

Impacts of Wildfire Rehabilitation and Plow-and-seed Land Treatments on Fitness Parameters of an Endemic Milkvetch

Steve J. Popovich and David A. Pyke

National Biological Service, Forest and Rangeland Ecosystem Science Center,
3200 SW Jefferson Way, Corvallis, OR 97331
Tel. (541) 750-7307; Fax (541) 758-7761; E-mail popovichs@fsl.orst.edu

Abstract. Picabo milkvetch *Astragalus oniciformis* Barneby is endemic to the sagebrush-steppe of three southern Idaho counties that are susceptible to wildfire. Rehabilitation after wildfire commonly includes seeding with competitive introduced perennial grasses. To determine short- and long-term effects of these revegetation treatments on *Astragalus* reproduction, we compared inflorescence and fruit production of plants in adjacent seeded and unseeded areas of 20- and 2-year-old seedlings. In the 2-year-old seeding, inflorescences and fruits per plant did not differ among treatments. Stipe production of adult plants in the 20-year-old seeded area was double that in an unseeded area, whereas there was no difference between juvenile plants. Similar to the 2-year-old-seeding, adults growing in the 20-year-old seeding produced 3-fold more seeds per fruit than those in the unseeded native site. In a second study, *Astragalus* densities were reduced similarly in controls and in seedlings done by aerial application followed by harrowing during the first three growing seasons after treatment. At a second site, drill application and aerial seeding without harrowing decreased *Astragalus* densities at rates similar to or less than the control. In a third study not involving fire rehabilitation, *Astragalus* density was 6.5 times lower in a plow-and-seed range improvement treatment as compared to the untreated control one year after treatment. Proportions of seedlings and juveniles to adults were also lower in the treated area. Adult plants produced more seeds per pod in the treated area than the control, but juvenile plants produced fewer seeds in treated areas than in the control. *Astragalus* is capable of reproducing quickly when conditions allow for germination and survival. A seedling demography study showed that 79% of surviving seedlings reproduced in their second growing season. We conclude that 1) seeding with introduced wheatgrasses for rehabilitation after wildfires does not appear to reduce *Astragalus* reproduction potential or established plant survival in the short- or long-term, 2) aerial, drill and harrow revegetation techniques do not appear to lower plant densities to levels of concern 3 years after treatment, 3) plow-and-seed disturbance causes reduced plant densities and lower reproductive output in juveniles sufficient enough to cause concern 1 year after

treatment, and 4) seedling establishment must be investigated to determine if fire rehabilitation or plow-and-seed range improvement practices reduce *Astragalus* populations over the long-term.

Introduction

The potential native vegetation on the semi-arid Snake River Plain of south-central Idaho is dominated by big sagebrush (*Artemisia tridentata* Nutt.) and bunchgrasses. Historically, vegetation is believed to have burned every 32-70 years (Wright and others 1979). Recently, there has been a substantial decrease in fire-free intervals and increases in size and numbers of fires due to human-caused influences and to the invasion of weedy annual exotics such as cheatgrass [*Bromus tectorum* L. (Pellant 1990)]. The resulting rangelands are generally declining in fire resistance, healthy functional conditions, and biological diversity (Whisenant 1990).

Since 1941, when record-keeping began for the 729,000-ha (1.8-million-acre) Shoshone Resource Area, Bureau of Land Management, an average of about 25,900 ha (64,000 acres) have burned annually by wildfires. Some areas have burned repeatedly at least 12 times between 1941 and 1995, mostly due to their proximity to human-caused fires and to their abundance of fine fuels afforded by a dominance of cheatgrass.

If soil erosion or invasion of weedy exotics such as cheatgrass is likely to occur following a wildfire on public lands, the federal government may attempt to rehabilitate an area by seeding. Rehabilitation often consists of a mix of vegetation containing crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] or its allies (e.g., *A. desertorum* J.A. Schultes, *A. sibericum* Beauv.), perennial grasses that establish quickly, tolerate grazing better than natives, and are suspected of being highly competitive with exotic annuals as well as many native plants. Such seedlings have altered landscapes in south-central Idaho at a regional level.

The milkvetch genus, *Astragalus*, is the most common genus of sensitive plant species in semi-arid communities of Idaho and Oregon. Picabo milkvetch is endemic to the north-central portion of the Snake River Plain (*sensu* Malde

1991) in Blaine, Lincoln, and Minidoka counties, Idaho. Its range extends roughly from south of Craters of the Moon National Monument, west and south to the towns of Picabo, Shoshone, and Kimama. It is found mostly on sandy soils in areas receiving 203–406 mm (8–16 inches) of annual precipitation. Elevation ranges from 1271 to 1572 m (4170 to 5160 ft). It is currently a “sensitive” species for the Bureau of Land Management, and a “monitor” species for the State of Idaho.

There are at least 70,000 individuals estimated on about 1,215 ha (3,000 acres) of known occupied habitat across 36 sites (Moseley and Popovich 1995). The degree of genetic isolation is unknown, and numerous “sites” may be subpopulations of larger, patchily-distributed populations. The species is a wiry, prostrate, tap-rooted perennial with small leaves and flowers, and produces small 3-angled, boat-shaped fruits by early June.

In 1992, 86,640 ha (214,000 acres) burned 15 sites containing about 50% of all known individuals of Picabo milkvetch. Together with grazing, invasion of exotics, and generic range improvement practices, repeated wild-fires and subsequent rehabilitation have altered the environment for Picabo milkvetch from its historic functioning condition, supporting a significant herb component including the milkvetch, to a degraded habitat or to one dominated by seeded or annual exotic plants. Much of Picabo milkvetch habitat is currently in such an altered ecological status.

Because fire rehabilitation seedings appear to be competitive and may alter ecological status, the question is raised: “Does seeding non-native wheatgrasses pose a threat to survival of populations of Picabo milkvetch?” In this paper, we address the impacts to *Astragalus* reproduction from various fire rehabilitation practices and from the “plow-and-seed” range improvement practice.

Methods

Prompted by a series of large fires in the fall of 1992, all studies began in 1993 and continue today. 1993 was wet with one of the coolest growing seasons in southern Idaho’s recorded history. It saw an explosion of plants in comparison to the drought of the previous 8 years. The drought resumed in 1994, but 1995 was again a cool, wet growing season. Detailed site locations and methodologies are available (Popovich 1994).

Study 1 — Impacts of crested wheatgrass on milkvetch reproduction and survival

In one part of this study, we compared milkvetch reproduction from adjacent unburned, burned and unseeded, and burned and drill seeded areas in the first (1993) and second (1994) years of a 3-year-old fire. The area burned in the summer of 1992, and was seeded with a rangeland drill without depth bands in late fall of the same year with

a seed mix containing crested wheatgrasses (Table 1). Rangeland drills used in all studies were not specialized (i.e., not deep-furrow or no-till drills).

Two replicate sites were selected subjectively. Selected sites had more than 25 milkvetch plants in each treatment area. Replicate sites are about 1.8 km (1.1 miles) apart, and are referred to as the “Laidlaw” sites. Laidlaw 1 and 2 were established in 1993 and 1994, respectively. Pre-burn vegetation was dominated by native bunchgrasses, herbs, and big sagebrush, with very few exotics present. The seeding was successful and is assumed to be exerting competition on the post-burn vegetation. At each site, 25 plants were randomly located from within each treatment area. Plants were permanently marked and numbered. Individual plants were monitored annually for survival, inflorescence production, and fruit production per plant. Seeds per fruit were determined for 50 fruits harvested randomly from 25–50 plants in each treatment area.

At these study sites as well as others randomly-selected across the range of the species, pollinators were collected when observed on flowers of Picabo milkvetch. They were sent to the USDA ARS Bee Lab in Logan, Utah for identification. Four were determined to be noteworthy for their global rarity or range extension.

In another part of the study, data were collected in 1994 to compare a 20-year-old crested wheatgrass rehabilitation drill seeding to an unseeded area about 1.6 km (1 mile) apart. These study sites are together referred to as the “Pagari seeding” sites. Both areas burned 4–5 times by the same fires beginning in 1941 and continuing until 1973, the time of seeding rehabilitation. It is possible, but unconfirmed, that both sites burned again in 1981. Site attributes were similar, and we assumed that burn severities were also similar. The seeding (Table 2) occurred in the fall of 1973 following that summer’s fire, with a rangeland drill without depth bands. Pre-burn vegetation was strongly dominated by big sagebrush, rabbitbrush (*Chrysothamnus* spp.), and cheatgrass. The seeded site is currently dominated by crested wheatgrass and non-native annuals, with some native annuals, and perennials. The other seeded species no longer persist on the site. Crested wheatgrass is assumed to be exerting influence

Table 1. Seed mix used at the Laidlaw sites. WG = wheatgrass.

Species	Gross pounds per acre
Critana Thickspike WG	1.00
Alkar Tall WG*	1.50
Siberian Crested WG*	1.00
Hycrest Crested WG*	1.50
Bozoisky Russian Wildrye*	0.75
Eski Sainfoin*	2.00
Total	7.75

*non-native

Table 2. Seed mix used at the Pagari sites. WG = wheatgrass.

Species	Gross pounds per acre
Pubescent WG*	1.00
Crested WG*	3.00
Russian Wildrye*	3.00
Rangeland alfalfa*	0.25
Total	7.25

*non-native

upon the plant community since the unseeded site is dominated by weedy exotic annuals, typical of many untreated milkvetch sites that have been burned and grazed repeatedly. Similar native annuals and perennials occur on both seeded and unseeded sites. In none of these studies did we know pre-burn or pre-treatment milkvetch densities.

Plot sizes were 30 X 30 m (98 by 98 feet) and included at least 50 plants per plot. Plots were not replicated. Sites and plants were selected as described above. Plants were permanently marked by inserting a 7-mm (1/4 inch) diameter reinforcing bar into the ground within 15 cm of the plant and leaving about 10 cm above ground with a numbered aluminum tag.

Based on plant size and on previous demographic studies, we were able to assign reproductive milkvetch plants into two classes, juveniles (rosettes about 25 cm or less; probably 2- to 3-years-old) and adults (rosettes > 25 cm; probably greater than 3-years-old). For each plant, total number of stipes (containing or once containing fruits or flowers) per inflorescence were counted for the first 30 randomly-selected inflorescences. The number of inflorescences remaining were then counted and multiplied by the average number of stipes to derive total number of stipes. This attribute is intended to represent total potential reproductive output per plant.

Two or three mature fruits per plant in each age category were randomly collected from 10 to 20 nearby juveniles and adults. Twenty-five fruits were then randomly selected from this pool and the number of plump, viable-looking (plump black) seeds were counted. Seeds were not counted if they appeared damaged, wrinkled, small, eaten, or otherwise aborted. The average number of seeds per fruit was then generated. This attribute is intended to represent actual reproductive output per fruit given microsite conditions, pollination vectors, and other influences during the growing season.

Numbers of stipes, fruits, and inflorescences per plant were transformed (natural log for stipes and fruits; square-root for inflorescences) to improve normality before analyses. Treatment differences were tested using a split-plot design with seeding (or burning) treatment as the main plot and individual plants as the subplots. Analysis of variance was applied using the appropriate split plot error terms to determine significant differences (PROC MIXED, SAS Institute 1994). Treatment differences were

determine using least-squared means. All reported means and standard errors were back-transformed.

Seeds per fruit were bimodal because of large numbers of fruits with no seeds, therefore, we analyzed difference among treatments using the non-parametric Kruskal-Wallis test (PROC NPAR1WAY; SAS Institute 1994). Median seeds per fruit were reported for each treatment.

Study 2 — Fire rehabilitation and milkvetch density

In a second study, we compared milkvetch density response to various fire rehabilitation application techniques and seed mixes to a burned untreated control area from a fire in the summer of 1992 and seeded in the fall of the same year. All seedings were successful and are assumed to be exerting competition on the post-burn native vegetation.

At one site, WSAIL, treatments included a native plus introduced species seed mix, aerially applied and harrowed, and an all native seed mix, also aerially applied

Table 3. Seed mixes and applications used at the WSAIL and WSAIL sites. WG = wheatgrass.

Species	Gross pounds per acre
Drill	
Whitmar Bluebunch WG	1.00
Secar Bluebunch WG	1.00
Critana Thickspike WG	0.75
Siberian Crested WG*	0.75
Alkar Tall WG*	0.50
Bozoisky Russian Wildrye*	0.50
Eski Sainfoin*	2.00
Appar Lewis Flax	0.25
Total	6.75
Alfalfa* contaminant - 635 seeds/lb.	
Aerial, native + introduced (harrowed at WSA II)	
Whitmar Bluebunch WG	1.25
Secar Bluebunch WG	1.25
Critana Thickspike WG	1.00
Siberian Crested WG*	1.00
Alkar Tall WG*	0.75
Bozoisky Russian Wildrye*	0.75
Eski Sainfoin*	2.50
Appar Lewis Flax	0.50
Fourwing Saltbush	0.75
total**	9.75
Aerial, all native (harrowed at WSA II)	
Whitmar Bluebunch WG	3.00
Secar Snake River WG	3.00
Critana Thickspike WG	2.50
Appar Lewis Flax	0.50
total**	9.00

*non-native

**rate for harrowed treatment was 10 total pounds/acre.

and harrowed (Table 3). At another site about 15 km (9.3 miles) away, WSAIII, treatments included a native plus introduced species seed mix that was drilled, a native plus introduced seed mix that was aerially applied, but not harrowed, and an all native seed mix that was aerially applied, but not harrowed (Table 3).

Site selection was made based upon criteria of representative soil type, burn characteristics, and pre-burn vegetation for a larger, more involved fire rehabilitation plant competition study. We were not aware of the presence of Picabo milkvetch at the time of site selection. Pre-burn vegetation was dominated by native bunchgrasses, annuals, perennials, and big sagebrush. Minor amounts of cheatgrass and other exotics were also present.

The drill treatment was performed with a rangeland drill without depth bands. Aerial application was performed by using a motorized whirlybird mounted to the back of a pick-up truck and evenly driving across the treatment area. Harrowing was accomplished using a spring-toothed harrow pulled behind a pick-up truck at the speed required to bury the seed mix to the proper depth after making two passes. At both sites, treatments were applied adjacent to each other in a completely randomized split-plot design (main plots were seeding treatment macroplots and subplots were randomly located sample plots), and this procedure was performed again in the immediately adjacent area (total number of replicates for each treatment = 2).

Macroplot size was 63.6- by 127.2-m (0.8 ha; 2 acres) for each treatment. Within each macroplot, 45, 0.5- by 3-m subplots were randomly placed each year. Milkvetch plants were counted within each subplot. Average densities were calculated from the combination of the 45 plots in the two main plots for each seeding treatment and each year, 1993, 1994 and 1995. Main plot replication effects were assumed to be non-significant and became part of the error term of the model.

Each site, WSAII and WSAIII, was analyzed separately because seeding treatments at each site differed slightly. Density of milkvetch over years was tested among seeding treatments at each site using a split-plot ANOVA (PROC MIXED, SAS Institute 1994). Treatment differences were determined using least-squared means.

Study 3 — Plow-and-seed rangeland improvements and milkvetch reproduction

In a third study, we monitored density and reproduction between a plow-and-seed range improvement treatment and an untreated control. About 85 ha (211 acres) were plowed with an off-set disk range plow in the spring of 1993, summer fallowed, and drilled that fall with a rangeland drill without depth bands. The objective of the treatment was to eliminate existing vegetation and replace it with a different, more desired vegetation composition designed to increase forage production. The seed mixture was dominated by non-native wheatgrasses (Table

Table 4. Seed mix used at the Tikura site. WG = wheatgrass.

Species	Gross pounds per acre
Fairway Crested WG*	5.45
Ephraim Crested WG*	2.60
Orchardgrass*	0.47
Ladak Alfalfa*	0.95
Appar Lewis Flax	0.71
Total	10.2

*non-native

4). This practice is generally more severe in its impacts on native plants, and disturbs the soil more than most fire rehabilitation practices. A small island about one ha (3 acres) in size was left undisturbed. It and the surrounding area contained the highest density of milkvetch in the project area. Visual inspection and quick counting methods before treatment showed that pre-treatment plant densities were similar between the island and the treated area.

This study site is very near the species' type locality in Picabo, Idaho, and is different than most sites in that the soils are finer textured, the area receives more precipitation, and it is cooler longer into the growing season. Compared to the closest other study sites, this site received 115 mm (4.52 inches) and 38 mm (1.48 inches) more precipitation from April through August in 1993 and 1994, respectively. Average monthly temperatures were 1.7°C (3.4°F) and 2.2°C (4.0°F) cooler during those same months and years, respectively. During the hottest months of July and August, the difference was 2.4°C (5.1°F) averaged over both years.

Pre-treatment understory vegetation was dominated by native bunchgrasses, annuals, and perennials, and the overstory exhibited a co-dominance of three-tip sagebrush (*Artemisia tripartita* Rydb.) and big sagebrush. There was considerable invasion of cheatgrass and other non-natives already on site.

In 1994 and 1995, the treatment area was strongly dominated by cheatgrass, with a few seedlings emerging from the perennial seed mix. We assumed cheatgrass was exerting competition upon residual native vegetation.

In the summer of 1994, one growing season after treatment, twelve parallel 1-m wide by 220-m long belt transects, touching each other length-wise, were established parallel to the boundary of the island and the treatment area. Beginning at the island's boundary, 6 were nested inside the island; six were parallel to those and were nested outside the island into the treatment area. In 1994, all *Astragalus* plants were tallied by lifestage (seedling, juvenile, and adult) within each transect and the total summed by treatment and control.

Ten randomly-selected adults and ten juveniles were permanently marked in the island transects using the reinforcing bar method discussed above. In the treatment transects, 25 randomly-selected adults and 15 juveniles

were marked. Differences between treated and control areas within each lifestage were compared for seeds per fruit for 25 randomly-collected fruit for each age class from nearby adult and juvenile plants using a two-sample t-test (seeds per fruit were normally distributed at this site) and for survival (density) using a likelihood-ratio chi-squared test of homogeneity (SAS Institute 1994).

Study 4 — Milkvetch survival

The Pagari Benchmark site is a relatively undisturbed site, serving as a "benchmark" to relate to other sites. It is only occasionally lightly and quickly grazed by trailing sheep in spring or fall, and has apparently not burned for at least 20 years. The area is dominated by native bunchgrasses, especially indian ricegrass [*Oryzopsis hymenoides* (Roemer & Schultes) Ricker], annuals, perennials, and big sagebrush.

Seedling and yearling survival study for milkvetch was concentrated at this site because other populations have not had adequate seedling numbers to justify the intensive mapping (Pyke 1990) approach. Eight plots (40 by 50 cm) were located in areas with a minimum of five seedlings. Plants were mapped initially in May 1993 and were monitored every 3 months for the first year and annually each year thereafter until all plants died or became reproductive.

The Mile 186 site (located near milepost 186 along US Highway 26) contains a 10- to 15-year-old drilled fire rehabilitation seeding of crested wheatgrass and an adjacent unseeded burned area. The original seed mix is unknown, but it was likely pure crested wheatgrass. Ten adult and ten juvenile milkvetch were marked with reinforcing bar, as above, in the treated and untreated areas during 1994 and mortality noted in 1995. This site will serve as an "old seeding" replicate to augment the Pagari seeding once data are more fully analyzed.

Another nearby unseeded milkvetch stand, the Pagari "HD" (high-density) site, had as many as 80 plants per square meter recorded in 1994. This density has not been observed at any of the other known sites for the species. In the same area in 1991 and 1992, only one to a few plants per square meter were recorded. Ten adults and ten juveniles were marked with reinforcing bar during 1994 as above and their mortality determined in 1995. We anticipated a high rate of density-dependent mortality.

Survival potential for all reproductive milkvetch plants was tested between seeded and unseeded sites at Pagari and Mile 186 using a likelihood-ratio chi-squared test of homogeneity (PROC FREQ, SAS Institute 1994, Pyke and Thompson 1986).

Results and Discussion

Study 1 — Impacts of crested wheatgrass on milkvetch

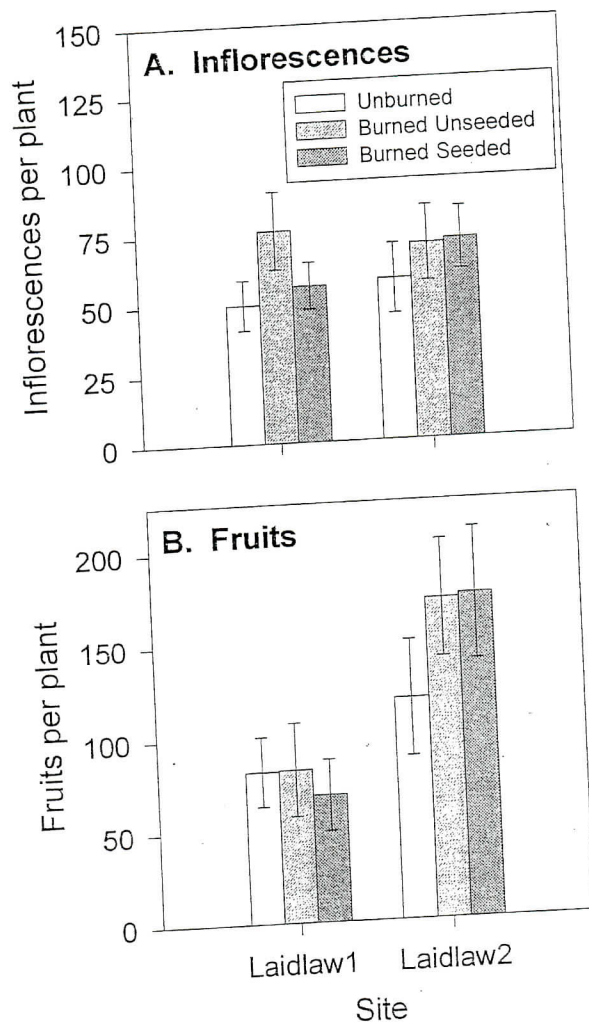


Figure 1. Mean (± 1 SE) (A) inflorescences per plant and (B) fruits per plant of *Astragalus oniciformis* during 1994 at two locations in southern Idaho growing in three treatments, an unburned, an unseeded and burned, and a seeded and burned treatment. Main effects and interactions were tested using ANOVA (Inflorescences $P > 0.18$ for all tests; Fruits - Location $P < 0.01$, all others $P > 0.44$).

reproduction

At the 2-year-old-seeding sites, neither the fire nor the seeding significantly affected the number of inflorescences on adult plants two years after the fire for either replicate site (Figure 1A). The same is true for the number of fruits produced per plant (Figure 1B). One site produced significantly more fruits per plant than the other; however, we assign no particular ecological significance to this. These findings lead us to believe that new, establishing grass seedlings, even highly competitive grasses such as 'Hycrest' crested wheatgrass (Francis and Pyke 1996), do not adversely impact milkvetch reproduction potential, at least for these sites.

Seed production was variable among fruits and years. Most fruits produced zero to one seed, while a few fruits produced ten or eleven seeds. An unexpected difference

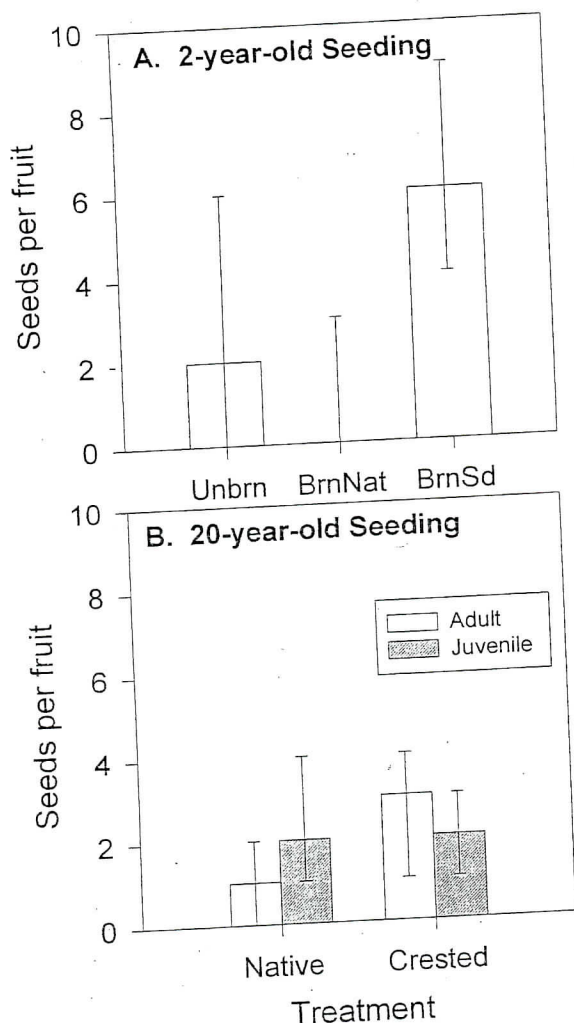


Figure 2. Median (± 1 quartile) seeds per fruit of *Astragalus oniciformis* for (A) three treatments, an unburned (Unbrn), an unseeded and burned (BrnNat), and a seeded and burned (BrnSd) treatment associated with a 2-year-old seeding ($P < 0.01$, $df = 2$), and for (B) adult and juvenile plants growing in a 20-year-old seeding that included crested wheatgrass (see Table 2) and an adjacent native community (native vs. crested within adults $P = 0.05$; all others $P > 0.09$).

occurred among treatments in 1993 with seeds per fruit in the burned and seeded area being 6-fold greater than the burned-untreated-native and unburned areas combined (Figure 2A). We speculate that this may be the result of the drill's mechanical disturbance to the soil, killing competitive plants and releasing greater nutrients or otherwise ameliorating conditions for those plants that survived the burn and the soil disturbance of the drill. No clear differences occurred in the second year. Plants in the seeded site had lower seed production in the second year while those in the burn and unseeded area increased.

For the 20-year-old seeding, life stages within treatments differed significantly, indicating that nearly twice as many stipes were produced on plants grown in the crested wheatgrass site than in the native site for adults,

but there was no significant difference for juveniles (Figure 3). Similar to the 2-year-old seeding data the first year after burning and seeding, adults growing in the 20-year-old crested wheatgrass site produced greater seeds per fruit than those in the native site (Figure 2B). These findings lead us to believe that old, established seedings do not adversely impact milkvetch reproduction potential, at least for this site.

Study 2 — Fire rehabilitation and milkvetch density

At the WSAII site, there was a significant reduction in numbers of milkvetch over time using pooled data from both treatments and the control (Figure 4A). The greatest densities were in 1994. The lowest were in 1995, and 1993 densities were somewhere in between. Differences among treatment areas in numbers of milkvetch are not as important as their proportion change over time since treatments did not begin with the same number of individuals. Although milkvetch densities declined, the proportional decline did not differ significantly between the untreated control and any of the seeding treatments (Figure 4B).

At WSAIII, the milkvetch density also decreased significantly over time (Figure 5A). The greatest densities occurred in 1993, with declines in the following two years. Similar to WSAII, none of the seeding treatments had proportional declines that differ significantly from the untreated control except the aerially seeded native species mixture (Figure 5B). This treatment decline, however, was significantly less than the decline in the control. The seeding treatment that caused the least disturbance, the

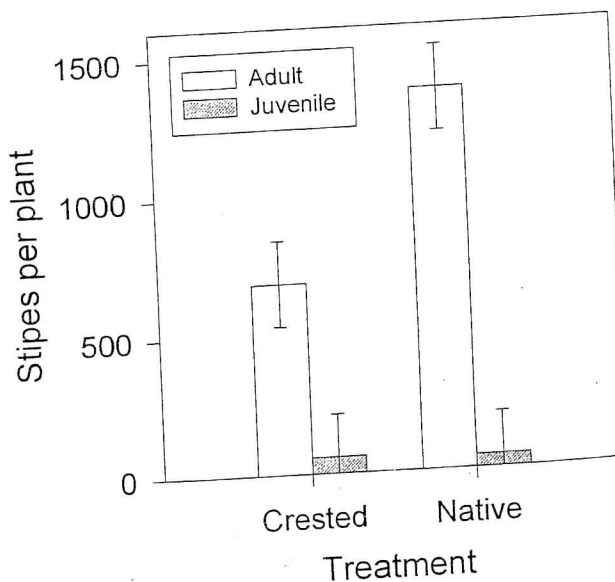


Figure 3. Mean (± 1 SE) stipes per plant of *Astragalus oniciformis* for adult and juvenile plants growing in a 20-year-old seeding that included crested wheatgrass (see Table 2) and an adjacent native community (treatment-by-lifestage interaction $P = 0.03$).

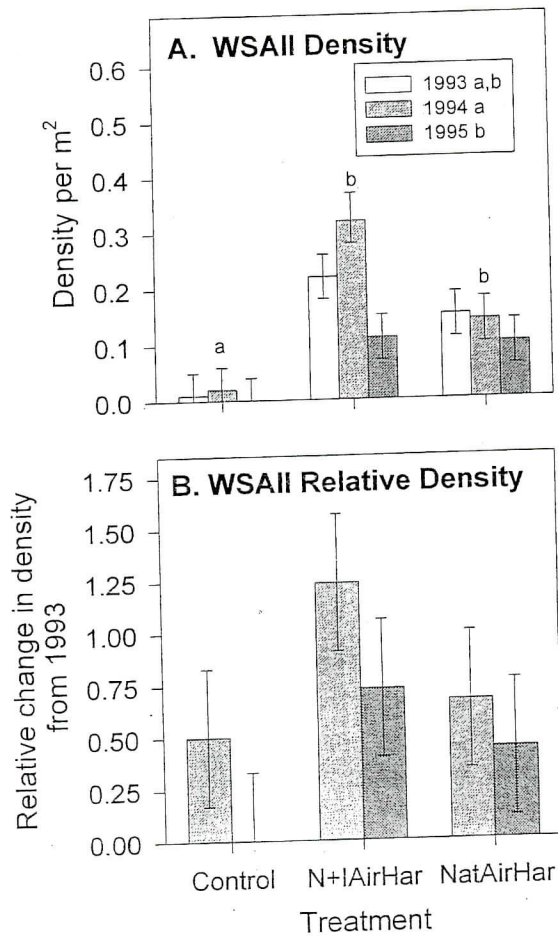


Figure 4. Mean (± 1 SE) (A) density per m^2 (years, $P = 0.05$; treatment, $P = 0.01$; interaction, $P = 0.19$) and (B) relative change in density during 1994 and 1995 from that of 1993 (main effects and interaction, $P > 0.15$) for *Astragalus oniciformis* growing at the WSAII site in three seeding treatments, unseeded (control), aerially seeded with a mixture of native and introduced species then harrowed (N+IAirHar), and aerially seeded with a native species mixture and harrowed (NatAirHar). Different lowercase letters associated years and treatments indicate significant differences using the least squared means approach ($P \leq 0.05$). Relative change in density (B) is calculated from each replicate and is not calculated directly from the mean density (A); therefore relative change may not directly correspond with density (e.g., 1993 to 1994 control).

aerially seeded native species mixture, had the lowest proportional decline in densities, but the treatment that caused the greatest soil disturbance, the drilled seed mixture that included native and introduced species, did not differ significantly from it (Figure 5B).

Our failure to detect any plants in the controls for both sites by the third year after the fire may be due to the fact that they had fewer plants to begin with, so even a small decrease affected these sites more drastically.

Although these seeding treatments were not initially designed to determine their impact on the milkvetch, we believe these results provide a conservative estimate of

the short-term impacts of fire rehabilitation treatments. We are not convinced that fire rehabilitation treatments reduce densities of the Picabo milkvetch in the short-term low enough to cause concern for the milkvetch's continued existence. The data do not clearly show that seed mixes with crested and other non-native species are any different from seed mixes with all native species in terms of their impacts on milkvetch densities during the initial establishment period.

Study 3 — Plow-and-seed rangeland improvements and milkvetch reproduction
Astragalus density in the belt transects was 6.5 times

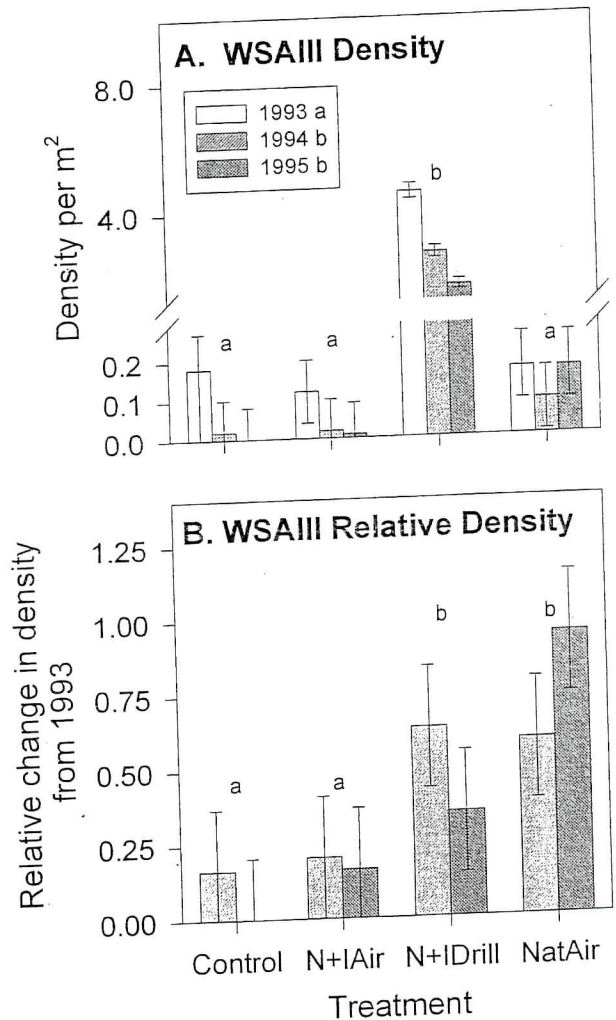


Figure 5. Mean (± 1 SE) (A) density per m^2 (years, treatment, and interaction, $P = 0.01$) and (B) relative change in density during 1994 and 1995 from that of 1993 (treatment, $P = 0.04$) for *Astragalus oniciformis* growing at the WSAIII site in four seeding treatments, unseeded (control), aerially seeded with a mixture of native and introduced species but not harrowed (N+IAir), drilled mixture of native and introduced species (N+IDrill), and aerially seeded with a native species mixture, but not harrowed (NatAir). See Figure 4 caption for explanation of letters and of relative density calculation.

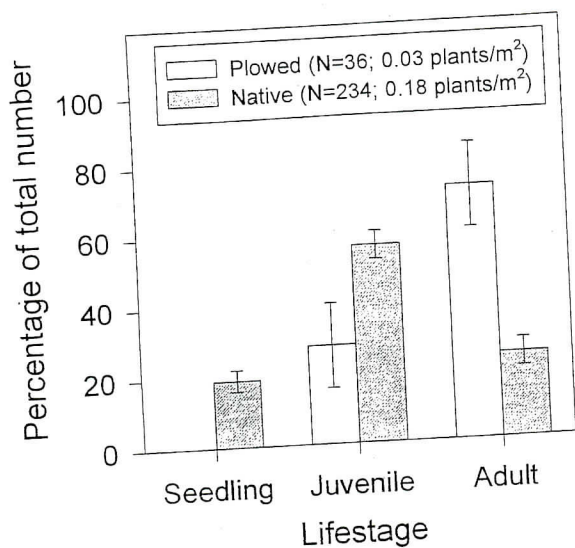


Figure 6. Mean (± 1 SE, $n = 6$) relative proportion of lifestages of *Astragalus oniciformis* plants in a 1-year-old plowed and seeded area and an adjacent unplowed and unseeded native plant community (N for each site indicates the total number of plants encountered).

lower in the treated area (36 total plants) as compared to the untreated area (234 total plants) one growing season after treatment. Proportions of seedlings and juveniles to adults were also significantly lower in the treated area, with no seedlings found in the treated area (Figure 6).

These data suggest that substantial mortality of plants occurs from the initial disturbance associated with plow-and-seed implementation. The lower proportion of juveniles may indicate that they are more affected than adults. The absence of seedlings probably indicates that the disturbed habitat is unsuitable for seedling establishment. An alternative explanation might be that seeds in the seed bank were buried during the plow-and-seed treatment. The fact that adult plants survived the treatment indicates that the soil was not totally turned over during the plowing; therefore seeds could have germinated and produced seedlings.

Adults produced more seeds per fruit in the treated area, but juveniles in the treated area produced less seeds than juveniles in the control (Figure 7). This is evidence that in addition to greater impact on juvenile mortality, juvenile reproductive output is also effected more than adult output. The increase in adult reproduction may be due to the decrease in competition and to the potential release of nutrients after the treatment, although there was a high density of cheatgrass present. The increase in seed production by adults in the disturbed area is similar to that seen in a disturbance treatment in Study 1.

These data give enough evidence for concern of continued viability of milkvetch populations in plow-and-seed treatments of the type studied.

Study 4 — Milkvetch survival

Few seedlings were found in any of the treatments at either two-year-old burn sites, therefore, we will use the seedling survival information for the Pagari Benchmark site as a conservative estimate of the probabilities for seedling survival for this species. Newly germinated seedlings have an average 52% (SD = 0.305; $N = 2$ cohorts; $n = 8$ plots) probability of surviving to the second year. Age to first reproduction was one year for 79% of the seedlings that survived the first summer drought. These young reproductive plants produced an average of 8 inflorescences with an average of 8.5 fruits. Although this only occurred for the cohort that emerged in 1993, the cool moist year, these plants reproduced in a drought year (1994). We believe this demonstrates the ability of this plant to quickly replace itself on appropriate sites as long as a seed source is near. We do not know the longevity of seeds in the seed bank, but we speculate that it may last several years.

Adult survival remained high (>90% at all sites and treatments) during the first two years of the study. Observations of adult plant survival during the first two years were easy to make since aboveground branches retained live short shoots through the winter and into early spring. During 1995, the morphology of adult plants changed, reflecting the potential stress of the previous year's drought, followed by a cool, wet year. Nearly all adults senesced their aboveground growth.

This change in morphology coincided with a general

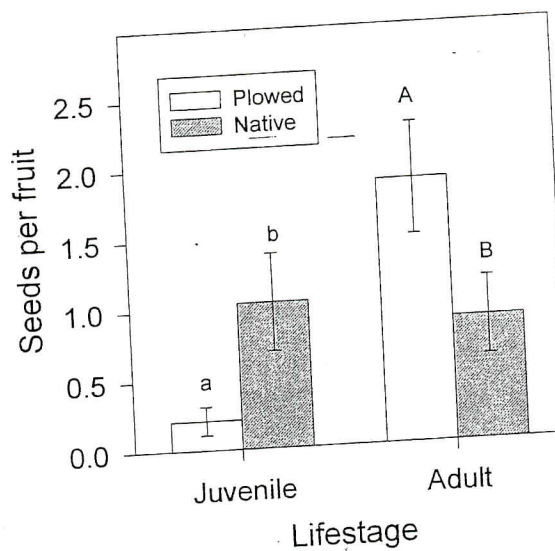


Figure 7. Mean (± 1 SE, $n = 25$) seeds per fruit of *Astragalus oniciformis* grown in a 1-year-old plowed and seeded area and an adjacent unplowed and unseeded native plant community. Comparisons were made between treatments within each lifestage, juvenile and adult ($P < 0.05$).

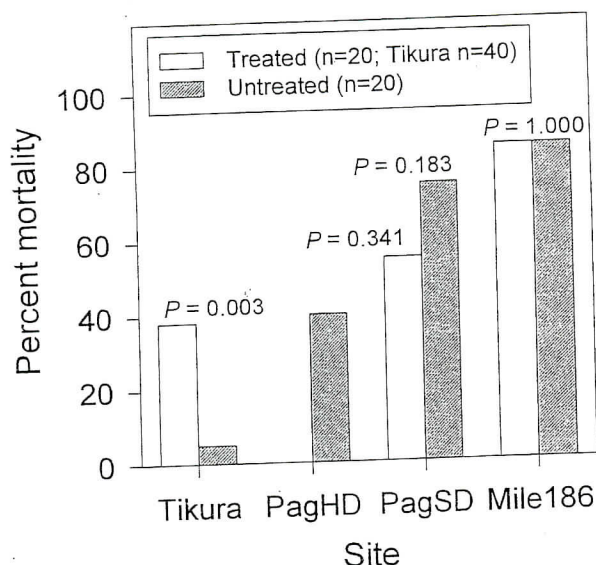


Figure 8. Percent mortality of combined adult and juvenile plants at four sites, plow and seed site (Tikura), a high density untreated site near Pagari (PagHD), the 20-year-old seeded site at Pagari (PagSD), and a 20-year-old seeded site near milepost 186 on U.S. Hwy 26 (Mile126). Treatments below P-values were tested using likelihood ratio chi-squared tests.

loss of plants that occurred across all sites between late summer 1994 and late summer 1995 (Figure 8). Interestingly, milkvetch appeared to survive and complete growth during the drought of 1994 with normal reproduction. When plants became dormant during the summer of 1994, they may have depleted resources to such a degree that they senesced to below ground tap roots or they died.

There were no differences in mortality rates between treatments at any of the sites monitored, except at the Tikura plow-and-seed (Figure 8). At Tikura, a significantly greater proportion of plants died the treated area than in the control. This suggests that the habitat alteration in combination with the environmental conditions were detrimental to survivorship of established plants, at least in the short-term. The lack of differences between treatments at other sites suggests that fire and seeding treatments do not increase immediate mortality of established plants as compared to unburned or untreated plants.

Both the Tikura control and treatment had the lowest overall mortality of all sites (Figure 8). We speculate that this may be due to the wetter and cooler growing conditions of this site, or to finer textured soils, possibly allowing longer water availability and less stress later into the growing season.

Mortality was similar among the Mile 186, Pagari Benchmark, and Pagari seeding sites. The high mortality rate (85%) at the Mile 186 site may be in part due to rodent herbivory, which occurred on 65% and 35% of juvenile and adult plants, respectively. When herbivory occurred, the entire plant was usually severely eaten. Sometimes the plant was uprooted and the tap root was miss-

ing.

The Pagari high-density site, where we expected density-dependent mortality to occur at a higher rate than other sites, showed only 40 percent mortality. This indicates that even at high densities, mortality can be similar or less than other, less dense sites, at least in the short-term.

There are surely various unmeasured factors influencing mortality at a given site. But the general consistency of mortality across most sites, irrespective of treatment, and the lowest mortality at the most ameliorated site (Tikura) may indicate that climatic factors are of paramount importance in affecting mortality.

To what degree mortality is event-driven, and what minimal number of plants are needed for population survival is still unknown. The generally high rate of mortality may or may not imply that a rather substantial recruitment and survival rate of new plants must occur if a viable, genetically-diverse population is to be maintained.

Pollinators. The pollinator collections from the milkvetch reveal the presence of two rare insects. A noteworthy range extension was made for *Andrena nigerrima*, which was not previously known to occur west of the east slope of the Rocky Mountains (Terry Griswold, pers. comm., USDA ARS Bee Lab, Logan, UT). The second insect, *Calliopsis barri*, is a rare species known only from a few sandy sites in the northern Great Basin and the Columbia Plateau. These pollinators can be very host-specific, and the greatest threat to their existence can come from adverse impacts to the host plant or to the insect's nesting microsites (Terry Griswold, pers. comm.). This underscores the importance of studying all factors influencing the continued milkvetch population survival, including pollinators and their needs.

Limitations of study and future needs. These studies have few or no replicates, limiting confidence in applying results over the entire range for this milkvetch. It is important to note, however, that Picabo milkvetch has been observed by the senior author to persist in numerous old and young fire rehabilitation seedings of all types across the species' range. It also seems that when this species does appear in a seeding, it is usually large and vigorous relative to unburned, untreated areas.

This study does not address how long an individual plant will survive in a seeding, or whether sufficient recruitment and replacement is occurring to provide long-term viability of affected populations. Nor does it examine the impact to populations by possible habitat fragmentation or microsite alteration, which could affect important variables such as pollination vectors and "safe sites" for germination and seedling survival. These parameters

must be further studied if meaningful long-term population survival probabilities are to be projected or modeled. Nonetheless, fear of immediate extinction of populations that are burned and rehabilitated (a major driving force in initiating this study) can be reasonably dismissed, and some management of the species can begin with the results presented.

Conclusions

- Fire rehabilitation seeding with crested wheatgrass and related allies does not appear to significantly reduce reproduction potential of Picabo milkvetch in the short- or long-term;
- Drill and harrow revegetation techniques assessed in this study do not appear to lead to plant densities low enough to cause concern three years after treatment;
- Plow-and-seed disturbance causes reduced plant densities and lower reproductive output in juveniles sufficient enough for concern one year after treatment, and
- Seedling establishment and plant replacement must be investigated further in fire rehabilitation and range improvement practices to determine the ability of this endemic species to maintain itself in the long-term under such scenarios. We are continuing research to address these questions.

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