

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14. ABSTRACT A two-day workshop provided information on new introduced- and native-grass germplasms adapted to the western United States and presented methods for fighting invasive weeds. The intent of the workshop was to help land managers choose native herbaceous plants to rehabilitate sites, reduce soil erosion, and increase training opportunities. Western rangelands are typically dry, with annual precipitation from 4 to 12 inches. Participants presented the land-management problems they face on their installations. Military facilities, which must balance training mission needs with environmental concerns, are seeking natives that are resistant to training activities and can germinate quickly in a semi-arid environment. ERDC-CRREL and the U.S. Department of Agriculture-Agricultural Research Service (USDA-ARS) in Logan, Utah, have developed new cultivars and germplasms of native and introduced grasses that establish rapidly, compete with invasive weeds, and are resistant to land disturbances caused by military training activities. These plants were developed by improving the native and introduced grasses already growing on military ranges in the western United States. The new germplasms are also appropriate for other federal, state, or local agencies; highway right-of-ways; mine spoils; and other disturbed areas; they also will help managers satisfy the Presidential Order on native plants. Three germplasms have been released to date and eight more will be available. Related establishment studies have shown that seed mixtures using the native grasses along with rapidly establishing introduced species can quickly form a grass cover that inhibits invasion of noxious weeds and prevents erosion, and that, over time, will develop into a stand of predominantly native grasses. Other methods to control areas of noxious weeds include use of chemicals, introduction of insects that feed on specific weed species, and judicious use of mechanical methods such as mowing, pulling, or controlled burns. Biocontrol research has shown successful control using insects targeting knapweed and musk thistle. Often, a combination of tools, taking into account the proper timing for each, provides the best results in controlling weeds.													
15. SUBJECT TERMS <table style="width: 100%; border: none;"> <tr> <td style="width: 25%;">Invasive weeds</td> <td style="width: 25%;">Military lands</td> <td style="width: 25%;">Plant germplasms</td> <td style="width: 25%;">Seeding techniques</td> </tr> <tr> <td>Land rehabilitation</td> <td>Native plants</td> <td>Revegetation</td> <td></td> </tr> </table>						Invasive weeds	Military lands	Plant germplasms	Seeding techniques	Land rehabilitation	Native plants	Revegetation	
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