AN ABSTRACT OF THE THESIS OF

Mark G. Estes for the degree of Master of Science in Rangeland Ecology and

Management and Animal Sciences presented on May 7, 2008.

Title: Nutritional Characteristics of Dormant Season Grazing Within a Winterfat

(*Krascheninnikovia lanata* (Gueldenstaedt)) Dominated Plant Community, and the Effect

of Seedbed Preparation on the Emergence and Survival of Winterfat and Squirreltail

(*Elymus elymoides* (Raf.) Swezey) Seedlings.

Abstract approved:

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The effect of seedbed preparation on the emergence and survival of winterfat

(*Krascheninnikovia lanata* (Gueldenstaedt)) and squirreltail (*Elymus elymoides* (Raf.)

Swezey)) seedlings was determined, while quantifying nutritional changes through the

dormant season for four range species. In November of 2004 twenty 9m x 8m plots were

randomly prepared with one of four treatments (rip, harrow, till, or control) for both

winterfat and squirreltail. Seed was hand broadcasted and chain harrowed to complete

the seeding. Seedling counts were taken in June, July, August, and September 2005, and

again in June of 2006. Mature perennial species, annual frequency, and soil moisture

were also monitored in each plot. Concurrently, forage samples of winterfat, squirreltail,

creeping wildrye (*Leymus triticoides* (Buckl.)*,* and Nuttall's saltbush (*Atriplex nuttallii*

(S. Wats.)) were collected for the months of November through April. Above ground biomass and fecal samples were also collected.

Winterfat seedling emergence and survival was highest in the tilled treatments. Tilling treatments had the highest amount of soil moisture and reduced mature perennials and annual frequency better than the ripping, tilling, and control treatments.

Squirreltail seedling emergence and survival did not differ between the treatments. However, surface roughness not provided by the tilled treatment may play a large role in capturing and providing microsite conditions necessary for natural recruitment.

Analysis of the forage sampling showed crude protein to be the limiting factor for cattle to maintain fat reserves during the dormant season grazing period. This was supported by the microhistological analysis of the fecal collections that revealed 50% of the animal's diet consisted of shrubby species, which were higher in crude protein than the grasses sampled.

The results of this study demonstrated the importance of winterfat to cattle grazing dormant winter range, and the surprising potential to use both it and squirreltail in range rehabilitation efforts. The study also revealed that cattle grazing the current plant community could maintain body condition given managed properly.

Nutritional Characteristics of Dormant Season Grazing Within a Winterfat
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of Seedbed Preparation on the Emergence and Survival of Winterfat and Squirreltail
(*Elymus elymoides* (Raf.) Swezey) Seedlings

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented May 7, 2008

Commencement June 2009

Master of Science thesis of Mark G. Estes presented on May 7, 2008.

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ACKNOWLEDGEMENTS

CONTRIBUTION OF AUTHORS

Dr. James Males was involved with the project design, analysis of data, and interpretation of results. Dr. David Bohnert was involved with the project design, data collection, and analysis of data. Dr. William Krueger was involved with project design, collection of data, data analysis, and interpretation of results. Dr. Tamzen Stringham was involved with project design, collection of data, data analysis, and interpretation of results.

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CHAPTER 1

INTRODUCTION

Livestock producers within the northern Great Basin historically have used native plant communities as a winter forage source to reduce winter feeding costs. However, this resource can be negatively affected with long-term continuous grazing. Desirable plant communities in some regions have changed in species proportion and composition because of an increase in annual weeds and other invasive species. These changes are cause for concern because of the loss of mature, native plants and the lack of recruitment into plant communities commonly used by wildlife and livestock during the winter months.

Winterfat Ecology and Nutritional Value

Winterfat, also known as Whitesage, [*Krascheninnikovia lanata* (Gueldenstaedt) syn. *Certoides lanata* (Pursh) J.T. Howell, syn. *Eurotia lanata* (Pursh) Moq.] is dicotyledonous (Hilton 1941) and belongs to the Chenopodiaceae family (Booth 1992).

This long-lived perennial (>120 yrs) (Clarke and Tisdale 1945) can be found throughout

much of the western United States and parts of Canada (Woodmansee and Potter 1971).

The half-shrub grows most frequently in the foothills, plains, and valleys (Woodmansee

and Potter 1971) in areas that range from 10.16 centimeters (4 inches) of annual

precipitation to 101.6 centimeters (40 inches) of annual precipitation (Stevens et al.

1977). Winterfat is common in areas that reach elevations of 2,438.4 meters (8,000 feet),

and less frequently to 3,048 meters (10,000 feet) (Woodmansee and Potter 1971). It is

adapted to many different soil types and textures, but prefers soils that have a slightly

alkali to neutral pH (Stevens et al. 1977). Winterfat's extensive fibrous root system (57

inches/144.78 centimeters below the surface) and deep penetrating taproot (up to 25

feet/7.62 meters below the surface) allow it to grow in harsh environments (Stevens et al.

1977). Its root biomass is more than three times the above ground biomass (Caldwell and

Camp 1974). Winterfat is a diaspore (Booth 1988) and can be monoecious or dioecious

(Riedl et al. 1964). Seed production varies from year to year and with climate. It

typically flowers in the spring/summer (May-August), and the fruit ripens from

September to November with dispersal in late fall and winter (Stevens et al. 1977).

Winterfat is highly palatable, nutritious, and drought tolerant (Hodgkinson 1975).

Smoliak and Bezeau (1967) found that during the leaf period of winterfat's growth stage

crude protein was 23.13 %, with 3.96% digestible protein, and 26.3% cellulose.

However, during the winter months as reported by Cook and Harris (1968) winterfat's

crude protein remained around 9%. Consequently, it is of great importance to western

rangelands (Dayton 1931) especially during the dormant season when nutrient quality of

standing grass is low (Hodgkinson 1975). Overgrazing during the growing season has

decreased or eliminated winterfat stands in areas where it was once extensive (Stevens et al. 1977). The recognized nutritional benefit of winterfat in overall forage production of rangelands has led to extensive research in the areas of seed anatomy and germination along with development of reestablishment techniques.

Winterfat seed/fruit anatomy and germination requirements can impact seeding methods. Germination and seedling survival of winterfat varies depending on mother-plant transpiration (Booth 1990), whether seed or fruit is planted, the age and size of the seed (Booth and Schuman 1983, Springfield 1973), how the seed is stored after harvest (Springfield 1968), and environmental conditions such as imbition temperature (Booth and McDonald 1994).

A study by Booth (1990) found mother-plant stress and nutrition affected germination and seedling vigor. Seed collected and planted from mother-plants that closed their stomata after seed set showed decreased vigor. Transpiration was the most important factor in seed production. When transpiration did not occur, diaspores did not receive the needed cations from the mother-plant and reduced seedling vigor resulted. This suggested that in years of reduced precipitation and prevalent wind, seed would not be as viable. Bonham et al. (1990) found that when winterfat plants grew in association with two different wheatgrasses transpiration rates of winterfat were decreased when compared to transpiration rates of winterfat growing next to winterfat. This study and Booth (1990) suggest that when moisture is limiting, winterfat seed from a pure stand is healthier than seed produced by winterfat plants associated with other species.

"The winterfat diaspore consists of 2 connate bracts enclosing a pubescent utricle (Booth 1988). White hairs cover the bracts, and the seed is flat. It has a thin testa and a

well developed peripheral-linear embryo lying obovoid around the perisperm" (Booth and McDonald 1994 p. 485). The bracts of the winterfat seed serve many important functions. Bracts aid in wind dispersal (Hilton 1941, Stevens et al. 1977), protect the seed, reduce precocious germination (Stevens et al. 1977), and act as nutrient reserves (Booth and McDonald 1994). In a study comparing threshed seed versus whole fruits, Booth and Schuman (1983) found that the bracts of the fruit helped anchor it to the soil and influenced geotropic response by the radicle. They also discovered that radicle growth of winterfat fruits was twice that of threshed seeds. Therefore, Booth and Schuman (1983) suggested that seeding results would be improved if winterfat fruits were planted rather than threshed seeds. The success of fruits over threshed seeds is partly explained by the morphology of the seed. Booth (1984) stated that using a hammer mill to thresh seed caused damage to the radicle apex of germinants. This damage resulted in 25% of the seeds having reduced geotropism. Consequently, Booth (1988) suggested that whole fruits be used in most revegetation studies.

The age of winterfat seeds should also be considered when selecting material for seeding. Hilton (1941) found that fresh seeds germinated better than stored seeds. Seeds stored for 2 to 3 years had a sharp decline in germination rates, and seeds stored for 4 to 5 years did not germinate, but the storage environment for this study was not defined. Booth et al. (1999) found that seed mitochondria and other organelles deteriorated with time even when stored at 5°C. Booth and Schuman (1983) found that fresh seeds were not as sensitive as aged seeds to imbition temperatures when measured by seedling vigor. If stored seed must be used Springfield (1968) found that cold storage of winterfat seeds prolonged viability.

Springfield (1973) suggested that larger seeds had a higher germination rate. This was supported by the findings of Hou and Romo (1998) who found that heavier seeds had the greatest rate of germination, and resulted in larger seedlings. The use of larger seeds might allow seeding rates to be reduced. However, when preparing to seed winterfat it might not be conducive to sort seed by size when seed is purchased from a commercial source.

Germination of winterfat is greatly influenced by environmental conditions. This was expressed by differences in seedling vigor, and ultimately seeding success (Booth and McDonald 1994). Winterfat seeds are able to germinate at a variety of temperatures; including 0°C (Dettori et al. 1984). Numerous research studies have investigated the temperature imbition of seeds and the relationship to increased seedling vigor. Bai et al. (1998) suggested that depending on seed source, winterfat seeds are going to have imbition temperatures that are adapted to the environment in which they originated. Booth and McDonald's (1994) research showed seeds imbibed at 25°C had faster hydration rates than seeds imbibed at 4°C, but the warmer imbibed seeds had a reduction in seedling vigor. It was hypothesized that this was due to membrane damage because of the increased imbition rate, but imbition rate was not found to be the cause for membrane damage. Why seeds that are imbibed at cold temperatures produce seedlings with higher vigor is not well understood. Booth et al. (1999) recommended seeds be imbibed at 0-5°C. Imbition at this temperature did not harm the seed and seed-vigor potential was protected. This was partially explained by Booth (1992) who stated that cold imbition helped retain stored carbohydrates for seedling growth. A seeding time such as late fall, winter, or early spring that would allow for cold imbition would have the greatest chance

of success (Booth 1992). Hou and Romo (1997) recommended a late fall/winter seeding

because smaller seedlings survive freezing temperatures better, and would allow

maximum seedling growth during the spring growing season. Other environmental

considerations are the exposure of seeds to light. Hilton (1941) found that light was not

critical to seed germination, but did find environmental conditions such as salt content of

the imbition water did affect germination. Hilton (1941) suggested winterfat seeds would

germinate best when imbition moisture contains 0.5 to 1% salt.

The method used to seed winterfat was also found to impact seeding success.

Booth and Schuman (1983) found that broadcasting diaspores was more successful than

other methods of seeding. They also recommended broadcasting onto a rough seedbed to

help catch and hold seed. The same study showed that a seeding depth of ¼ in.(0.635

cm) or less was best. Research done by Springfield (1971) supported this shallow

seeding depth, but had better results at $1/16^{th}$ of an inch (0. 41 cm). Romo (2004) had

success seeding winterfat at a rate of 20 diaspores per square meter using a late autumn

seeding date, for it allowed seeds time to after-ripen. This supported research by

Springfield (1972) who found it takes 10-25 weeks for winterfat seeds to after-ripen

when stored at 2°C, 7°C, and at room temperature. Romo (2004) also found that

seedbeds that were tilled or treated with glyphosate reduced the resource uptake of

established vegetation, therefore, leaving more available resources for the winterfat

seedlings. Seedbeds were also prepared on sites where winterfat was known to grow

naturally. In the same study by Romo (2004), it was found that light to moderate litter on

seedbeds moderated temperature and moisture extremes for the seedlings. Hou and

Romo (1997) also found that litter could protect seeds from freezing. Seedbeds that

protected seedlings from prolonged dessication also have increased success. Winterfat can withstand some drying and rehydrating, but prolonged periods of desiccation are not favorable. The litter would also increase humidity, which was found to have a positive effect on seeding success (Hou et al. 1999).

Minimizing competition from other species also positively affected seedling establishment. Bonham and Mack (1990) suggested if a multiple species seed mix was used, species selection should consider overlap in rooting characteristics. This would help minimize competition between species for moisture. *Bromus tectorum* had a negative impact on winterfat density (Freeman and Emleu 1995), which suggested introduced annuals might greatly impact seeding results.

With public land managers often limited to the use of native species in rangeland rehabilitation projects, winterfat offers many nutritional attributes that make it a desirable plant from both a wildlife and livestock perspective. Winterfat's leaves, stems, and stalks are highly palatable year long, but are preferred during periods of active growth. The plant maintains a high level of carbohydrates throughout the year thus suggesting it could serve as a good source of energy within the diet of rangeland animals. Winterfat was also found to be highly tolerant to grazing (Stevens et al. 1977). However, Stevens et al. (1977) and Cook and Stoddart (1963) suggested that winter grazing had the least amount of impact on the plant and helped to maintain plant vigor. The grazing time suggested for winterfat is inversely correlated to the plants crude protein levels. Crude protein (CP) is highest in the spring (Stevens et al. 1977), but this was found to be the most detrimental time to graze (Cook and Stoddart 1963). Riedl et al. (1964) took weekly samples of winterfat from August 8th to October 26th in Laramie WY. During this sampling period

winterfat crude protein was the highest on August 15th at 17.08% and the lowest on

October 14th at 8.08%. The highest crude fiber (CF) measurement came on October 21[rst]

at 36.72% and the lowest crude fiber measurement occurred on September 19th at

29.62%. Smoliak and Bezeau (1967) found that during the leaf period of winterfat's

growth stage crude protein was 23.13%, with 3.96% digestible protein, and 26.3%

cellulose. During the flowering or heading stage of growth, winterfat had 18.5% crude

protein, 4.40% digestible protein, and 26.6% cellulose. During seed ripening stage crude

protein was 12.07%, while digestible protein was 4.32%, and cellulose was 32.6%. The

researchers used the percent of protein and the coefficient of digestibility of cellulose to

determine digestible protein under the assumption that the digestibility of cellulose is

indicative of the digestibility of protein. This could be an explanation of why digestible

protein numbers from this study are so low. Cook and Harris (1968) reported that during

the winter grazing season in Utah (October 1[rst] to March 15th) winterfat was 3.4% ether

extract, 9.1% total protein, 13.3% ash, 11.7% lignin, 27.7% cellulose, and had a gross

energy of 1808 kcal/lb. Winterfat appeared to lose crude protein as it matured while it

gained in crude fiber (Riedl et al. 1964). However, during the winter months as reported

by Cook and Harris (1968) winterfat's crude protein remained around 9%. They also

reported that digestible protein was 4.8% and metabolizable energy was 635 Kcal/lb.

Bottlebrush Squirreltail Ecology and Nutritional Quality

Bottlebrush Squirreltail or squirreltail [*Elymus elymoides* (Raf.) Swezey syn.

Sitanion hystrix (Nutt.) J.G. Smith] is a cool-season, native perennial grass (Arredondo et

al. 1998) often found growing in association with winterfat in the northern Great Basin.

Squirreltail is distributed throughout many geographical locations and found in a variety of environments in the western United States (Clary 1975). Squirreltail is an early to mid-seral species (Hardegree et al. 2002), but depending on the site may also be a climax species. Young and Miller (1985) supported this finding suggesting it can be successional or climax depending on genotype and potential for the site. Its ecological characteristics, such as the ability to increase with disturbance, and produce abundant viable seeds that are highly germinable, have made it well suited for rehabilitating disturbed sites (Young and Evans 1977). Squirreltail's ability to self-pollinate and tolerate competition helps it colonize sites. Its ability to self-pollinate also allows it to propagate even when the stand is small (Arredondo et al. 1998). Squirreltail has been extensively researched for its potential to invade sites dominated by weedy annuals (Arredondo et al. 1998, Hironaka and Sindelar 1973, 1975). Squirreltail is not the most desirable forage species (Young and Evans 1977), but because of its competitive ability proves promising for rehabilitation efforts. Hironaka and Sindelar (1973) suggested it might be the first perennial grass of importance in reestablishing perennials.

Squirreltail seed was found to germinate over a wide range of temperatures when adequate moisture was available. However, if moisture is limiting, the range of germination temperatures narrows (Young and Evans 1977). Young and Evans (1977) found that optimum germination environment in a lab setting occurred with cold periods ranging in temperature from 5-20°C alternating with warm periods with a range of temperature between 10-35°C. They found that squirreltail would not germinate below -6°C however, at -4°C some germination still occurred. On average, germination was the fastest at 20°C.

Young and Evans (1977) reported that fresh seeds germinated as well as seeds stored for 3 months. This suggests that squirreltail had no after-ripening requirement. In contrast, Allen et al. (1995) reported increased germination rates when seeds were allowed to after-ripen for 14 weeks at room temperature. Beckstead et al. (1995) found a 4-month after-ripening period in dry storage for squirreltail. As with winterfat, a late fall seeding may be appropriate to allow seeds time to after-ripen while conditions for germination are not favorable.

Numerous research studies have investigated the possibility of increasing germination by priming seeds prior to planting. A study by Hardegree (1994 a) found that matric priming between 10 and 25°C of squirreltail seed and other native perennial grasses increased low temperature germination rates. The author expressed concern for the use of priming on large seedlots, such as would be involved in a range seeding. Hardegree (1994 b) found that seeds that were primed, allowed to dry, and stored still had faster germination rates than unprimed seeds. The study showed that freshly primed seeds had superior germination rates to stored primed seeds, but stored primed seeds out performed unprimed seeds. Hardegree and Van Vactor (2000) found that priming increased total emergence in the field, but was dependent upon seedlot, planting date, and soil type. Priming in this study appeared to have the best results in earlier and cooler planting dates. This suggested that seed priming might be inappropriate unless seed can be planted early in the spring to take advantage of the priming effect. Pierson and Wight (1991) expressed concern with priming because of the variability in seedbed microclimate. This would make it difficult to know what response priming would have in a range seeding application. Hardegree et al. (2002) suggested that priming in the lab

might only be a representation of the maximum performance of primed versus unprimed seeds. They suggested that seeds should be expected to vary with collection, processing, and storage. This supports Jones (1998) who suggested that because of the large amount of variation in heading time, seed production, and other reproductive factors, it was highly important to match plant material to the rehabilitation site factors of elevation, precipitation, and soil texture.

A study by Arredondo et al. (1998) examined the competitive ability of different cultivars of squirreltail with annual weeds. The study found that certain varieties such as Sand Hollow© had a higher specific leaf area that allowed it to compete with annual weeds, whereas, the cultivar Red Deer River© had a higher specific root length that allowed it to compete for soil moisture. If a germplasm could be developed that incorporated both leaf area and root length it should be even more competitive. It is important that the cultivar selected for a seeding project matches the characteristics of the site being seeded.

There is little published information on seeding methods for squirreltail. Wood et al. (1992) examined the influence of crusting soil on seedling emergence and plant establishment. They found that plowing 10-15 cm deep to prepare a seedbed actually caused crusting, and decreased seedling emergence. However, the number of plants that were established increased with plowing. The study reported some success with broadcasting seed and using simulated trampling to bury the seed. This study was done in mid-October. The authors suggested the plowing treatment was successful because the decreased emergence of seedlings was out weighed by the increased number of plants established and because plowing had other beneficial affects on the soil. Plowing

decreased the amount of competition, improved tilth by incorporating organic matter, created microtopography to catch and store water that increases soil moisture, and increased porosity and aeration. Young and Evans (1977) found that squirreltail seed that was barely buried germinated and emerged better than seed left on the surface. However, seed buried deeper than 6cm did not emerge, and seeds that were planted in loam soils emerged better than seeds planted in clay. They also found that the long awns of the squirreltail seed could be removed without hindering germination as long as the embryo end of the seed was not damaged. Hironaka and Sindelar (1973) reported some success at broadcast seeding squirreltail into medusahead (*Taeniatherum asperum*) infested ranges at a rate of 50 seeds per square foot (538 seeds per square meter).

Microsite conditions influence the establishment of squirreltail. Squirreltail plants that grow in less fertile soil are conditioned to be less affected by periods of moisture stress (Schlatterer and Hironaka 1972). In addition, the authors reported that plants preconditioned at high temperatures were better adapted to withstand periods of moisture stress. This finding further enforced the fact that seedings should utilize seeds from plants growing in similar environments. Hironaka and Sindelar (1975) found that plant establishment a function of the plants ability to store enough root reserves to survive the dormant period of the summer. Squirreltail exhibited this characteristic.

Squirreltail's nutrient content is not as impressive nor as well documented as winterfats. However, it does provide another source of forage for grazing animals. Cook and Harris (1968) reported that during the winter grazing season in Utah squirreltail was 2.6% ether extract, 4.5% total protein, 17.1% ash, 8.7% lignin, 37.5% cellulose, and contained 1730 Kcal/lb. Although total protein was 4.5% digestible protein was only

1.1% and metabolizable energy was 732 Kcal/lb through the winter months. In a study

by Ganskopp and Bohnert (2001), in the northern Great Basin, they found that

squirreltail's crude protein level declined from late April through late June reaching its

lowest level of crude protein by late July. This was typical of most of the rangeland

grasses studied. They also found that squirreltail responded to summer and fall

precipitation with green growth because of its shallow rooting characteristics. The

authors noted that the addition of fall or summer moisture was often followed by an

increase in crude protein levels. Neutral Detergent Fiber (NDF) levels followed a pattern

typical of most grasses rising as the plant matured. However, summer or fall moisture

caused NDF levels to drop as the crude protein levels increased. In years with late season

moisture squirreltail would provide better late-season forage than many perennial grass

species. Squirreltail's ability to respond to summer and fall moisture, and its ability to

compete with invasive annual plants make it a valuable species for rangeland

rehabilitation efforts therefore it is important to understand how to increase the success of

squirreltail seedings.

Ecology and nutritional quality of Nuttall's saltbush and creeping wildrye

Winterfat plant communities located within the basins of the northern Great Basin

often are associated with *Atriplex nuttallii* S. Wats. (Nuttall's saltbush) and *Leymus*

triticoides (Buckl.) Pilger (creeping wildrye). The nutritional quality of these associated

species are poorly understood. *A. nuttallii* as reported by Cook and Harris (1968) offers

2.2% ether extract, 7.2% total protein, 21.5% ash, 9.9% lignin, 19.2% cellulose, and has

1676 Kcal/lb energy. Digestible protein in the winter was 3.4% and metabolizable

energy was 599 Kcal/lb. The nutritional status of creeping wildrye, during the dormant period has not been documented.

Livestock Nutritional Needs During Winter

The typical cow-calf operation in the northern Great Basin targets a calving period between late February and early April. Therefore, cows on winter range are near the middle third of gestation and last years calves have been weaned. The National Research Council (NRC) states that during this stage of pregnancy a 500kg dry cow requires 0.92 Mcal/kg DM (dry matter) in the diet to meet the net energy for maintenance (NEm) requirement. On a DM basis, cows in the second trimester of pregnancy should also be receiving 7% of total intake as protein (NRC 1984). During the last third of pregnancy energy and protein requirements for maintenance increase to 1.08 Mcal/kg NEm DM and 7.8% intake of protein on a DM basis (NRC 1984).

Microhistological analysis was used to analyze animal diet because of its many advantages. Holechek et al. (1982) stated that determining botanical composition of fecal samples did not interfere with the animal's normal behavior, large sample sizes were easily obtained, and it can be used when animals graze over mixed plant communities. Another advantage was the minimal amount of equipment needed to sample. However, Holecheck et al. (1982) did express concern about the accuracy of this technique. Vavra et al. (1978) found that botanical composition of feces would often overestimate the percentage of grasses in the diet, and underestimate the percentage of forbs. However, the accuracy increased during the dormant season. Using fecal samples in this project seemed the most feasible since fistulating animals was not an option, and the area being

sampled was so vast. The project also took place during the dormant season when accuracy was the highest. Vavra and Holecheck (1980) also provided steps to follow to ensure sample accuracy. These steps included grinding samples in a Wiley mill through a 1-mm screen and soaking in sodium hydroxide, developing regression equations to correct for different rates of digestibility, collecting large reference samples, and correcting for the destruction of epidermal structures during digestion.

Body condition scoring (BCS) can be used to estimate the fat reserves of cattle, and give insight to the appropriateness of the diet. It was based on a 1 to 9 scale with 1 being emaciated, and 9 being extremely fat. A score of 5 is the mid-point and corresponds to a cow in moderate condition. BCS is correlated to reproductive performance (Kellems and Church 2002). Morrison et al. (1999) implied that BCS was the one most important factor affecting net calf-crop in mature beef cows. They suggested that a score of five in the last trimester of pregnancy is critical to maintain postpartum reproduction. They suggested that a cow can lose and gain weight during pregnancy, but an average score of five should be maintained.

The two-year research project proposed examined the ability to seed and reestablish winterfat and squirreltail species, monitored the nutritional value of the forages that now comprise the plant community, determined diet quality, and determined how well cattle performed on the current plant community based on body condition scores.

CHAPTER 2

RESTORATION OF A WINTERFAT (*Krascheninnikovia lanata* (Gueldenstaedt))

DOMINATED PLANT COMMUNITY: ASSESSMENT OF

FOUR SEEDBED PREPARATIIONS

Mark G. Estes, Tamzen K. Stringham, William C. Krueger, James R. Males

and David W. Bohnert.

Abstract

Seedbed preparation is a key factor in the success or failure of rangeland seedings. *Krascheninnikovia lanata* (Gueldenstaedt) (winterfat) a native half shrub in the northern Great Basin is an important forage and browse species particularly during the winter months. Due to overgrazing during the growing season, winterfat stands have steadily declined and even disappeared in many areas where they were once extensive (Stevens et al. 1977). The decline in this important plant community has led to efforts to rehabilitate degraded winterfat rangelands. The literature is rich with information on seed ecology, however knowledge on appropriate seeding methods is limited. This project, located in southeastern Oregon tested four seedbed preparation methods. In November of 2004, three seedbed treatments consisting of ripping, tilling, harrowing plus a control were randomly assigned to twenty 9m x 8m plots within a 4.08 ha (10acre) exclosure. Winterfat seed was hand broadcast at 5lbs of pure live seed (PLS) per acre and all treatments were lightly harrowed to complete the seeding. A census of seedling numbers was taken in June, July, August, and September 2005. A final census for survival was taken in June of 2006. Plots with the tilled seedbed preparation had the highest amount of seedlings emergence and survival. Tilling as a seedbed preparation increased the success of the seeding for this site.

Introduction

Winterfat, also known as Whitesage, [*Krascheninnikovia lanata* (Gueldenstaedt) syn. *Certoides lanata* (Pursh) J.T. Howell, syn. *Eurotia lanata* (Pursh) Moq.] is dicotyledonous (Hilton 1941) and belongs to the Chenopodiaceae family (Booth 1992). This long-lived perennial (>120 yrs) (Clarke and Tisdale 1945) can be found throughout much of the western United States and parts of Canada (Woodmansee and Potter 1971). The half-shrub grows most frequently in the foothills, plains, and valleys (Woodmansee and Potter 1971) in areas that range from 10.16 centimeters (4 inches) of annual precipitation to 101.6 centimeters (40 inches) of annual precipitation (Stevens et al. 1977). Winterfat is also common in areas that reach elevations of 2,438.4 meters (8,000 feet), and less frequently to 3,048 meters (10,000 feet) (Woodmansee and Potter 1971). It is adapted to many different soil types and textures, but prefers soils that are slightly alkali to neutral pH (Stevens et al. 1977). Winterfat's extensive fibrous root system (57 inches/144 centimeters below the surface) and deep penetrating taproot (up to 25 feet/7.72 meters below the surface) allow it to grow in harsh environments (Stevens et al. 1977). Its root biomass is more than three times the above ground biomass (Caldwell and Camp1974). Winterfat is a diaspore (Booth 1988) and can be monoecious or dioecious (Riedl et al. 1964). Seed production varies from year to year and with climate. It typically flower in the spring/summer (May-August), and the fruit ripens September to November with dispersal in late fall and winter (Stevens et al. 1977). Winterfat is highly palatable, nutritious, drought tolerant (Hodgkinson 1975). Smoliak and Bezeau (1967) found that during the leaf period of winterfat's growth stage crude protein was 23.13%, with 3.96% digestible protein, and 26.3% cellulose. However, during the winter months

as reported by Cook and Harris (1968) winterfat's crude protein remained around 9%.

Consequently, it is of great importance to western rangelands (Dayton 1931) especially

during the dormant season when nutrient quality of standing grass is low (Hodgkinson

1975). Overgrazing during the growing season has decreased or eliminated winterfat

stands in areas where it was once extensive (Stevens et al. 1977). The recognized

nutritional benefit of winterfat in overall forage production of rangelands has led to

extensive research in the areas of seed anatomy and germination, however, limited

information is available on reestablishment techniques. In the fall of 2004, in an effort to

address the limited knowledge on seedbed preparation for winterfat seedings, we initiated

a research project to test three methods of seedbed preparation: tilling, ripping, and

harrowing. We quantified seedling emergence and survival in June, July, August, and

September 2005and again in June 2006.

Site Description

The project site was located in southeast Oregon in the Catlow Valley, a historical

Pleistocene lakebed. The ecological site description for the research area characterizes

the soils as deep, somewhat poorly drained silty clay loam over clay loam (Stringham and

Bahn 2005). The soil sereies is described as Spangenburg silty clay loam with a

historical plant community comprised of Winterfat [*Krascheninnikovia lanata*

(Gueldenstaedt)], squirreltail [*Elymus elymoides* (Raf.) Swezey], Nuttall's saltbush

[*Atriplex nuttallii* S. Wats], and a small portion of Sandberg bluegrass [*Poa secunda* J.

Presl]. The valley floor elevation ranges between 1219 and 1248 meters (4,000 to 4,100

feet). The ecological site description indicates an average annual precipitation of 15 to

25 centimeters (6-10 inches) most occurring in the winter months in the form of snow.

The long term (1979 – 2000) average precipitation at the P-Ranch Refuge located

approximately 40 miles north of the research site near Frenchglen, Oregon was 12.3

inches. The average annual temperature was reported as 47.8ºF with a maximum of

102.0ºF and a minimum of   –32.3ºF. The spring of 2005 experienced above average

precipitation with the month of May receiving measurable precipitation on 26 days for a

total of 5.23 inches. Total annual precipitation for 2005 was 16.6 inches (OCS 2008).

Methods and Materials

Experimental Design

A 10-acre (4.05 ha) cattle and wild ungulate exclosure was established in the

summer of 2004 in the Catlow valley. Twenty 9m x 8m plots were installed running

south to north within the exclosure along the east fence. One meter was left between

each plot as a buffer. Three seedbed treatments and a control were randomly assigned to

each of the twenty plots. Each treatment and control was replicated five times.

Treatments were assigned using a completely randomized statistical design. Treatments

consisted of tilling with a tractor-mounted roto-tiller, ripping with a tractor-mounted

ripper, and a surface disturbance using a meadow harrow. The controls had no seedbed

preparation but were seeded. Ripping disturbed the soil to a depth of 18 inches (45.72

cm), with ripping paths approximately two feet (.6096 m) apart creating an uneven

planting surface with some existing vegetation remaining. Tilling removed all existing

vegetation and disturbed the soil to a depth of five inches (12.7 cm). The harrowing

treatment was applied using the short-tooth side of a harrow and provide minimal soil

surface and vegetation disturbance across the entire plot. Tilling, ripping, and harrowing treatments were completed prior to seed being distributed. Survival of one plant per square meter was used as a measure of success in this seeding trial.

<u>Seed Distribution</u>

Seed was broadcast by hand and a chain harrow was drug over each plot twice to achieve a seeding depth between 1/8 and ¼ inch. Seeds were dispersed at a rate of 12 seeds per square foot or 129 seeds per square meter (9.19 lbs/acre dirty seed or 5 lbs/acre pls) (1.69 kg/ha dirty seed or .91 kg/ha pls) for uncleaned winterfat seed. Seed was weighed and placed into individual bags for each plot prior to broadcast seeding to insure each plot received the same amount of seed. Plots were seeded the 12th of November 2004. The winterfat seed used is sold under the trade name of Open Range®, and was purchased from Wind River Seed Co. in Wyoming. Open Range was developed by the USDA plant materials center in Bridger, Montana. It is a dwarf variety developed for cold, high desert ecosystems and was similar to the native Catlow Valley winterfat in form and size.

<u>Seedling Emergence and Survival Measurements</u>

Permanent 7m x 7m plots were established within the original 9m x 8m plots to eliminate border effects. The 7m x 7m plots were permanently marked with rebar stakes at the corners, and 12 inch spikes were used to mark transect lines. Transect lines were randomly chosen to start at the 1m or 0m mark measured from the west side baseline of the 7m x 7m plot. Transect lines ran north and south for all plots such that the equipment lines left by seedbed preparation were perpendicular to the transect lines. Emergence and survival of seedlings was quantified using census sampling. Seedlings were counted in

June, July, August, September 2005 and June 2006. Census sampling was used to ensure that sampling was not under or over estimated due to a patchy distribution pattern in seedling emergence. Mature perennial plants, with the exception of creeping wildrye, were alsocensused in each plot. Creeping wildrye density was measured using thirty 50 cm quadrats per plot. Starting position and cardinal direction along with transect lines were randomly determined for quadrat placement within each plot. Due to the rhizomatous growth form of creeping wildrye the individual tiller was the sampling unit. Mature plants and creeping wildrye numbers were recorded in June of 2005 and 2006.

The frequency of annual plants within each plot was measured in June of 2005 using a 20cm, 30cm, 50cm, and a 1m square nested quadrat. Five transect lines with 6 randomly determined quadrat positions per line were sampled for a total of 30 quadrats per plot. A test sample for the frequency of annuals in 2006 revealed all plots contained annuals within the 20 cm frame, therefore frequency was not repeated in 2006.

Soil Moisture Monitoring

Soil moisture probes were installed in plots in April 2005 to measure volumetric moisture differences between treatments. Five control plots were randomly selected from the five controls in the winterfat seeding and the five controls in the neighboring squirreltail seeding. All winterfat seedbed treatments received at least one probe. Ripped treatment plots were instrumented with two probes each located at a depth of 5-6 inches/12.7-15.24 centimeters and as close to the centers of the plots as possible depending upon transect line location.to determine if there was a difference in moisture between ridges and valleys in the plot. Micro-loggers placed between plots on metal T-posts recorded data for the two adjacent plots. Loggers were programmed to take a

reading every minute and record the hourly average for a total of 24 soil moisture averages per day.

Statistical Analysis

Monthly seedling counts were analyzed for differences between treatments at specific dates using analysis of variance (ANOVA) with treatment as the dependent variable and winterfat seedling numbers as the independent variable. If significant differences were found between treatments, a Tukey HSD multiple comparison test was used to determine which treatments differed from each other. All multiple comparisons were run using a Tukey test, because according to Ramsey and Schafer (2002) the Tukey test is not the most conservative or liberal test and is appropriate when family wise comparisons include pairwise differences. Main-effects ANOVA was used to determine differences between treatments across all dates and differences between years. If differences were found, a Tukey HSD test was used to determine which treatments differed.

Mature perennial plant data was also analyzed using main-effects ANOVA. Data were analyzed using treatment and date as the independent variable and number of plants or tillers in the case of creeping wild rye as the dependent variable. If significant differences were found between treatments the Tukey HSD test was used to test treatment pairs. Data were then analyzed to determine the effects mature species had on seedling numbers using a simple linear regression model.

Annual frequency data was sorted into the two dominant species found in the plots. The data were then analyzed using ANOVA with treatment as the independent

variable and the numbers of 20 cm quadrats containing annuals as the independent

variable. Tukey HSD was used to determine individual treatment differences.

Soil moisture was analyzed for differences between treatments at specific dates

using analysis of variance (ANOVA) with treatment as the dependent variable and soil

moisture content as the independent variable. If significant differences were found

between treatments, a Tukey HSD multiple comparison test was run to determine which

treatments differed from each other. P-values reported for specific differences between

treatments were generated from the multiple comparison tests. Main-effects ANOVA

was then used to determine differences between treatments across all dates and

differences between all dates. If differences were found, a Tukey HSD test was used to

determine exactly which treatments differed.

Results and Discussion

<u>Seedling Emergence and Survival</u>

Winterfat seedling numbers by treatment and date were significantly different

($p<0.001$) for both treatment and date. Tilled treatments averaged across all sampling

dates had the highest number of seedlings at 78 per $7m^2$ plot or 11.1 seedlings per $1m^2$.

Ripped treatments had 49 seedlings per $7m^2$ plot (7 seedlings/$1m^2$), followed by

harrowed treatments with 25 seedlings per $7m^2$ plot (3.6 seedlings/$1m^2$). Control plots

only contained 10 seedlings per $7m^2$ plot (1.4 seedlings/$1m^2$). Winterfat seedling

numbers by date showed a significant increase ($p<0.05$) from June 2005 to July 2005 that

indicating a second germination event in response to May and June precipitation (Figure

2.1). This response was consistent with Romo (2004) who found that winterfat planted in

the autumn continued to germinate from May until September in northern Saskatchewan.

Figure 2.1 Study area total monthly precipitation for May through September 2005 in millimeters.
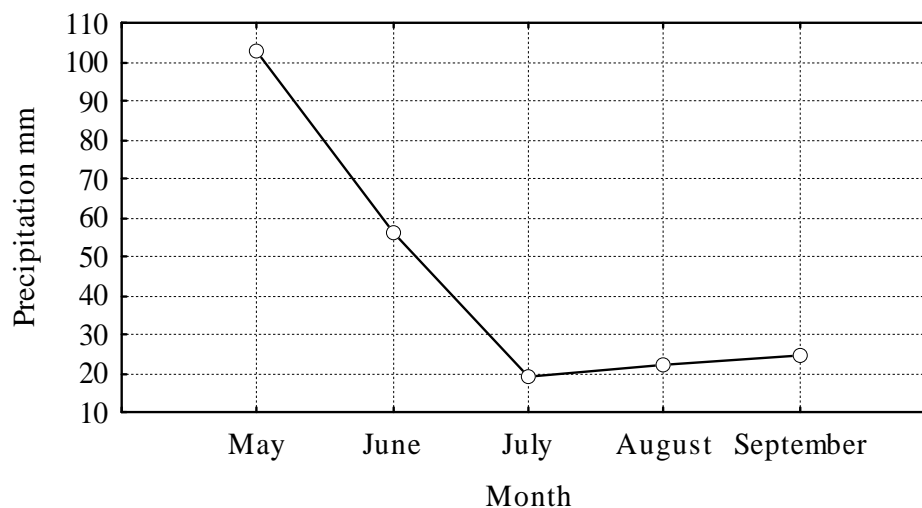
Seedling numbers in September 2005 were not different from June or July 2005 ($p > 0.05$), however there was a significant decline in seedling numbers between September 2005 and June 2006 ($p < 0.05$). The number of seedlings present in September 2005 represented the emergence response for winterfat seedlings, whereas the number of seedlings present in June 2006 represented the number of seedlings that survived the first year. When seedling numbers, by treatment, were compared between September 2005 and June 2006, the ripped and harrowed treatments showed a significant decline in seedling numbers ($p < 0.10$). In contrast, the tilled treatment showed no difference between emergence and survival ($p = 0.72$). However, there was no statistical difference ($p > 0.05$) between June 2005 and June 2006 indicating the number of seedlings that survived the first year was statistically the same as the number of seedlings that originally emerged in June 2005 (Figure 2.2). Based on the rapid decline in the amount of precipitation from July to September, the assumption could be made that the seedlings that emerged in July or later did not have the resources to withstand the harsh summer environment.

Figure 2.2 Average number of winterfat seedlings for all treatments at each sampling date.

Figure 2.2 Average number of winterfat seedlings for all treatments at each sampling date.
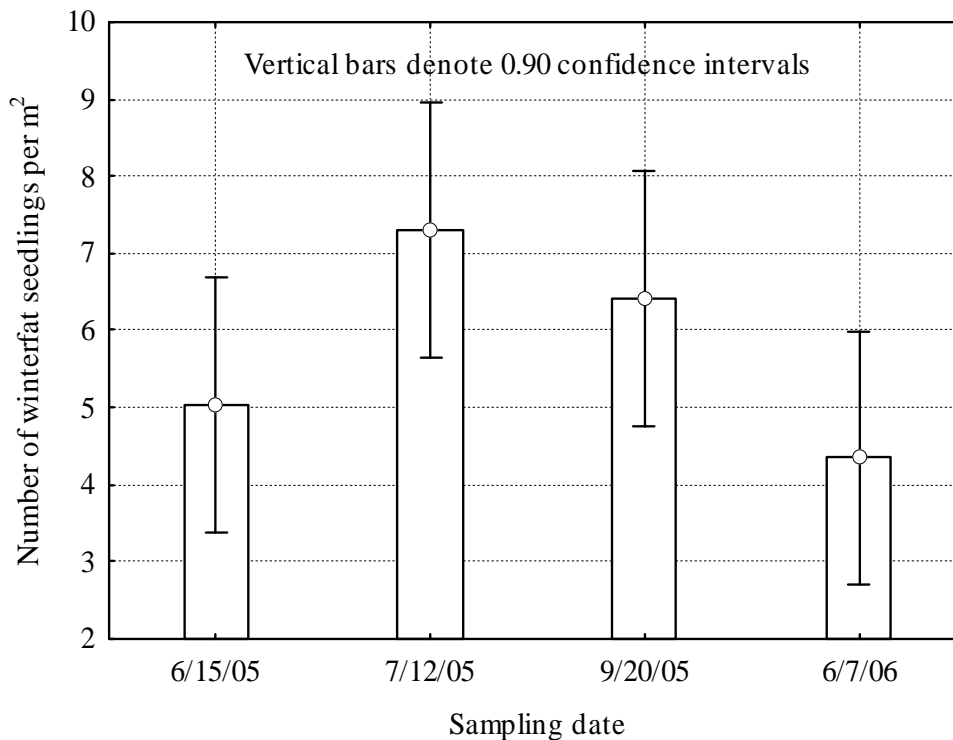
Winterfat seedling numbers compared by treatment between sampling dates were significantly different for June 2005, July 2005, September 2005, and June 2006 ($p<0.001$). Till and rip treatments seedling numbers were consistently higher than the control (Table 2.1). Winterfat seedling emergence and survival was enhanced by the heavy disturbance treatments of ripping and tilling suggesting that there is an interaction between seedlings and soil structure, and/or an interaction between seedlings and mature plant species present that were not removed with the control or harrowed seedbed preparation. These findings are supported by findings reported by Romo (2004) who found tilling or the application of glyphosate reduced the plant density of the existing plant community, making more resources available for winterfat seedlings as compared to a control. The results from the Catlow Valley study suggest that the following seedbed and environmental characteristics favor winterfat germination and survival: 1) heavily

disturbed seedbed 2) early spring germination 3) removal of mature perennials 4)

removal of annuals and 5) late spring precipitation.

Table 2.1 Multiple comparison results of seedling numbers for each treatment by sampling date.

Treatment	Mean number of winterfat seedlings at sample Date							
	6/15/2005	*	7/12/2005	*	9/20/2005	*	6/7/2006	*
Rip	48	a	55.2	ac	51.2	ac	41.8	a
Harrow	14.8	b	45.8	bc	36.6	bc	4.4	b
Till	70.4	a	84.4	a	80.2	a	75.4	c
Control	7.8	b	19.2	b	11.6	b	0.2	b

* Treatments not sharing like letters differ significantly
(p<0.05)

Table 2.2 Number of winterfat seedlings per m^2 by sampling date.

Treatment	Mean number of winterfat seedlings per m^2 at sample date			
	6/15/05	7/12/05	9/20/05	6/7/06
Rip	1	1.1	1	0.9
Harrow	0.3	0.1	0.7	1
Till	1.4	1.7	1.6	1.6
Control	0.1	0.4	0.3	0

Mature Plants

  Squirreltail and Nuttall's saltbush were significantly different between treatments

when compared at the emergence date of June 2005 (p<0.001) (Table 2.3).

Table 2.3 Multiple comparison results of mature plant numbers for each treatment June 2005

| Treatment	Mean number of mature plants by species							
	Squirreltail	*	Nuttall's Saltbush	*	Winterfat	*	Sandberg Bluegrass	*
Rip	4.4	a	99.8	a	0.6	a	83.4	a
Harrow	26.6	b	243.4	c	2	a	15.6	a
Till	1.2	a	6.6	b	0.4	a	6.4	a
Control	34.2	b	228	c	3.2	a	0.6	a

* Treatments not sharing like letters differ significantly (p<0.05)

Squirreltail was more prevalent in the harrowed and control plots than the ripped and tilled plots (p<0.001), indicating squirreltail responded negatively to high disturbance treatments. The tilling treatment was most effective at reducing Nuttall's saltbush (p<0.001), followed by ripping (p<0.05) with no difference between harrowing and control (p>0.05). Mature winterfat plants were not prevalent enough in the study area to show differences between treatments though the data suggests that the rip and till treatments reduced the number of mature winterfat per plot. Sandberg bluegrass had too much variance between plots to indicate treatment effects.

The number of squirreltail and Nuttall's saltbush increased from year one to year two (p<0.001). Sandberg bluegrass and mature winterfat remained the same (p>0.05) from year one to year two. Production by species also increased from year one to year two alluding to the amount and timing of precipitation received in the second year of the study. Total production for the three pastures was 291.93 lbs\acre in year one compared with 815.17 lbs\acre in year two. June 2006 mature perennial data was not compared for treatment differences. It was assumed that the increase in plant numbers from year one to year two was not a function of an increase in mature perennials but the result of seedling survival or recruitment of seedlings. The data does suggest that the seedbed treatments have only a short-term effect on these mature species.

Nuttall's saltbush had the strongest significant negative correlation to the number of winterfat seedlings ($R^2 = 0.54$) (Figure 2.3). Squirreltail and mature winterfat both exhibited weak negative correlations with winterfat seedling numbers ($R^2 = 0.27$, $R^2 = 0.18$). These results suggest mature plants present within the seedbed suppress the emergence and survival of winterfat seedlings.

Figure 2.3 Linear regression of Nuttall's saltbush and the number of winterfat seedlings.
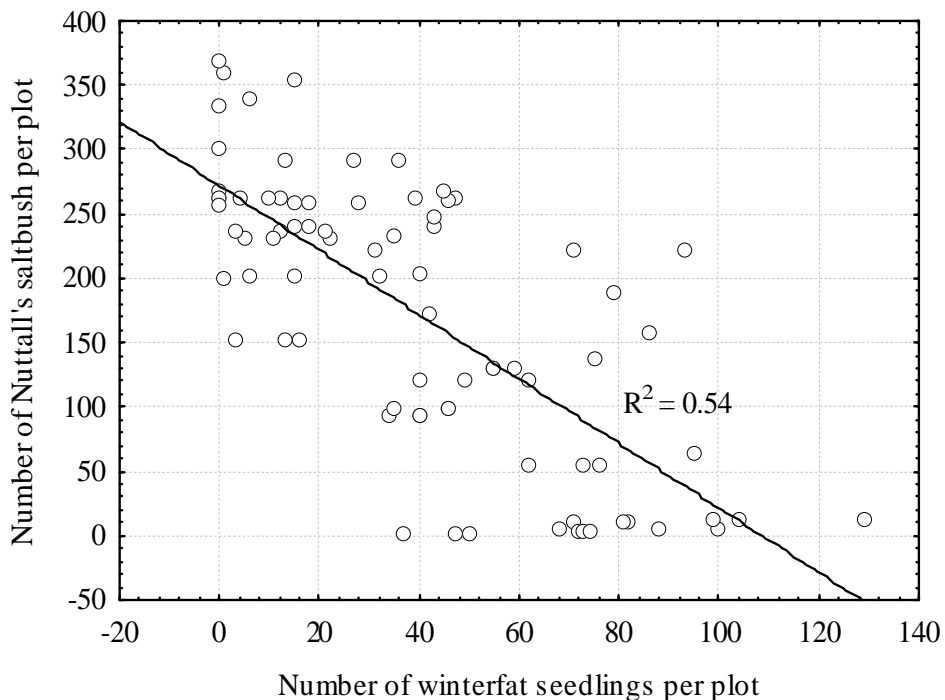
Creeping Wildrye Density

Creeping wildrye density did not differ significantly between treatments in 2005 or 2006 (p>0.05). There was also no difference found in the number of tillers per treatment between years (p>0.05). The regression analysis between creeping wildrye and winterfat seedlings indicated a lack of relationship ($R^2 = 0.02$). This may be because the study site chosen for this project had a patchy distribution of creeping wildrye thus a number of plots were devoid of this plant.

Annual Frequency

Frequency of annual mustard and clasping leaf pepperweed differed significantly between treatments (p<0.05). Mustard was best controlled using the rip treatment, which was significantly better than the till treatment (p=0.05). However, tilling was significantly better than the harrow and control (p<0.001) with no difference being noted

among the harrow and control treatments (p=0.25) (Figure 2.4). Year two data is not

present because after sub-sampling each plot it was apparent all 30 quadrats would have

mustard and clasping leaf pepperweed present in the 20cm nested frame size.

Figure 2.4 Mean number of quadrats containing annual mustard by treatment.
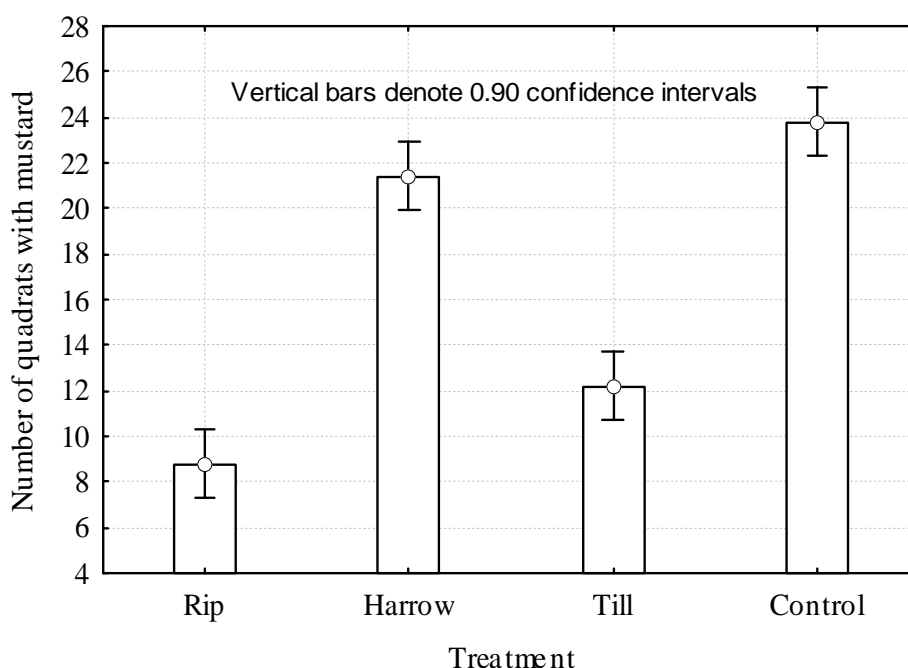
The tilled treatment reduced the frequency of clasping leaf pepperweed more than

the ripped treatment (p<0.001), which still controlled pepperweed frequency better than

the harrowed treatment and control (p<0.001). There was again no difference between

the harrowed treatment and control (p=1.00) (Figure 2.5).

Linear regression for both annuals measured, had a significant effect on winterfat

seedlings. Mustard frequency had only a small impact on winterfat seedlings ($R^2 = 0.26$),

while pepperweed frequency had a more substantial impact ($R^2 = 0.56$). Both species

appeared to reduce the number of winterfat seedlings as the frequency of annuals

increased with a combined R^2 of 0.50(Figure 2.6).

Figure 2.5 Mean number of quadrats containing annual pepperweed by treatment.
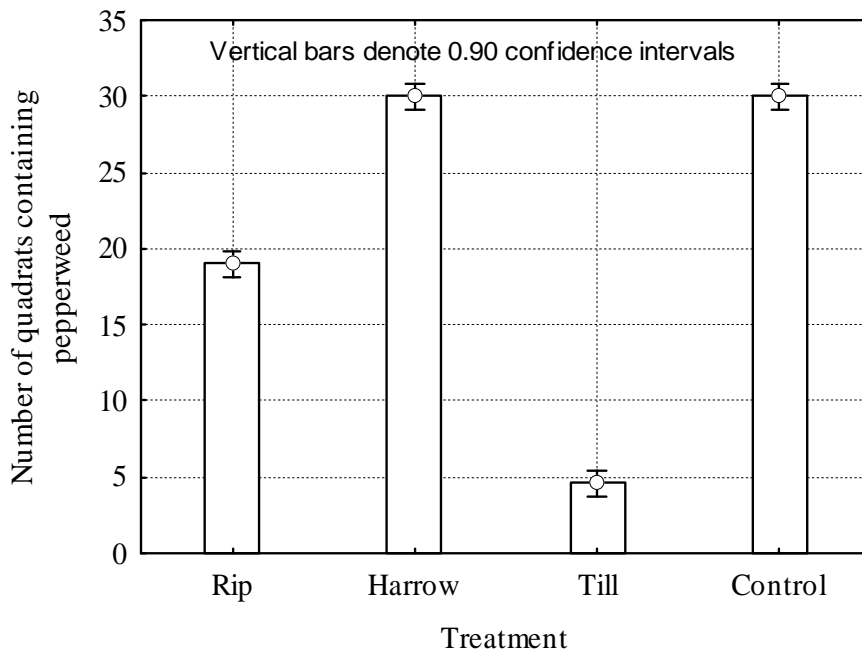
Figure 2.6 Linear regression of mustard and pepperweed combined.
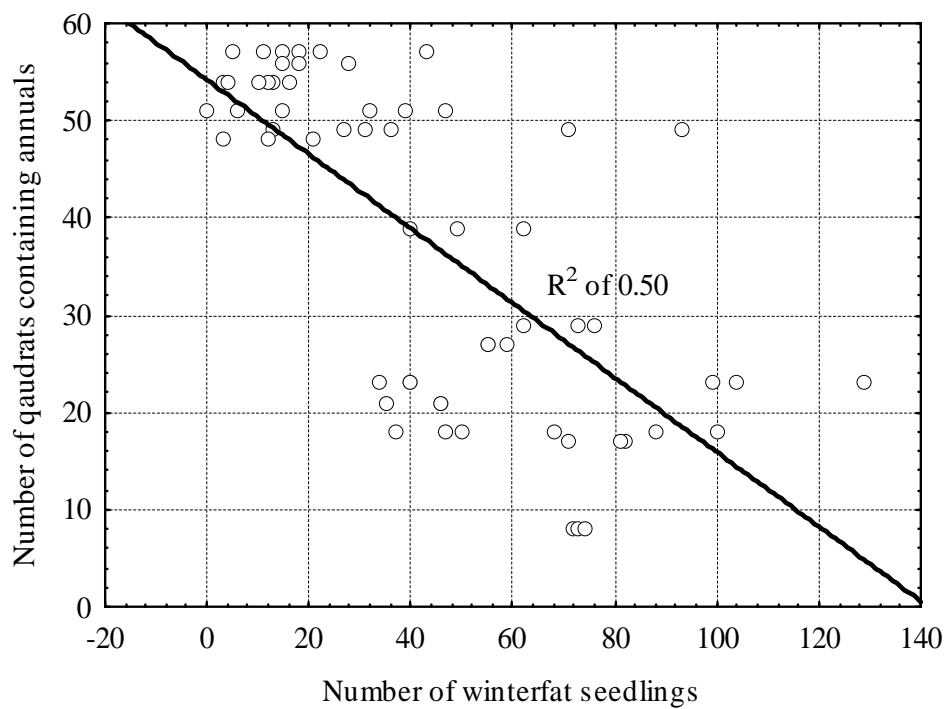
<u>Soil Moisture</u>

Soil moisture when analyzed by day was the highest in the tilled treatment from

May to November 2005 ($p<0.001$) followed by the harrowed treatment ($p<0.001$). The

ripped treatment and control were not different ($p=0.97$). When analyzed by treatment

for the entire sampling period the same trend was found with tilled exibiting the highest

soil moisture ($p<0.001$), followed by the harrowed treatment ($p<0.001$), and no difference

between the ripped treatment and the control ($p=0.29$). Treatments were also

significantly different by date ($p<0.05$).

Figure 2.7 Average soil moisture per treatment for May to November 2005.
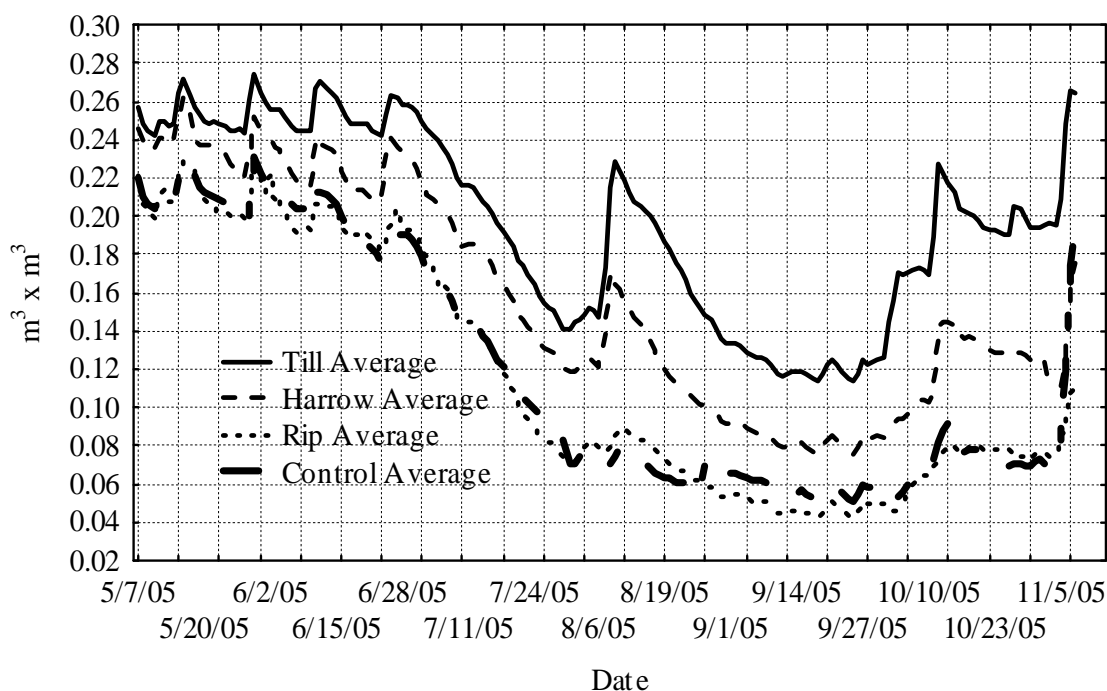
Conclusions

Seedbed preparation is a necessary consideration for the establishment of

winterfat. Tilling provided the best opportunity for the emergence and survival of

winterfat seedlings. The tilling treatment reduced the number of mature perennial plants

and annual species, retained the most soil moisture, and ultimately had the highest

number of seedlings. Although different methods of planting winterfat seed was not

tested in this project the broadcast seeding method followed by a light chain harrow to

bury seed produced a successful seeding to the tilled and ripped seedbeds. Further

research is needed to establish whether tilling provided the best results due to the physical

structure of the seedbed or because the treatment removed all mature plants and

significantly reduced annual species. The design of this study does not allow us to

separate the role of mature plants and annuals from the role of the physical seedbed on

winterfat seedling emergence and survival.

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CHAPTER 3

USE OF SQUIRRELTAIL (*Elymus elymoides* (Raf.) Swezey) AS A RANGE

RESTORATION SPECIES: ASSESSMENT OF FOUR SEEDBED PREPARATIONS

Mark G. Estes, Tamzen K. Stringham, William C. Krueger, James R. Males

and David W. Bohnert.

Abstract

Seedbed preparation is an important consideration in restoration of native plant communities. In November of 2004 three seedbed treatments (ripping, tilling, harrowing) and a control were randomly assigned to twenty 9m x 8m plots within an exclosure in the Catlow Valley of southeastern Oregon to test the effects of seedbed preparation on the emergence and survival of *Elymus elymoides* (Raf.) (squirreltail). Seeds were hand broadcasted and lightly harrowed to complete the seeding. A census of seedling numbers was taken in June, July, August, and September 2005. A final census for survival was completed in June of 2006. There were no differences in the number of squirreltail seedlings for any of the seedbed treatments. Squirreltail's ability to propagate in a wide variety of seedbed conditions makes it a very promising species to use for restoration of native rangelands.

Introduction

Bottlebrush Squirreltail or just squirreltail [*Elymus elymoides* (Raf.) Swezey syn. *Sitanion hystrix* (Nutt.) J.G. Smith] is a cool-season, native perennial grass (Arredondo et al. 1998). It is another species available as winter forage in the northern Great Basin. Squirreltail is distributed throughout many geographical locations and found in a variety of environments in the western United States (Clary 1975). Squirreltail is thought to be an early to mid-seral plant (Hardegree et al. 2002), but depending on the environmental attributes of the site it may also be a climax species. Young and Miller (1985) stated squirreltail can be successional or climax depending on genotype and potential for the site. Its ecological characteristics, such as the ability to increase with disturbance and to produce abundant viable seeds that are highly germinable with adequate moisture and temperature make it well suited for rehabilitating disturbed sites (Young and Evans 1977). Squirreltail's ability to self-pollinate and to tolerate competition helps it colonize sites. Its ability to self-pollinate also allows it to propagate even when the stand is small (Arredondo et al. 1998). Squirreltail has been extensively researched for its potential to invade sites dominated by weedy annuals (Arredondo et al. 1998, Hironaka and Sindelar 1973, 1975). Squirreltail is not the most desirable winter forage species (Young and Evans 1977) compared to plants that maintain high levels of crude protein and digestibility, but because of its competitive ability proves promising for rehabilitation efforts. Hironaka and Sindelar (1973) suggested it might be the first perennial grass of importance in reestablishing perennials. Squirreltail's ability to compete with weedy annuals make it an important species in rangeland restoration projects. Understanding

seedbed requirements for squirreltail will enhance our ability to produce successful

rangeland seedings.

Site Description

The project site was located in southeast Oregon in the Catlow Valley, a historical

Pleistocene lakebed. The ecological site description for the research area characterizes

the soils as deep, somewhat poorly drained silty clay loam over clay loam (Stringham and

Bahn 2005). The soil sereies is described as Spangenburg silty clay loam with a

historical plant community comprised of Winterfat [*Krascheninnikovia lanata*

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[*Atriplex nuttallii* S. Wats], and a small portion of Sandberg bluegrass [*Poa secunda* J.

Presl]. The valley floor elevation ranges between 1219 and 1248 meters (4,000 to 4,100

feet). The ecological site description indicates an average annual precipitation of 15 to

25 centimeters (6-10 inches) most occurring in the winter months in the form of snow.

The long term (1979 – 2000) average precipitation at the P-Ranch Refuge located

approximately 40 miles north of the research site near Frenchglen, Oregon was 12.3

inches. The average annual temperature was reported as 47.8ºF with a maximum of

102.0ºF and a minimum of   –32.3ºF. The spring of 2005 experienced above average

precipitation with the month of May receiving measurable precipitation on 26 days for a

total of 5.23 inches. Total annual precipitation for 2005 was 16.6 inches (OCS 2008).

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Experimental Design

A 10-acre (4.05 ha) cattle and wild ungulate exclosure was established in the summer of 2004 in the Catlow valley. Twenty 9m x 8m plots were installed running south to north within the exclosure along the east fence. One meter was left between each plot as a buffer. Three seedbed treatments and a control were randomly assigned to each of the twenty plots. Each treatment and control was replicated five times. Treatments were assigned using a completely randomized statistical design. Treatments consisted of tilling with a tractor-mounted roto-tiller, ripping with a tractor-mounted ripper, and a surface disturbance using a meadow harrow. The controls had no seedbed preparation but were seeded. Ripping disturbed the soil to a depth of 18 inches (45.72 cm), with ripping paths approximately two feet (.6096 m) apart creating an uneven planting surface with some existing vegetation remaining. Tilling removed all existing vegetation and disturbed the soil to a depth of five inches (12.7 cm). The harrowing treatment was applied using the short-tooth side of a harrow and provide minimal soil surface and vegetation disturbance across the entire plot. Tilling, ripping, and harrowing treatments were completed prior to seed being distributed. Survival of one plant per square meter was used as a measure of success in this seeding trial.

Seed Distribution

Seed was broadcast by hand and a chain harrow was drug over each plot twice to achieve a seeding depth between 1/8 and ¼ inch. Seeds were dispersed at a rate of 30 seeds per square foot, 323 seeds per square meter (6.35 lbs/acre dirty seed or 4 lbs/acre pls) (1.18 kg/ha dirty seed or .74 kg/ha pls) for dirty squirreltail seed. Seed was weighed

per plot. A test sample for the frequency of annuals in 2006 revealed all plots contained annuals within the 20 cm frame, therefore frequency was not repeated in 2006.

Soil Moisture Monitoring

Soil moisture probes were installed in plots in April 2005 to measure volumetric moisture differences between treatments. Five control plots were randomly selected from the five controls in the squirreltail seeding, and the five controls in a neighboring winterfat seeding. All squirreltail seedbed treatments received at least one probe. Probes were placed at a depth of 5-6 inches (12.7-15.24 cm) and as close to the centers of the plots as possible depending upon transect line location. Micro-loggers were placed between plots on metal T-posts and recorded data for the two adjacent plots. Loggers were programmed to take a reading every minute and record the hourly average for a total of 24 soil moisture averages per day.

Statistical Analysis

Monthly seedling counts were analyzed for differences between treatments at specific dates using analysis of variance (ANOVA) with treatment as the dependent variable and squirreltail seedling numbers as the independent variable. If significant differences were found between treatments, a Tukey HSD multiple comparison test was used to determine which treatments differed from each other. All multiple comparisons were run using a Tukey test, because according to Ramsey and Schafer (2002) the Tukey test is not the most conservative or liberal test and is appropriate when family wise comparisons include pairwise differences. Main-effects ANOVA was used to determine differences between treatments across all dates and differences between years. If

differences were found, a Tukey HSD test was used to determine which treatments differed.

Mature perennial plant data was also analyzed using main-effects ANOVA. Data were analyzed using treatment and date as the independent variable and number of plants or tillers in the case of creeping wild rye as the dependent variable. If significant differences were found between treatments the Tukey HSD test was used to test treatment pairs. Data were then analyzed to determine the effects mature species had on seedling numbers using a simple linear regression model.

Annual frequency data was sorted into the two dominant species found in the plots. The data were then analyzed using ANOVA with treatment as the independent variable and the numbers of 20 cm quadrats containing annuals as the independent variable. Tukey HSD was used to determine individual treatment differences.

Soil moisture was analyzed for differences between treatments at specific dates using analysis of variance (ANOVA) with treatment as the dependent variable and soil moisture content as the independent variable. If significant differences were found between treatments, a Tukey HSD multiple comparison test was run to determine which treatments differed from each other. P-values reported for specific differences between treatments were generated from the multiple comparison tests. Main-effects ANOVA was then used to determine differences between treatments across all dates and differences between all dates. If differences were found, a Tukey HSD test was used to determine exactly which treatments differed.

Results and Discussion

Seedling Emergence and Survival

The mean number of squirreltail seedlings was not different between treatments when compared across all sampling dates (p=0.52). Ripped treatments averaged 168 seedlings per 7m^2 plot (24 seedlings per m^2), tilled treatments contained 148 seedlings per 7m^2 plot (21 seedlings per m^2), harrowed treatments had 138 seedlings per 7m^2 plot (20 seedlings per m^2), and control plots averaged 146 seedlings per 7m^2 plot (21 seedlings per m^2). Furthermore, no difference was found between treatments compared between sampling dates (p=0.41). Seedling numbers when compared just by date were different (p<0.001) (Figure 3.1). Mean seedling numbers in June 2005 was not different than September 2005 (p=0.79), however both June 2005 and September 2005 mean seedling numbers were lower than July 2005 and June 2006 numbers. Delayed germination of some of the planted seed could explain the higher number of seedlings in July, and natural recruitment may be the cause of the increase in seedling numbers from September 2005 to June 2006.

Seedling survival was defined by the number of seedlings per square meter in the second growing season following seeding (June 2006). Statistical analysis of the number of seedlings by treatment between the September 2005 and June 2006 data indicated a significant increase in seedlings within the ripped and controlled plots (p=0.002, p=0.08). Altough the harrow treatment did not indicate a significant difference the data indicates an increase of 53 plants per 7m^2 plot in June 2006. The number of seedlongs per meter squared in the tilled treatments did not differ between September 2005 and June 2006 (p=0.25), however the numerical differences showed a decrease from 141 plants per 7m^2

plot in September to 114 plants per $7m^2$ plot in June 2006. Two explanations for the mixed response between treatments are offered. First, by September 2005 many of the squirreltail seedlings had finished their lifecycle and produced inflorences. This may have caused observers to assume these plants were not seedlings and thus they would have underestimated the number of seedlings present (tilled treatment). Secondly, squirreltail is an aggressive colonizer and moisture conditions in spring 2005 were excellent for seed production thus the increase in seedlings from September 2005 to June 2006 may be a function of natural recruitment (ripped, harrowed, control treatments). If the natural recruitment explanation is true, then why did the tilled treatment show a decline in seeding numbers? Squirreltail seed is wind dispersed therefore increased surface roughness created by ripping and by the presence of mature plants (harrow and control) would provide an opportunity to hold seed on site. Observations of squirreltail seed caught in the remaining mature plants in September 2005 lends support to this idea. The tilled seedbed was smooth and devoid of mature plants therefore the opportunity to catch windblown squirreltail seed would be less than on the other treatments. In addition, Winkel et al. (1991) found that three species of grasses emerged best from seedbeds containing safe sites provided by gravel followed by litter, and then cracks. Tilled treatments would eliminate most of these microsites.

Figure 3.1 Average number of squirreltail seedlings for all treatments by sampling date.

Vertical bars denote 0.90 confidence intervals
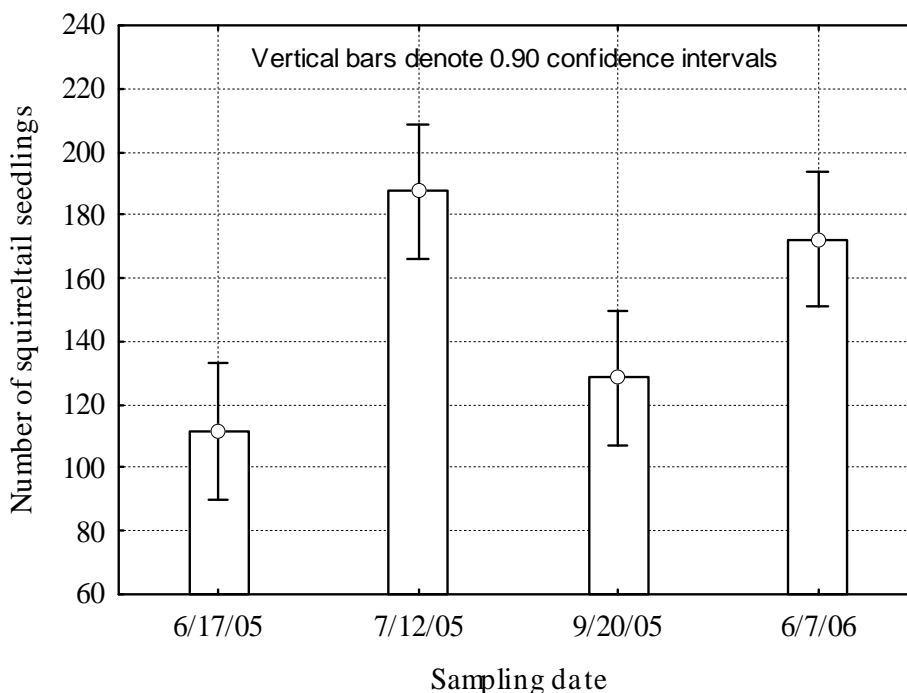
Mature Plant Census

Mature plants were sorted by species and analyzed using analysis of variance

ANOVA to determine differences among treatments for the emergence date of June

2005. Nuttall's saltbush and Sandberg bluegrass were the only mature perennials that

differed significantly (p<0.001) (Table 3.1).

Table 3.1 Multiple comparison results of mature plant numbers for each treatment
June 2005

Treatment	Mean number of mature plants by species							
	Squirreltail	*	Nuttall's saltbush	*	Winterfat	*	Sandberg bluegrass	*
Rip	56.9	a	137.5	a	0.65	a	3.8	a
Harrow	80	a	237.4	c	1.2	a	1.55	a
Till	29	a	56.1	b	0	a	3.85	a
Control	79.2	a	267.1	c	0.45	a	21.6	B

* Treatments not sharing like letters differ significantly
(p<0.05)

Squirreltail, and winterfat, showed no differences between treatments (p>0.05).

Tilled treatments had significant less Nuttall's saltbush than all other treatments with 56.1

plants per plot (p<0.001). Ripped treatments also showed significantly less Nuttall's

saltbush than the harrow or control treatment, however the ripped treatment did not

reduce Nuttall's saltbush as effectively as the tilling Treatment (p<0.001). Sandberg

bluegrass was significantly higher in the control than all other treatments (p<0.05), but

did not differ between the tilled, harrow or ripped treatments (p>0.05).

Squirreltail and Nuttall's saltbush increased from year one to year two (p<0.001),

while Sandberg bluegrass and winterfat remained the same (p>0.05). Production by

species also increased from year one to year two alluding to the amount and timing of

precipitation received in the second year of the study. Total production for the three

pastures was 291.93 lbs\acre in year one compared with 815.17 lbs\acre in year two.

June 2006 mature perennial data was not compared for treatment differences. It was

assumed that the increase in plant numbers from year one to year two was a function of

natural recruitment and not an increase in the number of mature perennials.

When seedling numbers were correlated to the different species of mature

perennials, no strong correlations made. The only significant correlation made was for

squirreltail ($R^2 = 0.09$).

Creeping Wildrye Density

Creeping wildrye density did not differ significantly between treatments in 2005

or 2006 (p>0.05). There was also no difference found in the number of tillers per

treatment between years (p>0.05). Linear regression of creeping wildrye tillers with the

number of squirreltail seedlings indicated no relationship between tiller density and seedling numbers ($R^2 = 0.06$).

Annual Frequency

Frequency of mustard was significantly different between seedbed treatments ($p<0.001$). Tilled and ripped treatments did not differ ($p>0.05$), however both treatments significantly reduced the amount of mustard per plot when compared to the harrow and control ($p<0.001$). The harrow treatment and control did not differ ($p>0.05$).

The frequency of annual clasping leaf pepperweed also differed by treatment ($p<0.001$). The tilled treatment significantly reduced the frequency of pepperweed when compared to all other treatments ($p<0.001$). The ripped treatment also reduced the frequency of pepperweed when compared to the harrow treatment and control ($p<0.001$) but was not as effective as the tilled treatment. There was no difference between the harrowed plots and the control plots ($p=0.94$), indicating the harrow treatment was ineffective in controlling annual clasping leaf pepperweed.

Frequency of annual mustard per plot had no significant effect on squirreltail seedlings ($R^2 = 0.02$), while regression results for pepperweed were slightly higher ($R^2 = 0.07$). However, the slope of the linear regression line suggests that as the annual frequency of pepperweed decreases, squirreltail seedlings increase. Year two data is not present because after sub-sampling each plot it was apparent all 30 quadrats would have mustard and pepperweed present in the 20cm nested frame size. Seedbed apparently controlled the frequency of annuals during the first year following treatment. This could be a significant window of opportunity for establishment of the desired species.

Soil Moisture

Soil moisture when analyzed across all days did not differ between treatments from May to November 2005 (p=0.11). However, when soil moisture was compared by treatment and date, both factors were significant (p<0.001). Control plots had significantly higher amounts of soil moisture on a daily basis than all other treatments (p<0.05). Till and ripped treatments contained more moisture than the harrowed treatment (p<0.05), but no difference was found between the two treatments (p=0.96). Soil moisture had little effect on seedling numbers ($R^2 = 0.02$). A possible explanation for this result could be the above average rainfall received during the spring mitigated soil moisture as a limiting factor.

Figure 3.2 Average volumetric soil moisture by treatment
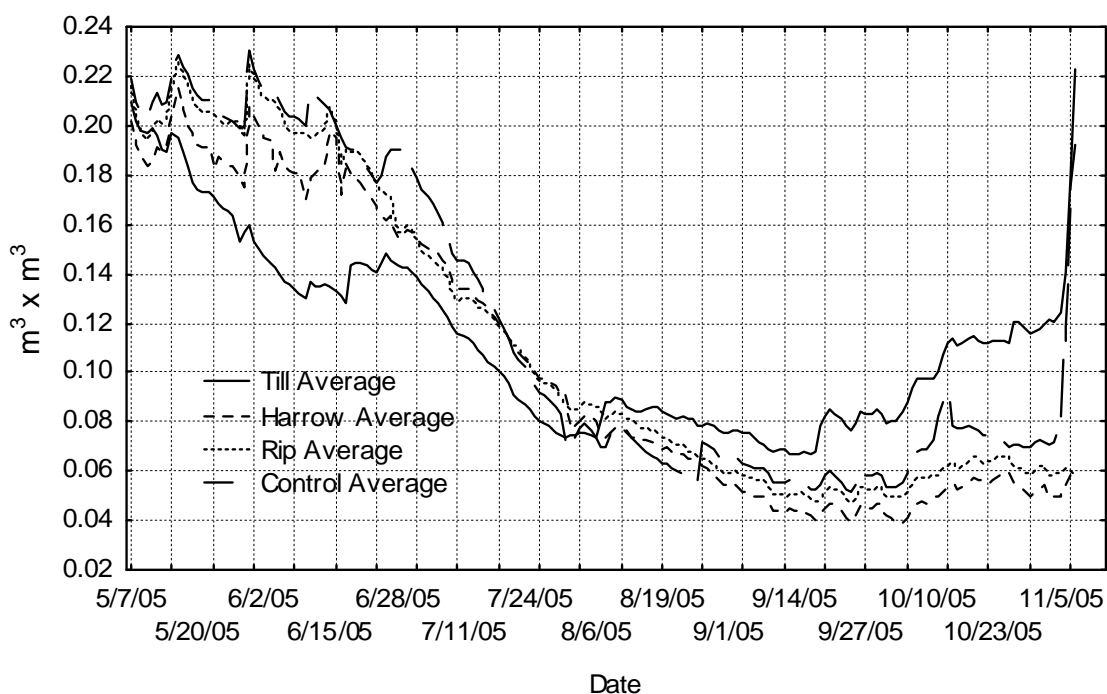
Conclusions

Squirreltail seedlings emerged and survived into the second growing season regardless of seedbed treatment. This result was surprising and encouraging, however the above average spring precipitation may be the primary factor responsible for the positive results. Although all seedbed treatments were considered successful the most expensive treatment, tilling showed a surprising decline in seedling numbers between the September 2005 and June 2006 sampling dates. This may indicate that a seedbed that increases or maintains surface roughness is more appropriate for squirreltail seedings. However, because of its ability to survive in multiple types of seedbeds, squirreltail would be an appropriate plant to include in a seed mix with species that have specific seedbed requirements. Furthermore, seedlings were not inhibited by mature perennials in this study and competed well with the annual weeds. Suggesting squirreltail may be an excellent choice in rehabilitation efforts on annual infested rangelands.

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CHAPTER 4

DORMANT SEASON NUTRITIONAL CONTENT OF WINTERFAT

(*Krascheninnikovia lanata* (Gueldenstaedt)) PLANT COMMUNITIES

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C. Krueger

Abstract

Native forages offer a low-cost alternative to feeding harvested forages to pre-parturition cattle. To insure success using these native forages it is necessary to understand what is nutritionally available for the animals. A two-year study designed to quantify the production, composition and nutritional changes of winterfat (*Krascheninnikovia lanata* (Pursh)), squirreltail *(Elymus elymoides* (Nutt.))*, creeping wildrye *(Leymus triticoides* (Buckl.))*, and Nuttall's saltbush (*Atriplex nuttallii* (S. Wats.)) during the dormant season was initiated in 2004. Additionally, diet quality and livestock diet composition and preference were determined. The study was located in the northern Great Basin and focused on three pastures used as wintering range for 1,500 to 1,800 head of English crossbred mother cows. Above ground biomass production by species was measured in fall of 2005 and 2005 after plants had senesced and before livestock entered the pastures. Forage samples by species were collected once every month during the dormant season and analyzed for crude protein, neutral detergent fiber (NDF), acid detergent fiber (ADF), dry matter, and ash. Body condition scores were taken on 10% of the herd by three observers as cattle were moved from pasture to pasture. Fecal samples were collected one week after cattle entered a pasture, and again just before they left the pasture. Fecal samples were analyzed for species composition using microhistological techniques. Nuttall's saltbush produced the most pounds of forage per acre, while it and winterfat contained the highest amounts of crude protein. Saltbush digestibility was the highest in NDF, and contained lowest amounts of ADF. It also made up the largest proportion of the diet that was identifiable. Cattle typically preferred winterfat the most.

Body condition scores were different upon entering the study pastures, and leaving the study pastures year one however, no difference was found in year two.

Introduction

Utilizing native pasture, as a winter forage source is an excellent way to reduce production costs for a cow-calf operation. The management challenge that arises is insuring the quality of feed the animals are eating is meeting their metabolic needs for their stage. Research has shown maintaining a body condition score of 5 or greater at calving time has a positive impact on reproductive performance (Morrison et al. 1999). With spring calving cows, it is important that the native winter range be sufficient to maintain a moderate level of fat reserves to insure reproductive performance. The National Research Council (NRC) states that a 500 kg dry cow in her second trimester of gestation requires 0.92 Mcal/kg dry matter (DM) in the diet to meet their net energy for maintenance (NEm). In addition, the NRC recommends 7% total protein in the diet on a dry matter basis (NRC 1984). The same cow entering the last trimester of pregnancy requires 1.08 Mcal/kg NEm DM and 7.8% total protein on a DM basis (NRC 1984). The grass species in the northern Great Basin have crude protein levels less than 7% during the dormant season (Ganskopp and Bohnert, 2001), However, shrubs such as winterfat and Nuttall's saltbush remain relatively high in crude protein through the dormant season. Therefore, it is important to understand the amount of available forage by species within the winter grazing season.

The objective of this study was to quantify the change in the nutritional content of *Krascheninnikovia lanata* (Pursh), *Elymus elymoides* (Nutt.)*, Leymus triticoides* (Buckl.)*,*

and *Atriplex nuttallii* (S. Wats.) throughout the dormant grazing season in the Catlow

Valley of southeast Oregon. A further objective was to quantify the production by these

species, determine diet quality, and assess cow performance throughout the winter

grazing period.

Site Description

The project site was located in southeast Oregon in the Catlow Valley, a historical

Pleistocene lakebed. The ecological site description for the research area characterizes

the soils as deep, somewhat poorly drained silty clay loam over clay loam (Stringham and

Bahn 2005). The soil sereies is described as Spangenburg silty clay loam with a

historical plant community comprised of Winterfat [*Krascheninnikovia lanata*

(Gueldenstaedt)], squirreltail [*Elymus elymoides* (Raf.) Swezey], Nuttall's saltbush

[*Atriplex nuttallii* S. Wats], and a small portion of Sandberg bluegrass [*Poa secunda* J.

Presl]. The valley floor elevation ranges between 1219 and 1248 meters (4,000 to 4,100

feet). The ecological site description indicates an average annual precipitation of 15 to

25 centimeters (6-10 inches) most occurring in the winter months in the form of snow.

The long term (1979 – 2000) average precipitation at the P-Ranch Refuge located

approximately 40 miles north of the research site near Frenchglen, Oregon was 12.3

inches. The average annual temperature was reported as 47.8ºF with a maximum of

102.0ºF and a minimum of –32.3ºF. The spring of 2005 experienced above average

precipitation with the month of May receiving measurable precipitation on 26 days for a

total of 5.23 inches. Total annual precipitation for 2005 was 16.6 inches (OCS 2008).

The study area contained three pastures North, Middle, and South comprised of 20,000,

24,000, and 61,000 acres respectively. These pastures are used as winter range for 1,500

to 2,000 head of commercial mother cows.

Methods And Materials

Production Sampling

Forage was clipped by species (*K. lanata, E. elymoides, L. triticoides* and *A.*

nuttallii) during late fall 2004 and 2005 within each of the 3 winter-grazed pastures to

determine biomass production. Clipping was completed prior to livestock entering the

pastures. One hundred random sampling points were generated within the plant

communities of interest, for each pasture, using geographic information system (GIS)

technology. Using a handheld GPS unit the sampling area was located and a random

sampling point was selected. A 9.6 square foot hoop was placed over the center of the

random point and all plants within the hoop were clipped by species to 90% utilization.

Thirty hoops were sampled within each pasture. Plant species were sorted, placed in

paper sacks, and a wet weight was taken in the field. Plants were dried at 90°C for 48

hours and reweighed to determine dry matter. The following equation: grams/frame *10

was used to determine pounds per acre of dry matter (NRCS 1997).

Forage Quality Sampling

The above ground biomass material was used to determine October forage quality

by species. Additional forage quality material was clipped each month throughout the

grazing period to establish a forage quality calendar for the Catlow Valley winterfat

communities. Dry matter, ash, crude protein, and acid detergent fiber as defined by the

Association of Analytical Chemists (1997). In addition, neutral detergent fiber, was determined following methods defined by Van Soest et al. (1997).

Microhistological Sampling

Fecal samples were collected 1 week after cattle moved into a pasture, and just before cattle left a pasture in order to determine shifts in diet composition. Ten random fecal piles were collected and combined to make one sample with a total of five samples collected during each sampling period. Thirty total samples were collected over the grazing period each year. Microhistological analysis was completed on the fecal samples to determine diet composition as outlined in Darambazar (2003).

Relative Preference Index

Relative preference was determined by dividing the percent diet composition of the animals grazing the study pastures by the percent plant composition of the study pastures. The percent plant community composition was derived by dividing the pounds per acre per species by the total production of all species sampled for each pasture. Diet composition was determined through microhistological techniques.

Body Condition Scoring

Two or three experienced observers recorded body condition scores four times each year. The four sampling periods occurred when cows entered the first pasture and at each pasture move thereafter until the livestock were removed from winter range. Scores were recorded on a scale of 1-9 with one being emaciated and ten indicating obese. Every 10th cow was scored as she moved through the pasture gate representing 10% of the herd. Observer's scores were averaged for each cow scored on each date. The

average of the observer scores were averaged over the total cows scored on each date to
produce an average body condition score for the cow herd.

Statistical Analysis

Annual biomass production was analyzed using an analysis of variance (ANOVA)
to test for differences between years, pasture, and species. Biomass was averaged by
species for each pasture for each year. Forage quality data and diet composition data
were analyzed by species, date, pasture and year ANOVA. If significant differences were
determined through ANOVA, a Tukey HSD multiple comparisons test was completed to
determine the components that differed. The Tukey HSD test is considered a moderately
conservative method for testing multiple comparisons and is appropriate when family
wise comparisons include pairwise differences (Ramsey and Schafer, 2002).

Linear regression was used to correlate diet composition to annual production.
Since annual production was determined prior to cattle entering a pasture, the linear
regression model was used to compare the diet composition of the animals as they
entered a pasture. Body condition scores were analyzed using ANOVA to test for
differences between sampling dates within year, and differences between years. If
differences were found a Tukey HSD test was applied to determine which dates differed.

Results and Discussion

Biomass Production

Biomass production by winterfat, squirreltail, Nuttall's saltbush, and creeping
wildrye was not different between study pastures for either year (p>0.05). Total biomass
production during the second year of the study was significantly higher than the first

(p=0.01). Total production for the three pastures was 291.93 lbs\acre in year one

compared with 815.17 lbs\acre in year two. Biomass produced in year two was also

different between the four species measured (p=0.01). Nuttall's saltbush produced the

most biomass at 416.27 lbs per acre. This was significantly higher (p=0.01) than

squirreltail (179.44 lbs\acre), winterfat (80.7 lbs\acre) and creeping wildrye (138.76

lbs\acre). There were no significant differences noted between squirreltail, winterfat, and

creeping wildrye (p>0.05). Nuttall's saltbush was the most available forage in this plant

community.

Forage Quality

Analysis of forage quality found no differences between pastures for crude protein (CP),

neutral detergent fiber (NDF), acid detergent fiber (ADF), or dry matter (DM) (p>0.05).

There was a higher amount of ash in the South pasture (p<0.05) that could be explained

by the higher calcium concentrations in the South pasture soil. When forage quality was

compared between species, significant differences were found for CP, NDF, ADF, DM,

and Ash (p<0.001). Winterfat and Nuttall's saltbush was higher in crude protein than

squirreltail and creeping wildrye (p<0.05). There was no significant difference between

the two shrubs or between the two grasses (p>0.05) highlighting the importance of the

shrub species as a protein source during the dormant season (Appendix A). NDF was the

lowest in Nuttall's saltbush (p<0.001) followed by winterfat and squirreltail, which did

not differ (p>0.05). Creeping wildrye was significantly higher in NDF than all other

species (p<0.001). Nuttall's saltbush contained the lowest amount of ADF (p<0.001),

while the other three species were not significantly different. Creeping wildrye had the

highest dry matter percentage (p<0.05), with no differences between Nuttall's saltbush,

squirreltail, and winterfat. Squirreltail contained more ash than the other three species (p<0.001). When forage quality was compared between years, DM was the only analysis not significantly different (p=0.10). Crude protein and ash were higher in year one than year two (p<0.05), while NDF and ADF were higher in the second year of the study (p<0.05). The lower crude protein levels, and higher NDF and ADF in year two could be the result of more moisture, therefore the plants growing faster and maturing sooner.

Diet Composition

Diet composition was not significantly different when compared by pasture, sample date, or year (p>0.05) (Appendix C). Cattle selected the same percentage of each species of plant regardless of what pasture they were in, or how much forage was available in the pasture. Holecheck et al. (1982) and Vavra et al. (1978) expressed concern about the accuracy of determining diet composition using fecal analysis. Most recommendations to ensure accuracy in diet determination were followed in this study, but regression equations to correct for different digestion rates were not completed. Because of this, the assumption was made that the unknown shrub content of the diet was actually winterfat and Nuttall's saltbush. Therefore, the "other shrub" category was allocated to winterfat and Nuttall's saltbush based on the percentage of those two shrubs in the diet. It was also assumed that most dormant range grasses would fall into a similar quality class as squirreltail (Ganskopp and Bohnert, 2001). The squirreltail forage quality was applied to the "other grass" category identified the diet composition data. It was also assumed that the unmeasured amount of protein supplement provided during the study would supply more actual energy than crude protein so the diet presented does not include any supplementation. Average diet quality by month is presented in Table 4.2.

When diet composition was analyzed by species, a significant difference was found

(p<0.001). Diet consisted of 23.8% Nuttall's saltbush, which was higher (p<0.05) than

creeping wildrye at 13.2% of the diet. Creeping wildrye was still significantly higher

than winterfat (6.9%) and squirreltail (4.8%), which did not differ (p>0.05). Linear

regression was utilized to determine if a correlation existed between the amount of

production by species and diet composition. The regression model was significant with

an R^2 of 0.25 (Figure 4.1).

<u>Relative Preference Index</u>

Krueger (1972) suggested that a relative preference index was an excellent way to

rank forages according to palatability under certain circumstances. In this study plants

were grazed during the dormant season when nutritional content was low. The model

used in this relative preference index was derived from Krueger's (1972) second model

that utilized percent range composition and percent diet composition. Krueger (1972)

recommended that using a plants range frequency and diet frequency would strengthen a

relative preference index, but frequency numbers were not taken in this study. However,

Krueger (1972) found that the model using frequency as well as composition ranked the

plants similar to the model used in this study. The model that included frequency did a

better job at describing plant distribution and consistency of intake. Relative preference

index one (RPI 1) was the preference of the cattle when they first entered a pasture. Diet

composition for RPI 1 was determined with the distribution of the "other grass" category

of the microhistological data into the creeping wildrye and squirreltail category at the

same proportion these two grasses were comprising the diet. This was done because few

other palatable species exist on the study site, and was believed that these "other grasses"

were in fact over looked creeping wildrye and squirreltail in the microhistological

analysis. The same procedure was done with the "other shrub" category by

proportionally placing it in the Nuttall's saltbush and winterfat categories. RPI 1

indicates that a preference for winterfat existed in every pasture with the exception of the

south pasture in year two (Table 4.1). This may be attributed to the patchy distribution of

winterfat in this pasture, or the timing at which it was grazed, having gone into the South

pasture last in year two. Nuttall's saltbush was preferred over the grass species in the

South and Middle pasture, but not in the North pasture. This was believed to be a

function of availability. RPI 1 shows the importance of the shrubby species to the diet

preference of the cattle dormant season grazing this site.

Figure 4.1 Linear regression of pounds of production per acre effect on % composition
of the diet.
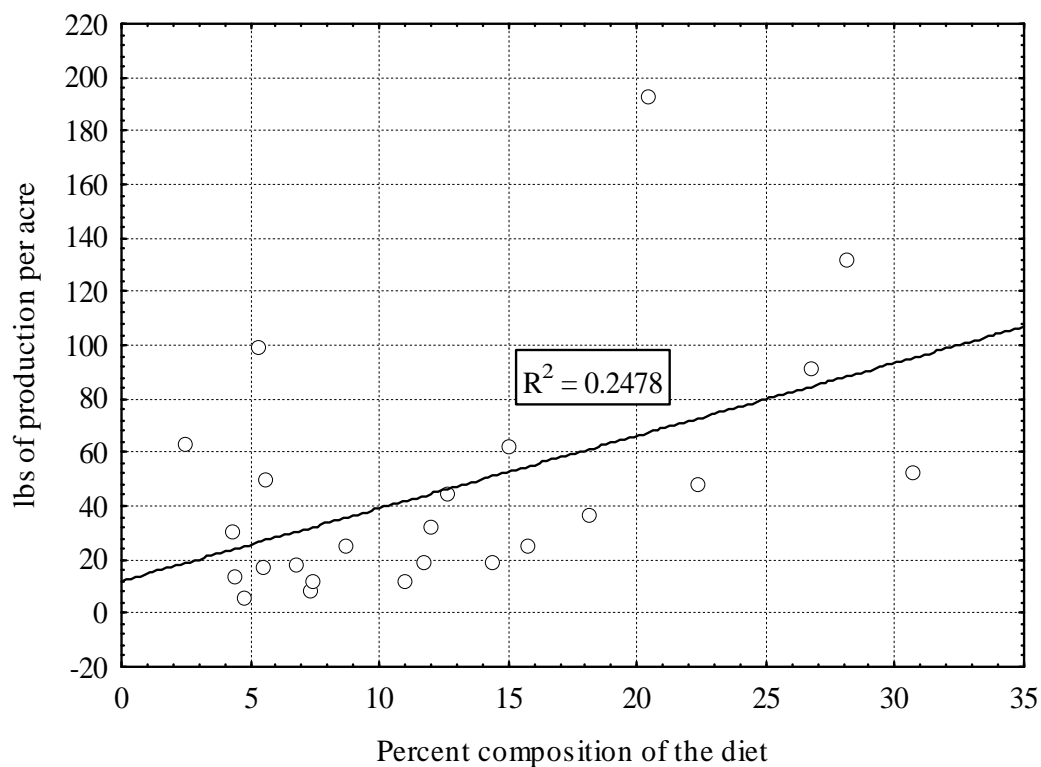
Table 4.1 Relative preference index for four species utilized by cattle during the dormant season grazing.

Pasture	Year	Species	lbs/acre	Plant Comp	Diet Comp	RPI 1
North	One	Nuttall's saltbush	36.6	0.42	0.224	0.528
		Creeping wildrye	11.43	0.13	0.110	0.830
		Squirreltail	30.23	0.35	0.043	0.123
		Winterfat	8.03	0.09	0.091	0.978
Middle	One	Nuttall's saltbush	52.07	0.52	0.428	0.826
		Creeping wildrye	25.1	0.25	0.158	0.632
		Squirreltail	17.83	0.18	0.068	0.383
		Winterfat	5.43	0.05	0.067	1.239
South	One	Nuttall's saltbush	47.67	0.45	0.366	0.808
		Creeping wildrye	24.7	0.23	0.087	0.371
		Squirreltail	13.57	0.13	0.044	0.341
		Winterfat	19.27	0.18	0.235	1.283
North	Two	Nuttall's saltbush	193.03	0.63	0.268	0.426
		Creeping wildrye	32.31	0.11	0.120	1.140
		Squirreltail	62.88	0.20	0.025	0.122
		Winterfat	18.69	0.06	0.154	2.529
Middle	Two	Nuttall's saltbush	132.17	0.43	0.489	1.131
		Creeping wildrye	62.35	0.20	0.150	0.735
		Squirreltail	99.21	0.32	0.053	0.163
		Winterfat	11.85	0.04	0.130	3.352
South	Two	Nuttall's saltbush	91.07	0.45	0.463	1.030
		Creeping wildrye	44.1	0.22	0.126	0.579
		Squirreltail	17.35	0.09	0.055	0.643
		Winterfat	50.16	0.25	0.096	0.388

Body Condition Scores

During the first year of the study body condition scores (BCS) differed between sampling date (p<0.001). Animals entered the South pasture with an average score of 4.7 and did not differ significantly (p>0.05) moving into the Middle pasture with an average score of 4.8. However, when the cattle were moved into the North pasture the average BCS dropped to 4.5 which was significantly different than the previous two scores (p<0.05). The average BCS remained at 4.5 for the remainder of the winter grazing period. Overall the average body condition score for the cow herd dropped from 4.7 to 4.5 over the course of the winter grazing period.

The second year of the study also displayed significant differences between sampling dates (p<0.001). Cattle started in the North pasture with a BCS of 4.6 and did not differ (p>0.05) upon moving into the Middle pasture with a body condition score of 4.7. Cattle entered the South pasture with an average score of 4.9 which was not different from the Middle pasture (p>0.05), but was different from when they started in the North pasture (p=0.001). The average cow herd BCS dropped to 4.4 during the South pasture grazing period, which was not significantly different then when they first entered the North pasture (p>0.05). However, the BCS was significantly lower than the 4.7 and 4.9 score recorded when the cattle entered the Middle and North pastures respectively (p<0.01). There was no difference in average BCS when tested between year one and year two (p=0.98).

Table 4.2 Average diet quality cattle would be receiving during the months they were grazing during year one and year two.

Year 1

Month	% CP	% NDF	% ADF	% DM	% Ash
November	7.63	62.04	38.11	96.82	22.05
December	6.31	63.33	37.37	97.05	17.77
January	7.06	63.7	36.71	96.18	16.89
February	5.74	60.82	38.43	92.43	

Year 2

Month	% CP	% NDF	% ADF	% DM	% Ash
December	5.16	64.16	39.33	94.06	10.99
January	4.35	66.73	41.14	94.19	12.36
February	5.33	62.98	37.92	93.6	12.75
March	5.2	62.75	38.7	94.5	13.69

Conclusions

Results of the two-year study indicate crude protein to be the limiting factor in the maintenance of livestock fat reserves during the dormant season. The importance of having shrubs such as winterfat and Nuttall's saltbush to supply needed protein is evident. The importance of the shrub component of the diet is further illustrated by the fact that 50% of the diet is composed of shrubs. The forage quality of Nuttall's saltbush was the biggest surprise in this study. The literature on forage quality of desert plant communities provides little if any information on this plant. Management factors such as stocking rate and intensity must be a consideration to insure cattle have adequate amounts of forage to meet nutritional needs and also to insure the health and productivity of the plant community. There was no difference in body condition scores between year one and year two, even though more forage was available in year two. This was likely due to the lower forage quality quantified in year two. However, since there were no differences

in average cow herd body condition scores between years, it is safe to assume that the

current plant community, under the current management, is capable of meeting the

nutritional needs of these mother cows.

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CHAPTER 5

CONCLUSIONS

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and David W. Bohnert.

The study area for this project is in a state of decline, not only from a range health standpoint, but also from a nutritional standpoint. Winterfat is slowly leaving the system and being replaced by Nuttall's saltbush, and weedy annuals. Winterfat offers site stabilization because it is a deep-rooted perennial, and its dense growth form protects the soil from wind and rain erosion. It also provides a large amount of litter back into the soil when it sets seed. Winterfat is one of the best quality forages that animals have to choose from during the dormant season. It is higher in crude protein than the grasses, and is fairly digestible. From the relative preference index it is also known that cattle select winterfat first the majority of the time. More production from this plant is what is currently needed. One way to increase production is to seed it back onto the site. With the success of this project it is evident that winterfat seedings can be successful. By double discing to mimic the tilling treatment used for this project, and broadcasting the seed, winterfat recruitment can be increased. However, the cost to do this seeding would be fairly substantial, and the availability of seed is not good. From a land management standpoint it must be decided if restoring winterfat back onto the site would be cost effective. If Nuttall's saltbush is able to fill the same environmental niche as winterfat, its increase may not be bad for site function. There would still be a deep-rooted perennial on site. Its growth form is not as dense to protect from erosion, and does not produce the amount of litter that winterfat does. From a nutritional standpoint Nuttall's saltbush is high in protein and reasonably digestible. However, the relative preference index ranked this plant third, suggesting they eat it mostly because it is what's available. With crude protein being a limiting factor in the available forage during the winter, the carrying

capacity of this winter range will keep declining. If this happens it will no longer be a cheap resource to replace hay supplementation. An increasing population of saltbush may be a way to maintain crude protein availability without costly inputs. Another option would be to seed squirreltail in large quantities all across the study site. It performed just as good with no seedbed preparation as it did with, and germinated well after being broadcasted. There would be minimal cost to method. By seeding squirreltail over the entire area the increase in weedy annuals, and possibly Nuttall's saltbush could be reduced. It is not as deep rooted as winterfat, but because the plants grow closer together may still offer good soil stability. Squirreltail's litter production would also increase soil fertility. Once the squirreltail is established plant community change may be halted until it becomes feasible to seed winterfat back into the system. The ability to restore the site back to a winterfat dominated community would benefit the function and stability of the site, but also insure that a protein source if available during the season these pastures are used. The needs of the ecological site would be met, as well as meeting the needs of the cattle and landowner.

Based on the diet presented and the lack of major change in cattle body condition, these animals are able to select a diet that meets their nutritional needs with the current plants community. However, based on the relative preference index, and the forage quality of winterfat, it becomes evident why winterfat is such an important part of the cattle diet during the dormant season. If money is available to restore this plant, and now that a technique is known how to do so, the range site and the cattle would benefit from increasing its abundance in these pastures.

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APPENDICES

APPENDIX A. MONTHLY FORAGE CALENDARS

Forage calender for year one.

Month	Species	% CP	% NDF	% ADF	% DM	% Ash
November	Nuttall's saltbush	8.57	58.88	33.74	96.99	16.27
	Winterfat	9.89	65.78	41.74	96.70	22.40
	Creeping wildrye	4.99	67.48	40.39	96.76	22.72
	Squirreltail	5.46	60.85	39.20	96.77	27.88
December	Nuttall's saltbush	7.00	61.80	33.90	97.43	10.25
	Winterfat	8.76	63.43	39.28	96.84	18.84
	Creeping wildrye	4.41	70.33	41.89	96.83	19.09
	Squirreltail	4.74	62.04	38.56	96.79	26.17
January	Nuttall's saltbush	10.05	57.19	30.01	96.01	12.60
	Winterfat	8.86	66.17	40.53	95.97	13.44
	Creeping wildrye	3.30	78.11	43.25	96.20	9.12
	Squirreltail	4.91	63.36	39.70	96.43	26.25
February	Nuttall's saltbush	9.77	55.16	30.01	90.62	11.59
	Winterfat	7.76	66.38	42.72	91.60	13.16

Month	Species					
April	Creeping wildrye	4.85	63.24	36.97	94.08	15.60
	Squirreltail	3.79	56.96	38.07	92.50	22.62
	Nuttall's saltbush	12.49	55.61	29.93	90.92	11.37
	Winterfat	11.62	64.36	39.82	92.03	12.62
May	Creeping wildrye	11.61	60.61	33.03	93.50	15.59
	Squirreltail	8.23	59.55	37.03	92.84	22.39
	Nuttall's saltbush	24.12	33.48	20.57	94.29	20.94
	Winterfat	19.89	57.50	32.80	92.85	17.72
	Creeping wildrye	17.47	61.19	30.58	95.80	10.82
	Squirreltail	17.86	52.86	27.79	94.95	12.91

Forage calender for year two.

Month	Species	% CP	% NDF	% ADF	% DM	% Ash
November	Nuttall's saltbush	7.71	54.63	29.71	94.20	11.19
	Winterfat	6.39	59.41	35.85	94.27	13.32
	Creeping wildrye	2.31	72.64	43.63	95.42	11.80

	Squirreltail	3.02	69.53	42.86	95.25	20.03
December	Nuttall's saltbush	7.64	56.19	31.11	93.31	9.99
	Winterfat	6.37	59.03	36.98	94.00	11.43
	Creeping wildrye	2.73	70.48	42.64	94.96	13.39
	Squirreltail	3.25	68.57	43.50	94.64	20.72
January	Nuttall's saltbush	8.11	55.95	31.15	93.54	10.45
	Winterfat	6.64	57.72	36.15	93.56	11.88
	Creeping wildrye	2.64	71.21	41.52	94.77	12.54
	Squirreltail	3.77	68.13	43.31	94.54	20.73
February	Nuttall's saltbush	7.19	58.33	32.99	92.93	9.41
	Winterfat	6.71	59.03	36.78	93.38	14.58
	Creeping wildrye	2.02	71.60	43.44	94.67	11.43
	Squirreltail	2.92	69.21	44.15	94.27	17.94
March	Nuttall's saltbush	8.03	55.03	30.81	94.30	10.74
	Winterfat	6.74	59.97	38.31	93.69	12.16
	Creeping	1.93	74.64	44.76	95.76	8.77

	wildrye				
	Squirreltail	2.91	67.54	44.21	94.67	18.34
April	Nuttall's saltbush	10.39	52.09	29.31	94.50	12.06
	Winterfat	11.62	58.73	36.51	93.63	9.90
	Creeping wildrye	1.74	69.53	42.85	95.49	12.26
	Squirreltail	5.38	63.01	41.52	94.82	22.23

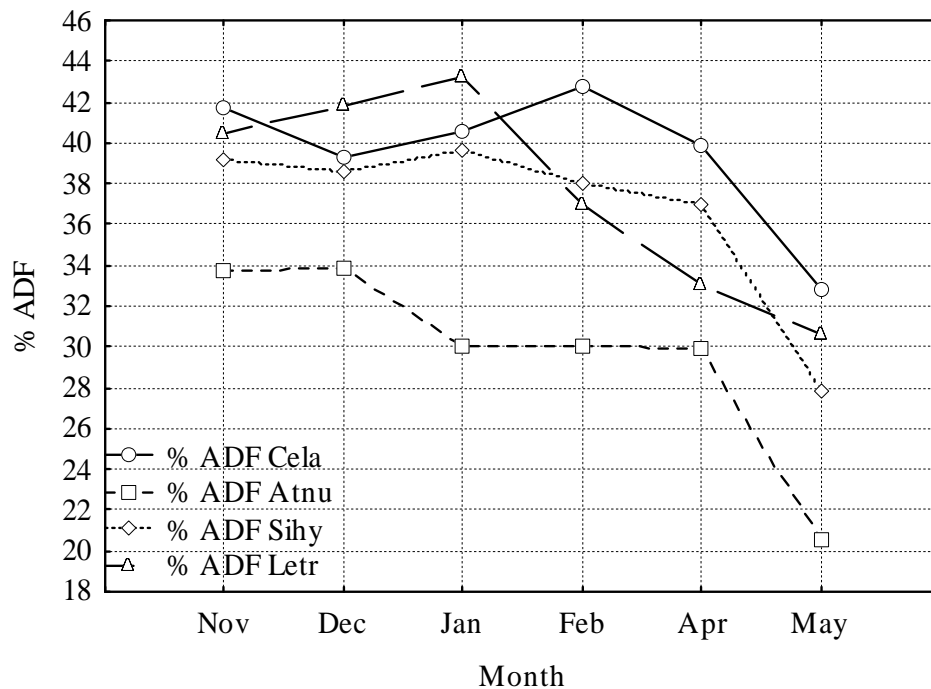**APPENDIX B. GRAPHS OF MONTHLY CRUDE PROTIEN, ADF, AND NDF**

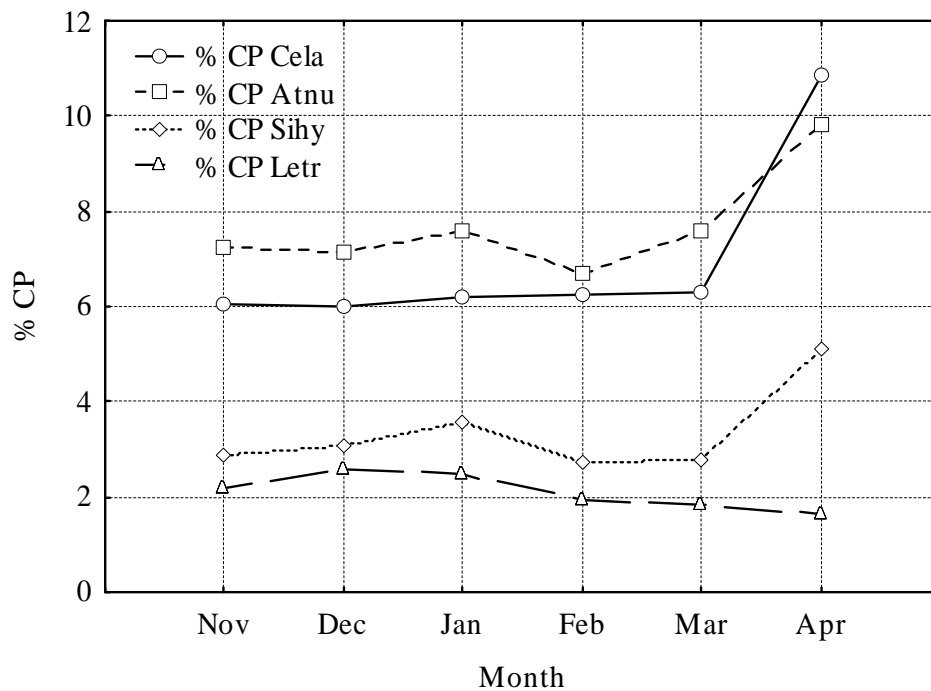Average crude protein by species for 2005.
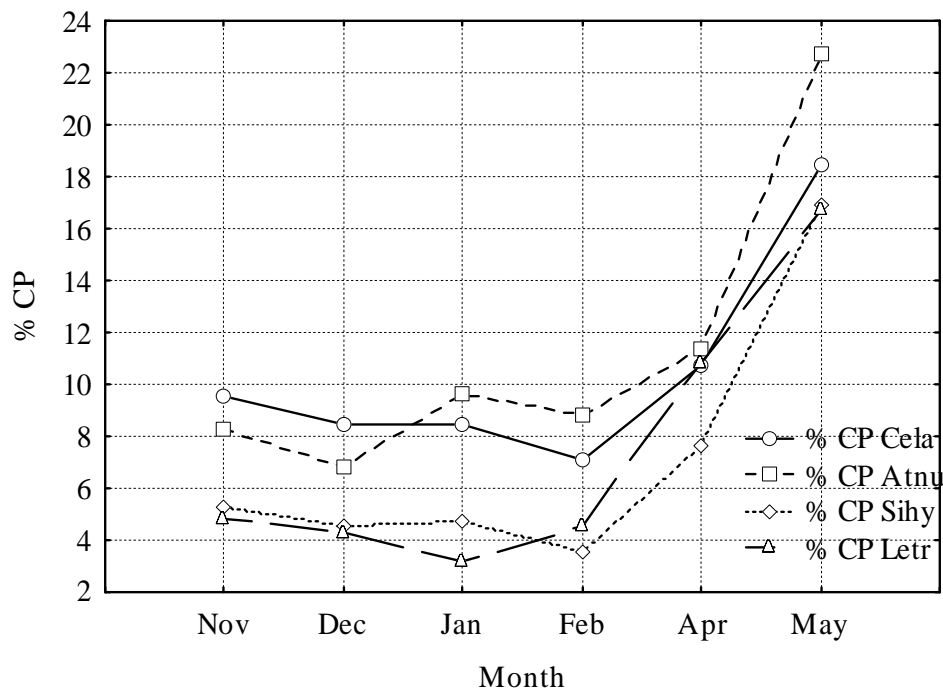
Average NDF by species for 2005.
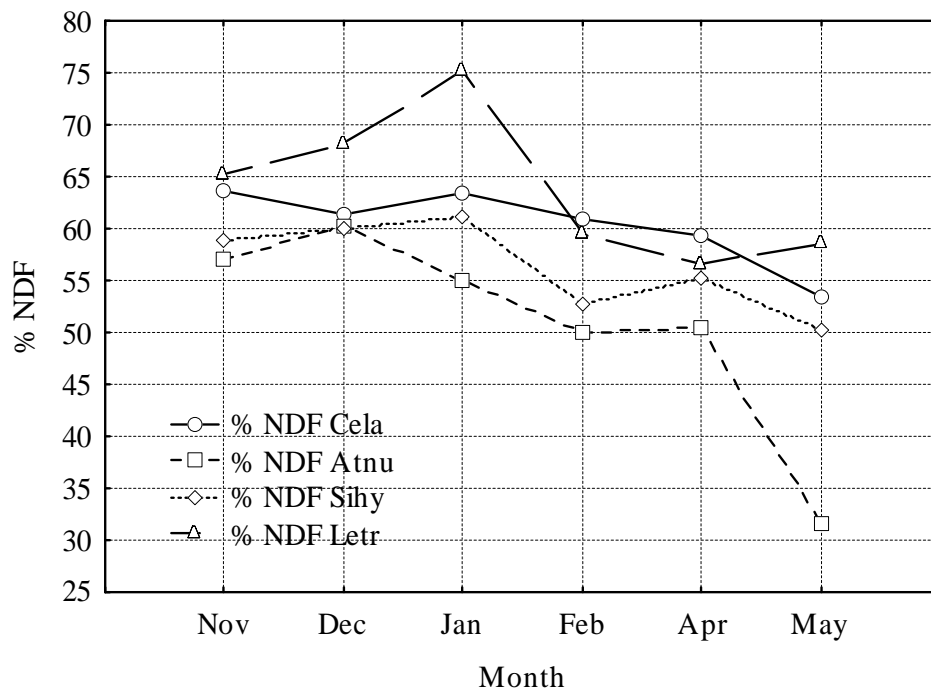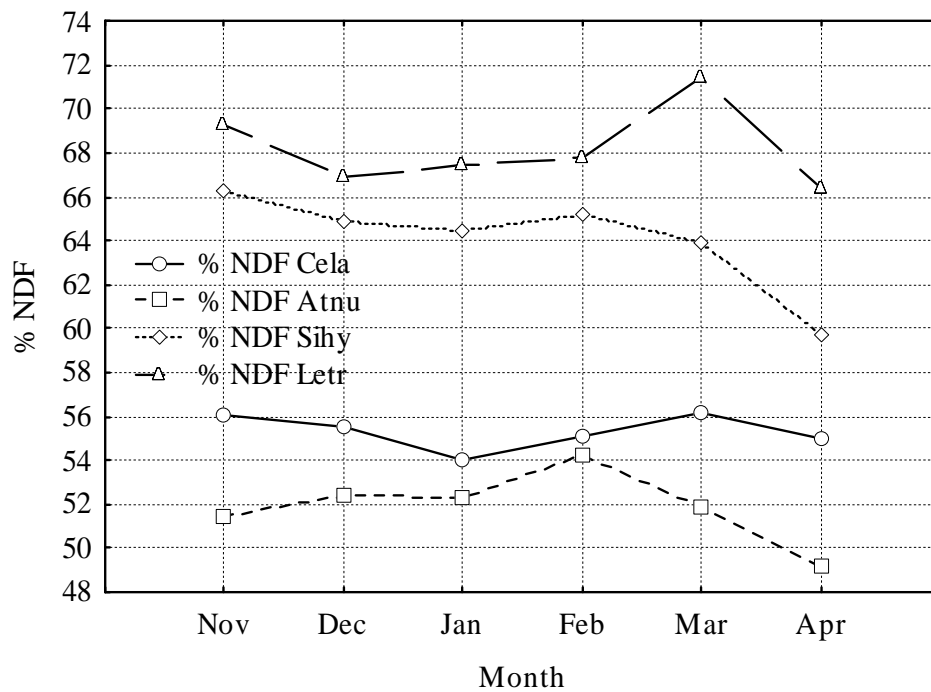
Average ADF by species for 2005.

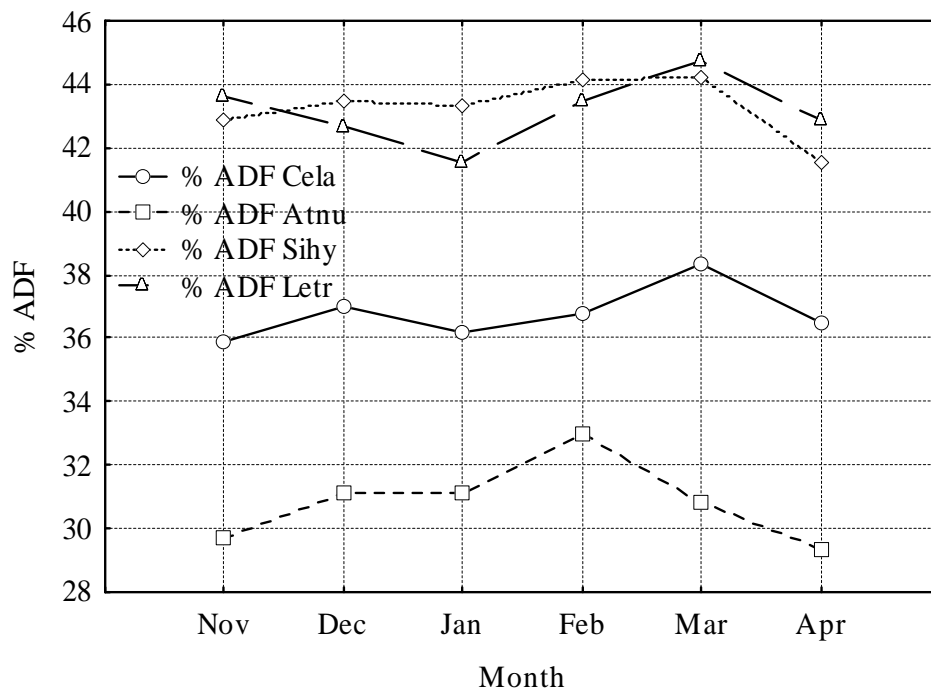Average crude protein by species for 2006.

Average NDF by species for 2006.

Average ADF by species for 2006.

APPENDIX C. TABLE OF DIET COMPOSITION BY SAMPLING DATE

Average diet composition by sample date, pasture, and species.

Date	Pasture	Species	% Comp	Date	Pasture	Species	% Comp
11/18/04	South	Creeping wildrye	8.73	12/13/05	North	Creeping wildrye	12.02
		Squirreltail	4.36			Squirreltail	2.51
		Nuttall's saltbush	22.40			Nuttall's saltbush	20.40
		Winterfat	14.41			Winterfat	11.74
		Other Grass	26.82			Other Grass	11.26
		Other Shrub	23.28			Other Shrub	15.59
12/18/04	South	Creeping wildrye	13.48			Crested wheatgrass	9.17
		Squirreltail	3.87			Kochia	17.31
		Nuttall's saltbush	26.02	01/25/06	North	Creeping wildrye	16.36
		Winterfat	6.73			Squirreltail	5.26
		Other Grass	25.75			Nuttall's saltbush	14.82
		Other Shrub	24.14			Winterfat	6.34
01/12/05	Middle	Creeping wildrye	15.80			Other Grass	20.26
		Squirreltail	6.80			Other Shrub	5.57
		Nuttall's saltbush	30.67			Crested wheatgrass	17.48
		Winterfat	4.78			Kochia	13.91
		Other Grass	27.90	02/01/06	Middle	Creeping wildrye	15.03
		Other Shrub	14.04			Squirreltail	5.29
01/19/05	Middle	Creeping wildrye	12.94			Nuttall's saltbush	28.14
		Squirreltail	6.16			Winterfat	7.42

Date	Location	Species	Value	Date	Location	Species	Value
		Nuttall's saltbush	29.98			Other Grass	17.79
		Winterfat	3.70			Other Shrub	26.32
		Other Grass	27.34	02/08/06	Middle	Creeping wildrye	13.02
		Other Shrub	19.89			Squirreltail	3.77
01/27/05	North	Creeping wildrye	11.04			Nuttall's saltbush	32.38
		Squirreltail	4.29			Winterfat	2.05
		Nuttall's saltbush	18.15			Other Grass	23.45
		Winterfat	7.33			Other Shrub	25.32
		Other Grass	17.16	02/22/06	South	Creeping wildrye	12.61
		Other Shrub	10.19			Squirreltail	5.51
		Crested wheatgrass	13.83			Nuttall's saltbush	26.72
		Kochia	18.01			Winterfat	5.60
02/27/05	North	Creeping wildrye	16.50			Other Grass	25.96
		Squirreltail	4.65			Other Shrub	23.60
		Nuttall's saltbush	14.33	03/22/06	South	Creeping wildrye	10.63
		Winterfat	7.84			Squirreltail	5.00
		Other Grass	18.68			Nuttall's saltbush	21.73
		Other Shrub	8.02			Winterfat	4.37
		Crested wheatgrass	14.71			Other Grass	33.42
		Kochia	15.28			Other Shrub	24.84