# Research to Practical Use: On-the-Ground Successes

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The US Department of Agriculture–Agricultural Research Service (USDA-ARS) Great Basin Rangelands Research Unit services a large area that runs from south-central Nevada to the Oregon border and from northeastern California to the Utah border. This vast array of landscapes has a variety of stakeholders who request assistance in addressing range, wildlife, and sustainable agriculture issues. At the 64th Annual Society for Range Management Meetings held in Billings, Montana, in February 2011 we were invited to present at a special symposium "Agency Accomplishments—Making a Difference on the Ground." Here we present three case studies of our efforts to 1) research the problem at hand, 2) deliver practical on-the-ground practices to minimize or eliminate the problem, and 3) improve sustainable agricultural practices.

## Case Study 1: Tall Whitetop Control and Rehabilitation

Tall whitetop (*Lepidium latifolium*), also known as perennial pepperweed, is native to Eastern Europe and Asia[1] and was accidentally introduced into North America in the 20th century.[2] Tall whitetop is a root-creeping exotic weed that has invaded native hay meadows, riparian areas, and agronomic fields throughout the western United States. Landowners and agriculture producers approached us in the early 1990s to address the numerous management problems tall whitetop was causing them, specifically, major losses in forage quality. We tested mechanical (discing), biological (goats), and chemical (herbicides), as well as a combination of these treatments to control tall whitetop infestations. In all we had a combination of 52 treatments. Here we report on what we consider the more important portions.

Discing, conducted in late May and early June, initially reduced tall whitetop cover from 95% cover down to 5% cover, but by the end of summer (October) tall whitetop cover was up to 30% and reached 100% the following July. Discing in early May followed by the application of herbicides (2-4D 2.2 kg/ha [2 pounds/acre] or Chlorsulfuron [Telar XP] 0.11 kg/ha [0.10 pounds/acre]) initially appeared to be very effective as tall whitetop leaves looked very necrotic. Even though tall whitetop failed to seed due to the combination of discing and spraying, tall whitetop became productive and vigorous by the following July, and cover increased to more than 20%. There were no significant[i] cover differences between the combination of discing and herbicide application and that of herbicide application by itself.

We also investigated the control of tall whitetop by grazing Spanish goats. Eight 0.1-ha (0.25 acre) enclosures were constructed of which four were grazed and combined with herbicide and seeding treatments while the remaining four enclosures were grazed and seeded. Heavy grazing of tall whitetop decreased forage yield by 78%, yet did not decrease the number of tall whitetop plants in the plots. Grazing tall whitetop as a control method was not successful as the sprouting perennial grass seedlings could not compete with the dense creeping rooted tall whitetop. The control of tall whitetop using goats and herbicide did not significantly[ii] reduce tall whitetop when compared to herbicide treatments by themselves.

Realizing that the increase in tall whitetop cover in such a short period was a major problem, we tested a variety of plant species in an attempt to suppress tall whitetop. After testing a variety of plant species we chose tall wheatgrass (*Elytrigia elongata*), which performed better in these salt-affected soils. We followed up the May/June (one-half bloom stage) herbicide application (same herbicides and rates) with the seeding of tall wheatgrass at (10.3 kg/ha [9 pounds/acre] rate). The objective was to reduce tall whitetop with the herbicide application and then suppress tall whitetop with a long-lived perennial grass. The following June, well after tall wheatgrass seedlings had emerged and developed three or more leaves, we applied 2-4D at 1.1 kg/ha (1 pound/acre) rate as to negatively affect tall whitetop yet not injure our tall wheatgrass seedlings with this selective herbicide. Tall wheatgrass seed-

[i] $P \geq 0.05$.
[ii] $P \geq 0.05$.

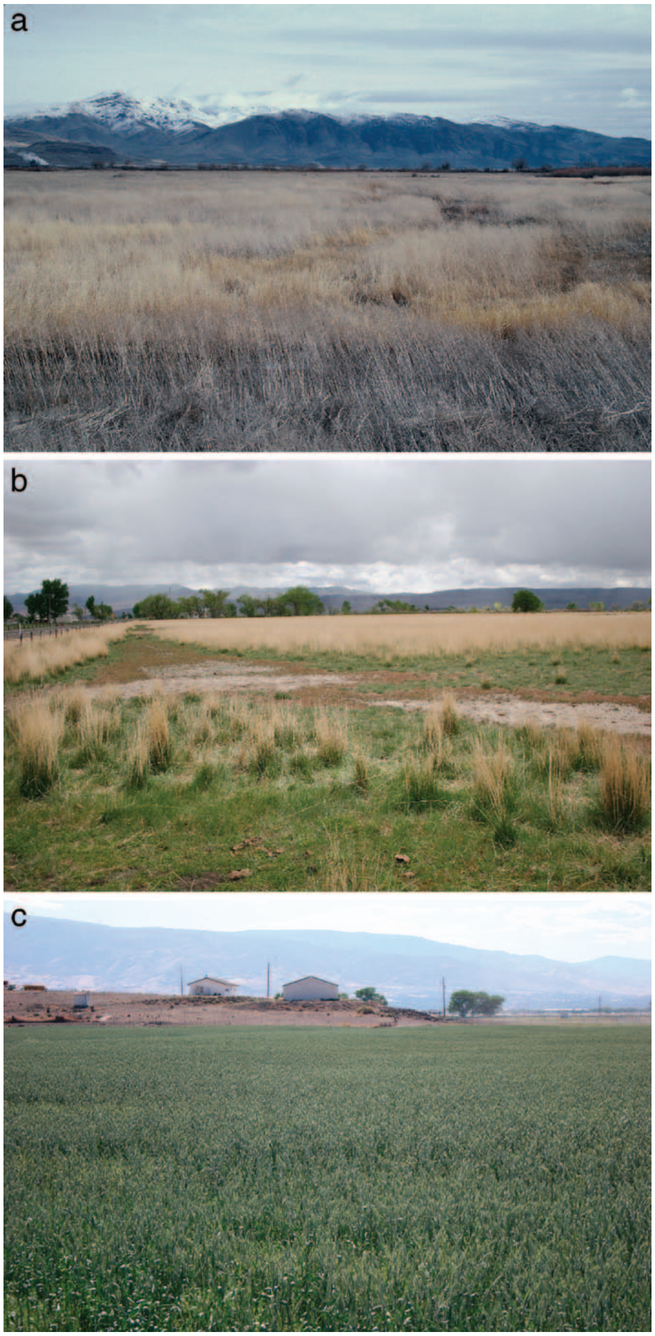


**Figure 1. a,** Tall whitetop density at the University of Nevada Agriculture Experiment Station before control treatments. **b,** Tall wheatgrass effectively suppressing tall whitetop 3 years following seeding. **c,** Following tall whitetop suppression, the site is returned back to production agriculture, as seen here with the field converted to *Triticades,* a rye/wheat cross.

lings in the Telar plots did not fair very well as the herbicide residue from Telar was still strong enough to kill the tall wheatgrass seedlings.[3] Following a couple of years of spot treating tall whitetop, tall wheatgrass had taken over the site and suppressed tall whitetop, and the site was converted back into production agriculture (Fig. 1). The cost of this effort was $40.30/ha ($99.50/acre).

## Case Study 2: Cheatgrass Suppression in Wyoming Big Sagebrush Communities

Cheatgrass (*Bromus tectorum*), native to central Eurasia, is a highly invasive annual grass that has invaded millions of hectares of rangelands throughout the Intermountain West and Columbia Basin Regions.[4] Cheatgrass has revolutionized secondary succession by providing a fine-textured, early-maturing fuel that increases the chance, rate, spread, and season of wildfires.[5] Whisenant[6] estimated the presence of cheatgrass has reduced the interval between wildfires from an estimated 60–110 years down to 5 years. Aldo Leoplold[7] recognized more than a half century ago how impossible it is to protect wildlife habitat from cheatgrass-fueled wildfires. Cheatgrass research has been going on for a very long time with pioneer researchers such as A. C. Hull, Joe Robertson, Ray Evans, Dick Eckert, and James A. Young being just some of the many to contribute important "lessons learned" information from seed germination to plant competition to possible control methods. Here we report on a group of private and state stakeholders that came to us for advice on how to successfully seed desirable perennial vegetation species on recently burned and/or cheatgrass-dominated rangelands in an effort to provide dependable forage and habitat for livestock and wildlife. We approached this task by depending on past experiences along with focusing on 1) timing of seeding, 2) mechanical control, 3) chemical (herbicide) control, and 4) plant material testing.

### *Timing of Seeding*

When a big sagebrush (*Artemisia tridentata*) community burns, our experience tells us that the presence of big sagebrush burns hot enough for a long enough period to kill a portion of the cheatgrass seed in the seed bank, which opens the window for long-lived perennial grasses to compete in these lower cheatgrass densities. If the site was previously dominated by cheatgrass, the wildfire simply burns too fast to kill the cheatgrass, and cheatgrass seeds are still present on the surface of the soil as well as in the seed bank. In northern Nevada we tested this theory by seeding a recently burned Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) dominated community. We tested the seeding of various species the first fall following the wildfire compared to waiting and seeding the second fall. Using a half-sized rangeland drill, we seeded four treatments:

a. Crested wheatgrass (*Agropyron cristatum*) (8 kg/ha [7 pounds/acre])
b. Sherman big bluegrass (*Poa ampla*) (2.3 kg/ha [2 pounds/acre])
c. Squirreltail (*Elymus elymoides*) (4.6 kg/ha [4 pounds/acre]) and
d. A mix of crested wheatgrass (4.6 kg/ha [4 pounds/acre]), Sherman big blue grass (1.1 kg/ha [1 pound/acre]), squirreltail (2.3 kg/ha [2 pounds/acre]), Indian ricegrass (*Achnatherum hymenoides*) (1.1 kg/ha [1 pound/acre]), 'Im-

**Figure 2.** Excellent establishment of crested wheatgrass. The suppression of cheatgrass following wildfires is critical if we are going to restore and rehabilitate burned rangelands.

**Figure 3.** The use of Landmark XP in northern Nevada. Notice the level of cheatgrass control as we prepare to seed the site.

migrant' forage kochia (*Bassia prostrata*) (0.6 kg/ha [0.50 pound/acre]), Wyoming big sagebrush (0.3 kg/ha [0.25 pound/acre]), and 'Ladak' alfalfa (*Medicago sativa*) (0.3 kg/ha [0.25 pound/acre]).

The mix experienced the best results with the establishment of 9.9 plants/m (3 plants/feet), (crested wheatgrass 4.2/m [1.3/feet], 'Immigrant' forage kochia 3.1/m [0.95/feet], Sherman big bluegrass 1.4/m [0.4/feet], squirreltail 0.7/m [0.2/feet], Indian ricegrass 0.3/m [0.09/feet], and Ladak alfalfa 0.2/m [0.06/feet]). Crested wheatgrass plots were very successful with the establishment of 9.6 plants/m (2.9 plants/feet) (Fig. 2). Sherman big bluegrass, 0.99/m (0.3/feet), and squirreltail, 1.3/m (0.4/feet), failed miserably. Seeding the first fall following the wildfire resulted in more seedling recruitment compared to seeding the second fall following the wildfire even though the site received only 14.5 cm (5.7 inches) of precipitation the first year compared to 23.5 cm (9.3 inches) the second year. Seedling recruitment and establishment in the second fall plots decreased in the mix plots down to 4.9/m (1.5/feet) (crested wheatgrass 1.8/m [0.55/feet], 'Immigrant' forage kochia 2.1/m [0.64/feet], Sherman big bluegrass 0.4/m [0.12/feet], Squirreltail 0.3/m [0.09/feet], Indian ricegrass 0.1/m [0.03/feet], and 'Ladak' alfalfa 0.2/m [0.06/feet]). Crested wheatgrass plots decreased to 4.3/m (1.3/feet). This early establishment is critical because long-lived perennial grasses are the best known method at suppressing cheatgrass densities and fuel loads (Fig. 2). Cheatgrass densities were suppressed to 9.9 plants/m² (3 plants/feet²) in the first year seeded crested wheatgrass plots but increased to 32.7/m² (24/feet²) in the second year seeded plots. The control plots that were not seeded had a cheatgrass density of 213.5/m² (64.7/feet²).

### Mechanical Fallow

Discing the seedbed to bury cheatgrass seeds deeper in the seed bank can also be a helpful tool at decreasing cheatgrass seed bank densities. The objective of this method is to disc the site before cheatgrass seed ripening (early May), decreasing that year's seed production while at the same time burying a portion of the remaining cheatgrass seed bank to depths that reduce cheatgrass germination the following fall and spring. The ability to reduce the cheatgrass seed bank decreases the competition for limited resources needed by the desirable seeded species you are trying to establish on specific sites. We reduced cheatgrass seed bank densities from 418.3 plants/m² (127.5/feet²) in the undisced plots down to 117.1/m² (35.7/feet²) in the disced plots. When our seeded species germinated and sprouted they competed against less cheatgrass, 10.8/m² (3.3/feet²) in the disced plots compared to the undisced plots, 46.6/m² (14.2/feet²).

### Herbicidal Fallow

Herbicides are also very useful tools in rangeland restoration and revegeation practices. With that said, herbicides must be approached very carefully and experimented with on a small-scale, replicated manner in various habitat conditions (soil types, climates, etc.). Two of the more popular herbicides we use for cheatgrass control are Imazapic (Plateau) and Sulfometuron (Landmark XP). These herbicides are not selective but can be effective at controlling cheatgrass and opening a window to successfully seed species that can compete with cheatgrass. We apply these herbicides in early fall and then fallow the site for 1 year as the herbicides are active for about 15 months. This application is very effective and largely eliminates fall, winter, and spring germination of our target species, cheatgrass (Fig. 3). The following fall the treated site is seeded to competitive or desirable species in an effort to reduce cheatgrass densities and wildfire frequencies. The objective here is to establish long-lived perennial grasses, reduce cheatgrass fuel loads and wildfire frequencies, and allow the necessary time needed to reestablish shrubs and other native species back into the site. In experimenting with different rates of these herbicides, we are most comfortable with Plateau at 420 g/ha (6 ounces/acre) and Landmark at 122.5

**Figure 4.** Of the 16 species tested at this site in northern Nevada, only two species (Sherman big bluegrass and crested wheatgrass) successfully established.

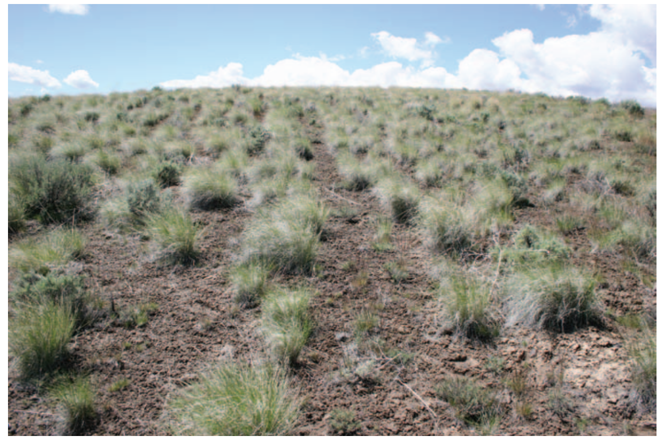

**Figure 5.** A successful seeding in a formerly Wyoming big sagebrush/bunchgrass community in northern Nevada. Bluebunch wheatgrass, crested wheatgrass, Wyoming big sagebrush, and 'Immigrant' forage kochia made up the seed mix.

g/ha (1.75 ounce/acre) rates. In our herbicide plots we have experienced a decrease in both the cheatgrass seed bank, 75%, and cheatgrass above-ground densities, 89%. Again, this decrease in cheatgrass seed bank and above-ground densities assists the seeded species in having the ability to establish in the face of less cheatgrass competition.

### *Plant Material Testing*

We have approached these restoration and revegetation efforts by looking at a variety of native and introduced plant materials to aid us in the selection of plant species to establish on a specific site. Soil maps, site description, and site inventories aid in this process, but we add to the tool box by experimenting with plant materials that we think may have the inherent ability to compete and establish in these challenging habitats. Not only did we investigate and learn from past researchers, such as Perry Plummer, on plant material selections, but we have also conducted our own tests to gain experience. For example, from 1999 through 2006 we tested 78 separate species of grasses, shrubs, and forbs (72 native, 6 introduced) in a variety of habitats (e.g., salt desert shrub and Wyoming big sagebrush) throughout our service area. Those species that perform the best or have high failure rates are recorded as such. Those species that have the highest inherent potential to germinate, sprout, and establish on a site are then used in the restoration and revegetation seeding efforts (Fig. 4). Again, the goal is to establish plant materials that will compete against and suppress cheatgrass, which will decrease fuel loads and the frequency of wildfires.

One of our more successful seedings occurred in northern Nevada and consisted of discing and fallowing the site, seeding the site with bluebunch wheatgrass (*Pseudoroegneria spicata* ssp. *spicata*) 4.6 kg/ha (4 pounds/acre) and crested wheatgrass 4.6 kg/ha (4 pounds/acre) using a traditional rangeland drill and then broadcasting 'Immigrant' forage kochia 1.1 kg/ha (1 pound/acre) and Wyoming big sagebrush 0.3 kg/ha (0.25 pound/acre) behind the drill. The site received 23.3 cm (9.2 inches) of precipitation following the seeding, which is not great, but the periodicity of precipitation events was good from October through June. The site has not burned for more than two decades and has in fact stopped adjacent fires from advancing.[8] Perennial grass density is excellent, and the shrub component far exceeds adjacent untreated habitats (Fig. 5). The cost of this effort was $47.65/ha ($117.60/acre).

When attempting the seeding of species on these arid western rangelands it must be understood that this is a high-risk endeavor at best. If you do nothing, you will get nothing. If you miss the open window we have discussed or use plant materials that do not have the inherent potential to be successful in the face of competition from cheatgrass and other weed species, you will fail. With all that said, Mother Nature still needs to help you with effective moisture for germination and establishment. Take it from personal experience: Nothing feels worse when attempting these restoration and revegetation efforts than to apply the tools mentioned above in an improper manner and then have an excellent winter and spring precipitation event go to waste! Understanding cheatgrass seed banks and methods of reducing these seed banks and above-ground densities, as well as the inherent potential of desirable seed species to achieve your goals, can lead to successful seedings, decrease wildfires, and protect life, property, wildlife habitat, and grazing resources (Fig. 5).

## Case Study 3: Restoration of Antelope Bitterbrush Communities

Antelope bitterbrush (*Purshia tridentata*) is an important browse species for livestock and wildlife[9] and is a key browse species in the diets of many mule deer (*Odocoileus hemionus*) herds.[10] Fire, excessive grazing and browsing, insects, drought, and other unfavorable weather conditions can all contribute to the deterioration of antelope bitterbrush communities. The lack of seedling recruitment has been a major problem for many years in most antelope bitterbrush communities, resulting in old decadent stands that lack nutritional quality as well as sufficient seed production.[11] In the mid-1990s wildlife advocates and livestock operators came to us with a request to improve the ability to restore antelope bitterbrush in these decadent and degraded habitats. We approached this task by researching the seed and seedling ecology of this species as well as the methods of seeding and transplanting this species back into critical habitats.[9,12]

Emor Nord, a pioneer in antelope bitterbrush research, pointed out the importance of granivorous rodents in the natural recruitment of antelope bitterbrush, but at the same time he reported that it was nearly impossible to successfully seed this important browse species.[13] Because of past unsuccessful attempts at restoring antelope bitterbrush through direct seeding, the California Fish and Game (CF&G), in cooperation with the Mule Deer Foundation, transplanted 79,000 antelope bitterbrush seedlings in northeastern California between 1993 and 1995. To increase establishment success the seedlings were protected by placing a sleeve-like fine netting over them to reduce browsing. This effort was a complete failure. We came onto the scene and implemented a number of treatments using two-year-old bare-stock transplants obtained from the same nursery supplier that the CF&G used:

1) Control—transplanting two-year-old bare stock (the same method as the CF&G)
2) Tillage to reduce competition followed by transplanting
3) Application of emulsifiable herbicide (Vantage) 560 g/ha (8 ounces/acre) to reduce competition followed by transplanting and
4) Inoculation of the microorganism *Frankia*, which is important in the formation of nodules on the roots of antelope bitterbrush plants and allows the plant to fix nitrogen.

All of these treatments were transplanted inside and outside of a mule deer exclosure to look at the browsing affect as well. Transplanting was significantly[iii] more successful inside the exclosure: 1) control = 6%, 2) tillage = 25%, 3) herbicide = 25%, and 4) inoculation = 27%. Outside the exclosure we experienced 1) control = 0% (which is what the CF&G experienced), 2) tillage = 15%, 3) herbicide = 8%, and 4) inoculation = 15%. At $1.10 per transplant, this effort can get very expensive. We also investigated seeding antelope bitterbrush using a number of techniques (e.g., manual hole punch and hand seeding to simulate rodent caches) and methodologies (e.g., seeding rates and seeding equipment).[14]

For the purpose of this paper we will discuss the results from mechanical seeding efforts. We seeded, cleaned, and uncleaned antelope bitterbrush at 2.3 kg/ha (2 pounds/acre) and 3.4 kg/ha (3 pounds/acre) rates using a traditional rangeland drill and a Duncan no-till drill (Fig. 6) at various sites in northwestern Nevada and northeastern California. The plots were seeded in the fall with half the plots being previously disced and fallowed to reduce herbaceous competition. Discing and fallowing the sites did not improve antelope bitterbrush seedling recruitment. There was no significant[iv] difference in seeding rates, so we are reporting the 3.4 kg/ha (3 pounds/acre) rate. Cleaned seed experienced higher antelope bitterbrush establishment, 921 shrubs/ha (2,275 shrubs/acre) to 310 shrubs/ha (766 shrubs/acre). The use of the Duncan no-till drill resulted in significantly[v] more established antelope bitterbrush shrubs, 3,175 shrubs/ha (7,840 shrubs/acre) to 1,015 shrubs/ha (2,505 shrubs/acre). These seedling numbers are actually too high as the shrubs are so close together that they are competing for very limited resources and take a longer period to get to reproductive age.


**Figure 6.** The use of the Duncan no-till drill causes very little soil disturbance and has excellent seed placement attributes. Obviously, rougher terrain would limit this type of equipment.

When attempting these types of restoration and revegetation practices we define success at the beginning of our efforts. For this specific study site we set our goals at 202 antelope bitterbrush shrubs/ha (500 shrubs/acre), which is the density in the adjacent unburned habitat. Following this research we recommended to our stakeholders the options of using a traditional rangeland drill on rougher ground, a no-till drill on more forgiving landscapes, and decreasing the seeding rate down to 2.3 kg/ha (2 pounds/acre). With approximately 7,256–8,163 seeds/kg (16,000–18,000/pound), 2.3 kg/ha (2 pounds/acre) appears to be a sufficient amount of seed to recruit antelope bitterbrush seedlings back into the community (Fig. 7). At roughly $6.80/kg ($15/pound) and seeding rate of 2.3 kg/ha (2 pounds/acre) we experienced excellent success at seeding costs of $30.38/ha ($75/acre), compared to more than $3,645/ha ($9,000/acre) to experience similar results with transplanting efforts at 15% success rates. In 1999, 730,000 ha (1.8 million acre) burned in the state of Nevada alone, and 1,962,465 kg (4,322,610 pounds) of seed was purchased for the restoration and revegagation efforts.

[iii] $P \leq 0.05$.

[iv] $P \geq 0.05$.

[v] $P \leq 0.05$.

**Figure 7.** Antelope bitterbrush seeding using a rangeland drill in northeastern California. Notice that the density of the shrubs is so high that they are actually smaller in size, showing that they are having a difficult time competing for limited resources.

Not a single pound of antelope bitterbrush was purchased for these seeding efforts; today that is not the case as this critical browse species is being seeded back onto rangelands.

## Lessons Learned

In this paper we report on three case studies in which we address issues and concerns of stakeholders through an integrated approach of solving problems on the ground in a cost-effective manner that is affordable to the stakeholder. As one stakeholder told us, "Don't waste your time researching this problem and come back to me with a solution that costs $3,000/acre." In our travels it is apparent to us that there is a true disconnect between research and management as well as research, management, and the stakeholders. How do we bridge this disconnect to benefit our natural resources? Our approach has been to work closely with resource managers and stakeholders to build a strong trustworthy relationship.

For example, in our efforts to study control methods for tall whitetop on the University of Nevada Agricultural Experiment Station, we held frequent field days with stakeholders, agency representatives, and university faculty to inform them of our daily efforts as well as lessons learned. We explained to them up front that results would be slow and reported accurately to reflect situations on the ground and that our goal here was to return this weed-infested land back to production agriculture. At the recent Western Section of Weed Science Meetings held in Reno, Nevada, an agriculture producer briefed us on his successful efforts to control tall whitetop and rehabilitate his land back to a grazing pasture from information he received from a stakeholder who had attended one of our field tours. The same approach is taken with all of our field studies.

Right now we are investigating cheatgrass control methods and rehabilitation of cheatgrass-dominated rangelands in the King's River Valley of northern Nevada. We do not send students and seasonal employees out to do the laborious work; we conduct all the work ourselves and involve the private landowner and other involved parties throughout the process. This hard work of discing, spraying, seeding, and monthly monitoring is all witnessed and is well received by all involved parties and helps build trustworthy relationships because they know you are busting your rear end to address this issue. The results presented are on-the-ground realities and open for discussion at any point so we can learn together.

Ray Evans, who started up the range research unit for USDA-ARS in Reno, Nevada, in the late 1950s, once told the senior author, "Son, statistics mean very little if you can't see the difference on the ground." This is why field visits and plot photos are so important. In Figure 4 you can see two species that were successfully seeded, yet there are scientists and resource managers who will disagree with each other and will look at that very site and still demand a seed mix of various grasses, shrubs, and forbs at a highly more expensive cost. When these types of decisions are made you can see the frustration in the stakeholders' eyes and hear it in the tone of their voice. This is a problem that leads to much of the disconnect we are experiencing. We invite other researchers, managers, and stakeholders to voice their opinion on the subject manner in an open respectful manner. We even propose that we try things from the way they would approach the problem by establishing plots right next to ours. If their approach works better, we will be the first to change our approach because the ultimate goal is to successfully solve the problem. Far too often lines are drawn and progress is halted for various reasons. One of the major issues that occurs on rangeland rehabilitation efforts is the argument of using native species only. We choose to test a variety of plant species in an effort to identify those species that have the best inherent potential to germinate, emerge, establish, and suppress such invasive weeds as cheatgrass. We try to add to the tool box when combating these aggressive invasive weeds, not remove possible tools that can aid us in meeting our objectives. You cannot change a transmission with a paintbrush.

Whether it is our example of antelope bitterbrush restoration or successfully suppressing cheatgrass through various control methods and testing of various plant materials, our building of relationships with folks on-the-ground has resulted in technology transfer of our lessons learned. At a glance this paper may appear that we have many answers when dealing with invasive weeds and restoring Great Basin rangelands. We have far more questions than answers. In our research efforts we have failed far more often than we have succeeded. If you do nothing you will get nothing, if you do things wrong you will fail, and if you do everything right you have a chance!

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