Special Report 897
June 1992

Ecology and Management of Rangeland Weeds

Agricultural Experiment Station
Oregon State University
in cooperation with
Agricultural Research Service, U.S. Department of Agriculture

DEDICATION

The faculty of the Department of Rangeland Resources dedicates the 1992 Range Field Day to Dr. Thomas E. Bedell. Tom is the Extension Rangeland Resources Specialist and retires June 30, 1992. Dr. Bedell has been a strong voice to help us all understand Oregon's natural resources and their uses. An internationally recognized professional and past-president of the Society for Range Management, he has dedicated his professional life to the education of all of us involved in the study and use of Oregon's rangelands. Tom, you have helped us all. We sincerely appreciate your leadership.

CONTENTS

AUTHORS

MICHAEL M. BORMAN
Range Scientist, BLM Cooperative Research Unit, Oregon State University

DOUGLAS E. JOHNSON
Associate Professor, Department of Rangeland Resources, Oregon State University

GARY L. KIEMNEC
Assistant Professor, Department of Crops and Soil Science, Oregon State University

WILLIAM C. KRUEGER
Head, Department of Rangeland Resources, Oregon State University

LARRY L. LARSON
Associate Professor, Department of Rangeland Resources, Oregon State University

MICHAEL L. MCINNIS
Assistant Professor, Department of Rangeland Resources, Oregon State University

RICHARD F. MILLER
Professor, Eastern Oregon Agricultural Research Center, Oregon State University
Burns, Oregon

RONALD T. MOBLEY
Superintendent, Southern Oregon Agricultural Experiment Station, Oregon State
University, Medford, Oregon

LESLEY RICHMAN
Research Assistant, Department of Rangeland Resources, Oregon State University

DAN SHARRATT
Agronomist, Oregon Department of Agriculture, Union, Oregon

ROGER SHELEY
Research Assistant, Department of Rangeland Resources, Oregon State University

TONY SVEJCAR
Range Scientist, USDA - ARS, Eastern Oregon Agricultural Research Center, Burns,
Oregon

FOREWORD

The encroachment of alien weeds onto western rangelands is one of the most perilous and perhaps least recognized problems facing land managers today. Oregon rangelands are under siege from ever-increasing numbers and distribution of exotic weeds. They threaten Oregon's economy and environmental quality by reducing livestock forage, wildlife habitat, watershed potential, recreational opportunities, and property values.

Successful weed management programs must be based on sound ecological principles. There are three components of a successful program on sites identified as being threatened by weeds:

(1) **Reduce** the competitive ability of the weed
(2) **Replace** the weed species with more desirable vegetation
(3) **Maintain** plant communities in high ecological condition

Weeds become established because they have evolved life strategies that allow them to capture resources (light, water, nutrients and space) in sufficient quantities to successfully complete their life cycles, especially on distrubed sites. Scientists study the ecology of weeds to learn how to exploit weak links in their life cycles for control using integrated methods of herbicide application, biological agents, and mechanical techniques.

However, control of weeds without replacement and maintenance of more desirable plant communities can only produce short-term gain, and retrogressive succession will result in re-invasion of weeds. In Oregon, rangeland scientists have sought methods of establishing and maintaining plant communities that will resist weed invasion.

The success of this approach is dependent upon our ability to incorporate ecological principles and vegetation management into weed control programs. The purpose of this Range Field Day is to introduce you to information, ideas, and activities that are currently being developed in Oregon to address the problem of weed encroachment.

Larry L. Larson
    Associate Professor,
    Rangeland Resources
    Oregon State University

Michael L.McInnis
    Assistant Professor,
    Rangeland Resources
    Oregon State University

LIFE STRATEGY ATTRIBUTES OF YELLOW STARTHISTLE: A DISCUSSION

Roger Sheley and Larry L. Larson

INTRODUCTION

Yellow starthistle (Centaurea soltitialis L.) is a winter-hardy annual introduced before 1900 into the western United States from the Mediterranean Basin (Roche and Talbott, 1986). Maddox and Mayfield (1985) report that the plant was brought into the United States on numerous occasions and that starthistle was most likely introduced as a contaminate of alfalfa (Medicago sativa L.) seed. Today, estimates of yellow starthistle infestation exceed 3 million ha in California (Maddox 1979, Maddox and Mayfield 1985) and 0.25 million ha in the Pacific Northwest (Talbott 1987).

Starthistle is a formidable competitor in new grass seedings. Research by Larson and McInnis (1989a) indicate that site manipulations associated with the planting of grass stands often favor starthistle establishment. For example, increases in soil nutrient availability resulted in a 214 percent increase in established starthistle plants when applications of 30/13/0 kg N/P/K per ha were made to new grass seedings. Soil disturbances such as drilling grass seed also improved the seedbed characteristics for starthistle, doubling the number of established plants. Without mitigation, these conditions resulted in a two-thirds reduction in grass biomass and continued site domination by starthistle.

Starthistle encroachment can also be a problem in established plant communities. Larson and McInnis (1989b) studied starthistle seedling establishment in two year old stands of grass (18 cm drill row spacing). Starthistle seedling emergence was observed in all grass stands but was less than half that observed on bare soil. Variations in starthistle survival were attributed to the degree of growth cycle overlap that existed between the starthistle and grass.

The information cited above illustrates the competitive nature of starthistle in range and cropland situations. To begin to understand the process of starthistle encroachment, it is necessary to look at the life strategy attributes that result in encroachment success. The purpose of this paper will be to provide a discussion of some of the attributes that make starthistle a successful alien species. In general, we can state that much of the success of yellow starthistle can be attributed to a high level of seed production and an ability to pre-empt resource utilization by other species. However, the process of starthistle encroachment is much more complex than this simple statement implies.

DISCUSSION

Seed Production

Yellow starthistle is an annual plant and is solely dependent upon seed reproduction for its maintenance within plant communities. Starthistle produces a large seed crop which increases its ability to saturate the area surrounding the parent plant with seed. In addition, starthistle has a two-phase seed dispersal pattern that disperses seed through time, once again increasing the likelihood of mature seed landing in an environment favorable to germination. Starthistle produces plumed and plumeless seed. Plumed seed are produced in the outer portion of the seed head and are dispersed away from the parent plant through wind action during the summer. Plumeless seeds are produced in the center of the seed head, are not released until winter, and then drop in the immediate vicinity of the parent plant.

For example, we observed the production of 21,000 starthistle seeds/m² in an established starthistle/cheatgrass community. The seed crop contained approximately 70 percent plumed seed (15,000) and 30 percent plumeless seed (6,000). The plumed seed were released in July and August, while plumeless seed were dispersed in November and December. The production of a large number of starthistle seed substantially increases the probability of seeds landing on sites where germination can take place.

Seed Germination

Yellow starthistle seed germinates and initiates root growth over a wide range of conditions. Starthistle seeds have germination rates of 80 to 90 percent and can germinate during the fall, winter, or spring. Seed germination occurs rapidly, often within 24 to 48 hrs, under a range of soil moisture conditions (0.5 to 0.0 -Mega Pascal). Initial root growth by germinated seed is tolerant of saline seedbed conditions (maximum electrical conductivity tested 12 ds/m) and root elongation is relatively unaffected until moisture stress exceeds 1.0 -Mega Pascal.

Plumed and plumeless starthistle seed do not germinate at an equal rate in the field. Our field germination and life history studies indicate that the soil seed bank for starthistle contains approximately 14 percent of the annual seed production. The seed bank is dominated with plumeless seed.

The seed germination characteristics of starthistle are well suited for the climate of the Pacific Northwest. Starthistle seeds germinate during the fall, winter, or spring depending upon yearly climatic conditions. Furthermore the process of germination and initial root growth does not require an extended period of soil moisture or non-saline seedbed conditions. These starthistle attributes result in a distinct advantage over many species that germinate only in the spring, since starthistle will tend to be the first species to occupy available sites within the plant community.

Initial Starthistle Establishment

Starthistle seedlings become established as a taprooted rosette. This growth form is adapted to the cool growing conditions that prevail during late winter and early spring in the Pacific Northwest. The rosette growth form places the leaves of starthistle near the soil surface where the best conditions for survival and photosynthesis are found. During this stage of growth, starthistle seedlings allocate much of their chemical energy toward the development of a taproot that is capable of extracting deep soil moisture later in the growing season.

A growth study was conducted utilizing early spring climatic conditions. The first 10-15 days of growth resulted in the development of a leaf rosette and a 15 cm taproot. We believe the rosette development is critical to the plant at this stage of growth because of the small size of starthistle seed and its subsequent lack of stored food to support initial growth. Penetration by the starthistle taproot exceeded 75 cm after 40 days of growth. The importance of this attribute to starthistle success become apparent as community resources become limited during the drought-prone summer months.

CONCLUSION

As stated in the foreword, weed management programs must include life strategy information to predict the response of desirable and undesirable species in specific management situations. This is true whether a land manager is faced with exotic weed encroachment in a revegetation project or in an established native plant community. In either case, land manager access to life strategy information is the first step toward the selection of the proper course of action.

LITERATURE CITED

Larson, L. and M. McInnis. 1989a. Response of yellow starthistle and grass biomass to grass, picloram, and fertilizer combinations. Weed Tech. 3:497-500.

Larson, L. and M. McInnis. 1989b. Impact of grass seedlings on establishment and density of diffuse knapweed and yellow starthistle. Northwest Science 62:162-166.

Maddox, D. M. 1979. The knapweeds: their economics and biological control in the western states, USA. Rangelands 1:139-141.

Maddox, D. and A. Mayfield. 1985. Yellow starthistle infestations are on the increase. Calif. Agric. 39(11-12): 10-12.

Roche, B. F., Jr., and C. J. Talbott. 1986. The collection history of *Centaureas* found in Washington state. Agric. Res. Cent., Wash. State Univ., Pullman.

VEGETATION IMPROVEMENTS IN THE LOWER ELEVATION ZONES OF JACKSON COUNTY, OREGON

Douglas E. Johnson, Michael B. Borman and Ronald T. Mobley

INTRODUCTION

Landowners in southwestern Oregon are actively seeking ways of reestablishing perennial grasses on oak savannas. Currently these ranges are dominated by annual grasses and forbs. Yellow starthistle (*Centaurea solstitialis* L.) is one of the most serious weeds on the foothills of the Rogue River basin. It is a major component of the herbaceous vegetation in many areas and may account for 75 percent or more of the aboveground production. Starthistle continues to expand its range. Several years ago, researchers from Oregon State University (OSU) began a series of experiments designed to increase our knowledge of the biology of this plant. We also wanted to identify perennial grasses that could survive on the low elevation foothills of southwestern Oregon, out-compete starthistle, and help to control it. Observation plots installed in 1984 provided enough positive results that more intensive studies were initiated in 1986.

For the first set of studies, perennial grasses were transplanted into a weed-free environment. After a growing season for establishment, annual weeds were allowed to reinvade which permitted evaluation of mature, complete stands of grasses for persistence, production, and competitiveness. Positive results from the first set of studies prompted us to initiate additional studies designed to evaluate herbicide use and seeding techniques that aid establishment of perennial grasses. Research efforts have been confined to perennial species that are competitive in the original transplanted mature stands.

PURPOSE

The first experiment was designed to evaluate the longevity, productivity, and competitiveness of established stands of ten species of perennial grasses on the foothills of southwestern Oregon when subject to invasion by annual grasses and yellow starthistle.

A second experiment (utilizing small plots) was designed to determine if a spring application of selected herbicides could be used to promote the establishment of newly seeded Palestine orchardgrass.

A third experiment (field size plots) also included herbicide treatments to enhance establishment. It was necessary to install larger scale seedings to get a better understanding of the population dynamics within the establishing plant communities and to determine if conversion from annual weeds to perennial grasses was practical for local landowners who would bear the cost.

PLANT MATERIALS

Ten species or varieties of perennial grasses (including two local natives) were evaluated:

Idaho fescue	*Festuca idahoensis* Elmer (native)
Junegrass	*Koeleria cristata* (L.) Pers. (native)
Tall Wheatgrass	*Agropyron elongatum* (Host.) Beauv. var Alkar
Intermediate Wheatgrass	*Agropyron intermedium* (Host.) Beauv. var Oahe
Intermediate Wheatgrass	*Agropyron intermedium* (Host.) Beauv. var Rush
Tall Fescue	*Festuca arundinacea* Schreb. var Alta
Perennial Ryegrass	*Lolium perenne* L. var Grimalda
Berber Orchardgrass	*Dactylis glomerata* L. var Berber
Palestine Orchardgrass	*Dactylis glomerata* L. var Palestine
Paiute Orchardgrass	*Dactylis glomerata* L. var Paiute

STUDY SITES

Two study sites were identified in the fall of 1986 in Jackson County, Oregon. The first site is located on the Ferns Ranch, 3 km east of Phoenix on a Darrow silty clay loam soil. It is west facing with a slope of 25 percent. The second site is located on the Dauenhauer Ranch 5 km north of Ashland, Oregon on a Carney clay soil. It is southwest facing with a 5-10 percent slope. Mean annual precipitation for these sites is approximately 500 mm; however, for the duration of the study precipitation averaged approximately 400 mm on an agricultural year basis.

RESULTS AND DISCUSSION

Many of the species that were originally deemed appropriate for restoring foothill rangelands did not survive on these sites when faced with competition from annual grasses and yellow starthistle. Five of the perennial species transplanted either were not adapted to these sites or could not withstand competition from resident plants (Figure 1). The native junegrass did not maintain a monocultural stand even though it was transplanted from adjacent rangelands where it was relatively common. Perennial ryegrass, tall fescue, Paiute orchardgrass lost vigor and site dominance by the end of the second year. It also became apparent soon after the experiment began that the clayey Dauenhauer site is harsher than the clay loam Ferns site.

7

Several of the transplanted species, however, show promise for restoring at least some of the foothills. Local Idaho fescue and Berber Orchardgrass appear to be the best adapted to the Dauenhauer site (Figure 2). Almost all of the mortality in the Idaho fescue occurred during the 1990-91 growing season. Berber orchardgrass continues to persist with better than 90 percent survival.

Five species were able to survive with varying degrees of success on the clay loam soil at the Ferns Ranch. Mortality of tall wheatgrass, Palestine orchardgrass, intermediate wheatgrass var. Oahe, Idaho fescue and Berber orchardgrass was much lower than at Dauenhauer's, as shown in Figure 3. Each of these species had less than 10 percent mortality.

Biomass and cover of these perennials is also reflective of their success at the Ferns site. Yields of the five best adapted species in late June 1991 varied from just over 1,000 kgDM/ha to over 3,600 kgDM/ha (Figure 4). Foliar cover values followed a similar pattern with Idaho fescue and Berber orchardgrass maintaining approximately 50 percent ground cover (Figure 5).

Throughout the course of this experiment these plants have consistently produced more forage that could be used by wildlife and domestic stock than the annual plant dominated adjacent rangelands or the control subplots. The green feed period has also been increased because these plants begin growth earlier in the fall, if rains are favorable, and continue to grow later into the summer. Preliminary work on the levels of crude protein in the plant tissue indicates that the perennials could be an important source of protein throughout the fall, winter, and summer. While plants of Idaho fescue, Berber orchardgrass, and Palestine orchardgrass were robust and vigorous at the Ferns Site, at the Dauenhauer site they were relatively weak. Idaho fescue would be overtopped by starthistle by mid-summer yet the perennial produced large amounts of biomass. This last year Idaho fescue suffered over 20 percent mortality and the dry matter production fell from 3,000 kgDM/ha in 1990 to 850 kg/ha in 1991. Only Berber orchardgrass was able to maintain a stand after five years. In 1991 it produced 2,500 kgDM/ha.

Yellow starthistle density was suppressed by the perennial grasses at the Ferns site (Figure 6). The open control plot contained about 120 plants/m^2 as compared to less than 20 plants/m^2 on plots with competition from perennial grasses. It should be remembered that only a few plants need to be present to have a problem.

Perennial grasses also suppressed growth of yellow starthistle. Each of the grasses shown in Figure 7 was effective in reducing starthistle; in some cases, only minor amounts were present. All perennials that were able to persist reduced starthistle considerably, however, those subplots with Berber orchardgrass and Idaho fescue best dominated the site. It appears that perennial grasses are competing directly with this weed. Perennial grasses extend their growth periods further into the summer and tap deeper layers of soil for water than do annual grasses. Starthistle remains green late in the year and therefore is more

vulnerable to perennial grasses than to the annual grasses normally found on these sites. Cover of yellow starthistle follows an identical pattern to that of aboveground biomass (Figures 7 and 8). It appears from these data that starthistle is not a particularly aggressive competitor but is opportunistic. The combination of annual grasses and yellow starthistle can be formidable. Annual grass grows rapidly when soil moisture is available but it only depletes the surface horizons. Yellow starthistle taps deep moisture that is unavailable to the annual grasses and completes its growth in late spring and summer. In reality, a perennial grass faces competition from a complex of annual species that have evolved mechanisms which permit coexistence.

Perennial grasses on the Ferns site have been able to reduce the production of annual grasses (Figure 9). Berber orchardgrass, Palestine orchardgrass, and Idaho fescue seem to be somewhat better at this than the wheatgrasses. This is probably because the wheatgrasses begin their growth later in the spring after the annuals have begun to mature. In either case, production of annual grasses was 40 percent or less when in competition with perennial grasses than without as represented by the control plots. Total production on all plots is similar with the exception of Idaho fescue at Ferns (Figure 10).

SMALL PLOT HERBICIDE STUDY

The small plot herbicide study was done at the Ferns Ranch site. The vegetative community was nearly a solid stand of yellow starthistle with small patches of medusahead, ripgut brome, and buckhorn plantain present. The plot area was burned in the fall and Palestine orchardgrass was broadcast seeded followed by raking to cover the seed. Herbicides were applied when the majority of the orchardgrass seedlings were at a 4-leaf stage during late spring. Herbicides applied were: clopyralid (Lontrel), dicamba (Banvel), picloram (Tordon), triclopyr (Garlon), 2,4-D, and a combination of clopyralid and 2,4-D.

The study demonstrated the effectiveness of spring application of picloram and clopyralid in controlling Yellow Starthistle (Figures 11 and 12) and allowing establishment of orchardgrass seedlings (Figures 13 and 14).

LARGE SCALE SEEDINGS

The field size seeding study was conducted at the Ferns Ranch site. Five herbicide treatments were applied. They consisted of Atrazine applied before planting, tordon applied before planting, Atrazine applied before planting followed by a spring 2,4-D treatment, 2,4-D applied in the spring, and a control. The plots were fall seeded with a rangeland drill to Palestine orchardgrass.

9

Preseeding treatment with picloram and with atrazine + 2,4-D was effective in suppressing yellow starthistle. The two treatments also promoted orchardgrass establishment and growth (Figure 15) except in patches where annual grasses (primarily ripgut brome and medusahead) were dominating the site.

Ripgut brome, the most prevalent annual grass on the site, was generally unaffected by the herbicide treatments with the exception of atrazine. By the third year after treatment annual grasses again were present on atrazine plots (Figure 16). 2,4-D effectively suppressed the annual forbs and released ripgut brome which doubled its biomass. Orchardgrass establishment and growth was not significantly improved by herbicide treatment on patches dominated by ripgut brome.

CONCLUSIONS

Competition is a major component of yellow starthistle control on the study reported here. Several perennial grasses show promise for restoring foothills, and controlling yellow starthistle in Jackson County, Oregon on a site specific basis. Local Idaho fescue, Berber orchardgrass, Palestine orchardgrass, Alkar tall wheatgrass and Oahe intermediate wheatgrass have all been able to persist for five years after transplanting on a loamy soil. On a clay soil only Idaho fescue and Berber orchardgrass have persisted and they lack vigor. Weeds, both annual grasses and yellow starthistle, are present even in vigorous plantings.

When herbicides are used in combination with seeding, several herbicides can reduce the density, cover and biomass of yellow starthistle. To improve the chance of a successful seeding it is necessary to control starthistle plants early after seeding and maintain control for a complete growing season. Orchardgrass stands will develop more rapidly when seeded in conjunction with picloram or clopyralid.

Once established seeded orchardgrass can reduce the biomass and cover of yellow starthistle, however the weed is present even in vigorous plantings. It is therefore important that pastures be managed to maintain grass vigor and health.

ACKNOWLEDGEMENTS

10

LITERATURE CITED

Pechanec, J.F. and G.D. Pickford. 1937. A weight estimate method for the determination of range or pasture production. J. Am. Soc. Agron. 29:894-904.
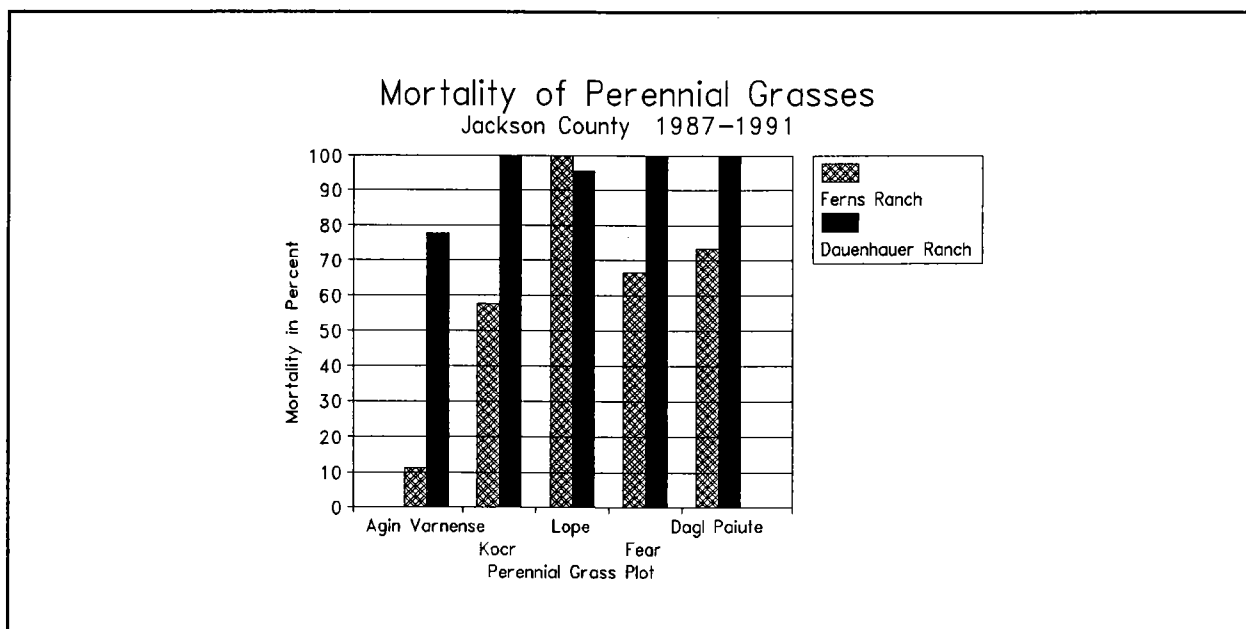
Figure 1. Mortality after five years of perennial grasses transplanted into two sites in Jackson Co. Oregon. Agin Varnense = Rush wheatgrass, Kocr = junegrass, Lope = perennial ryegrass, Fear = tall fescue, Dagl Paiute = Paiute orchardgrass.
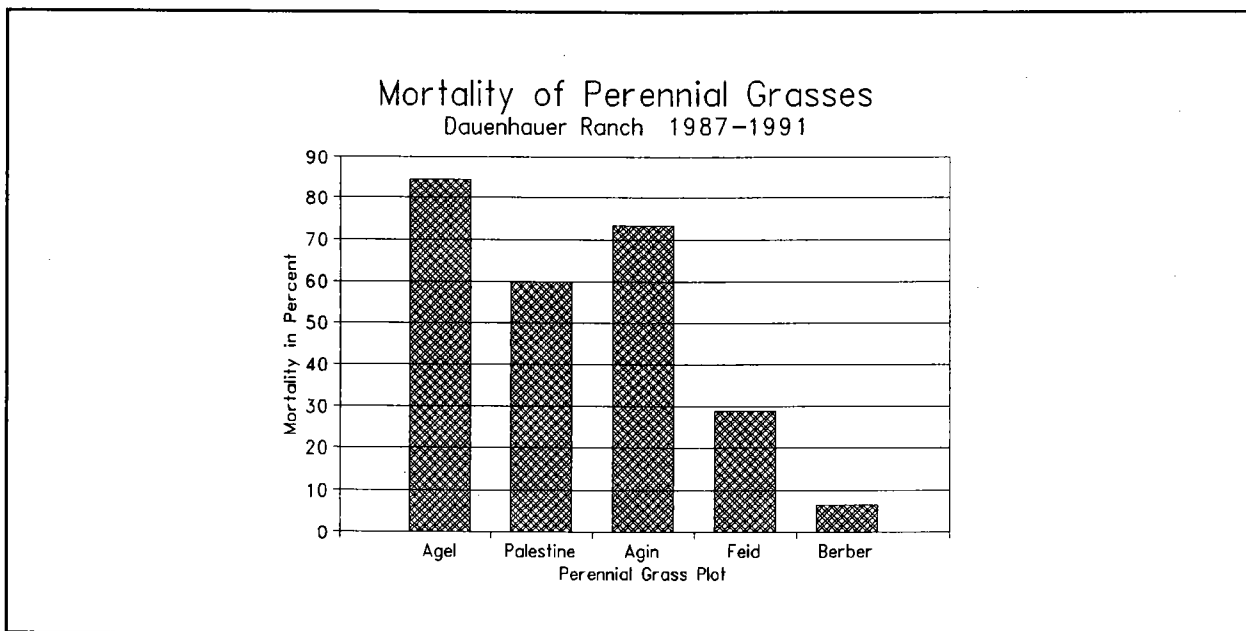

Figure 2. Mortality of selected species of perennial grasses transplanted at the Dauenhauer Ranch site. Agel = tall wheatgrass, Palestine = Palestine orchardgrass, Agin = intermediate wheatgrass, Feid = Idaho fescue (local), Berber = Berber orchardgrass.
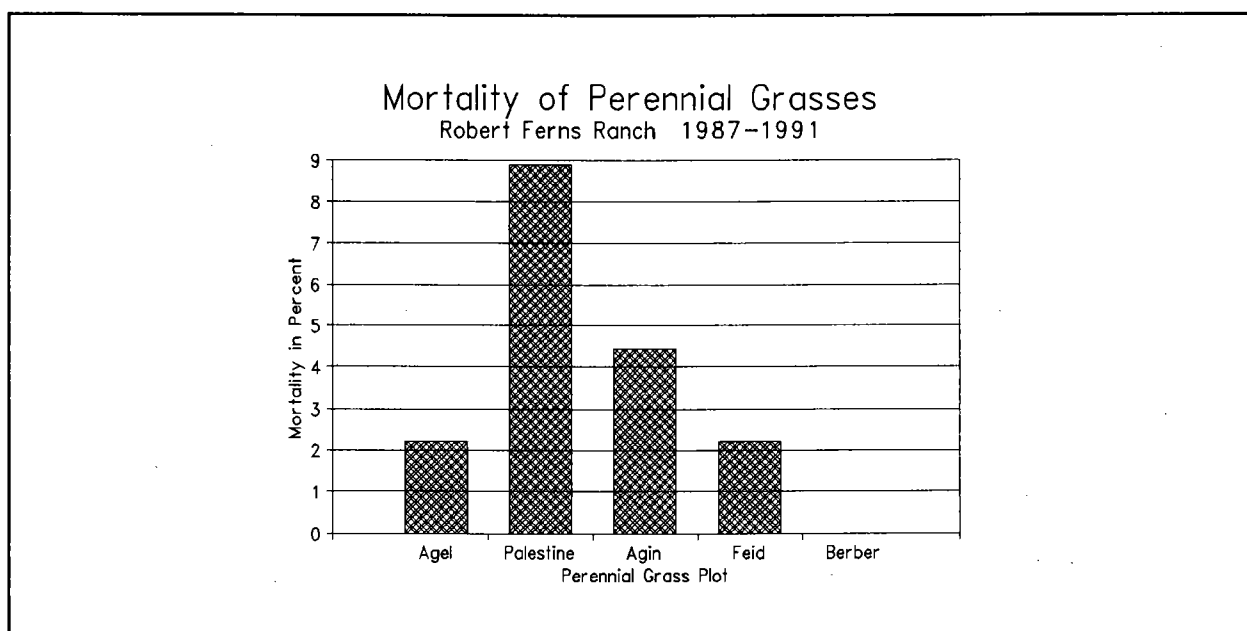
Mortality of Perennial Grasses
Robert Ferns Ranch 1987–1991

Figure 3. Mortality of selected perennial grasses at the Ferns Ranch site after 5 years.

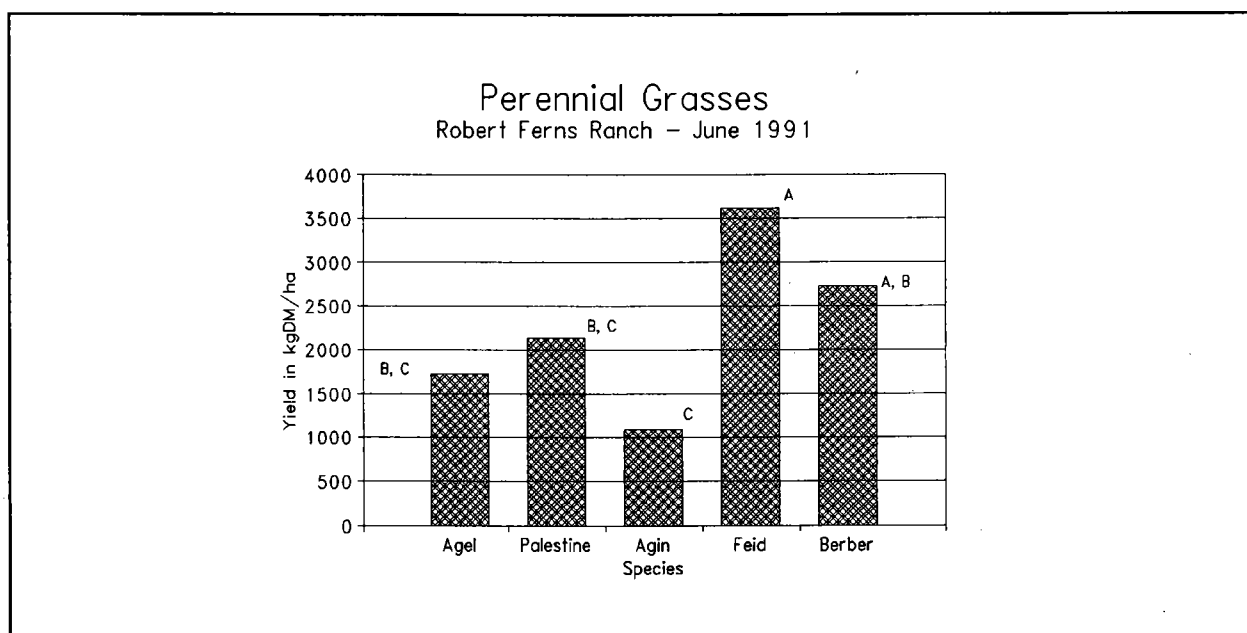**Perennial Grasses**
Robert Ferns Ranch – June 1991

Figure 4. Above ground dry biomass of selected perennial grasses in June 1991. Species with the same letter are not statistically different at p = 0.05%.

Cover of Perennial Grasses
Robert Ferns Ranch — June 1991

[Bar chart: "Cover in Percent" (y-axis, 0 to 60) vs "Species" (x-axis). Bars: Agel ≈ 19 (C, D), Palestine ≈ 30 (B, C), Agin ≈ 10 (D), Feid ≈ 51 (A), Berber ≈ 44 (A, B)]
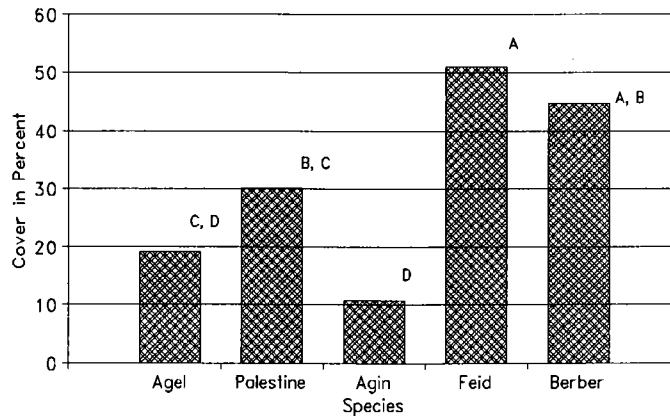
Figure 5. Cover of perennial grasses at the Ferns Ranch site in June 1991. Bars with the same letter are not statistically different at p = 0.05%.

Density of Starthistle
Robert Ferns Ranch — June 1991

[Bar chart: "Number per Square Meter" (y-axis, 0 to 140) vs "Perennial Grass Plot" (x-axis). Bars: Agel ≈ 16 (B), Palestine ≈ 7 (B), Agin ≈ 22 (B), Feid ≈ 10 (B), Berber ≈ 4 (B), Open ≈ 123 (A)]
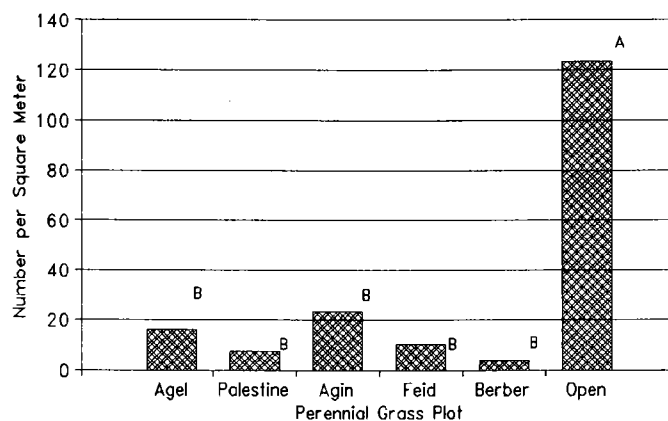
Figure 6. Density of yellow starthistle at the Ferns Ranch site. Agel = tall wheatgrass, Palestine = Palestine orchardgrass, Agin = intermediate wheatgrass, Feid = Idaho fescue, Berber = Berber orchardgrass, Open = control (no perennial grass)
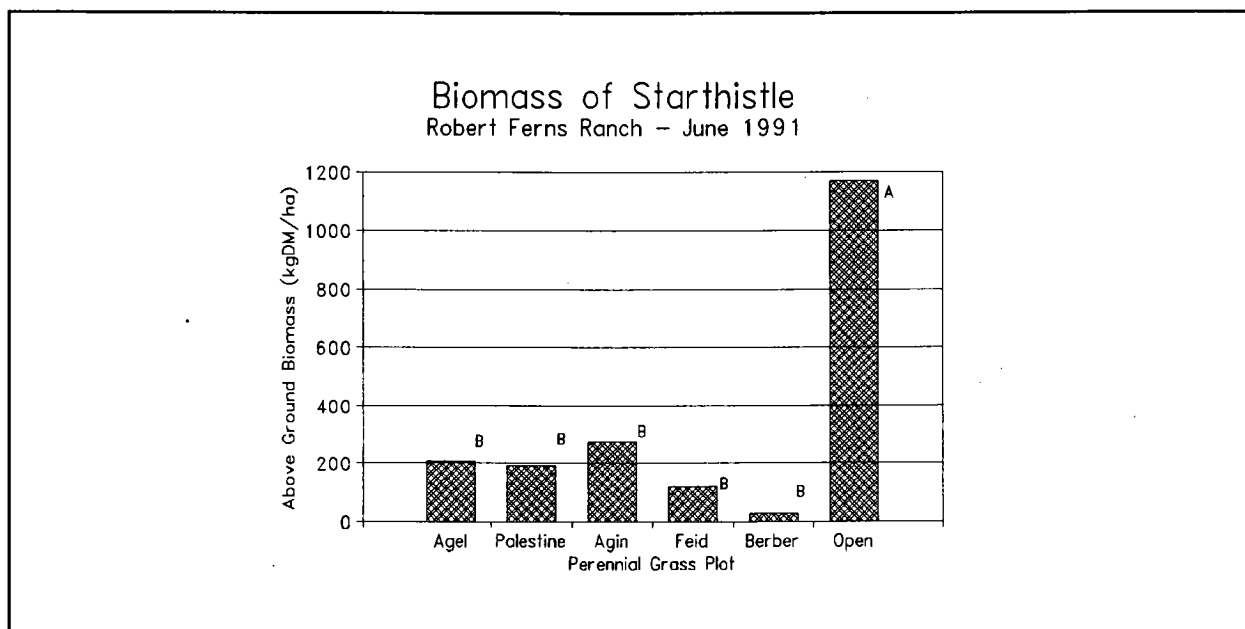
14

Figure 7. Above ground biomass of yellow starthistle in selected perennial grass subplots five years after establishment (June 1991). Bars followed by the same letter are not different at p = 0.05%.
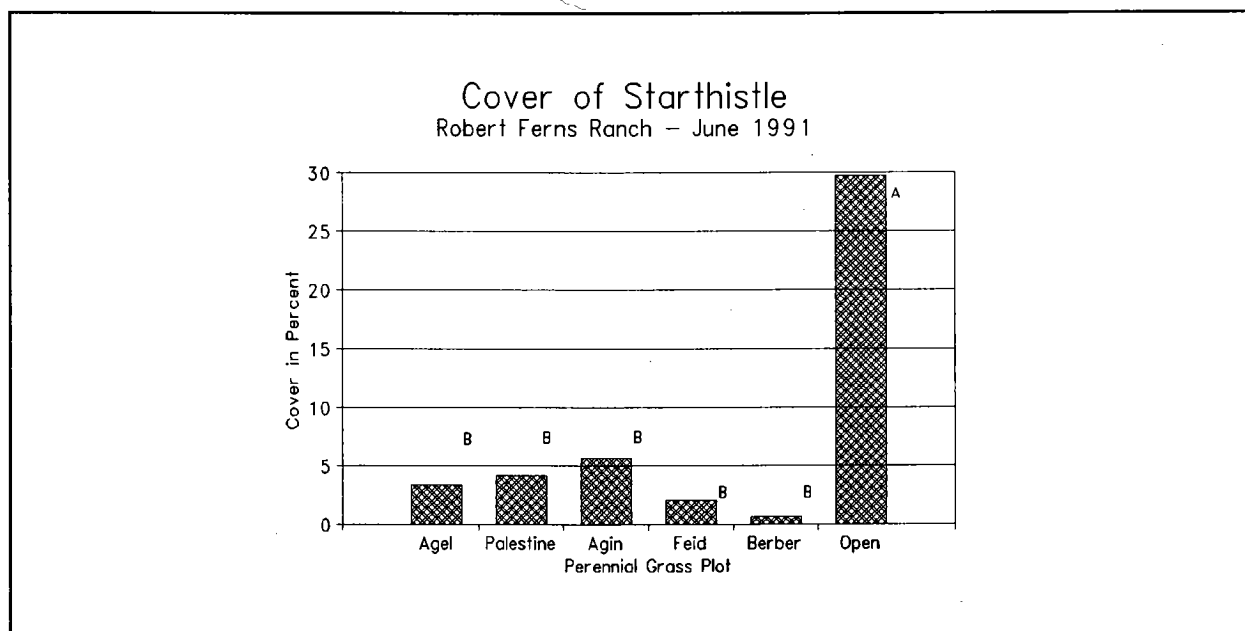

Figure 8. Cover of starthistle on the Ferns Ranch site in June 1991.
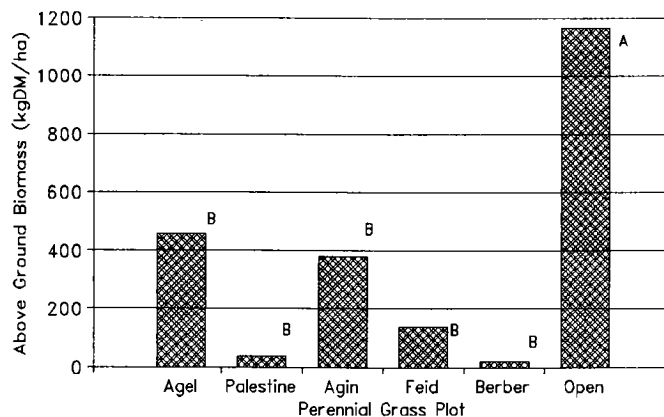
Figure 9. Above ground biomass of annual grasses on subplots of selected perennial grasses five years after establishment. Bars with the same letter are not different at p = 0.05%.
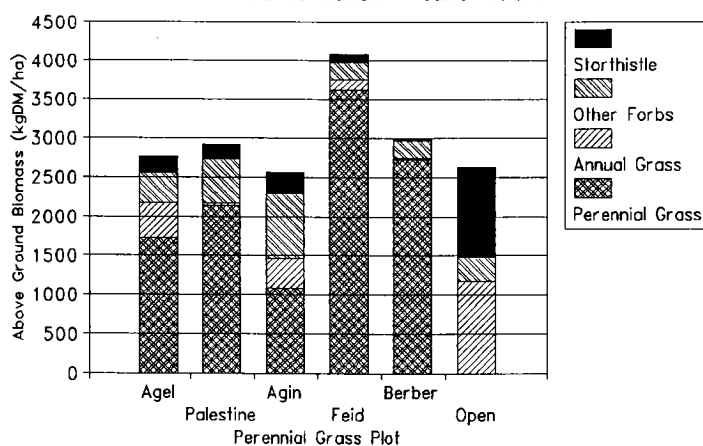

Figure 10. Total above ground dry biomass of selected perennial species at the Ferns Ranch site in June 1991.
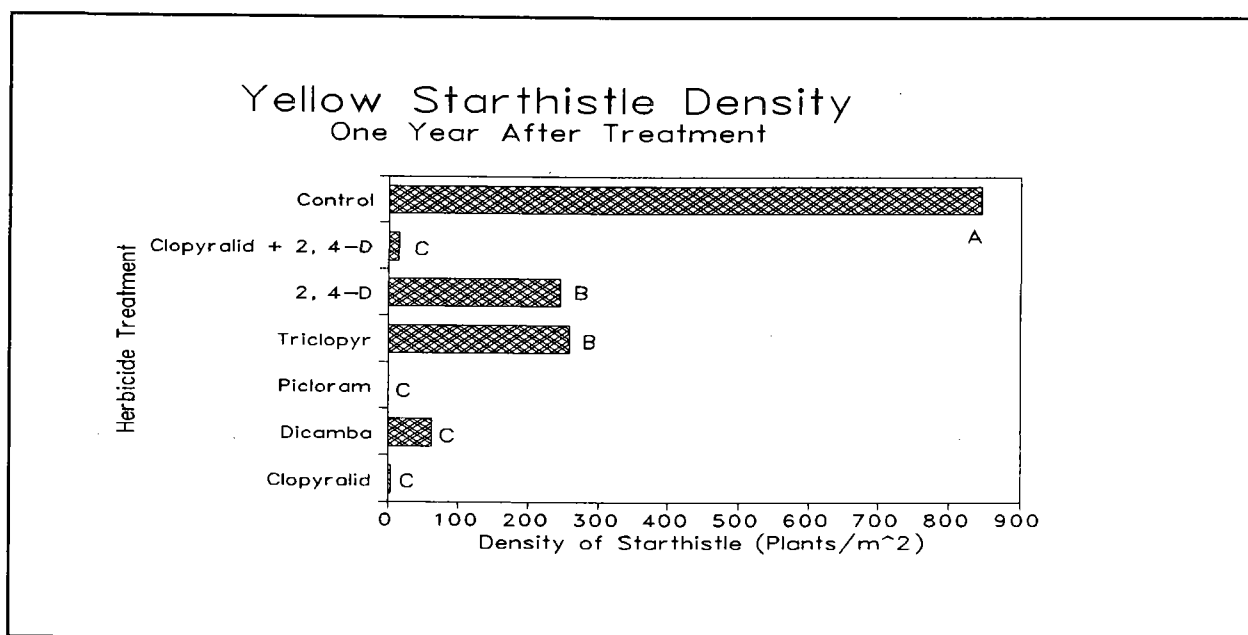
Figure 11. Density of yellow starthistle growing on the small scale herbicide plots at the Robert Ferns Ranch, Phoenix, Oregon in early July 1991.
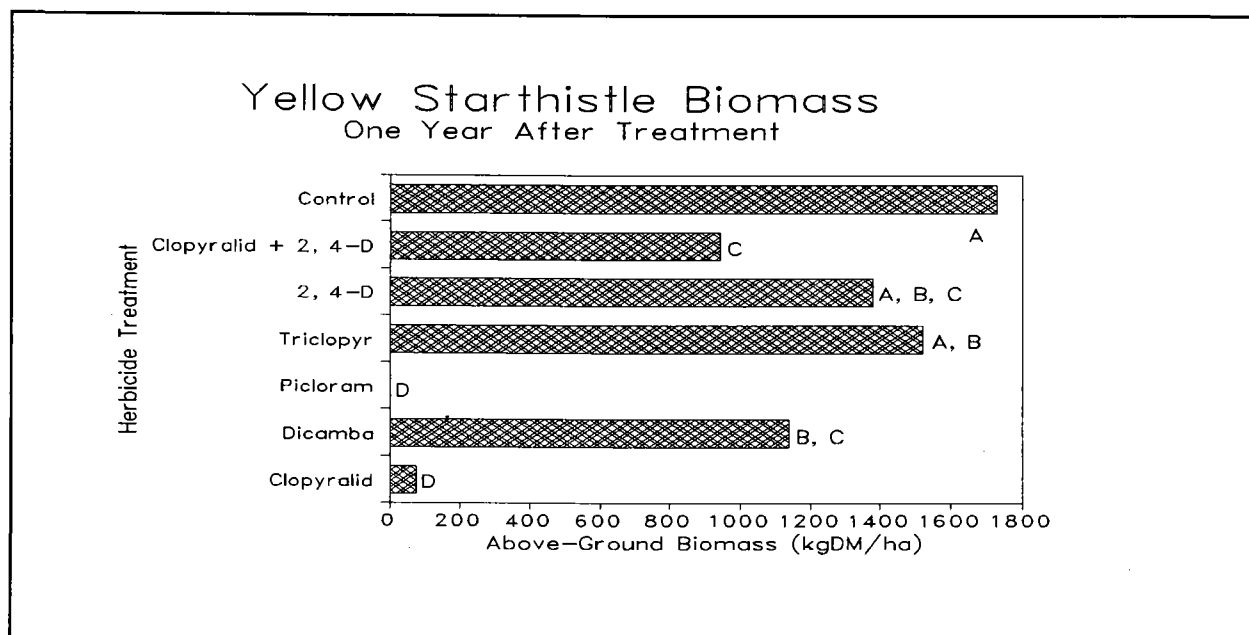
Figure 12. Yellow starthistle aboveground dry biomass on the small scale herbicide plots in early July 1991.
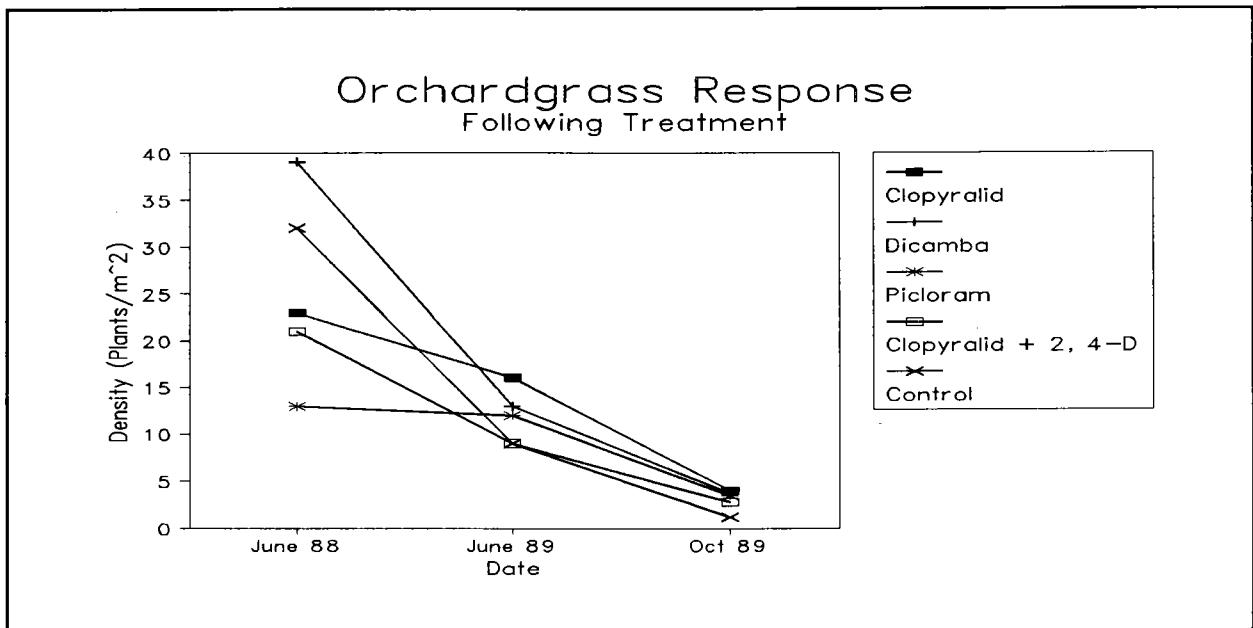
Figure 13. Changes in the density of orchardgrass seedlings in the year following seeding on the small scale herbicide plots, Robert Ferns Ranch, Phoenix, Oregon.
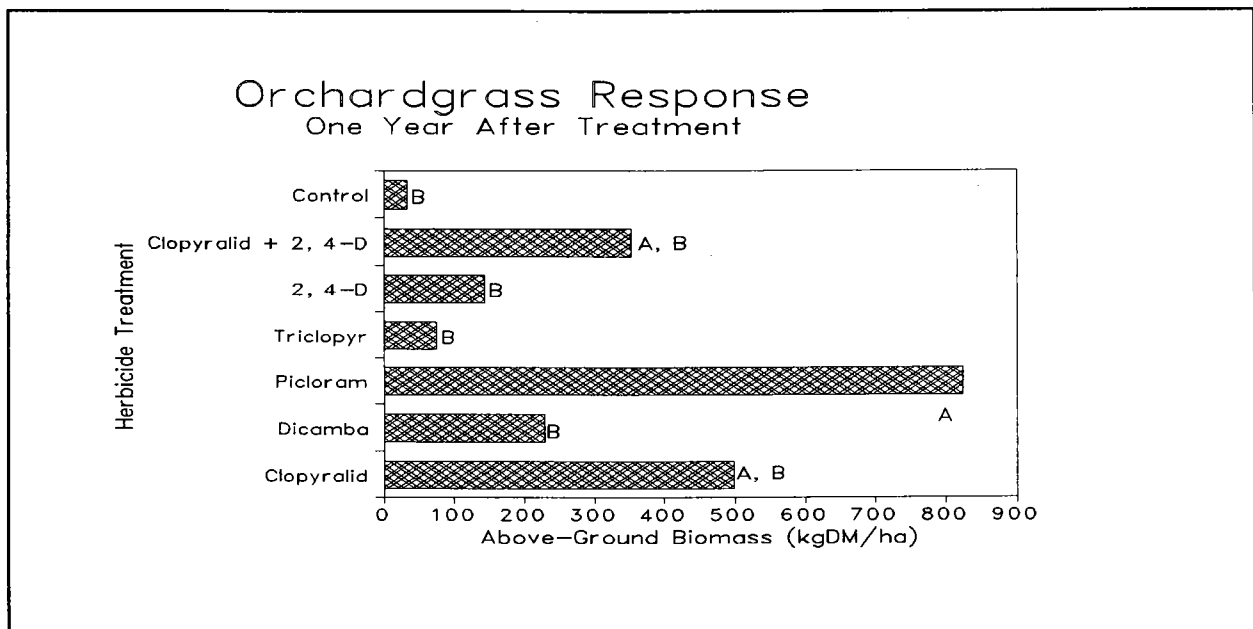
`Figure 14.** Palestine orchardgrass dry aboveground biomass on the small scale herbicide plots.

18
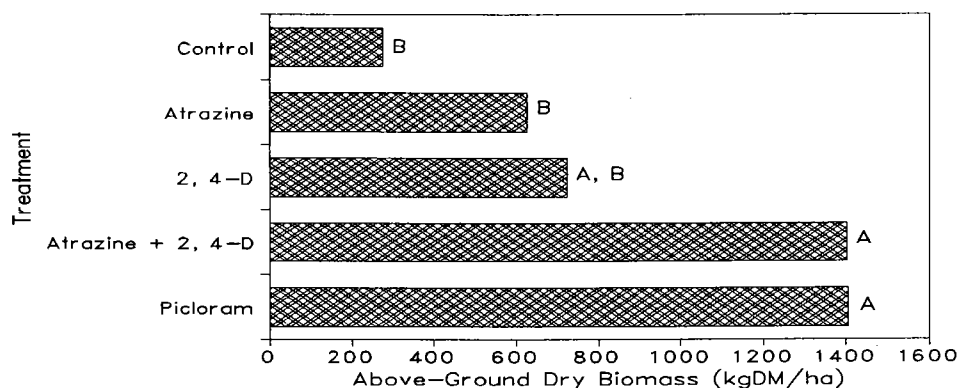
Figure 15. Aboveground dry biomass of Palestine orchardgrass in early July 1991 on the large scale herbicide plots.
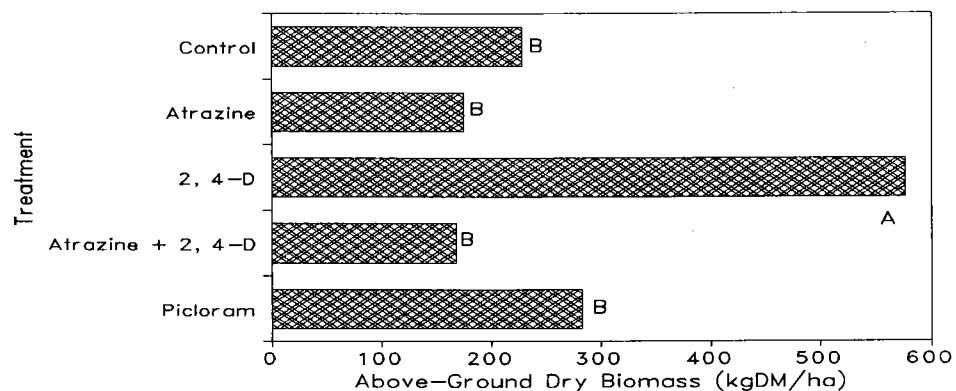
Figure 16. Ripgut brome dry above ground biomass on the large scale herbicide plots (July 1991).

GOAT GRAZING POTENTIAL FOR REHABILITATION OF DEGRADED SAGEBRUSH STEPPE RANGELANDS

Lesley Richman & Douglas E. Johnson

INTRODUCTION

The sagebrush steppe represents a large ecosystem type in the Intermountain West. It encompasses approximately 110 million acres. Currently significant portions of this region are in degraded condition. Degraded sites are often characterized by an increasing density of woody plants at the expense of the perennial grasses and forbs. There is often a corresponding increase in noxious alien species on these sites.

Management practices commonly employed to reduce woody plant densities include fire, herbicide application, and mechanical controls such as chaining, brush-beating, and chainsawing. These practices are not always possible, nor are they always effective. Where understory fine-fuels are absent, fires may not carry. In close proximity to dwellings or where mosaic vegetation is desired, fire is not always possible. Widespread herbicide use can be very costly and is becoming less and less acceptable in our society. Mechanical controls are often quite expensive and not cost-effective on marginally productive lands.

Some of the most pressing problem species include juniper, sagebrush, rabbitbrush, white top, and several of the knapweeds.

Juniper

In areas where western juniper is expanding into shrub/bunchgrass communities, it commonly dominates the site (Dealy et al. 1978). Ecologically, juniper increase results in a changeover from a diverse ecosystem able to accommodate use by both wildlife and livestock, to a near-monoculture which continues to decline. As western juniper dominates the site there is a loss of soil stabilizing vegetation. This can result in unrestricted overland flow of water, both water and wind soil erosion (Doughty 1987) and stream and lake sedimentation.

An Oregon BLM Task Force report (1991) indicates that western juniper is actively moving into most vegetation types including almost all sagebrush bunchgrass communities, aspen, mountain mahogany, bitterbrush, ponderosa pine, bluebunch wheatgrass, and riparian areas. In areas where juniper establishment was achieved between 1900 and 1960, stands are thickening rapidly with 1,000 trees per acre and a crown cover greater than 30 percent fairly common. In the Lakeview, Burns, Prineville and Vale Districts, estimated encroachment of trees less than four feet tall is between 300,000 and 500,000 acres. The additional acreage susceptible to encroachment in the next 20 years is estimated to be between 900,000 and

1,200,000 acres.

Sagebrush

Woody species of sagebrush dominate over 94 million acres in the western United States (USDA Forest Service 1972). Sagebrush is a component of healthy, balanced plant communities in this system. However, over the past 80-100 years management practices and climatic changes have encouraged an increase in sagebrush density which is detrimental to the understory perennial grass and forb species. Areas which once produced over 800 pounds of air-dry grasses and forbs per acre now produce less than 100 pounds per acre (Winward 1991). On sites such as these, there is often an increased occupancy by noxious alien species such as cheatgrass, halogeton, and knapweeds. Sagebrush density increases are accompanied by increases in bare ground which result in increased erosion and a reduced ability for the site to capture, store, and safely release moisture.

The costs of sagebrush density reduction can be prohibitive and often are only possible on the most productive sites. Land management agencies with poor condition sagebrush rangeland are often constrained by limited budgets and insufficient personnel. Improvement programs therefore are actively restoring only a small portion of these ranges. Private ranchers are often operating on such a slim margin of return that they cannot afford rehabilitative practices on large portions of their private lands.

Intensified prescribed burning is the most reasonable program for rehabilitating these sagebrush dominated sites. However, not all acres are suitable for burning. Some sites were probably never maintained by fire regimes because of their dryness and absence of fuels. Other sites no longer have the fine-fuel (herbaceous) component left in sufficient quantities to carry fires. Some sites are co-dominated by sprouting shrubby species such as rabbitbrush which responds to fire by sprouting profusely and becomes excessively dominant after a burn. In other areas, large-scale sagebrush removal such as often occurs with fire management can be detrimental to critical wildlife habitat.

Mechanical removal of sagebrush accomplished by chaining or brush-beating is extremely costly and only utilized on relatively small areas. Herbicide removal, while effective for killing sagebrush, may have a deleterious effect on many of the desired understory species as well. It is costly and at times, unpredictable. In addition, herbicide use is a controversial societal issue and many public agencies have been banned from using herbicides on lands they manage.

21

Other Species

There are a wide variety of problematic species in the sagebrush steppe that have an ability to degrade sites and, once established, spread rapidly to other areas. White top (*Cardaria draba*), Russian, diffuse and spotted knapweed (*Centaurea spp.*) are among these species. Control efforts have been marginally successful and new alternatives must be found.

GOATS FOR CONTROL

Because of their ability to utilize and destroy coarse forages, goats are well suited to brush control efforts (Merrill 1975). Goats graze more diverse kinds of vegetation and distribute themselves more evenly than either cattle or sheep (Taylor 1983). Goats have been used in many parts of the world for brush control. They have been used successfully for controlling or suppressing such species as gorse, acacia, eucalyptus, groundsel, Gambel's oak, juniper, shin oak, hackberry, and pricklyash. They are currently being investigated at the U.S. Sheep Experiment Station in Dubois, Idaho for leafy spurge control and in fact are successfully employed on public lands in Montana for that purpose.

Our research was designed to investigate the possibilities that exist for manipulating vegetation on sagebrush grasslands through managed goat browsing. Goats are very uncommon in the sagebrush steppe region of the United States although they are a dominant livestock species in sagebrush regions on a worldwide basis. We monitored goat diets intensively for 18 months at the Squaw Butte Experimental Range in eastern Oregon. Our intention was to provide preliminary information regarding plant selection and species preference by goats in the sagebrush steppe of eastern Oregon.

Many of the native woody species in the sagebrush region produce anti-herbivory compounds in their leaves and stems. Many species are high in volatile oils including phenolic monoterpenoids. Introduced domestic herbivores (sheep and cattle) tend to avoid or limit consumption of these species (Kelsey et al. 1983). We feel that goats may provide a method for focused browsing on the woody components and help shift the competitive advantage more toward grasses and forbs. By targeting problematic plant species for grazing, we may be able to curb their expansion and increasing density.

DIET EVALUATION

We investigated the diets of goats using 30 mature angora does and 28 angora kids. They were introduced to the Squaw Butte Experimental Range site in the summer of 1990. Diets were evaluated for five consecutive seasons using intensive bite-count observations. Fecal production and forage digestibility were analyzed as an alternative estimate of intake. Goat weights were closely monitored and winter supplementation was carefully correlated to maintain animal health without interfering with foraging.

22

RESULTS AND DISCUSSION

Our study indicates that grasses made up the largest proportion of the diets of doe goats for all seasons (Figure 1). Shrubs were consistently near 2 percent of total intake for all seasons except spring. In the spring of 1991, shrub consumption was 14 percent and primarily consisted of sagebrush and rabbitbrush. Kids, on the other hand, consumed substantial amounts of shrubby species during the summer, fall and winter of 1990-1991 (Figure 2). Shrub consumption in kid diets was 20 percent of total intake during the summer of 1990, 42 percent of total intake in the fall and 18 percent of total intake during the winter. Shrubs were also consumed readily in the spring by kids and amounted to 12 percent of intake.

There was strong seasonality of use for species selected, especially shrubs (Figures 3 and 4). Both does and kids would switch from plant species to plant species as the seasons progressed and the relative abundance and phenology of plants changed. By the second summer (1991) doe and kid diets were similar.

Big sagebrush was consumed most heavily in the spring by does, when it averaged 9 percent of total diet (Figure 5). Green rabbitbrush was also consumed most heavily in the springtime when it made up 4 percent of total diet. Rabbitbrush consumption remained somewhat higher through the summer of 1991 than was seen in the summer of 1990. Big sagebrush and green rabbitbrush had spring crude protein levels of 11 percent and 13 percent respectively and digestibilities of approximately 75 percent.

Fall and winter sagebrush and rabbitbrush consumption by kids was substantial. During this time kids ate dead as well as live sagebrush and were more exploratory in their diet. Kids ate the least sagebrush in the summer of 1991.

Our study site did not have western juniper present in sufficient quantity for statistical analysis of this dietary component; however, our observations indicate that juniper is readily eaten by goats with the most energetic consumption occurring in the summer and fall. Several juniper trees on our site less than 6 feet in height were completely consumed by the fall of 1990. Upon completion of our diet study (in July, 1991), the goats were moved to a neighboring pasture which had more young junipers (approximately 150 trees in a 20 acre area). We monitored the time-frame of juniper consumption daily and noticed an interesting pattern. Within the first three days, all terminal buds on all branches of all trees had been nipped off. By the third week, the central trunks of virtually all trees had been stripped of bark. Some trees had been totally consumed by the third week. Both trees with mature and juvenile foliage were consumed readily. The goats continued to eat juniper trees until the flock was removed from the site, after a four-week grazing period.

There was no whitetop or knapweed on our study site and we were thus unable to assess goat preference for these species. It has been shown that sheep consume whitetop and knapweeds and therefore propose that goats would also find them palatable. Our study was

designed only to provide preliminary, base-line information from which to design more intensive investigations as to the effects of goat grazing on specific target species and the associated vegetation. We feel that because goats are selective browsers, they could consume significant amounts of juniper, rabbitbrush, and sagebrush if managed correctly.

We believe that goats show promise as a tool for rangeland rehabilitation. Because preference for plants change with season and plant development, it is likely that strategies can be developed that damage target plants without severely impacting associated vegetation. Development of these strategies should be given priority and support by research organizations.

LITERATURE CITED

Dealy, J.E., J. M. Geist, and R.S. Driscoll. 1978. Western juniper communities on rangelands of the Pacific Northwest. Proc. First Int. Range Congress. pp.201-204.

Doughty, J.W. 1987. The problems with custodial management of pinyon-juniper woodlands. Proc. Pinyon-Juniper Conference. pp.29-33. USDA For. Ser. Gen. Tech. Rpt. INT-215

Kelsey, R.G., W.E. Wright, F. Sneva, A. Windward, and C. Britton. 1983. The concentration and composition of big sagebrush essential oils from Oregon. Biochem. Syst. and Ecol. 11:353-360.

Merrill, L.B. 1975. The role of goats in biological control of brush. Beef Cattle Science Handbook. 12:372-376.

Taylor, C.A. Jr. 1983. Foraging strategies of goats as influenced by season, vegetation and management. Ph.D. Diss. Texas A & M Univ. College Station, Texas.

Winward, A.H. 1991. A renewed commitment to management of sagebrush grasslands. IN: Miller, R.F. (ed.) 1991. Management in the sagebrush steppe. Special Rept. 880. Oregon State U. Expt. Station, Corvallis, OR. 48 pp.

USDA Forest Service. 1972. The nation's range resources - A forest-range environmental study. Forest Resource Report No. 19, USDA Forest Serv. Washington D.C.

Figure 1. Diet of doe goats grazing a sagebrush grassland on the Squaw Butte Experimental Range near Burns, Oregon during 1990 and 1991.
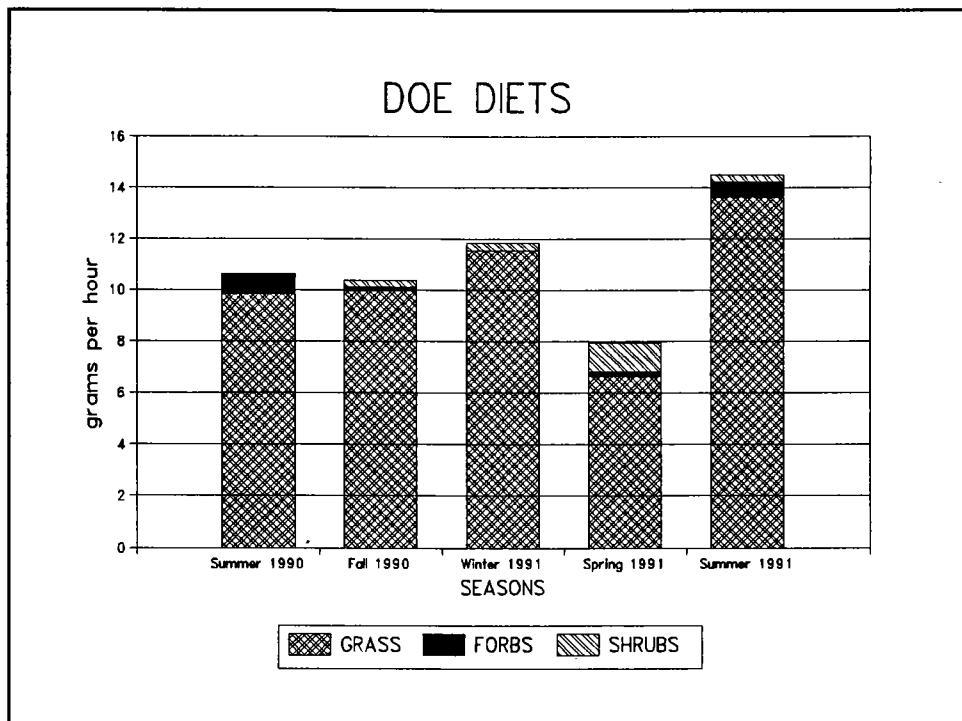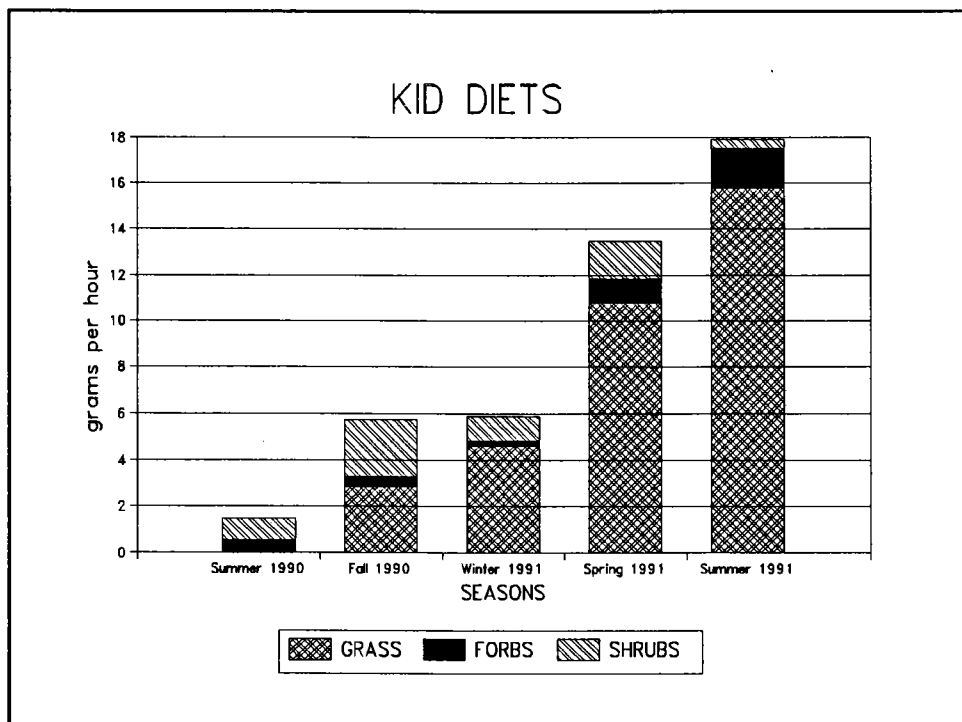

Figure 2. Diets of goat kids grazing a sagebrush grassland at the Squaw Butte Experimental Range near Burns, Oregon during 1990 and 1991.

25
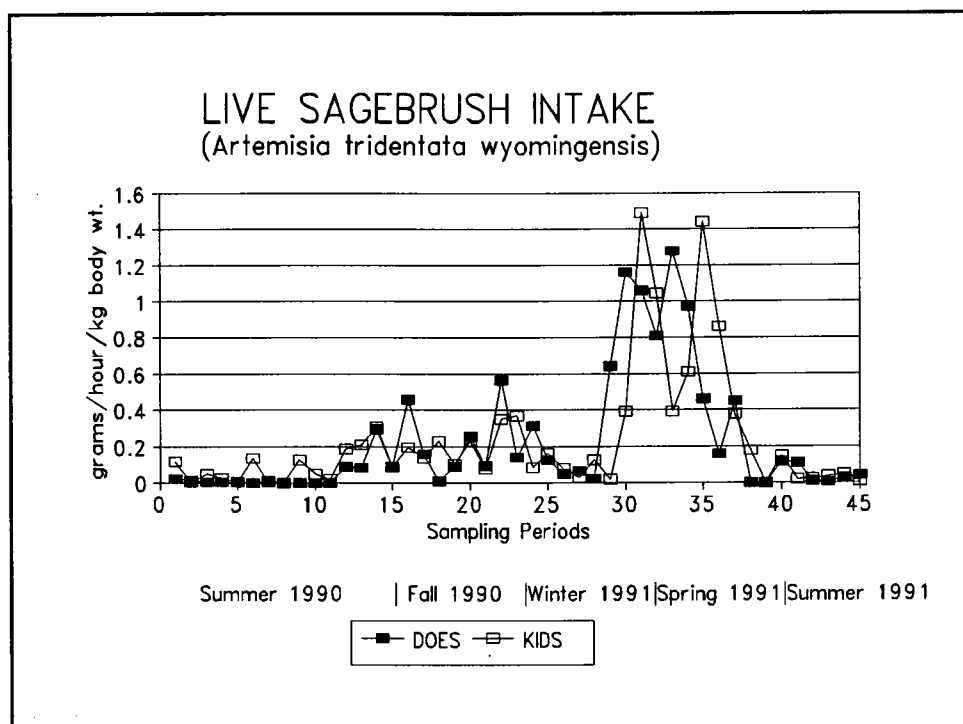
Figure 3. Intake of live sagebrush by goats at the Squaw Butte Experimental Range near Burns, Oregon.
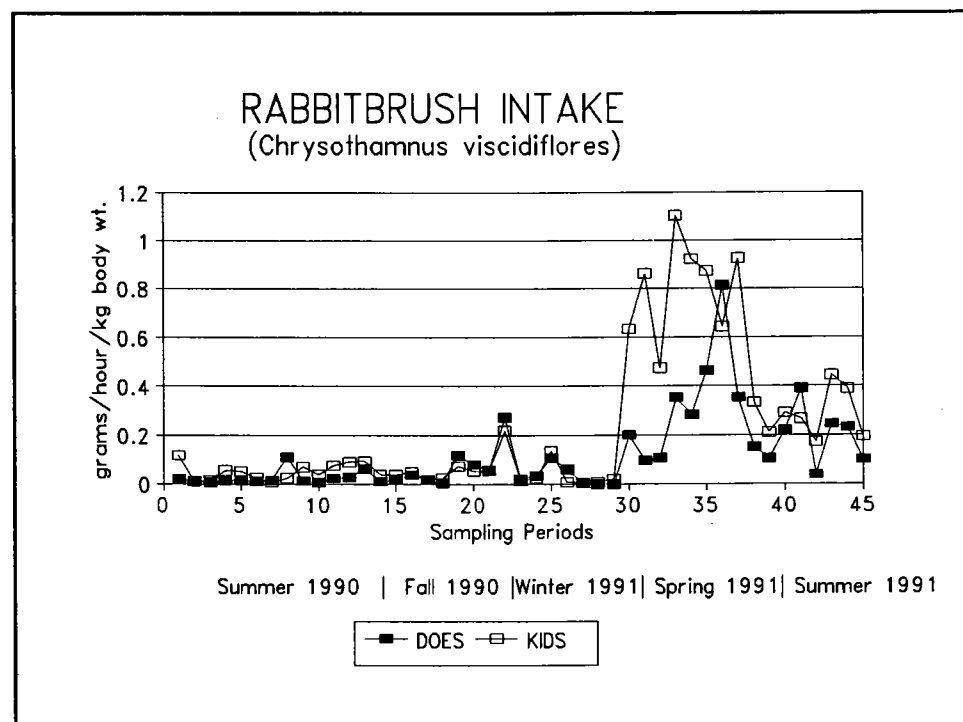
Figure 4. Intake of rabbitbrush by goats at the Squaw Butte Experimental Range near Burns, Oregon.

26

Doe Diet
Spring 1991

Others (10.5%)
SIHY (7.4%)
STTH (3.2%)
ARTR (9.2%)
CHVI (3.9%)
AGDE (11.8%)
AGSP (7.0%)
FEID (5.2%)
KOCR (0.5%)
POASPP (41.2%)

Figure 5. Diet of does in the spring of 1991 at the Squaw Butte Experimental Range near Burns, Oregon.

Kid Diet
Spring 1991

Others (9.8%)
STTH (5.0%)
SIHY (8.8%)
ARTR (6.1%)
CHVI (6.0%)
AGDE (15.3%)
AGSP (5.7%)
FEID (5.0%)
KOCR (0.8%)
POASPP (37.7%)

Figure 6. Diet of goat kids during the spring of 1991 grazing the Squaw Butte Experimental Range near Burns, Oregon.

PHYSIOLOGY, GROWTH AND MANAGEMENT IMPLICATIONS
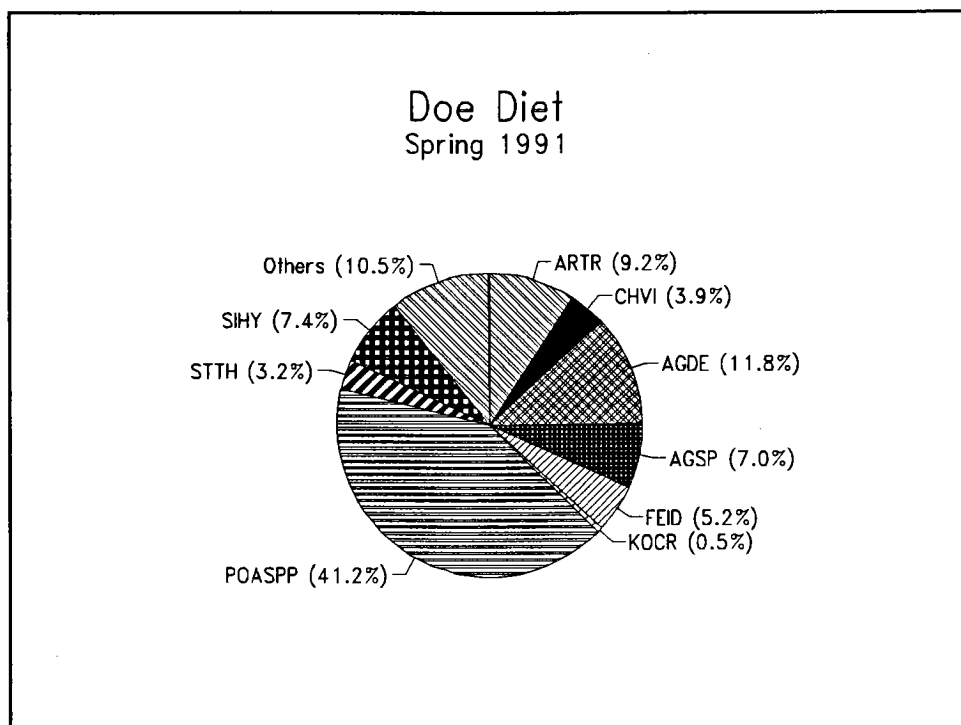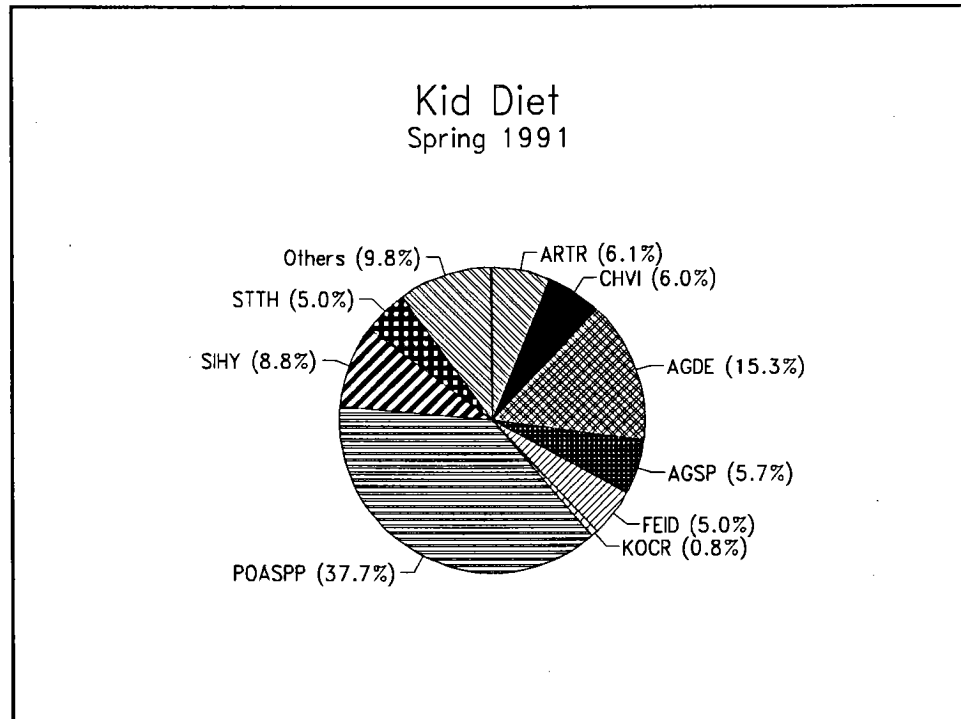## OF WHITETOP (*Cardaria draba*)

Richard F. Miller, Tony Svejcar, and Michael L. McInnis

INTRODUCTION

Whitetop (*Cardaria draba* (L.) Desv.), also known as hoary cress, is a noxious introduced weed. Whitetop is a deep rooted perennial capable of reproducing from seed and from vegetative shoots originating on underground stems. This species, first reported in New York in 1862, has invaded cropland and rangeland in British Columbia, Alberta, Saskatchewan, Washington, Oregon, Idaho, northern California, Nevada, and Arizona. It grows in open unshaded areas and is well adapted to alkali soils.

Whitetop can produce large numbers of viable seed and vegetative shoots allowing it to rapidly invade cultivated and disturbed areas. It is capable of gradually choking out alfalfa and is known to have a major economic impact on agronomic crops. Different species of whitetop (globe-pod and lens-pod), are well-adapted to moist sites but not vigorous on semi-arid environments in Saskatchewan. However, in the western United States where heart-pod whitetop (*Cardaria draba*) appears to be the widest-spread species of this genus, movement of this weed from cultivated fields to adjacent semi-arid upland big sagebrush communities is common. Its recent movement into the sagebrush ecosystem in the northwestern United States on a rather large scale is cause for concern. In eastern Oregon, whitetop is estimated to occupy over 250,000 acres. It has been observed growing in big sagebrush communities in different seral stages and communities seeded to crested wheatgrass.

Past research has addressed chemical and biological control of whitetop. Chemical treatments usually have to be repeated several times, or combined with farming practices for successful control. Thus, treatment has become economically prohibitive, particularly on rangeland. The effectiveness of chemical control also has been highly variable and unpredictable. To date, biological control methods have not been effective in controlling whitetop.

Our goal was to describe plant growth and water stress of whitetop in two sagebrush communities differing in site potential. We also wanted to describe the seasonal pattern of carbohydrate allocation for whitetop which influences the movement of foliar-applied herbicides.

METHODS

The study area was located approximately 3 miles north of Keating, Oregon, during the 1988 and 1989 growing seasons. The overall climate in the Keating Valley is maritime with cold winters and hot summers. The growing season typically begins in early March and ends about mid-June. The nearest weather station is approximately 22 miles to the east in Richland, Oregon. Although weather varies greatly across short distances, precipitation throughout this region was below normal during the crop year of 1987-1988 (Sept-June) and near normal during the 1988-1989 crop year. Soils on the study site were of granitic origin.

The two sites selected for study were an upland and adjacent terrace site. The upland was located on a 15 percent west facing slope with a soil depth averaging 20 inches. The plant community is currently dominated by Wyoming big sagebrush and crested wheatgrass. Based on a few remnant plants on the site, the dominant understory was bluebunch wheatgrass and Thurber's needlegrass. The bottom site is located on level terrace with soils deeper than 48 inches. The plant community is dominated by basin big sagebrush and crested wheatgrass. The few remnant plants in the understory suggest the site was originally dominated by basin wildrye.

Measurements recorded throughout the growing season were soil water content and temperature, air temperature, phenology, winter survival, above and below ground biomass, plant water stress and carbon allocation.

RESULTS AND DISCUSSION

In October 1987 and 1989, soil water was limiting in the upper 48 inches of the soil profile on the bottom site, however, new leaves developed. This may indicate that plant roots extended to the water table (estimated to be 20 feet below the surface). New leaves did not develop in the fall on the upland site, probably due to the hardpan restricting root penetration to the water table. Leaves developed during the fall did not overwinter. However, buds near the soil surface which developed during the fall did overwinter, and initiated new leaf growth during the following spring. All plants studied in permanently-marked plots in both years originated from underground shoots. No plants in the plots developed from seed. By late April, reproductive stems began to develop, becoming fully elongated by early May and in full flower by mid May. Seed development occurred during June. Although soil temperatures, air temperatures and water availability were different between the two sites during the growing season, phenology between the bottom and upland was similar. Only in the early growing period was leaf development on the upland ahead of the bottom site, probably due to warmer soil and air temperatures. However, we observed a large degree of phenological variability within sites. While the majority of the stand was flowering, plants in the rosette stage were also common.

We measured above-ground and below-ground biomass in the upper 24 inches of the soil profile on the deep soil site. Plots were purposely located where whitetop was nearly a pure stand. Above-ground and below-ground biomass was 4,200 and 13,600 lbs/acre, respectively (Table 1). Below-ground biomass in the upper 24 inches was 3 times greater than aboveground production. Of the below-ground biomass, 56 percent was rhizomes and 44 percent roots. The majority of the roots were located in the upper 8 inches while rhizomes were more evenly distributed throughout the profile.

Although phenological development was similar between the two sites plant water stress differed between sites. Plants on the upland site became drought stressed during the second half of the growing season while plants growing on the bottom were not stressed until late summer. However, plants on the upland still were able to complete their life cycle, producing viable seed.

Plants were exposed to labeled carbon which is absorbed through the leaves, incorporated into sugars via photosynthesis, then moves to different parts of the plant. A portion of the labeled carbon absorbed through the leaves was transferred to below-ground plant parts within one hour, with maximum levels being reached within 24 hours of exposure. Maximum transfer of carbon to the roots and rhizomes occurred during full flower (Figure 1). Allocation of carbon from leaves to rhizomes was 170 to 200 percent higher during full flower than at any other phenological stage. Most foliar applied herbicides are moved through the plant vascular system with the sugars. The above data indicates that foliar applied herbicides would begin moving to the rhizomes in less than one hour after application, accumulating to maximum concentration within 24 hours following application. Maximum movement of herbicides to roots and rhizomes would occur during full flower.

The variability in success of herbicide control on whitetop is probably due to a combination of: (1) the short period of maximum transfer of herbicides to roots and rhizomes, (2) the high degree of variability of phenology within a stand, and (3) the high proportion of biomass located below ground. The high proportion of roots and rhizomes, and the large number of growing points on the rhizomes necessitates transport of herbicide below-ground; otherwise only the above-ground portion is killed and resprouting occurs.

CONCLUSIONS

Whitetop appears to be well-adapted to growing and successfully competing in a Wyoming big sagebrush community. However, on the deeper soil site it was more productive and remained physiologically active later into the summer. The concentration of roots near the surface makes this plant very competitive with grasses. This species also appears to have a very deep root system in deep soil sites and rhizomes that grow deep in the soil profile. The high amount of variability in phenology and the short time of maximum movement of chemical below ground and the large proportion of biomass located below ground make this species difficult to control with chemical and mechanical methods.

Table 1.   Above- and below-ground biomass; root:shoot, and root:rhizome ratios of
            whitetop.

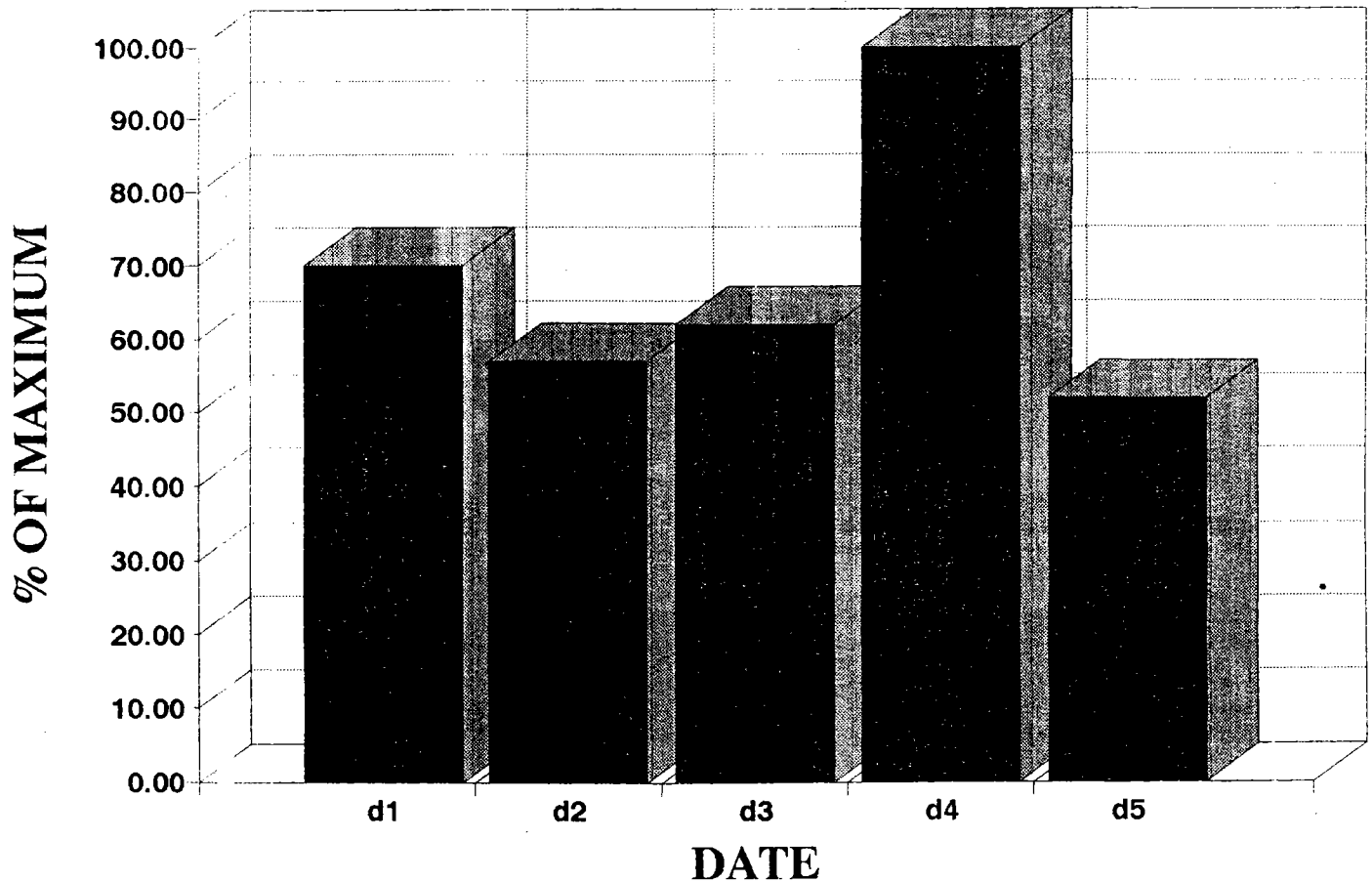|	Above-ground	Below-ground	Root:shoot
Biomass (lb/ac)	4,200	13,600	3.24
		Soil Depth (mm)	
% Distribution	0-200	200-400	400-600
		% Distribution	
Roots	73	16	11
Rhizomes	40	38	22
	1.41	Root/Rhizome 0.33	0.40

Figure 1. The relative amount of carbon transferred to the roots and rhizomes in whitetop during the rosette stage (d1), early elongation of the flowering stem (d2), early flowering (d3), full bloom (d4) and seed formation (d5).

WHITETOP ECOLOGY AND STRATEGIES FOR MANAGEMENT

Michael L. McInnis, Larry L. Larson, Dan Sharratt, Gary L. Kiemnec and Richard F. Miller

INTRODUCTION

The encroachment of alien weeds will continue to be a serious threat to rangelands throughout the 1990s. Land managers approach this problem by developing integrated pest management programs. The success or failure of such programs will depend upon the ability of managers to (1) understand and exploit the ecology or life strategy of the targeted weed species to reduce its competitive abilities, and (2) establish and maintain plant communities that are capable of competing effectively against weeds with minimal long-term energy input by man.

Whitetop or heart-podded hoary cress (*Cardaria draba* (L.) Desv.) is a member of the mustard family and is a native of Eurasia. The plant was probably introduced by settlers from Europe in the 1800's and was first collected in the United States at Long Island, New York, in 1862 (Mulligan and Frankton 1962). By the early 1900's, whitetop was recognized as a noxious weed of agronomic croplands in many areas (Mulligan and Findlay 1974). Scientists at Oregon State University have been working toward understanding the ecology of whitetop. In this paper, we will review the status of our knowledge of the ecology and life strategy of this troublesome weed.

DISCUSSION

Seed Production and Germination

Whitetop is a perennial plant that reproduces from seeds and from shoots produced by creeping roots. Seeds mature in late July to early August. A Canadian study determined a single plant could produce 1,200 to 4,800 seeds, of which 84 percent are viable (Selleck 1965). Oregon State University scientists measured the production in a single year of nearly 180,000 viable whitetop seeds/yard^2 on a site near Keating, Oregon (McInnis et al. 1990). Seedlings have a better chance of becoming established on disturbed sites such as ditch banks, roadsides and gopher mounds. Seeds can be distributed to new sites in hay contaminated with seedheads, seedheads attached to the undercarriages of vehicles and equipment, in surface runoff and running water, and through the digestive tracts of animals. Although whitetop does not appear to be highly palatable, cattle will consume seedheads in the fall when other forage is less available. A preliminary study is being conducted by OSU scientists to determine the passage rate and viability of whitetop seeds force-fed steers.

We have conducted studies on whitetop in the sagebrush ecosystem since 1985. During that time, we have observed an annual seed viability between 75 to 90 percent. Our studies indicate that after seed drop occurs, whitetop seeds are not likely to germinate until the following spring (February - April), and then predominately in toe-slope and bottomland positions of the landscape (Smergut et al. 1992). Germination trials conducted in environmental chambers support these observations, indicating whitetop seeds require approximately 4 days of near-optimum moisture and temperature conditions to germinate and that reduction of moisture conditions below field capacity will result in reduced germination and initial root development. Further, whitetop germination and initial root development has not been adversely affected in saline soils (Kiemnec and Larson 1991).

Establishment

Plants established from seeds on open ground reach full size about 3 weeks after spring germination, when they begin to develop lateral roots (Scurfield 1962). A single plant growing in the absence of competition can spread over an area of 12 feet in diameter and produce 455 shoots the first year of establishment. An OSU study reported an average of 484 shoots/yard^2 on a site fully occupied by whitetop (McInnis et al. 1990). The prolific seed and shoot production of whitetop makes it an effective competitor with desirable forage. Our research has shown a 5 percent reduction in crested wheatgrass biomass for every 89 lbs/ac increase in whitetop (Larson et al. 1990). A site fully occupied by whitetop produced 2,865 lbs/ac of this weed, and only 695 lbs/ac of associated vegetation, most of which was cheatgrass (McInnis et al. 1990).

We conducted field trials in 1987 and 1988 to assess seedling emergence and survival in annual grass, wheatgrass and sagebrush/grass plant communities. These trials indicated seedling emergence and survival was greatest in annual grass communities and disturbed soils (Larson et al. 1989).

Potential Toxicity of Whitetop

In 1990, we completed a study examining the chemical composition of whitetop relative to animal nutrition (McInnis et al. 1992). Plants were collected from eight sites in Baker County, Oregon, during each of five growth stages: rosette (April 12), bolting (April 24), early bloom (May 12), full bloom (June 10) and hard seed (July 7). Chemical analysis of whole plants from rosette to hard seed, respectively, indicated the following trends: crude protein (28.8 to 7.9 percent), neutral detergent fiber (13.1 to 52.8 percent), acid detergent fiber (12.0 to 41.8 percent), cellulose (9.9 to 32.1 percent), lignin (1.9 to 9.4 percent), ether extract (1.6 to 2.4 percent), in vitro organic matter digestibility (77.3 to 49.1 percent) and digestible energy (2.9 to 1.8 Mcal/kg). Leaves were higher than stems in crude protein, ether extract, in vitro organic matter digestibility and digestible energy. Analysis of 11 micro-and macro-elements revealed sulfur levels ranged from 0.73 to 2.69 percent, and were therefore

34

higher than the reported maximum tolerable level (0.4 percent).

In discussing the nutritive value of whitetop to range livestock, a report from Nevada in 1931 stated whitetop "contains an irritant principle and may cause trouble under conditions of forage shortage". It is now known that 11 plant families, including mustards, contain glucosinolates (mustard-oil glucosides) that yield one or more potentially-toxic products upon hydrolysis by an enzyme found in the plant and released when plant material is crushed. More than 60 glucosinolates are present in the mustard family and all are sulfur-containing compounds. This accounts for the high levels of sulfur we found in our samples.

Potentially-toxic hydrolysis products of glucosinolates at neutral pH include thyocyanates and isothyocyanates. The former may inhibit iodine uptake by the thyroid, and can cause thyroid enlargement (goiter) and growth depression. The effect is most pronounced when dietary iodine is low but can be overcome by increasing the iodine level of the diet. Thiocyanate ion also lowers the iodine content of milk of lactating animals, and can cause goiter in nursing young. Further, placental transfer of glucosinolates can occur, causing goiter in young animals. Isothyocyanates are irritating vesicants that cause blistering of tissues, severe gastro-enteritis, salivation and diarrhea. Under some hydrolysis conditions, such as low pH, nitriles are produced that can result in liver and kidney lesions and poor growth.

Total glucosinolate levels in whitetop collected from Baker County varied from 28.4 $umol/g$ (whole plants, rosette) to 84.0 $umol/g$ (mature seeds). The lower value is close to values reported for low-glucosinolate cultivars of rape ("Candle" and "Regent"), while the higher value approaches levels reported for high-glucosinolate cultivars of rape ("Torch").

In the Pacific Northwest, sheep may consume whitetop during its early growth stage, and cattle apparently find the seedheads most palatable during the fall when other forages are less available and concentrations of glucosinolates in whitetop are greatest. Until future research establishes the nutritional toxicology of whitetop, prudence suggests managers use caution when allowing animals to graze whitetop-infested rangelands. The potential of animal poisoning may be lessened by providing supplemental iodine; utilizing mature, non-lactating animals; and reducing opportunities for animals to consume the plant, including preventing its invasion into new areas and controlling whitetop where it exists.

Management Implications

The management implications resulting from our studies of whitetop are threefold. First, the initial encroachment of whitetop into new areas is probably by seed reproduction. Whitetop produces prolific seeds with a high percentage of viability. Seeds are easily transported to new sites in numerous ways including surface runoff, moving water, under the carriages of vehicles and equipment, in hay, and in the digestive tracts of animals. However, the conditions for successful germination are restrictive. Warm, moist spring conditions

followed by a moderate summer are needed for seed germination and seedling establishment. The toe-slope and bottomland positions of the landscape are at greatest risk in the sagebrush ecosystem and soil disturbance induced by man or associated with rodent activity greatly enhances the likelihood of successful seeding establishment.

Second, once seedlings become established, the survival of whitetop populations is heavily dependent upon vegetative reproduction through the creeping root system. The ability to expand or contract above-ground populations through root bud stimulation permits responsiveness to annual climatic fluxuations. Disturbances such as rodent activity or plowing can increase the production of shoots from root buds.

Finally, long-term whitetop control must include reduction of encroachment into new areas by seed, control of soil disturbance, reduction of existing infestations and establishment and maintenance of desirable plant communities that can resist invasion through competitive interactions.

LITERATURE CITED

Kiemnec, G.L., and L.L. Larson. 1991. Germination and root growth of two noxious weeds as affected by water and salt stress. Weed Tech. 5:612-615.

Larson, L.L., M.L. McInnis, R.F. Miller, and J.A. Tanaka. 1989. Forage reduction and seedling emergence by whitetop in the sagebrush ecosystem. NW Sci. 63:67.

Larson, L.L., M.L. McInnis, R.F. Miller, and J.A. Tanaka. 1990. Whitetop (*Cardaria draba*) encroachment in the sagebrush ecosystem of Oregon. Abstr. of Papers. 43rd Ann. Meeting, Soc. Range Manage., Reno, NV.

McInnis, M.L., L.L. Larson, and R.F. Miller. 1990. First-year defoliation effects on whitetop (*Cardaria draba* (L.) Desv.). NW Sci. 64:107.

McInnis, M.L., L.L. Larson, and R.F. Miller. 1992. Nutrient composition of whitetop (*Cardaria draba* (L.) Desv.). J. Range Manage. In press.

Mulligan, G.A., and J.N. Findlay. 1974. The biology of Canadian weeds. 3. *Cardaria draba*, C. chalepensis, and C. pubescens. Can. J. Plant Sci. 54:149-160.

Mulligan, G.A., and C. Frankton. 1962. Taxonomy of the genus Cardaria with particular reference to the species introduced into North America. Can. J. Bot. 40:1411-1425.

Scurfield, G. 1962. *Cardaria draba* (L.) Desv. J. Ecology 50:489-499.

Selleck, G.W. 1965. An ecological study of lens- and globe-podded hoary cress in Saskatchewan. Weeds 13:1-5.

Smergut, T., L.L. Larson, and G.L. Kiemnec. 1992. Hoary cress germination in a sagebrush ecosystem. Unpublished manuscript in review.