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Cultural Thinning of Native Sagebrush Stands to Increase Seed Yields

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ABSTRACT

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Wyoming big sagebrush (*Artemisia tridentata* Nutt.) is an important native shrub in the Great Basin because of its wide distribution where it dominates over 60 million ha and provides essential habitat and forage for many varied species. The hand collection of sagebrush seed often results in seed scarcity and the available seed quantities are at times inadequate to revegetate large areas that have been disturbed, resulting in a demand for sagebrush seed. Study locations were selected near Scipio and Sahara sand dunes of Utah, and treatments were 1-) control, no treatment applied area left undisturbed 2-) general chemical strip thinning 3-) general chemical thinning of entire stand, 4-) general mechanical strip thinning, and 5-) general mechanical thinning of the entire stand. Significant differences among treatments in seed yields were collected in 2011 at Scipio but not at Sahara. At Scipio, the mechanical strip of competing sagebrush in 3m strips was the most effective of all treatment and produced 2.47kg/ha compared to 4.624kg/ha in the control, but the mechanical land area was only utilizing half the compared control area. The chemical treatments produced 1.819kg/ha and 1.31kg/ha. The percent of sagebrush mortality by each treatment determined the level of competition killed in treatment areas. All treatments at both locations killed at least 57% of the sagebrush. Chemical treatments had a consistent kill rate at both locations, although lower than anticipated, but mechanical kill was the highest at 93% in Scipio. Both mechanical and chemical treated plots had increased cover levels of cheatgrass when compared to the control plots.

Keywords: sagebrush, seed yield, cheatgrass, seed collection, treatment

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

Introduction

The high fire fuel loading by a number of invasive plant species in the Great Basin has resulted in millions of acres burned in the last 10 years. Much of this area returns in 3-10 year cycles, with added fuels is more frequent than the traditional 40-100 year cycles (Whisenant S.G 1990). The Great Basin is found in five states (Oregon, Idaho, Nevada, California, and Utah) and the destruction of native plant communities, watersheds, and subsequent soil movement reduces habitat for wildlife, and grazing for livestock. It also diminishes recreational opportunities and results in more dangerous and costly firefighting. These devastating results have prompted restoration efforts towards plant community diversity so the wildlands will be more resilient to disturbance and invasive species. Government agencies seek native plant seeds to restore ecosystems to their natural state, and stabilize soils and maintain watersheds (Meyer 1994).

The use of native species in restoration efforts has resulted in collection of native seed becoming an important aspect of multiple-use on public lands. Thriving seed industries have developed around the collection, processing, and sale of native plant seed grown naturally. The hand collection of native seed often becomes to cost prohibitive. The available seed quantities are at times inadequate to revegetate large areas that have been disturbed. Part of restoration is the reestablishment of native shrubs, integral to the proper function of these ecosystems (BLM 1999). There is great demand for native shrub seeds in the United States, especially for revegetation efforts by private landowners, federal and state agencies. Wyoming big sagebrush (*Artemisia tridentata* Nutt.) which is an important native shrub for restoration, has a wide distribution in the Western United States which dominates over 60 million ha (Wambolt and Hoffman 2001) and provides essential habitat and forage for many animal and bird species (Connelly et al. 2004).

Sagebrush plays an important role for other wildlife and is important to the native environment as it alters microclimates through the creation of windbreaks, absorption of moisture from the soil profile, and facilitating establishment of native plant life. Unfortunately, excessive livestock grazing, invasive plants, large fires and expansion of agricultural cropland (Anderson and Inouye 2001; Knick 1999; Knick and Rotenberry 1997; Noss and others 1995) have resulted in fragmentation of sagebrush stands. The necessity of sagebrush seeds for rehabilitation is a priority for federal and state agencies in the conservation of natural resources.

Large shrub areas on federal and state lands can be a solution to the costly seed problem by harvesting the necessary sagebrush seeds and then using the seeds for restoration purposes (Welch 2005). A large percentage of big sagebrush seed that has been collected and sold has come from these wild land stands (Meyer 1994). Establishment of Wyoming big sagebrush is often difficult because natural factors such as spatial and temporal circumstances, temperatures, and moisture restrictions all limit initial growth, maturation, and ultimately survival. However, it has several adaptive features such as variable growth forms, response to fires, the production of allelopathic substances in roots and leaves, the ability for late germination and photosynthesis at low temperatures, seed dispersal strategies, seed size, as well as structure and timing of seed maturation that influence its distribution and persistence (Blaisdell et al 1982; Kelsey 1986; Meyer and Monsen 1992; Peterson 1995).

Seed production of sagebrush begins in the second year following germination and occurs annually except during years of severe drought stress (Meyer and Monsen 1992). Seed production is initiated in the fall when flowers emerge following the summer drought stress, the fruits (achenes) mature from mid-fall to early winter when the seed matures and falls to the ground (Meyer 2003). Achenes are small (about 1 by 1.5 mm) and shiny with a deciduous pappus (Meyer 2003). They are dispersed by wind and gravity but do not have any additional adaptations to aid wind dispersal (Meyer 1994). Seeds can potentially be blown by wind across snow surfaces and or dispersed by animals or water (Tisdale and Hironaka 1981; Young and Evans 1989a). The maximum dispersal distance of seeds is 30 m with most seeds (85 to 90 percent) falling within 1 m of the shrub canopy (Meyer 1994; Young and Evans 1989a).

Widespread growth of Wyoming big sagebrush is attributed to an efficient two-component root system (West and Young 2000). The first component is the fibrous root system that captures water and nutrients near the soil surface, permitting plants to take advantage of summer precipitation (West and Young 2000). The second component is the taproot that allows for utilization of water and nutrients deep within the soil profile and below the main rooting zone of associated herbaceous species (West and Young 2000). By reduction of the stand, these additional resources can be utilized by the remaining plants.

Ideally, sagebrush seeding should take place in the winter months. This schedule should work well with seed availability because Wyoming big sagebrush seed matures in late fall and after-ripening occurs in late November or December. Shrub seedling establishment in January through March have also been very successful. Establishment is dependent heavily on precipitation, which varies in the climate of the Great Basin. Big sagebrush seed is available from seed companies both from wildland collections and seed orchard production; but regardless of where the seed originates, it is important to ensure that good quality seed is purchased or collected, because this is a critical factor in successful establishment on disturbed lands. Big sagebrush seed viability has been shown to persist for at least 4 years in a seeding; thus, increasing the opportunity for adequate moisture and temperature conditions to occur over that period of time and provide for adequate seedling density (Blaisdell et al. 1982; Kelsey 1986; Meyer and Monsen 1992; Peterson 1995).

The potential competition between Wyoming big sagebrush plants within a stand during periods of drought can also affect flowering and seed production by redirecting energy to compete for the moisture and available nutrients (Meyer 1994). Various herbaceous plants may also impact the success of sagebrush establishment. For example, invasive grass seed germinates earlier than Wyoming big sagebrush and reduces seedling establishment by monopolizing available soil moisture (Blaisdell 1949; Fortier 2000; Schuman, 1998; Cook and Lewis 1963; Sturges 1977). Consequently, Wyoming big sagebrush seedlings have had little success competing for natural resources in areas containing invasive annual grasses like cheatgrass (Meyer 2003). Purposefully introduced perennial grass like crested wheatgrass (*Agropyron cristatum (L.) Gaertn*), can also reduce sagebrush establishment (Richardson et al. 1986). Competition losses are due to similar root distributions and growth periods during times of limited resources. Invasive grass species also increase the likelihood of fires and big sagebrush seeds are generally short lived and do not survive fires, resulting in decreased sagebrush lands (Young and Evans 1989a).

Seeding areas with Wyoming big sagebrush seed through aerial broadcast over the soil surface is the typical restoration practice. Aerial broadcasting has been effective to a point; yet the percent of establishment is highly variable in amount, cover, and density of shrubs. This indicates how complex the factors influencing the establishment of sagebrush, from both natural populations and from artificial seeding can be. Aerial seeding of Wyoming big sagebrush has had typically low success rates. Nearly all sagebrush seed is collected from wildland stands so there is need to ensure a viable solution to seed production to curb the costly and sometimes unavailable seed (Armstrong 2007). Due to fires, there is an ever increasing demand for seed that has managers seeking for expanded production at lower cost (Beetle and Young, 1960). Seed harvesting has become an important part of restoration of public lands. High climate variability creates unstable sagebrush seed production. In most years and especially dry years, seed harvest of sagebrush is best along road sides where water shedding from road surfaces increase moisture availability to plants growing adjacent the roadsides. Similarly, studies have shown that removing competition can increase seed yield by 300% (Armstrong 2007). Possible options for competition removal at an operational scale are through chemically killing competing plants or mechanically killing plants by a harrow.

The herbicide 2,4-D was developed during World War II, aiming to increase crop yields for a nation at war. In 1946, it was commercially released and became the first successful selective herbicide and allowed for greatly enhanced weed control in agricultural farming. It is absorbed through the leaves and is translocated to the meristems of the plant causing unsustainable growth. The symptoms include stem curl-over, leaf withering, and eventual plant death (Forest Service 1984). Normal plant growth processes are disrupted by 2,4-D as it interferes with the uptake of compounds through its leaves, stems and roots. Breakdown occurs with time and is influenced by a variety of biological and chemical pathways (National Research Council Canada, 1978).

The herbicide 2,4-D has a large variety of applications and is the most widely used herbicide on the planet. Through everything from agricultural production and large-scale aquatic weed control to use by individual homeowners and professional turf managers it has proven to be a tool for the elimination of problematic broadleaf weeds from Europe to Africa and North America to New Zealand (Industry Task Force II 2010). Wyoming big sagebrush is thinned/killed through foliar applications of 2,4-D (Shown et al. 1969; Martin 1970; Castrale 1982; Sturges1993). Essentially, chemical control is effective on both large and small plants and could effectively be used on any size area, although specialized equipment would be needed for aerial application on larger areas. Chemical treatment with 2,4-D has produced mixed results at various locations; sometimes complete death of sagebrush occurs, but more often the crown of the plants are killed. The herbicide 2,4-D can result in a severe reduction of Sagebrush and reduce competition for limited resources essential for plant growth and seed production

(Shown et al. 1969; Martin 1970; Castrale 1982; Sturges1993). Therefore, desired killing of sagebrush, reduced seed production, ease of application, cost, production, and effectiveness of 2,4-D qualifies it to be resource good option to chemically kill sagebrush. (Burke, I. C, W.A Reiners, D. L. Sturges and P.A Matsonet al., 1987).

Various types of machinery are used to remove plants from wild landareas. A common practice is chaining, which is used to kill all woody and perennial plants. Chaining occurs when a large vessel boat chain is attached to two bulldozers that drag the chain between them knocking over and tearing the plants from the soil. This method is best used to kill all vegetation on large sections of land. Mechanically cutting is another readily applicable option for small areas or in situations where larger areas will be treated on an intermittent basis but has limited large-scale application due to higher costs (Valentine 1980).

The Dixie harrow is another alternative for thinning Wyoming big sagebrush that has been successfully used by public land agencies for sagebrush control. The Dixie harrow consists of several pipes about 10-15 cm in diameter that are attached to a metal 25 cm I-beam. The I-beam is attached to a tractor that pulls the harrow across the landscape. The pipes are attached so that they have movement and rotate as they are pulled across the terrain; the rotation clears them of plant debris as it builds up. Effectiveness of a Dixie harrow decreases in rocky terrain because the harrow brings many rocks to the surface and the rocks raise the harrow off the ground resulting in limited damage to sprouting shrubs and annuals (Valentine 1980). A kill rate of 30-70% of big sagebrush is common and makes it a good option for mechanical thinning.

The Dixie harrow can also be used to eliminate shrubs with multiple passes of the harrow. This study was designed to expand previous research by determining if thinning native stands of Wyoming big sagebrush on an operational scale can improve seed yields for the stand.

The intent of my research is to determine if competitive removal of sagebrush can increase seed yield over natural stands. General thinning of the population could provide surviving plants significant competitive advantage over resources which will increase yield in the long-term. The objectives of this research are: 1- determine if general chemical and mechanical thinning of sagebrush stands will impact early post treatment seed production compared to both strip thinning and untreated controls; 2- determine if general chemical and mechanical strip thinning of sagebrush will provide competitive advantage over resources for plants left in untreated strips which will increase seed production; and 3- compare the difference between chemical and mechanical treatments and determine which treatments are viable options for seed production.

Material and Methods

Two locations in Utah were chosen based on available area (50 acres or larger), and sagebrush stand uniformity and density. The locations were selected with the help of the state lands department and Bureau of Land Management (BLM). The appropriate surveys were undertaken and cleared prior to any treatment application. One location is approximately 10 miles south of Scipio (39º 16’52.28”N, 112º 21’11.12”W) along the I-15 corridor and is referred to as “Scipio” This site receives an average of 32.9 cm of total precipitation per year (Western Regional Climate Center 2005). The second location is in central Utah (39º 70’49.89”N, 112º 32’50.30”W) approximately 10 miles south east of Eureka at the main entrance to the little Sahara recreation area and is referred to as “Sahara”. This site receives an average of 28.27 cm of total precipitation per year (Western Regional Climate Center 2012).

Five treatments were applied at each location, 1- control, no treatment applied area left undisturbed 2- general chemical strip thinning, alternating spraying on 3 m of sagebrush leaving a 3 m non-sprayed area 3- general chemical thinning of entire stand, completely spraying the entire plot; 4- general mechanical strip thinning, pulling the Dixie harrow over the stand three times across the same strip leaving 3 m between each strip; and 5- general mechanical thinning of entire stand, pulling the

Dixie harrow over the entire stand. Individual treatment plots were 230 m. long by 50 m. wide. All treatments were randomized and replicated four times within each site. The chemical thinning treatments were sprayed with 2, 4-D LV6 (low volatile ester with six pounds of active ingredient). The LV6 product was used due to the ester formulation, which is more active on the sagebrush and was applied at 10 liters/ha in 275L of water/ha. Applications were made with a John Deere Model 5520. The spray unit was calibrated to spray the above rates for ideal application with TJ60-8002VS TeeJet® TwinJet Flat Spray Tip nozzles being used to apply a uniform coverage that penetrates dense foliage and has smaller droplets for thorough coverage. The chemical kill treatment was sprayed in 3 meter (m) strips with a 3 m strip of living brush between each killed strip; it was sprayed at .8 liters/ha with a surfactant (LI 700 Loveland Products Inc) at 6L added to 275L of water/ha. The highest label rates along with a surfactant were used to maximize sagebrush kill (Industry Task Force II 2010).

General population thinning treatments were achieved by pulling the Dixie harrow over the entire treatment once. Strip thinning treatments were achieved by 3 passes with the Dixie harrow alternating between treated and untreated strips. Seed yield data was collected from the edge of the strips and covered 3m meters into the undisturbed area. Ten samples were taken from each treatment plot at each location.

A visual comparison with a reference unit plant was used to determine how many inflorescences there was in a 1.5 by 3.0 m quadrate and from that a seed yield was estimated. The reference unit was approximately 25 cm long with a full inflorescences head. Ten samples from each treatment plot at each location were collected. All sampled locations were 30 meters apart and extended the length of the plot. In the chemical and mechanical kill treatments, samples were collected from sagebrush that was on the border between treated and non-treated areas. The Wyoming Seed Certification Lab was used to evaluate seed samples, and to determine seed purity by adhering to the standardized Association of Official Seed Analysis (AOSA) rules for testing seed @ .75 gr with PSU number 50 used for *Artemisia tridentata*. Variation can be high due to the material containing a lot of inert matter. The use of a third party seed evaluator was beneficial because it ensured the best and cleanest sample to test, and also reduced the chance of bias.

During the growing season of 2011, one year after the treatments were applied, a nested frequency frame was placed at random points along a transect to collect understory basal ground cover, frequency of plant species, and plant cover (Forest and Range 2012). A transect spread out to a 100-m distance was used to place the nested frequency frame at ten random points along the transect. The mortality rate of sagebrush was also estimated using the line intercept method. The percentage cover of sagebrush and understory living plants was also estimated and helped to determine treatment efficacy.

All studies were conducted in a randomized complete block design with four replications. Data from all trials were analyzed using mixed models PROC GLM with Tukey-Kramer adjustments in SAS (SAS Institute, Cary, NC). An alpha level of 0.05 was used to determine statistical significance for mean separation.

Results

All treatments were initiated during the 2010 growing season and no seed was produced that year except in the control plots. At Scipio, the control treatment was different from the mechanical strip ($P=0.042$) and the chemical strip ($P=0.103$). The difference between the mechanical thin and the chemical thin were ($P=0.174$), the differences between mechanical strip and chemical thin ($P=0.026$). The difference between chemical thin and chemical strip was ($P=0.064$) (Table 2). All other treatment differences had a ($P\geq0.265$). At Sahara the control treatment was different compared to the mechanical strip with a ($P=.035$) and different from the chemical strip ($P=0.148$). The mechanical thin was different from the mechanical strip ($P=0.038$) and the chemical strip ($P=0.159$). The mechanical strip was different from the chemical thin ($P=0.109$). All other treatment differences had a ($P\geq0.40$).

Mechanical strip thinning at Scipio was lower when comparing equivalent land areas but higher when comparing 1.5 m by 3 m stands of sagebrush (Figure 1). Statistical analysis was not performed comparing locations because of the amount of variation at each location but there was a trend to have lower seed yields at the Sahara location.

The percent of sagebrush mortality by each treatment determines the level of competition removed from plants that would produce seed. All treatments at both locations killed at least 57% of the sagebrush. All treatments at Scipio were compared against the control, the chemical strip was (P=0.061), chemical thinning was (P=0.001), mechanical strip was (P=0.043), and mechanical thin was (P=0.001). Chemical thinning produced the least amount of kill, likely due to the reduced rate of herbicide application and no surfactant added to the tank. All treatments at Sahara were compared against the control, the chemical strip was (P=0.098), chemical thinning was (P=0.016), mechanical strip was (P=0.285), and mechanical thin was (P=0.003). At Sahara, the chemical treatments had lower killing percentages than the mechanical treatments (Figure 2 and Table 2). The same trend occurs at Scipio but the chemical killing treatment had good efficacy with 80% sagebrush kill. Limited damage was observed in the control plots, although some damage may have been due to chemical drift. Physically damaging the sagebrush with a Dixie harrow caused consistent kill at both locations (Figure 2). Three passes with a Dixie harrow increased sagebrush death by 18% at Scipio but did not result in an increased kill at Sahara.

Over 30 different species of plants were identified within the research area, all of which compete with sagebrush (Table 1). A large portion (maybe 50%) of the ground at Sahara has exposed soil and this percentage did not change with any of the treatments (Figure 3). Rock covered a small portion of the ground surface and was not significantly different than the control, however the treatments tended to expose rocks (likely due to the tractor work). The two chemical treatments significantly ($P \leq 0.05$) increased plant litter on the ground surface, and they significantly lowered the cryptogramic surface. Scipio and Sahara showed a decrease of cryptogramic crust cover within the chemical treatments (Figure 3). Similar results occurred with the litter and cryptogramic ground cover at the Scipio location; however the differences were not as great or significant. The percentage of exposed soil at Scipio was higher than the Sahara location.

Cheatgrass had the highest frequency of any plant at both locations. The next most frequent plant varied according to location but sagebrush was always in the top six (Figure 4 and Table 2). The chemical treatments gave an advantage to cheatgrass and increased bulbous bluegrass at the Scipio location. The plant species (*Alyssum alyssoides)* alyssum, (*Agropyron cristatum)* crested wheatgrass at Sahara, and (*Poa secunda)* sandberg bluegrass*, (Lomatium Raf)* Desert parsley, and sagebrush at Scipio tended to have a higher frequency in the non-disturbed control plots. Other species like cheatgrass, (*Pascopyrum smithi)* western wheatgrass, and (*Elymus elymoides)* bottlebrush squirreltail increased in frequency when compared to the control plots (Figure 4) (Table 2).

Sagebrush had the highest percent cover at Sahara while cheatgrass was the highest at Scipio (Figure 5 and Table 2). Cheatgrass had the greatest amount of cover in both the mechanical and chemical treatments when compared to the control plots. Other plant species that had high levels of cover in the mechanical and chemical treatments were alyssum at Sahara, and bulbous bluegrass at Scipio (Figure 5 and Table 2).

Discussion

During periods of drought, or other times when resources are limited, sagebrush shrubs limit growth and size and redirect energy to compete for the moisture and available nutrients (Meyer 1994). The availability of water is a major limiting factor for plant growth in the Great Basin, and the removal of sagebrush in direct competition with living sagebrush did not produce significant increases in seed yields one year after our treatment application. The mechanical removal of competing vegetation was the most effective method identified on the Scipio location for Wyoming big sagebrush. Shrubs produced 2.56 g of seed per 4.5 m^2 (2.47kg ha) at Scipio. Although the seed yield is lower in the treatment areas compared to the control. It shows that by half the available sagebrush to harvest yields more seed than untreated areas, therefore less time and resources spent on collection. Visual observation at each site confirmed that mechanical removal was more effective than the other treatments applied. More time is needed to determine what will be the overall best application for mass seed production. If competition from annual grasses and forbs increases, the benefit achieved from competing shrub removal may be negated. Further reduction in growth may be an indication that competition for resources is still being reduced and that the sagebrush needs more light, water, and nutrients (Valentine 1980).

In our study, losses of sagebrush due to treatments ranged between 58-90%, which was sufficient to test whether mechanical thinning increases seed production by reducing competition. The kill treatment by the Dixie harrow at Scipio and the control produced the highest seed production; however, in time the effects may continue to differentiate themselves. Unfortunately, there were no differences among the treatments and seed production in general tended to be lower at the Sahara location; but differences may become apparent with time. Differences between the locations may be due to rocks, soil types, rainfall, or other environmental factors.

The Dixie harrow is reported to have decreased efficacy in rocky terrain because the harrow brings many rocks to the surface that will raise the harrow off the ground resulting in reduced shrub death (Valentine 1980). By pulling the Dixie harrow in different directions over the Sagebrush in this study, the roots and stems were broken and caused high rates of plant death. This was most effective at the Scipio location where the soil had more clay and rock that may have held the roots and stems more secure so that physical pressures from the harrow caused more broken roots and stems.

The Sahara location had less sagebrush mortality, possibly because of the sandy soil that allowed the sagebrush to move and shift slightly in the soil rather than brake, so the Dixie harrow was not as effective at breaking plant parts. The sandy soil may have had some influence on exposing more soil surface area, as was indicated by the nested frequency frame. Valentine (1980) found that the Dixie harrow would expose sites because of the ripping and dragging actions associated with the harrow. When the soil is so varied from treatment area to treatment area, the amount of passes with Dixie harrow should be increased or decreased to ensure sufficient damage in order to leave more resources for the surviving sagebrush (Burke et al. 1987). Regardless of the environmental factors influencing seed production, the element of time will determine if the treatments can minimize environmental influences and increase seed production by lowering competitive effects as determined by Armstrong (2007).

Both chemical treatments negatively influenced seed yields at Scipio when compared to the control treatment; again the same results were not observed at Sahara where all treatments were similar. These results may have been due to drifting chemicals because the boom on the sprayer had to be raised to approximately 1.5m to get over the sagebrush, and the undulating surfaces at Sahara likely played a factor in the application and subsequent varied response to the chemical treatments. Lasting effects of 2,4-D on the sagebrush are still being observed even a year after the treatment was applied, which indicates that the potential of treatment effects may not be known in the immediate future and the sagebrush may need several years to recover (Forest Service 1984).

Differences in seed production may change with time, but Blaisdell (1982) and Hubbard (1957) both reported that grass competition with sagebrush reduced survivability and stand establishment, so resources may still be limited due to the increase in the grass understory at our research locations. The chemical 2,4-D clearly gave cheatgrass an unintentional competitive advantage since it was a broad leaf herbicide and the understory data indicated an increase in cheatgrass frequency and cover. There were also wheatgrass and some desert poa varieties such as secunda and bubosa that had increases in frequency and cover in the understory. By using a nested frequency frame we were able to account for 30 plus varieties of understory plants. However, sagebrush my be slow to recover because the grasses may have gained a competitive edge through the use of 2,4-D. Hopefully, an increase in sagebrush seed yield, a healthy understory that can be used for forage and cover by birds and animals, and the potential for more resources distributed among plants will outweigh the initial increase in grass frequency.

Chemical treatments had a consistent kill rate at both locations, although lower than anticipated, it was a good indicator that treatment rates caused consistent damage despite variation associated with each location. The chemical thinning had the lowest kill rate at both Sahara and Scipio locations. This is not surprising considering leaving the surfactant out of the tank mix reduced the efficacy. The company (Industry Task Force II) noted its effectiveness in killing sagebrush but also noted that it requires perfect timing and high rates to cause 100% mortality, which is rarely achieved without multiple applications.

Both chemical treatments increased plant litter on the ground underneath the sagebrush. This is not surprising considering the plants would drop dead leaves, stems, and twigs with pressure from the wind and rain. A decrease in the cryptogamic cover was also noted at both locations and may be due to death from to the 2,4-D; however, the physical make-up of the cryptogamic crust—being a mixture of moss, fungi, algae, and lichens—should not have been affected by the broadleaf herbicide, therefore we cannot explain why the percent cover dropped in our chemical treatments (Chang and Stritzke 1977). Scipio has been an area where cattle and wildlife have foraged, which could have attributed to the difference between the cryptogamic crust but it is not the same situation at Sahara. Time will be a factor to see if crust can return to a healthier state.

It was suspected that cheatgrass would be a predominant understory plant prior to this study, and there was a significant increase in cheatgrass frequency over the control especially in the chemical treatments. It appears that chemical treatments and a wet winter over 2010-2011 fostered an environment for cheatgrass to thrive regardless of location. The removal of competitive plants and good resources allowed cheatgrass to gain or maintain an advantage over 30 different species of plants

(Anderson and Inouye 2001). Other grasses, wheatgrass and bluegrass, also had an increase in frequency and likely benefited from a 2,4-D application, but sagebrush remained a predominant plant at both locations. A concern with this type of treatment on wildlands is the increase in cheatgrass, which will in turn increase the chance for a fire because cheatgrass dries during the summer and is very flammable. If fire were to burn these areas it would take years for the sagebrush to recover and no seed could be produced.

Both mechanical and chemical treated plots had increased cover levels of cheatgrass when compared to the control plots. This was likely caused from the disruption of the soil and plant life by the treatments. If either practice was to be implemented in a commercial situation, it may be beneficial to over seed immediately after mechanical applications with some various native plant seed mix and try to limit the establishment of cheatgrass (Valentine 1980).

The need to find a viable solution to increase sagebrush seed supplies is an enormous task. If sagebrush seed is to be collected from native stands treated to minimize competition and subsequently increase seed production, then a protocol with effective treatments is essential. Bare lands with erodible soils, variation in climatic conditions, and periodic catastrophic fires makes it even more important to have seed supplies to aid in such an event or situation where seeding is necessary (Blaisdell et al. 1982). By continuing this study for several years, we hope to determine if treatments influencing sage-brush density can be the best and most cost effective solution to produce desperately needed seed to plant onto disturbed lands in the Great Basin.

Management Implications

Based on the recent study of thinning sagebrush stands we saw an improvement in seed yield through the use of general mechanical strip thinning. However, with additional research data we can determine which of the four treatments could potentially be the best alternative to be used on a larger commercial scale to utilize the existing sagebrush stands.

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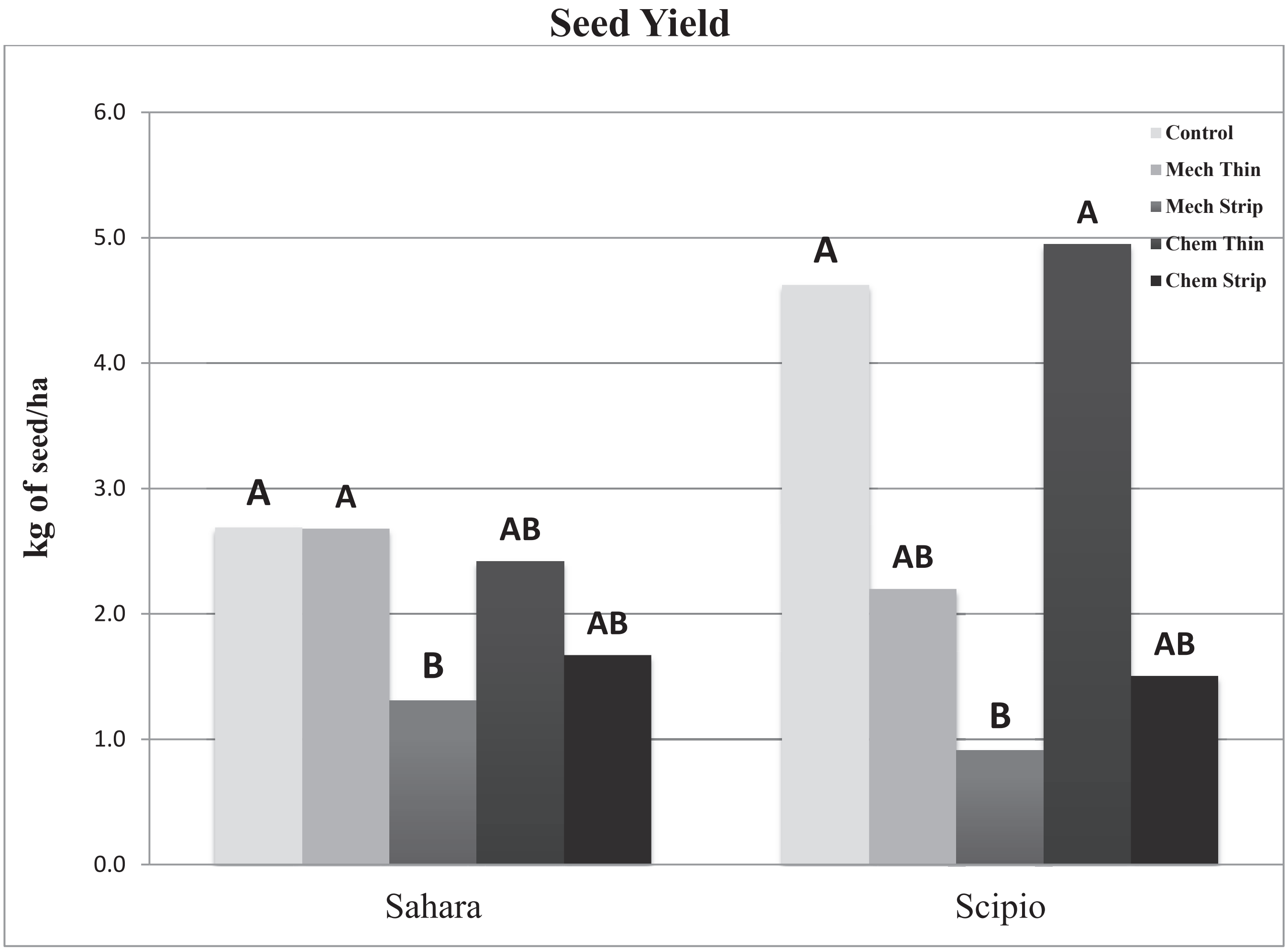


FIGURE 1. Sagebrush seed yield at the Scipio and Sahara locations one year after the application to reduce competitive sagebrush with the five treatments: control – native stand untouched; mechanical thinning – one pass with a Dixie harrow; mechanical kill – three passes over a 3 m strip; chemical thin – sprayed with 2,4-D LV6; and chemical kill – sprayed with 2,4-D LV6 and a surfactant.

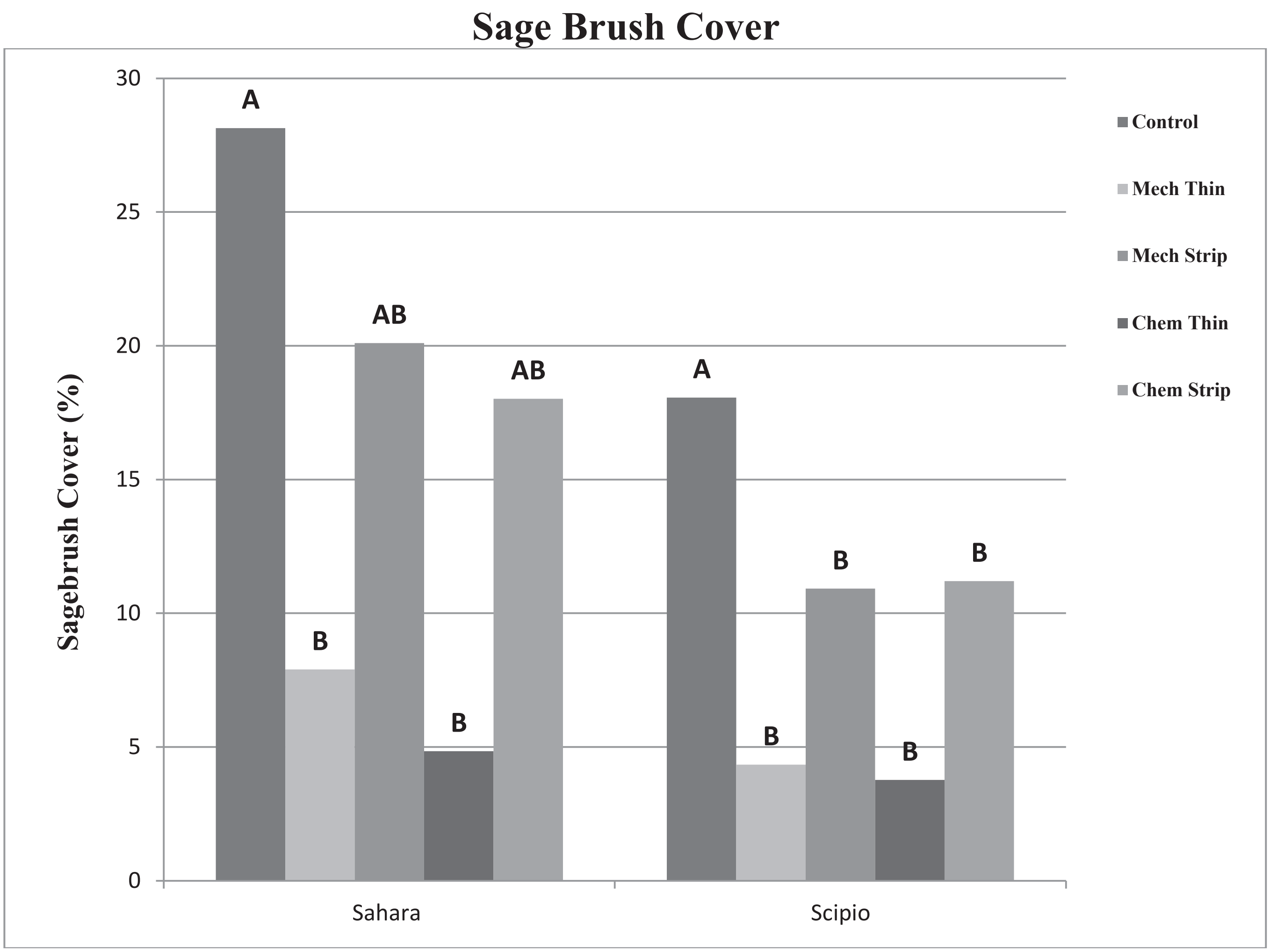


FIGURE 2. The percent of sagebrush cover at the Scipio and Sahara locations one year after application of the five treatments: control – native stand untouched; mechanical thinning – one pass with a Dixie harrow; mechanical kill – three passes over a 3 m strip; chemical thin – sprayed with 2,4-D LV6; and chemical kill – sprayed with 2,4-D LV6 and a surfactant.

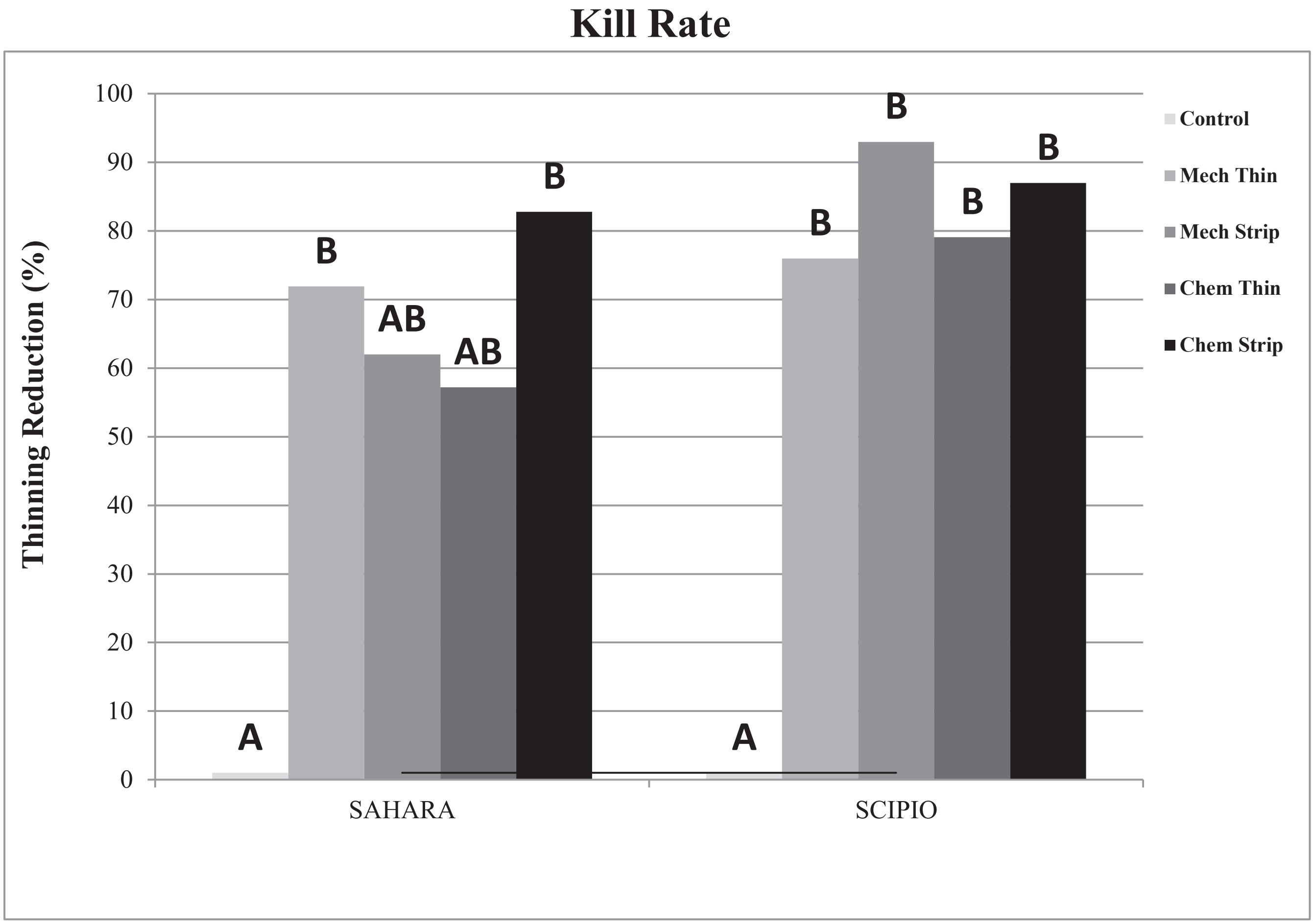


FIGURE 3. The percent of sagebrush killed compared to the amount of sagebrush at the control plot at the Scipio and Sahara locations one year after application of the five treatments: control – native stand untouched; mechanical thinning – one pass with a Dixie harrow; mechanical kill – three passes over a 3 m strip; chemical thin – sprayed with 2,4-D LV6; and chemical kill – sprayed with 2,4-D LV6 and a surfactant.

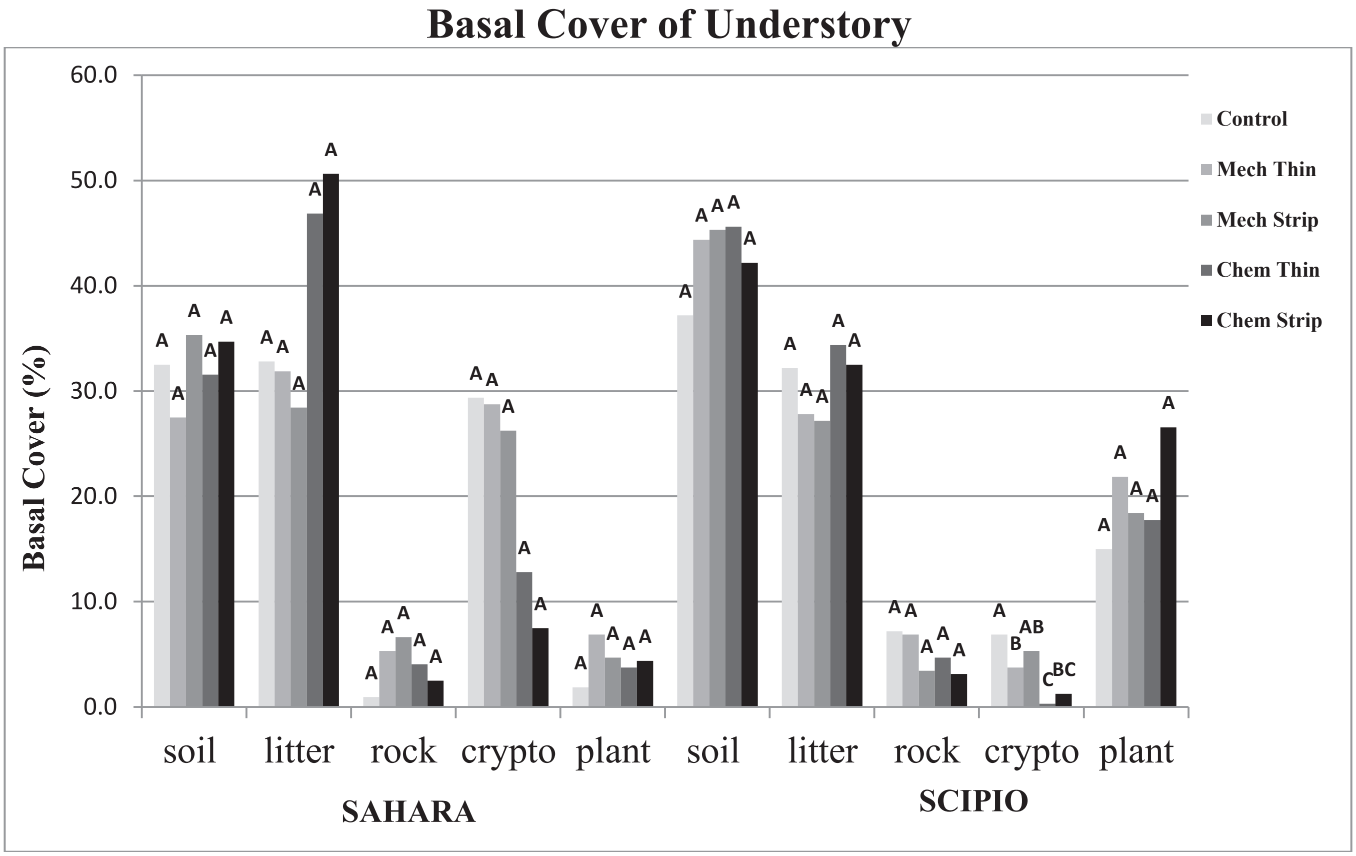


FIGURE 4. Basal cover of soil, litter, rock, cryptogramic crust and other plant life at the Sahara and Scipio locations.

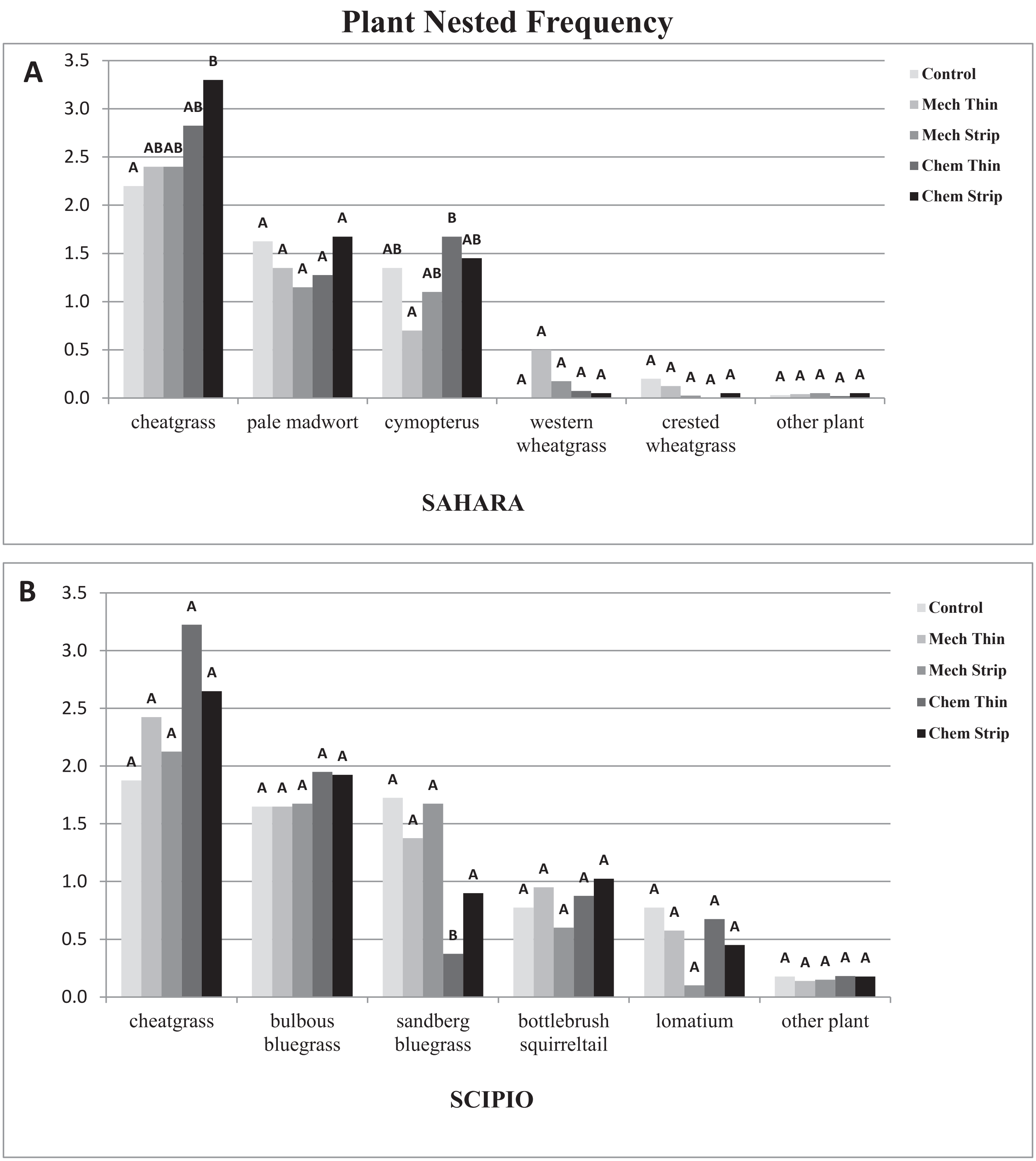


FIGURE 5. The six most frequent plant species identified by using a nested frequency frame at the Sahara (A) and Scipio (B) locations treated with the five treatments: control – native stand untouched; mechanical thinning – one pass with a Dixie harrow; mechanical kill – three passes over a 3 m strip; chemical thin – sprayed with 2,4-D LV6; and chemical kill – sprayed with 2,4-D LV6 and a surfactant.

Canopy Cover

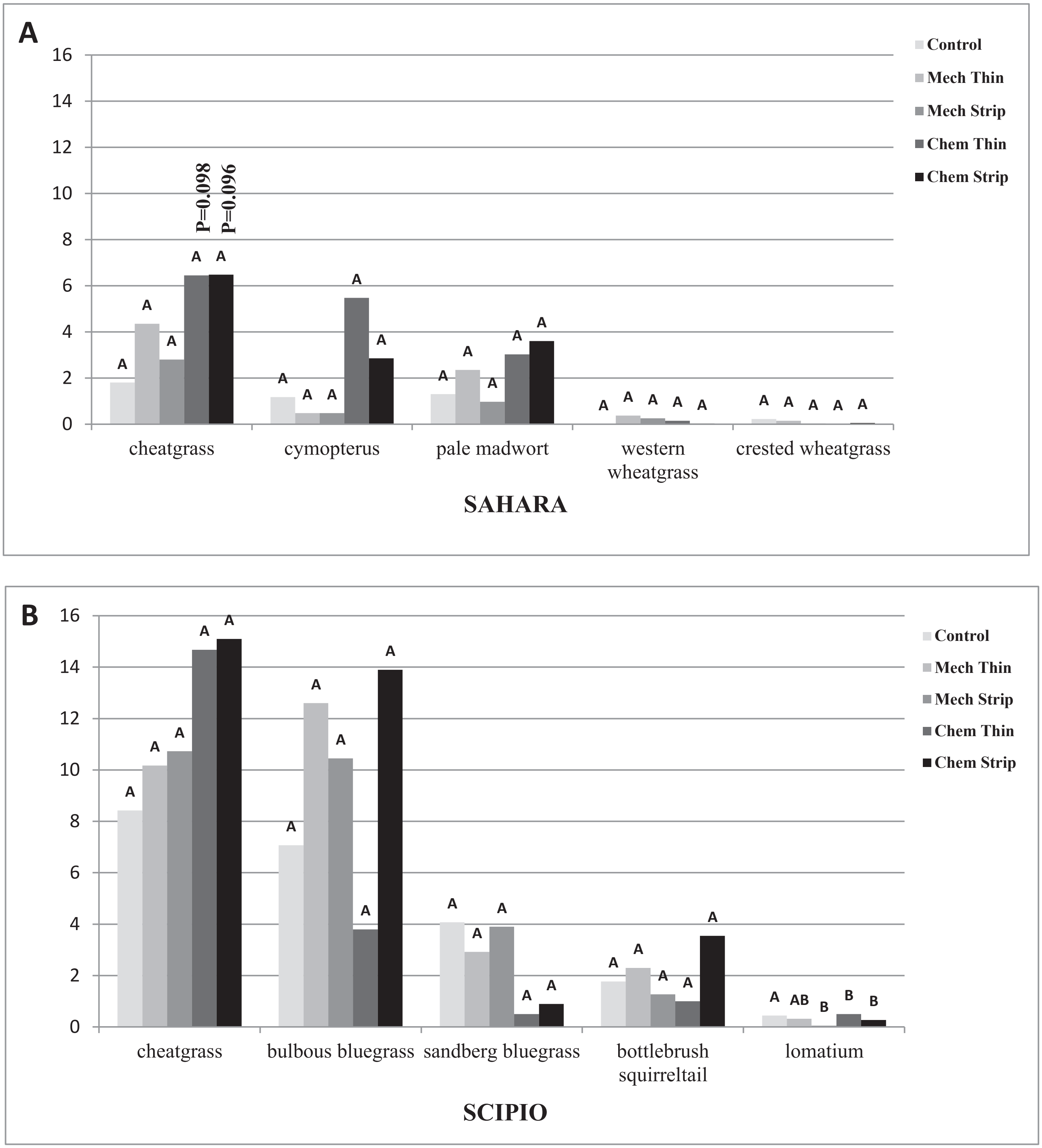


FIGURE 6. Five plant species covering the ground at the Sahara (A) and Scipio (B) locations treated with the five treatments: control – native stand untouched; mechanical thinning – one pass with a Dixie harrow; mechanical kill – three passes over a 3 m strip; chemical thin – sprayed with 2,4-D LV6; and chemical kill – sprayed with 2,4-D LV6 and a surfactant.

FIGURE 7. Chemical Kill application, you can see the variation of live foliage to the dead area where the chemical has been applied.

FIGURE 8. Mechanical thin where the Dixie Harrow was dragged once over the stand to reduce the density.

APPENDIX

Treatments

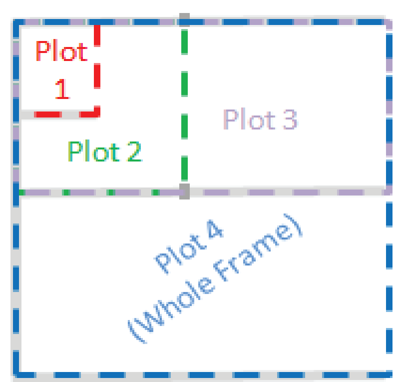
1- Mechanical thinning: pull the Dixie harrow over the entire treatment area once.

2- Mechanical Strip: pull the Dixie harrow over the treatment area alternating leaving 3m of live sagebrush and 3m of ripped sagebrush from the Dixie harrow. The Dixie harrow is to go over pulled area 3 times, each time in a different direction to get the desired kill.

3- Chemical thinning: attach boom sprayer with clearance a few centimeters above the highest sagebrush and spray entire treatment area of sagebrush with 2-4D at 10 liters/ha in 275L of water/ha appropriate rates.

4- Chemical Strip: attach spray boom and have only one section spraying alternating 3m meters of sagebrush and untreated 3m meters of sagebrush. Using 2-4D at 10 liters/ha in 275L of water/ha and a surfactant at 0.8 liters/ha.

Understory Collection



Estimate the percentage cover of understory plants using the nested frequency frame. The nested frequency frame is placed on one side of the line transect, while the opposite side of the tape is where we walk. Place the nested frequency frame at ten random points along the transect, Select the ten random points using a random number generator-several can be found on line. The frame is placed on the ground and all plants found in the frame were given the number associated with the frame. A number of 4 is associated within plot 1 meant it had a high frequency while a 1 is associated within plot 4 represents the whole frame and meant it was in low frequency. This frequency scale is continued in plots 2 and 3.

Sagecover Estimation

Spread a measuring tape 100-m distance, when sagebrush intersects the transect then add all areas together for the 100m.

Seed Collection

A visual comparison with a reference unit plant is used to determine how many inflorescences there are in a 1.5 by 3.0 m quadrate and from that a seed yield was estimated. The reference unit was approximately 25 cm long with a full inflorescences head. Ten samples from each treatment plot at each location were collected. All sampled locations were 30 meters apart and extended the length of the plot. Ensure samples for the strip treatment are collected on the fringe of the strip and sagebrush. Send samples to Wyoming Seed Analysis Laboratory, 747 Road 9 Powell, Wyoming 82435.

TABLE 1. List of all the plants, soil, rock, litter, and cryptogamic crust identified within the treatments at the Sahara and Scipio locations. Measurements were made using a nested frequency frame to identify the frequency, estimate canopy cover, and sample basal cover using the frame points. Over 30 different species of plants were identified within the research area, all of which compete with the sagebrush.

Plant Collection Sahara

SCIENTIFIC	COMMON NAME	TREATMENT	FREQUENCY	COVER	BASAL (%)
Achnatherum hymenoides	Indian ricegrass	CONTROL	0	0	0
Achnatherum hymenoides	Indian ricegrass	CHEM THIN	0	0	0
Achnatherum hymenoides	Indian ricegrass	CHEM STRIP	0.075	0.5	0.3125
Achnatherum hymenoides	Indian ricegrass	MECH THIN	0	0	0
Achnatherum hymenoides	Indian ricegrass	MECH STRIP	0.125	0.075	0
Agropyron cristatum	Crested Wheatgrass	CONTROL	0.2	0.225	0.625
Agropyron cristatum	Crested Wheatgrass	CHEM THIN	0.125	0.15	0
Agropyron cristatum	Crested Wheatgrass	CHEM STRIP	0.075	0.025	0
Agropyron cristatum	Crested Wheatgrass	MECH THIN	0	0	0
Agropyron cristatum	Crested Wheatgrass	MECH STRIP	0.05	0.05	0
Alopecurus brachystachus	Foxtail	CONTROL	0	0	0
Alopecurus brachystachus	Foxtail	CHEM THIN	0	0	0
Alopecurus brachystachus	Foxtail	CHEM STRIP	0	0	0
Alopecurus brachystachus	Foxtail	MECH THIN	0.1	0.05	0
Alopecurus brachystachus	Foxtail	MECH STRIP	0	0	0
Alyssum alyssoides	Alyssum	CONTROL	1.625	1.3	0
Alyssum alyssoides	Alyssum	CHEM STRIP	1.35	2.35	0
Alyssum alyssoides	Alyssum	MECH STRIP	1.15	0.975	0
Alyssum alyssoides	Alyssum	CHEM THIN	1.275	3.025	0.9375
Alyssum alyssoides	Alyssum	MECH THIN	1.675	3.6	0.625
Artemisia Tridentata	Sagebrush	CONTROL	0.025	0.025	0
Artemisia Tridentata	Sagebrush	CHEM THIN	1.625	1.3	0
Artemisia Tridentata	Sagebrush	CHEM STRIP	0.35	5.25	0.025
Artemisia Tridentata	Sagebrush	MECH THIN	0	0	0
Artemisia Tridentata	Sagebrush	MECH STRIP	0.2	0.225	0.05
Astragalus	Astragalus	CONTROL	0.025	0.025	0
Astragalus	Astragalus	CHEM THIN	0	0	0
Astragalus	Astragalus	CHEM STRIP	0	0	0
Astragalus	Astragalus	MECH THIN	0.025	0.025	0
Astragalus	Astragalus	MECH STRIP	0	0	0
Bromus tectorum	Cheatgrass	CONTROL	2.2	1.8	0.625
Bromus tectorum	Cheatgrass	CHEM THIN	2.4	4.35	2.1875
Bromus tectorum	Cheatgrass	CHEM STRIP	2.4	2.8	1.5625
Bromus tectorum	Cheatgrass	MECH THIN	2.825	6.45	1.875

Bromus tectorum	Cheatgrass	MECH STRIP	3.3	6.475	2.5
Calochortus nuttallii	Sego Lily	CONTROL	0.075	0.025	0
Calochortus nuttallii	Sego Lily	CHEM THIN	0	0	0
Calochortus nuttallii	Sego Lily	CHEM STRIP	0	0	0
Calochortus nuttallii	Sego Lily	MECH THIN	0	0	0
Calochortus nuttallii	Sego Lily	MECH STRIP	0	0	0
Ceratocephala testiculata	Bur Buttercup	CONTROL	0	0	0
Ceratocephala testiculata	Bur Buttercup	CHEM THIN	0	0	0
Ceratocephala testiculata	Bur Buttercup	CHEM STRIP	0	0	0
Ceratocephala testiculata	Bur Buttercup	MECH THIN	0	0	0
Ceratocephala testiculata	Bur Buttercup	MECH STRIP	0.075	0.025	0
Chrysothamnus Nutt	rabbitbrush	CONTROL	0	0	0
Chrysothamnus Nutt	rabbitbrush	CHEM THIN	0	0	0
Chrysothamnus Nutt	rabbitbrush	CHEM STRIP	0.15	0.575	0.3125
Chrysothamnus Nutt	rabbitbrush	MECH THIN	0.1	1.25	0.625
Chrysothamnus Nutt	rabbitbrush	MECH STRIP	0	0	0
Cymopterus Raf.	springparsley	CONTROL	1.35	1.175	0.3125
Cymopterus Raf.	springparsley	CHEM THIN	0.7	0.475	0
Cymopterus Raf.	springparsley	CHEM STRIP	1.1	0.475	0
Cymopterus Raf.	springparsley	MECH THIN	1.675	5.475	0.3125
Cymopterus Raf.	springparsley	MECH STRIP	1.45	2.85	0.3125
Elymus elymoides	Bottlebrush squirreltail	CONTROL	0.075	0.025	0
Elymus elymoides	Bottlebrush squirreltail	CHEM THIN	0.525	0.75	0.9375
Elymus elymoides	Bottlebrush squirreltail	CHEM STRIP	0.325	0.35	0.625
Elymus elymoides	Bottlebrush squirreltail	MECH THIN	0	0	0
Elymus elymoides	Bottlebrush squirreltail	MECH STRIP	0.025	0.025	0
Gutierrezia sarothrae	Snakeweed	CONTROL	0	0	0
Gutierrezia sarothrae	Snakeweed	CHEM THIN	0.15	1.025	0
Gutierrezia sarothrae	Snakeweed	CHEM STRIP	0.025	0.25	0
Gutierrezia sarothrae	Snakeweed	MECH THIN	0.075	0.625	0
Gutierrezia sarothrae	Snakeweed	MECH STRIP	0.025	0.125	0
Holosteum umbellatum	Jagged Chickweed	CONTROL	0.15	0.05	0
Holosteum umbellatum	Jagged Chickweed	CHEM THIN	0	0	0
Holosteum umbellatum	Jagged Chickweed	CHEM STRIP	0	0	0
Holosteum umbellatum	Jagged Chickweed	MECH THIN	0	0	0
Holosteum umbellatum	Jagged Chickweed	MECH STRIP	0.05	0.025	0
Lactuca	Prickly Lettuce	CONTROL	0	0	0
Lactuca	Prickly Lettuce	CHEM THIN	0	0	0
Lactuca	Prickly Lettuce	CHEM STRIP	0	0	0
Lactuca	Prickly Lettuce	MECH THIN	0	0	0
Lactuca	Prickly Lettuce	MECH STRIP	0.125	0.075	0
Litter		CONTROL	0	0.025	32.8125
Litter		CHEM THIN	0	0	31.875

Litter		CHEM STRIP	0	0	28.4375
Litter		MECH THIN	0	0	46.875
Litter		MECH STRIP	0	0	50.625
Lomatium Raf.	Desertparsley	CONTROL	0	0	0
Lomatium Raf.	Desertparsley	CHEM THIN	0.1	0.425	0.3125
Lomatium Raf.	Desertparsley	CHEM STRIP	0	0	0
Lomatium Raf.	Desertparsley	MECH THIN	0	0	0
Lomatium Raf.	Desertparsley	MECH STRIP	0	0	0
Moss		CONTROL	0	0.025	29.375
Moss		CHEM THIN	0	0	28.75
Moss		CHEM STRIP	0	0	26.25
Moss		MECH THIN	0	0	12.8125
Moss		MECH STRIP	0	0	7.5
Pascopyrum smithii	Western Wheatgrass	CONTROL	0	0	0
Pascopyrum smithii	Western Wheatgrass	CHEM THIN	0.5	0.375	0.3125
Pascopyrum smithii	Western Wheatgrass	CHEM STRIP	0.175	0.25	0.625
Pascopyrum smithii	Western Wheatgrass	MECH THIN	0.075	0.15	0
Pascopyrum smithii	Western Wheatgrass	MECH STRIP	0.05	0.025	0
Phlox longifolia	Longleaf Phlox	CONTROL	0	0	0
Phlox longifolia	Longleaf Phlox	CHEM THIN	0	0	0
Phlox longifolia	Longleaf Phlox	CHEM STRIP	0	0	0
Phlox longifolia	Longleaf Phlox	MECH THIN	0	0	0
Phlox longifolia	Longleaf Phlox	MECH STRIP	0.05	0.025	0
Poa Secunda	Sandberg Bluegrass	CONTROL	0	0	0
Poa Secunda	Sandberg Bluegrass	CHEM THIN	0.025	0.025	0
Poa Secunda	Sandberg Bluegrass	CHEM STRIP	0.05	0.025	0
Poa Secunda	Sandberg Bluegrass	MECH THIN	0	0	0
Poa Secunda	Sandberg Bluegrass	MECH STRIP	0	0	0
Pose		CONTROL	0	0	0
Pose		CHEM THIN	0	0	0
Pose		CHEM STRIP	0.125	0.05	0
Pose		MECH THIN	0	0	0
Pose		MECH STRIP	0	0	0
Rock		CONTROL	0	0.025	0.9375
Rock		CHEM THIN	0	0	5.3125
Rock		CHEM STRIP	0	0	5.625
Rock		MECH THIN	0	0	4.0625
Rock		MECH STRIP	0	0	2.5
Salsola iberica	Russian thistle	CONTROL	0	0	0
Salsola iberica	Russian thistle	CHEM THIN	0	0	0
Salsola iberica	Russian thistle	CHEM STRIP	0	0	0
Salsola iberica	Russian thistle	MECH THIN	0	0	0
Salsola iberica	Russian thistle	MECH STRIP	0.125	0.05	0

Soil		CONTROL	0	0.125	32.5
Soil		CHEM THIN	0	0	27.5
Soil		CHEM STRIP	0	0	35.3125
Soil		MECH THIN	0	0	31.5625
Soil		MECH STRIP	0	0	34.6875
Syssimbrium altissimum	Tumble Mustard	CONTROL	0	0	0
Syssimbrium altissimum	Tumble Mustard	CHEM THIN	0	0	0
Syssimbrium altissimum	Tumble Mustard	CHEM STRIP	0	0	0
Syssimbrium altissimum	Tumble Mustard	MECH THIN	0	0	0
Syssimbrium altissimum	Tumble Mustard	MECH STRIP	0.075	0.025	0

Plant Collection Scipio

SCIENTIFIC	COMMON NAME	TREATMENT	FREQUENCY	COVER	BASAL (%)
Agropyron cristatum	Crested Wheatgrass	CONTROL	0.15	0.15	0
Agropyron cristatum	Crested Wheatgrass	CHEM THIN	0.075	0.075	0
Agropyron cristatum	Crested Wheatgrass	CHEM STRIP	0.05	0.3	0.625
Agropyron cristatum	Crested Wheatgrass	MECH THIN	0.275	0.675	0.3125
Agropyron cristatum	Crested Wheatgrass	MECH STRIP	0.125	0.125	0
Alyssum alyssoides	Pale madwort	CONTROL	0.15	0.05	0
Alyssum alyssoides	Pale madwort	CHEM THIN	1.45	1.025	0
Alyssum alyssoides	Pale madwort	CHEM STRIP	0	0	0
Alyssum alyssoides	Pale madwort	MECH THIN	0	0	0
Alyssum alyssoides	Pale madwort	MECH STRIP	0	0	0
Artemisia tridentata	Wyoming Big Sagebrush	CONTROL	0.35	5.25	0.3125
Artemisia tridentata	Wyoming Big Sagebrush	CHEM THIN	0.475	7.175	0.9375
Artemisia tridentata	Wyoming Big Sagebrush	CHEM STRIP	0.65	10.875	0
Artemisia tridentata	Wyoming Big Sagebrush	MECH THIN	0.275	2.925	0
Artemisia tridentata	Wyoming Big Sagebrush	MECH STRIP	0.65	6.65	0.9375
Astragalus	Astragalus	CONTROL	0	0	0
Astragalus	Astragalus	CHEM THIN	0	0	0
Astragalus	Astragalus	CHEM STRIP	0	0	0
Astragalus	Astragalus	MECH THIN	0.075	0.05	0
Astragalus	Astragalus	MECH STRIP	0	0	0
Bromus japonicas		CONTROL	0	0	0
Bromus japonicas		CHEM THIN	0.1	0.025	0
Bromus japonicas		CHEM STRIP	0.075	0.025	0
Bromus japonicas		MECH THIN	0	0	0
Bromus japonicas		MECH STRIP	0	0	0
Bromus tectorum	Cheatgrass	CONTROL	1.875	8.425	2.5
Bromus tectorum	Cheatgrass	CHEM THIN	2.425	10.175	1.875
Bromus tectorum	Cheatgrass	CHEM STRIP	2.125	10.725	1.25

Bromus tectorum	Cheatgrass	MECH THIN	3.225	14.675	7.5
Bromus tectorum	Cheatgrass	MECH STRIP	2.65	15.1	1.3125
Calochortus nuttallii	Sego Lily	CONTROL	0.15	0.075	0
Calochortus nuttallii	Sego Lily	CHEM THIN	0.05	0.025	0
Calochortus nuttallii	Sego Lily	CHEM STRIP	0	0	0
Calochortus nuttallii	Sego Lily	MECH THIN	0.075	0.025	0
Calochortus nuttallii	Sego Lily	MECH STRIP	0.175	0.075	0
Ceratocephala testiculata	Bur Buttercup	CONTROL	0.05	0.025	0
Ceratocephala testiculata	Bur Buttercup	CHEM THIN	0.35	0.1	0.625
Ceratocephala testiculata	Bur Buttercup	CHEM STRIP	0.225	0.075	0
Ceratocephala testiculata	Bur Buttercup	MECH THIN	0.125	0.075	0
Ceratocephala testiculata	Bur Buttercup	MECH STRIP	0.275	0.075	0.3125
Crypto gamit crust		CONTROL	0	0	6.875
Crypto gamit crust		CHEM THIN	0	0	3.75
Crypto gamit crust		CHEM STRIP	0	0	5.3125
Crypto gamit crust		MECH THIN	0	0	0.3125
Crypto gamit crust		MECH STRIP	0	0	1.25
Elymus elymoides	Barkworth Squirreltail	CONTROL	0.775	1.775	0.625
Elymus elymoides	Barkworth Squirreltail	CHEM THIN	0.95	2.3	0.9375
Elymus elymoides	Barkworth Squirreltail	CHEM STRIP	0.6	1.275	1.875
Elymus elymoides	Barkworth Squirreltail	MECH THIN	0.875	1	0.9375
Elymus elymoides	Barkworth Squirreltail	MECH STRIP	1.025	3.55	2.1875
Elymus smithii	Western Wheatgrass	CONTROL	0	0	0
Elymus smithii	Western Wheatgrass	CHEM THIN	0	0	0
Elymus smithii	Western Wheatgrass	CHEM STRIP	0	0	0
Elymus smithii	Western Wheatgrass	MECH THIN	0.2	0.35	0
Elymus smithii	Western Wheatgrass	MECH STRIP	0	0	0
Elymus trachycaulus	Slender Wheatgrass	CONTROL	0.025	0.025	0
Elymus trachycaulus	Slender Wheatgrass	CHEM THIN	0	0	0
Elymus trachycaulus	Slender Wheatgrass	CHEM STRIP	0.075	0.025	0
Elymus trachycaulus	Slender Wheatgrass	MECH THIN	0.05	0.125	0
Elymus trachycaulus	Slender Wheatgrass	MECH STRIP	0	0	0
Epilobium brachycarpum	Autumn Willowherb	CONTROL	0	0	0
Epilobium brachycarpum	Autumn Willowherb	CHEM THIN	0	0	0
Epilobium brachycarpum	Autumn Willowherb	CHEM STRIP	0	0	0
Epilobium brachycarpum	Autumn Willowherb	MECH THIN	0.025	0.025	0
Epilobium brachycarpum	Autumn Willowherb	MECH STRIP	0	0	0
Erigeron clokeyi	Clokey's Fleabane	CONTROL	0	0	0
Erigeron clokeyi	Clokey's Fleabane	CHEM THIN	0	0	0
Erigeron clokeyi	Clokey's Fleabane	CHEM STRIP	0	0	0
Erigeron clokeyi	Clokey's Fleabane	MECH THIN	0	0	0
Erigeron clokeyi	Clokey's Fleabane	MECH STRIP	0	0	0
Erodium cicutarium	Stork's-bill	CONTROL	0	0	0

Erodium cicutarium	Stork's-bill	CHEM THIN	0	0	0
Erodium cicutarium	Stork's-bill	CHEM STRIP	0.025	0.025	0
Erodium cicutarium	Stork's-bill	MECH THIN	0.075	0.05	0
Erodium cicutarium	Stork's-bill	MECH STRIP	0.05	0.025	0
Gutierrezia sarothrae	Snakeweed	CONTROL	0.075	0.95	0
Gutierrezia sarothrae	Snakeweed	CHEM THIN	0	0	0
Gutierrezia sarothrae	Snakeweed	CHEM STRIP	0	0	0
Gutierrezia sarothrae	Snakeweed	MECH THIN	0.15	0.075	0
Gutierrezia sarothrae	Snakeweed	MECH STRIP	0.1	0.375	0
Helianthus annuus	Sunflower	CONTROL	0	0	0
Helianthus annuus	Sunflower	CHEM THIN	0.05	0.025	0
Helianthus annuus	Sunflower	CHEM STRIP	0.075	0.05	0
Helianthus annuus	Sunflower	MECH THIN	0.225	0.1	0
Helianthus annuus	Sunflower	MECH STRIP	0	0	0
Holosteum umbellatum	Jagged Chickweed	CONTROL	0.15	0.05	0.3125
Holosteum umbellatum	Jagged Chickweed	CHEM THIN	0.5	0.125	0
Holosteum umbellatum	Jagged Chickweed	CHEM STRIP	2.8	3.125	1.5625
Holosteum umbellatum	Jagged Chickweed	MECH THIN	0.075	0.025	0.3125
Holosteum umbellatum	Jagged Chickweed	MECH STRIP	0.225	0.1	0
Lactuca serriola	Prickly Lettuce	CONTROL	0.075	0.05	0
Lactuca serriola	Prickly Lettuce	CHEM THIN	0	0	0
Lactuca serriola	Prickly Lettuce	CHEM STRIP	0.3	0.125	0
Lactuca serriola	Prickly Lettuce	MECH THIN	0.125	0.05	0
Lactuca serriola	Prickly Lettuce	MECH STRIP	0	0	0
Litter		CONTROL	0	0	27.1875
Litter		CHEM THIN	0	0	34.375
Litter		CHEM STRIP	0	0	32.5
Litter		MECH THIN	0	0	32.1875
Litter		MECH STRIP	0	0	27.8125
Lomatium Raf.	Desertparsley	CONTROL	0.775	0.45	0
Lomatium Raf.	Desertparsley	CHEM THIN	0.575	0.325	0
Lomatium Raf.	Desertparsley	CHEM STRIP	0.1	0.05	0
Lomatium Raf.	Desertparsley	MECH THIN	0.675	0.5	0
Lomatium Raf.	Desertparsley	MECH STRIP	0.45	0.275	0.9375
Malvastrum hispidum	Hispid False Mallow	CONTROL	0.075	0.025	0
Malvastrum hispidum	Hispid False Mallow	CHEM THIN	0.175	0.7	0.625
Malvastrum hispidum	Hispid False Mallow	CHEM STRIP	0.15	0.05	0
Malvastrum hispidum	Hispid False Mallow	MECH THIN	0	0	0
Malvastrum hispidum	Hispid False Mallow	MECH STRIP	0	0	0
Orobanche fasciculata	Cluster Cancerroot	CONTROL	0.25	0.1	0
Orobanche fasciculata	Cluster Cancerroot	CHEM THIN	0	0	0
Orobanche fasciculata	Cluster Cancerroot	CHEM STRIP	1.575	0.65	0
Orobanche fasciculata	Cluster Cancerroot	MECH THIN	0.075	0.025	0

Orobanche fasciculata	Cluster Cancerroot	MECH STRIP	0.15	0.05	0
Pascopyrum smithii	Western Wheatgrass	CONTROL	0.2	0.2	0
Pascopyrum smithii	Western Wheatgrass	CHEM THIN	0.225	0.35	0
Pascopyrum smithii	Western Wheatgrass	CHEM STRIP	0.475	0.85	0.3125
Pascopyrum smithii	Western Wheatgrass	MECH THIN	0.075	0.25	0
Pascopyrum smithii	Western Wheatgrass	MECH STRIP	0.1	0.075	0
Phlox longifolia	Longleaf Phlox	CONTROL	0	0	0
Phlox longifolia	Longleaf Phlox	CHEM THIN	0.225	0.125	0.3125
Phlox longifolia	Longleaf Phlox	CHEM STRIP	0	0	0
Phlox longifolia	Longleaf Phlox	MECH THIN	0.125	0.05	0
Phlox longifolia	Longleaf Phlox	MECH STRIP	0.25	0.075	0
Poa Bulbosa	Bulbosa Bluegrass	CONTROL	1.65	7.075	7.5
Poa Bulbosa	Bulbosa Bluegrass	CHEM THIN	1.65	12.6	14.375
Poa Bulbosa	Bulbosa Bluegrass	CHEM STRIP	1.675	10.45	12.8125
Poa Bulbosa	Bulbosa Bluegrass	MECH THIN	1.95	3.8	3.4375
Poa Bulbosa	Bulbosa Bluegrass	MECH STRIP	1.925	13.9	10.625
Poa pratensis	Kentucky Bluegrass	CONTROL	0	0	0
Poa pratensis	Kentucky Bluegrass	CHEM THIN	0.05	0.025	0
Poa pratensis	Kentucky Bluegrass	CHEM STRIP	0	0	0
Poa pratensis	Kentucky Bluegrass	MECH THIN	0	0	0
Poa pratensis	Kentucky Bluegrass	MECH STRIP	0	0	0
Poa Secunda	Sandberg Bluegrass	CONTROL	1.725	4.075	1.25
Poa Secunda	Sandberg Bluegrass	CHEM THIN	1.375	2.925	0.625
Poa Secunda	Sandberg Bluegrass	CHEM STRIP	1.675	3.9	1.5625
Poa Secunda	Sandberg Bluegrass	MECH THIN	0.375	0.5	0
Poa Secunda	Sandberg Bluegrass	MECH STRIP	0.9	0.9	0
Rock		CONTROL	0	0	3.4375
Rock		CHEM THIN	0	0	4.6875
Rock		CHEM STRIP	0	0	3.125
Rock		MECH THIN	0	0	7.1875
Rock		MECH STRIP	0	0	4.875
Soil		CONTROL	0	0	37.1875
Soil		CHEM THIN	0	0	42.375
Soil		CHEM STRIP	0	0	45.3125
Soil		MECH THIN	0	0	42.1875
Soil		MECH STRIP	0	0	45.625
Sphaeralcea	Globemallow	CONTROL	0.125	0.05	0.3125
Sphaeralcea	Globemallow	CHEM THIN	0.025	0.025	0
Sphaeralcea	Globemallow	CHEM STRIP	0	0	0
Sphaeralcea	Globemallow	MECH THIN	0	0	0
Sphaeralcea	Globemallow	MECH STRIP	0.075	0.125	0
Trichostema brachiatum	Fluxweed	CONTROL	0.15	0.125	0
Trichostema brachiatum	Fluxweed	CHEM THIN	0.25	0.075	0

Trichostema brachiatum	Fluxweed	CHEM STRIP	0.2	0.075	0
Trichostema brachiatum	Fluxweed	MECH THIN	0.025	0.025	0
Trichostema brachiatum	Fluxweed	MECH STRIP	0.175	0.075	0.3125
Unknown 1		CONTROL	0.2	0.05	0
Unknown 1		CHEM THIN	3	1.95	3.75
Unknown 1		CHEM STRIP	0	0	0
Unknown 1		MECH THIN	0.1	0.05	0
Unknown 1		MECH STRIP	2.525	1.725	0.625
Unknown 2		CONTROL	0.1	0.05	0
Unknown 2		CHEM THIN	0	0	0
Unknown 2		CHEM STRIP	0	0	0
Unknown 2		MECH THIN	0	0	0
Unknown 2		MECH STRIP	0	0	0
Vicia americana	American Vetch	CONTROL	1.1	0.9	0.3125
Vicia americana	American Vetch	CHEM THIN	1.15	1.775	0
Vicia americana	American Vetch	CHEM STRIP	1.125	0.9	0
Vicia americana	American Vetch	MECH THIN	1.05	0.7	0.625
Vicia americana	American Vetch	MECH STRIP	1.575	1.275	0.3125

TABLE 2. Description of P values for seed weights, kill rate, frequency, cover, basal and sagecover.

Seed Weights				**Seed Weights**		
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	1		CONTROL	MECH THIN	0.265
CONTROL	MECH STRIP	0.035		CONTROL	MECH STRIP	0.042
CONTROL	CHEM THIN	0.957		CONTROL	CHEM THIN	0.998
CONTROL	CHEM STRIP	0.148		CONTROL	CHEM STRIP	0.103
MECH THIN	MECH STRIP	0.037		MECH THIN	MECH STRIP	0.784
MECH THIN	CHEM THIN	0.967		MECH THIN	CHEM THIN	0.174
MECH THIN	CHEM STRIP	0.159		MECH THIN	CHEM STRIP	0.9
MECH STRIP	CHEM THIN	0.109		MECH STRIP	CHEM THIN	0.026
MECH STRIP	CHEM STRIP	0.903		MECH STRIP	CHEM STRIP	0.983
CHEM THIN	CHEM STRIP	0.39		CHEM THIN	CHEM STRIP	0.064
KILL RATE				**KILL RATE**		
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.003		CONTROL	MECH THIN	0.001
CONTROL	MECH STRIP	0.285		CONTROL	MECH STRIP	0.042
CONTROL	CHEM THIN	0.016		CONTROL	CHEM THIN	0.0009
CONTROL	CHEM STRIP	0.097		CONTROL	CHEM STRIP	0.06
MECH THIN	MECH STRIP	0.103		MECH THIN	MECH STRIP	0.286
MECH THIN	CHEM THIN	0.852		MECH THIN	CHEM THIN	0.999
MECH THIN	CHEM STRIP	0.298		MECH THIN	CHEM STRIP	0.213
MECH STRIP	CHEM THIN	0.437		MECH STRIP	CHEM THIN	0.207
MECH STRIP	CHEM STRIP	0.952		MECH STRIP	CHEM STRIP	0.999
CHEM THIN	CHEM STRIP	0.822		CHEM THIN	CHEM STRIP	0.151
Frequency	**Cymopterus**			**Frequency**	**Bottlebrush**	
SAHARA				**SCIPIO**	**Squirreltail**	
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.326		CONTROL	MECH THIN	0.948
CONTROL	MECH STRIP	0.935		CONTROL	MECH STRIP	0.948
CONTROL	CHEM THIN	0.852		CONTROL	CHEM THIN	0.993
CONTROL	CHEM STRIP	0.997		CONTROL	CHEM STRIP	0.838
MECH THIN	MECH STRIP	0.737		MECH THIN	MECH STRIP	0.617
MECH THIN	CHEM THIN	0.07		MECH THIN	CHEM THIN	0.997
MECH THIN	CHEM STRIP	0.211		MECH THIN	CHEM STRIP	0.997
MECH STRIP	CHEM THIN	0.436		MECH STRIP	CHEM THIN	0.788

MECH STRIP	CHEM STRIP	0.817		MECH STRIP	CHEM STRIP	0.444
CHEM THIN	CHEM STRIP	0.955		CHEM THIN	CHEM STRIP	0.969
Frequency	**Cheatgrass**			**Frequency**	**Cheatgrass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.979		CONTROL	MECH THIN	0.96
CONTROL	MECH STRIP	0.979		CONTROL	MECH STRIP	0.997
CONTROL	CHEM THIN	0.447		CONTROL	CHEM THIN	0.504
CONTROL	CHEM STRIP	0.061		CONTROL	CHEM STRIP	0.876
MECH THIN	MECH STRIP	1		MECH THIN	MECH STRIP	0.995
MECH THIN	CHEM THIN	0.76		MECH THIN	CHEM THIN	0.863
MECH THIN	CHEM STRIP	0.153		MECH THIN	CHEM STRIP	0.998
MECH STRIP	CHEM THIN	0.76		MECH STRIP	CHEM THIN	0.678
MECH STRIP	CHEM STRIP	0.153		MECH STRIP	CHEM STRIP	0.996
CHEM THIN	CHEM STRIP	0.683		CHEM THIN	CHEM STRIP	0.953
Frequency	**Crested Wheat-grass**			**Frequency**	**Sandberg Blugrass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.984		CONTROL	MECH THIN	0.784
CONTROL	MECH STRIP	0.755		CONTROL	MECH STRIP	0.999
CONTROL	CHEM THIN	0.66		CONTROL	CHEM THIN	0.006
CONTROL	CHEM STRIP	0.84		CONTROL	CHEM STRIP	0.116
MECH THIN	MECH STRIP	0.956		MECH THIN	MECH STRIP	0.861
MECH THIN	CHEM THIN	0.908		MECH THIN	CHEM THIN	0.044
MECH THIN	CHEM STRIP	0.984		MECH THIN	CHEM STRIP	0.556
MECH STRIP	CHEM THIN	0.999		MECH STRIP	CHEM THIN	0.008
MECH STRIP	CHEM STRIP	0.999		MECH STRIP	CHEM STRIP	0.15
CHEM THIN	CHEM STRIP	0.996		CHEM THIN	CHEM STRIP	0.465
Frequency	**Western Wheat-grass**			**Frequency**	**Bulbous Blue-grass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.253		CONTROL	MECH THIN	1
CONTROL	MECH STRIP	0.937		CONTROL	MECH STRIP	1
CONTROL	CHEM THIN	0.997		CONTROL	CHEM THIN	0.661
CONTROL	CHEM STRIP	0.999		CONTROL	CHEM STRIP	0.725
MECH THIN	MECH STRIP	0.632		MECH THIN	MECH STRIP	1
MECH THIN	CHEM THIN	0.393		MECH THIN	CHEM THIN	0.661
MECH THIN	CHEM STRIP	0.342		MECH THIN	CHEM STRIP	0.725

MECH STRIP	CHEM THIN	0.991		MECH STRIP	CHEM THIN	0.725
MECH STRIP	CHEM STRIP	0.98		MECH STRIP	CHEM STRIP	0.786
CHEM THIN	CHEM STRIP	1		CHEM THIN	CHEM STRIP	1
Frequency	**All plants**			**Frequency**	**All Plants**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.874		CONTROL	MECH THIN	0.716
CONTROL	MECH STRIP	0.84		CONTROL	MECH STRIP	0.889
CONTROL	CHEM THIN	1		CONTROL	CHEM THIN	1
CONTROL	CHEM STRIP	0.875		CONTROL	CHEM STRIP	1
MECH THIN	MECH STRIP	1		MECH THIN	MECH STRIP	0.996
MECH THIN	CHEM THIN	0.857		MECH THIN	CHEM THIN	0.661
MECH THIN	CHEM STRIP	1		MECH THIN	CHEM STRIP	0.702
MECH STRIP	CHEM THIN	0.82		MECH STRIP	CHEM THIN	0.849
MECH STRIP	CHEM STRIP	1		MECH STRIP	CHEM STRIP	0.879
CHEM THIN	CHEM STRIP	0.857		CHEM THIN	CHEM STRIP	1
Frequency	**Pale Madwort**			**Frequency**	**Lomatium**	
SAHARA				**SCIPIO**		
Treatments	Comparison	P Value		Treatments	Comparison	P Value
CONTROL	MECH THIN	0.862		CONTROL	MECH THIN	0.967
CONTROL	MECH STRIP	0.479		CONTROL	MECH STRIP	0.271
CONTROL	CHEM THIN	0.73		CONTROL	CHEM THIN	0.997
CONTROL	CHEM STRIP	0.999		CONTROL	CHEM STRIP	0.84
MECH THIN	MECH STRIP	0.95		MECH THIN	MECH STRIP	0.584
MECH THIN	CHEM THIN	0.998		MECH THIN	CHEM THIN	0.997
MECH THIN	CHEM STRIP	0.778		MECH THIN	CHEM STRIP	0.994
MECH STRIP	CHEM THIN	0.991		MECH STRIP	CHEM THIN	0.411
MECH STRIP	CHEM STRIP	0.387		MECH STRIP	CHEM STRIP	0.802
CHEM THIN	CHEM STRIP	0.63		CHEM THIN	CHEM STRIP	0.95
Cover	**Cymopterus**			**Cover**	**Bottlebrush**	
SAHARA				**SCIPIO**	**Squirreltail**	
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.994		CONTROL	MECH THIN	0.995
CONTROL	MECH STRIP	0.994		CONTROL	MECH STRIP	0.996
CONTROL	CHEM THIN	0.176		CONTROL	CHEM THIN	0.98
CONTROL	CHEM STRIP	0.875		CONTROL	CHEM STRIP	0.726
MECH THIN	MECH STRIP	1		MECH THIN	MECH STRIP	0.947
MECH THIN	CHEM THIN	0.094		MECH THIN	CHEM THIN	0.886
MECH THIN	CHEM STRIP	0.677		MECH THIN	CHEM STRIP	0.889

MECH STRIP	CHEM THIN	0.094		MECH STRIP	CHEM THIN	0.999
MECH STRIP	CHEM STRIP	0.677		MECH STRIP	CHEM STRIP	0.525
CHEM THIN	CHEM STRIP	0.596		CHEM THIN	CHEM STRIP	0.421
Cover	**Cheatgrass**			**Cover**	**Cheatgrass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.566		CONTROL	MECH THIN	0.999
CONTROL	MECH STRIP	0.972		CONTROL	MECH STRIP	0.999
CONTROL	CHEM THIN	0.098		CONTROL	CHEM THIN	0.977
CONTROL	CHEM STRIP	0.096		CONTROL	CHEM STRIP	0.971
MECH THIN	MECH STRIP	0.88		MECH THIN	MECH STRIP	1
MECH THIN	CHEM THIN	0.72		MECH THIN	CHEM THIN	0.993
MECH THIN	CHEM STRIP	0.712		MECH THIN	CHEM STRIP	0.99
MECH STRIP	CHEM THIN	0.249		MECH STRIP	CHEM THIN	0.996
MECH STRIP	CHEM STRIP	0.243		MECH STRIP	CHEM STRIP	0.994
CHEM THIN	CHEM STRIP	1		CHEM THIN	CHEM STRIP	1
Cover	**Crested Wheat-grass**			**Cover**	**Sandberg blue-grass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.992		CONTROL	MECH THIN	0.0902
CONTROL	MECH STRIP	0.78		CONTROL	MECH STRIP	0.999
CONTROL	CHEM THIN	0.703		CONTROL	CHEM THIN	0.111
CONTROL	CHEM STRIP	0.849		CONTROL	CHEM STRIP	0.18
MECH THIN	MECH STRIP	0.948		MECH THIN	MECH STRIP	0.943
MECH THIN	CHEM THIN	0.906		MECH THIN	CHEM THIN	0.399
MECH THIN	CHEM STRIP	0.976		MECH THIN	CHEM STRIP	0.563
MECH STRIP	CHEM THIN	0.999		MECH STRIP	CHEM THIN	0.138
MECH STRIP	CHEM STRIP	0.999		MECH STRIP	CHEM STRIP	0.22
CHEM THIN	CHEM STRIP	0.998		CHEM THIN	CHEM STRIP	0.997
Cover	**Western Wheat-grass**			**Cover**	**Bulbous blue-grass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.503		CONTROL	MECH THIN	0.884
CONTROL	MECH STRIP	0.807		CONTROL	MECH STRIP	0.978
CONTROL	CHEM THIN	0.962		CONTROL	CHEM THIN	0.98
CONTROL	CHEM STRIP	1		CONTROL	CHEM STRIP	0.785
MECH THIN	MECH STRIP	0.98		MECH THIN	MECH STRIP	0.996
MECH THIN	CHEM THIN	0.858		MECH THIN	CHEM THIN	0.602

MECH THIN	CHEM STRIP	0.565		MECH THIN	CHEM STRIP	0.999
MECH STRIP	CHEM THIN	0.991		MECH STRIP	CHEM THIN	0.8
MECH STRIP	CHEM STRIP	0.858		MECH STRIP	CHEM STRIP	0.976
CHEM THIN	CHEM STRIP	0.98		CHEM THIN	CHEM STRIP	0.48
Cover	**All Plant**			**Cover**	**All Plant**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.871		CONTROL	MECH THIN	0.122
CONTROL	MECH STRIP	0.616		CONTROL	MECH STRIP	0.025
CONTROL	CHEM THIN	1		CONTROL	CHEM THIN	0.33
CONTROL	CHEM STRIP	0.997		CONTROL	CHEM STRIP	0.043
MECH THIN	MECH STRIP	0.986		MECH THIN	MECH STRIP	0.879
MECH THIN	CHEM THIN	0.867		MECH THIN	CHEM THIN	0.933
MECH THIN	CHEM STRIP	0.969		MECH THIN	CHEM STRIP	0.967
MECH STRIP	CHEM THIN	0.61		MECH STRIP	CHEM THIN	0.999
MECH STRIP	CHEM STRIP	0.799		MECH STRIP	CHEM STRIP	0.997
CHEM THIN	CHEM STRIP	0.996		CHEM THIN	CHEM STRIP	0.999
Cover	**Pale Madwort**			**Cover**	**Lomatium**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.951		CONTROL	MECH THIN	0.977
CONTROL	MECH STRIP	0.999		CONTROL	MECH STRIP	0.412
CONTROL	CHEM THIN	0.773		CONTROL	CHEM THIN	0.999
CONTROL	CHEM STRIP	0.555		CONTROL	CHEM STRIP	0.928
MECH THIN	MECH STRIP	0.882		MECH THIN	MECH STRIP	0.728
MECH THIN	CHEM THIN	0.99		MECH THIN	CHEM THIN	0.928
MECH THIN	CHEM STRIP	0.913		MECH THIN	CHEM STRIP	0.999
MECH STRIP	CHEM THIN	0.652		MECH STRIP	CHEM THIN	0.307
MECH STRIP	CHEM STRIP	0.435		MECH STRIP	CHEM STRIP	0.842
CHEM THIN	CHEM STRIP	0.994		CHEM THIN	CHEM STRIP	0.842
Basal Cover	Cymoptera			Basal Cover	Bottlebrush	
SAHARA				SCIPIO	Squirreltail	
Treatments	Comparison	P Value		Treatments	Comparison	P Value
CONTROL	MECH THIN	0.876		CONTROL	MECH THIN	1
CONTROL	MECH STRIP	0.876		CONTROL	MECH STRIP	0.999
CONTROL	CHEM THIN	1		CONTROL	CHEM THIN	0.482
CONTROL	CHEM STRIP	1		CONTROL	CHEM STRIP	0.998
MECH THIN	MECH STRIP	1		MECH THIN	MECH STRIP	0.999
MECH THIN	CHEM THIN	0.876		MECH THIN	CHEM THIN	0.51
MECH THIN	CHEM STRIP	0.876		MECH THIN	CHEM STRIP	0.999

MECH STRIP	CHEM THIN	0.876		MECH STRIP	CHEM THIN	0.597
MECH STRIP	CHEM STRIP	0.876		MECH STRIP	CHEM STRIP	1
CHEM THIN	CHEM STRIP	1		CHEM THIN	CHEM STRIP	0.626
Basal Cover	**Cheatgrass**			**Basal Cover**	**Cheatgrass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.734		CONTROL	MECH THIN	1
CONTROL	MECH STRIP	0.942		CONTROL	MECH STRIP	0.999
CONTROL	CHEM THIN	0.856		CONTROL	CHEM THIN	0.883
CONTROL	CHEM STRIP	0.593		CONTROL	CHEM STRIP	0.617
MECH THIN	MECH STRIP	0.986		MECH THIN	MECH STRIP	1
MECH THIN	CHEM THIN	0.999		MECH THIN	CHEM THIN	0.834
MECH THIN	CHEM STRIP	0.999		MECH THIN	CHEM STRIP	0.551
MECH STRIP	CHEM THIN	0.999		MECH STRIP	CHEM THIN	0.778
MECH STRIP	CHEM STRIP	0.942		MECH STRIP	CHEM STRIP	0.487
CHEM THIN	CHEM STRIP	0.986		CHEM THIN	CHEM STRIP	0.983
Basal Cover	**Crested Wheat-grass**			**Basal Cover**	**Bulbous blue-grass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.534		CONTROL	MECH THIN	0.497
CONTROL	MECH STRIP	0.534		CONTROL	MECH STRIP	0.711
CONTROL	CHEM THIN	0.534		CONTROL	CHEM THIN	0.862
CONTROL	CHEM STRIP	0.534		CONTROL	CHEM STRIP	0.94
MECH THIN	MECH STRIP	1		MECH THIN	MECH STRIP	0.995
MECH THIN	CHEM THIN	1		MECH THIN	CHEM THIN	0.127
MECH THIN	CHEM STRIP	1		MECH THIN	CHEM STRIP	0.892
MECH STRIP	CHEM THIN	1		MECH STRIP	CHEM THIN	0.227
MECH STRIP	CHEM STRIP	1		MECH STRIP	CHEM STRIP	0.983
CHEM THIN	CHEM STRIP	1		CHEM THIN	CHEM STRIP	0.457
Basal Cover	**Western Wheat-grass**			**Basal Cover**	**Lomatium**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.928		CONTROL	MECH THIN	1
CONTROL	MECH STRIP	0.534		CONTROL	MECH STRIP	1
CONTROL	CHEM THIN	1		CONTROL	CHEM THIN	1
CONTROL	CHEM STRIP	1		CONTROL	CHEM STRIP	0.16
MECH THIN	MECH STRIP	0.928		MECH THIN	MECH STRIP	1
MECH THIN	CHEM THIN	0.928		MECH THIN	CHEM THIN	1

MECH THIN	CHEM STRIP	0.928		MECH THIN	CHEM STRIP	0.16
MECH STRIP	CHEM THIN	0.534		MECH STRIP	CHEM THIN	1
MECH STRIP	CHEM STRIP	0.534		MECH STRIP	CHEM STRIP	0.16
CHEM THIN	CHEM STRIP	1		CHEM THIN	CHEM STRIP	0.16
Basal Cover	**All Plant**			**Basal Cover**	**All Plant**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.907		CONTROL	MECH THIN	1
CONTROL	MECH STRIP	0.851		CONTROL	MECH STRIP	0.961
CONTROL	CHEM THIN	1		CONTROL	CHEM THIN	0.988
CONTROL	CHEM STRIP	0.999		CONTROL	CHEM STRIP	0.939
MECH THIN	MECH STRIP	0.999		MECH THIN	MECH STRIP	0.951
MECH THIN	CHEM THIN	0.907		MECH THIN	CHEM THIN	0.992
MECH THIN	CHEM STRIP	0.949		MECH THIN	CHEM STRIP	0.925
MECH STRIP	CHEM THIN	0.851		MECH STRIP	CHEM THIN	0.789
MECH STRIP	CHEM STRIP	0.907		MECH STRIP	CHEM STRIP	1
CHEM THIN	CHEM STRIP	0.999		CHEM THIN	CHEM STRIP	0.739
Basal Cover	**Pale Madwort**			**Basal Cover**	**Sandberg blue-grass**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	1		CONTROL	MECH THIN	0.917
CONTROL	MECH STRIP	1		CONTROL	MECH STRIP	0.993
CONTROL	CHEM THIN	0.441		CONTROL	CHEM THIN	0.495
CONTROL	CHEM STRIP	0.768		CONTROL	CHEM STRIP	0.495
MECH THIN	MECH STRIP	1		MECH THIN	MECH STRIP	0.73
MECH THIN	CHEM THIN	0.441		MECH THIN	CHEM THIN	0.917
MECH THIN	CHEM STRIP	0.768		MECH THIN	CHEM STRIP	0.917
MECH STRIP	CHEM THIN	0.441		MECH STRIP	CHEM THIN	0.295
MECH STRIP	CHEM STRIP	0.768		MECH STRIP	CHEM STRIP	0.295
CHEM THIN	CHEM STRIP	0.975		CHEM THIN	CHEM STRIP	1
Basal Cover	**Soil**			**Basal Cover**	**Soil**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.98		CONTROL	MECH THIN	0.887
CONTROL	MECH STRIP	0.997		CONTROL	MECH STRIP	0.837
CONTROL	CHEM THIN	1		CONTROL	CHEM THIN	0.819
CONTROL	CHEM STRIP	0.999		CONTROL	CHEM STRIP	0.996
MECH THIN	MECH STRIP	0.907		MECH THIN	MECH STRIP	0.999
MECH THIN	CHEM THIN	0.99		MECH THIN	CHEM THIN	0.999

MECH THIN	CHEM STRIP	0.929		MECH THIN	CHEM STRIP	0.998
MECH STRIP	CHEM THIN	0.993		MECH STRIP	CHEM THIN	1
MECH STRIP	CHEM STRIP	1		MECH STRIP	CHEM STRIP	0.994
CHEM THIN	CHEM STRIP	0.996		CHEM THIN	CHEM STRIP	0.991
Basal Cover	**Rock**			**Basal Cover**	**Rock**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.645		CONTROL	MECH THIN	1
CONTROL	MECH STRIP	0.587		CONTROL	MECH STRIP	0.81
CONTROL	CHEM THIN	0.853		CONTROL	CHEM THIN	0.946
CONTROL	CHEM STRIP	0.986		CONTROL	CHEM STRIP	0.764
MECH THIN	MECH STRIP	1		MECH THIN	MECH STRIP	0.852
MECH THIN	CHEM THIN	0.994		MECH THIN	CHEM THIN	0.966
MECH THIN	CHEM STRIP	0.894		MECH THIN	CHEM STRIP	0.81
MECH STRIP	CHEM THIN	0.986		MECH STRIP	CHEM THIN	0.995
MECH STRIP	CHEM STRIP	0.853		MECH STRIP	CHEM STRIP	1
CHEM THIN	CHEM STRIP	0.986		CHEM THIN	CHEM STRIP	0.99
Basal Cover	**Litter**			**Basal Cover**	**Litter**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	1		CONTROL	MECH THIN	0.99
CONTROL	MECH STRIP	0.981		CONTROL	MECH STRIP	0.984
CONTROL	CHEM THIN	0.448		CONTROL	CHEM THIN	0.999
CONTROL	CHEM STRIP	0.242		CONTROL	CHEM STRIP	1
MECH THIN	MECH STRIP	0.992		MECH THIN	MECH STRIP	1
MECH THIN	CHEM THIN	0.389		MECH THIN	CHEM THIN	0.958
MECH THIN	CHEM STRIP	0.204		MECH THIN	CHEM STRIP	0.987
MECH STRIP	CHEM THIN	0.216		MECH STRIP	CHEM THIN	0.943
MECH STRIP	CHEM STRIP	0.104		MECH STRIP	CHEM STRIP	0.98
CHEM THIN	CHEM STRIP	0.989		CHEM THIN	CHEM STRIP	0.999
Basal Cover	**Cryptogamic**			**Basal Cover**	**Cryptogamic**	
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	1		CONTROL	MECH THIN	0.356
CONTROL	MECH STRIP	0.996		CONTROL	MECH STRIP	0.866
CONTROL	CHEM THIN	0.382		CONTROL	CHEM THIN	0.011
CONTROL	CHEM STRIP	0.162		CONTROL	CHEM STRIP	0.31
MECH THIN	MECH STRIP	0.998		MECH THIN	MECH STRIP	0.866
MECH THIN	CHEM THIN	0.417		MECH THIN	CHEM THIN	0.274

MECH THIN	CHEM STRIP	0.181		MECH THIN	CHEM STRIP	0.558
MECH STRIP	CHEM THIN	0.571		MECH STRIP	CHEM THIN	0.06
MECH STRIP	CHEM STRIP	0.274		MECH STRIP	CHEM STRIP	0.154
CHEM THIN	CHEM STRIP	0.972		CHEM THIN	CHEM STRIP	0.976
Sage Cover				**Sage Cover**		
SAHARA				**SCIPIO**		
Treatments	**Comparison**	**P Value**		**Treatments**	**Comparison**	**P Value**
CONTROL	MECH THIN	0.047		CONTROL	MECH THIN	0.002
CONTROL	MECH STRIP	0.099		CONTROL	MECH STRIP	0
CONTROL	CHEM THIN	0.14		CONTROL	CHEM THIN	0.001
CONTROL	CHEM STRIP	0.02		CONTROL	CHEM STRIP	0.0008
MECH THIN	MECH STRIP	0.99		MECH THIN	MECH STRIP	0.8
MECH THIN	CHEM THIN	0.961		MECH THIN	CHEM THIN	0.99
MECH THIN	CHEM STRIP	0.987		MECH THIN	CHEM STRIP	0.946
MECH STRIP	CHEM THIN	0.999		MECH STRIP	CHEM THIN	0.892
MECH STRIP	CHEM STRIP	0.879		MECH STRIP	CHEM STRIP	0.994
CHEM THIN	CHEM STRIP	0.779		CHEM THIN	CHEM STRIP	0.983