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# Leafy spurge control with angora goats and herbicides

RODNEY G. LYM, KEVIN K. SEDIVEC, AND DONALD R. KIRBY

*Authors are professor, Plant Sciences Dept., and rangeland management specialist and professor, Animal and Range Science Dept., North Dakota State University, Fargo, N.D. 58105.*

## Abstract

**A 4-year experiment to evaluate herbicide treatments with grazing by goats to improve long-term leafy spurge (*Euphorbia esula* L.) control compared to either herbicides or goats was established on the Sheyenne National Grasslands and the Gilbert C. Grafton South State Military Reservation in North Dakota. Six treatments were evaluated including an untreated control, grazing alone, herbicides applied in the spring or fall alone, grazing following spring-applied herbicides, or grazing during the season prior to fall-applied herbicides. Leafy spurge was rotationally grazed at the Sheyenne National Grasslands but was grazed season-long at Camp Grafton South. Grazing combined with fall-applied herbicide treatment reduced leafy spurge density rapidly and maintained control longer than either method used alone. Picloram (4-amino-3,5,6-trichloro-pyridinecarboxylic acid) plus 2,4-D [(2,4-dichlorophenoxy)acetic acid] applied annually in the spring reduced leafy spurge density similar to or better than the same treatment combined with grazing. Also, leafy spurge control tended to be more rapid with continuous than rotational grazing. The best treatments averaged over both locations were picloram plus 2,4-D at 0.5 plus 1.1 kg ha$^{-1}$ applied in the fall alone or preceded by spring grazing. These treatments reduced the stem density by 98% from an average of 16 stems per 0.25 m$^2$ at the start of the experiment to 0.3 stem per 0.25 m$^2$ 3 years later. Leafy spurge stem density still only averaged 1 stem per 0.25 m$^2$ 12 months after the last treatment of season-long grazing plus a fall herbicide treatment compared to 6.5 stems per 0.25 m$^2$ when either method was used alone. Grazing and herbicide treatments alone or in combination reduced the root protein content at both locations but the effect on root carbohydrate content was minimal.**

**Key Words: integrated pest management, cost-effective range weed control, picloram, 2,4-D, grazing.**

Leafy spurge (*Euphorbia esula* L.) is a long-lived perennial weed that primarily infests pasture and rangeland where it decreases herbage production by as much as 75% (Lym and Kirby 1987). Annual losses in grazing capacity were estimated to cost the livestock industry in Montana, North Dakota, South Dakota, and Wyoming $37.1 million in sales and $34.2 million in annual production expenditures (Leitch et al. 1994). Some of this loss is due to decreased herbage production from leafy spurge competition (Lym and Messersmith 1985, Lym and Kirby 1987). However, additional herbage losses occur as cattle avoid grazing areas infested with leafy spurge. Leafy spurge contains a substance that causes scours and weakness in cattle and may result in death (Muenscher 1948).

Although leafy spurge is not utilized by cattle, it is readily grazed by sheep and goats (Landgraf et al. 1984). Sheep and goats have long been used for weed control. Modern examples include dock (*Rumex obtusifolius* L.) control in Japan (Sakanoue et al. 1995), gorse (*Ulex europaeus* L.) in New Zealand (Radcliffe 1985) and Spain (Sineiro 1982), and general brush clearing in Texas (Merrill and Taylor 1976), and California (Adams and Hughes 1977). Sheep and goats prefer to eat more broadleaf plants than cattle, while sheep consume more grass than goats (Hanson 1994, Walker et al. 1994). Goats increased in popularity as biological control agents for leafy spurge in the northern Great Plains in the mid 1980's and 1990's (Hanson 1994, Olson and Lacey 1994). Sheep were effective in controlling leafy spurge topgrowth in the 1930's (Helgeson and Thompson 1942) but have been little utilized. Grazing with goats may be preferred over sheep by cattle ranchers because the dietary overlap of sheep and cattle averaged 20 to 35% compared to only 5 to 20% with goats (Olsen and Hansen 1977). Grazing with angora goats for 2 to 3 years reduced leafy spurge cover by 45 to 55% in North Dakota (Sedivec et al. 1995). Although stem densities and cover were reduced, no studies have shown that grazing with goats will kill leafy spurge (Olson and Lacey 1994). As with other control methods, once the animals were removed, leafy spurge began to regrow to its original densities.

Herbicides are the most widely used treatments for leafy spurge control (Lym and Messersmith 1985). However, control with herbicides is not always practical due to the high cost of treating large areas of infestation. Also, the weed frequently occurs in environmentally sensitive areas, such as near water or desirable trees and shrubs, where herbicide use is restricted. The purpose of this research was to evaluate herbicide treatments with goat grazing for long-term leafy spurge control.

## Materials and Methods

An experiment to evaluate herbicide treatment with grazing to improve long-term leafy spurge control compared to either control method alone was established in May 1992 in southeast and east-central North Dakota. Six treatments were evaluated includ-

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ing an untreated control, grazing alone, herbicides applied in the spring or fall alone, grazing following spring-applied herbicides, or grazing during the season prior to fall-applied herbicides.

The study sites were on the Sheyenne National Grasslands near McLeod and on the Gilbert C. Grafton South State Military Reservation near McHenry, N.D. The dominant grasses on the Sheyenne National Grasslands were Kentucky bluegrass (*Poa pratensis* L.), western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Löve], needle-and-thread (*Stipa comata* Trin. & Rupr.), porcupine grass (*Stipa spartea* Trin.), blue grama [*Bouteloua gracilis* (Michx.) Torr.], big bluestem (*Andropogon gerardii* Vitman) and sedges (*Carex* spp.). The dominant grasses at Camp Grafton South were Kentucky bluegrass, smooth brome (*Bromus inermis* Leyss.), little bluestem [*Schizachyrium scoparium* (Michx.) Nash-Gould], western wheatgrass, blue grama, and needle-and-thread.

Both sites had at least an 80% ground cover of leafy spurge. Camp Grafton South contained other perennial plants like western snowberry (*Symphoricarpos occidentalis* Hook.) and prairie wild rose (*Rosa arkansana* Porter). The Sheyenne National Grasslands site included approximately 50% cover of mature and dying cottonwood trees [*Populus deltoides* Marsh. subsp. *monilifera* (Ait) Eckenw.]. Average annual precipitation in southeastern and east-central North Dakota is 50 and 45 cm, respectively, with 77% received during the growing season (April through September). Annual precipitation received at Camp Grafton South was highly variable during the study, while that received at the Sheyenne National Grasslands slightly exceeded the long-term annual average (Table 1).

## Leafy Spurge Control

The effect of grazing alone or combined with herbicides to control leafy spurge was evaluated at 2 locations with the treatments arranged in a randomized complete block design with 3 replications at each location. Herbicides were applied to 8 by 15 m plots and included picloram (4-amino-3,5,6-trichloro-2-pyridinecarboxylic acid) applied with 2,4-D [(2,4-dichlorophenoxy)acetic acid] at 0.28 plus 1.1 kg ha$^{-1}$ in the spring or 0.56 plus 1.1 kg ha$^{-1}$ in the fall. These are the standard treatments for leafy spurge control in the region (Lym and Whitson 1991). Less picloram is translocated to the leafy spurge root system during the fall compared to the spring growth stage. Thus, the picloram application rate must be increased to obtain similar control from both treatments. Herbicides were applied with a tractor-mounted sprayer or hand-held sprayer delivering 80 liter ha$^{-1}$ water at 240 kPa. Spring treatments were applied during the leafy spurge true-flower growth stage in mid June and fall treatments were applied in mid-September approximately 30 days after grazing had ceased and leafy spurge plants were in the vegetative growth stage.

Grazing was prevented in the non-grazed treatments using 5- by 5-m portable exclosures. The exclosures were kept in place for the herbicide only and untreated control treatments, but were removed following the spring-applied herbicide treatments for all grazing treatments. Exclosures were not used for the grazing only and fall-applied herbicide following season-long grazing treatments.

Angora goats (*Capra hircus*) were used to graze leafy spurge at both locations using different grazing regimes. The study area at Camp Grafton South was managed using repeated seasonal grazing. Thirty-five angora goat nannies were stocked on a 5.6 ha paddock in 1992, 1993, and 1994. Annual grazing dates were 19 May to 24 August 1992 (97 days), 20 May to 18 August 1993 (90 days), and 26 May to 7 July, then 1 August to 21 August 1994 (63 days). Stocking rates declined from 1992 to 1994 due to the reduction of leafy spurge. The recommended stocking rate for good condition native pasture (overflow range site) in this vegetative region is 2.4 AUM ha$^{-1}$ [(animal-unit month) ha$^{-1}$] (USDA-SCS 1984). Stocking rates at Camp Grafton South during the trial were 2.9, 2.8, and 2.1 AUM ha$^{-1}$ for 1992, 1993, and 1994, respectively. Cattle were not present during the study.

The study area at the Sheyenne National Grasslands was managed using a rotational grazing system. Grazing was initiated in early May of each year using approximately 1,300 goats. A herder was employed to concentrate the goats on areas of heavy

**Table 1. Precipitation amounts and deviation from the long-term average at the 2 experiment sites.**

| | Precipitation/year | | | | | |
|---|---|---|---|---|---|---|
| | 1992 | | 1993 | | 1994 | |
| Location and month | Total | Dev[a] | Total | Dev[a] | Total | Dev[a] |
| Camp Grafton South | (cm) | (%) | (cm) | (%) | (cm) | (%) |
| April | 1.1 | 35 | 2.7 | 70 | 2.7 | 72 |
| May | 4 | 71 | 10 | 177 | 7 | 127 |
| June | 5.3 | 60 | 18.9 | 218 | 13.4 | 155 |
| July | 4 | 63 | 23.4 | 351 | 8.1 | 122 |
| August | 4.9 | 78 | 9.7 | 142 | 4.2 | 61 |
| September | 4.1 | 84 | 1.2 | 23 | 12.2 | 239 |
| Annual total | 32.4 | 73 | 74.8 | 169 | 69.1 | 156 |
| Sheyenne National Grasslands | | | | | | |
| April | 2.4 | 62 | 2.4 | 60 | 4.9 | 129 |
| May | 8.3 | 135 | 10.5 | 166 | 3.5 | 6 |
| June | 18.2 | 208 | 15.1 | 190 | 2.7 | 34 |
| July | 3.6 | 47 | 13 | 160 | 16.6 | 205 |
| August | 10.6 | 138 | 2.9 | 44 | 5.7 | 88 |
| September | 6.2 | 135 | 1.5 | 29 | 3 | 61 |
| Annual total | 61 | 125 | 56 | 114 | 51 | 105 |

[a]Deviation from long-term average, National Weather Service, Fargo, N.D.

leafy spurge infestations. Goats were rotated through 7 paddocks in succession, one of which included the experimental location. Goats grazed the experimental location 3 times in 1992 and twice in 1993 and 1994. Animals were allowed to graze leafy spurge in an area until most plants had been grazed before being moved to another paddock. The animals grazed for 2 to 3 hours in the morning and again in late afternoon. The animals were held in field pens the remainder of the day. Cattle were present in paddocks, and cattle and goats both were rotated according to Forest Service grazing agreements.

Leafy spurge density was determined each season prior to grazing and in the fall following grazing but prior to a fall herbicide treatment. Sampling was conducted at similar times in 1995 although no herbicide treatments were applied and grazing had been suspended. Leafy spurge stems were counted in four 0.25-$m^2$ quadrats per plot at approximately the same location each year.

### Root Nutrient Content

Leafy spurge roots were analyzed for carbohydrate and protein content as a measure of vigor. Roots were collected from a 0 to 15 cm depth for each treatment approximately 1 November of each year after the soil temperature was 4.4°C or lower. Plant material was placed in coolers with ice for transport, washed and frozen within 3 hours, and then dried at 60°C and stored frozen.

Both water-soluble (mostly sucrose) and insoluble (starch) carbohydrates were determined colorimetrically using the Dubois et al. (1956) phenol acid method as modified by Lym and Messersmith (1987). Total N and soluble proteins were determined using the Kjeldahl method (Goyal and Hafez 1990) as described by the Association of Analytical Chemists official method 988.05 (Anonymous 1990).

### Statistical Analysis

The data for leafy spurge control and root nutrient content were analyzed using the general linear models procedure (SAS Institute 1982). Analyses of variance were used to test for significance with a protected F-test. Grazing management differed by location, so the data are discussed separately.

## Results and Discussion

### Leafy Spurge Control

Grazing by goats combined with an annual fall application of picloram plus 2,4-D reduced leafy spurge density rapidly and maintained control longer than either method used alone (Figs. 1 and 2). Picloram plus 2,4-D applied annually in the spring reduced leafy spurge density similar to or better than the same treatment combined with grazing. Also, season-long grazing at Camp Grafton South either alone or combined with herbicides, reduced leafy spurge density more rapidly than rotational grazing used at the Sheyenne National Grasslands. This is in agreement with Bowes and Thomas (1978) who reported annual intensive, continuous grazing by sheep was necessary to reduce leafy spurge density in Saskatchewan.

All treatments at Camp Grafton South, including season-long grazing alone, reduced leafy spurge density the growing season following the first treatment (May 1993), compared to the untreated control (Fig. 1). After 1 year, the combination treatment of grazing in the spring followed by picloram plus 2,4-D in the fall was the only treatment that reduced leafy spurge density more than season-long grazing alone. Leafy spurge stem density averaged only 0.1 stem per 0.25 $m^2$ in May 1993 with the combination treatment compared to 5 stems per 0.25 $m^2$ from grazing alone. Stem density decreased to zero with the spring grazing plus fall-applied herbicide combination treatment in May 1994. This was the only treatment to eliminate leafy spurge topgrowth on any evaluation date during the study at Camp Grafton South, but the leafy spurge was not eradicated.

Season-long grazing alone at Camp Grafton South reduced leafy spurge stem density to only 1 stem per 0.25 $m^2$ following 3 years of grazing management (Fig. 1). Thus, it required 2 years longer for grazing alone to reduce leafy spurge density to the level that the grazing plus fall-applied herbicide treatment had after one season. The combination treatment of a spring-applied herbicide followed by grazing did not increase control compared to the spring applied herbicide alone and may have been slightly antagonistic.

Although all treatments reduced leafy spurge density to 1 stem per 0.25 $m^2$ or less after 3 years, the long-term control varied after treatments ceased in 1994 (Fig. 1). The spring-applied herbicide treatment alone or grazing plus a fall-applied herbicide treatment maintained leafy spurge control better than grazing or fall-applied herbicide treatments alone 1 year after the last application. Leafy spurge stem density averaged 1 stem per 0.25 $m^2$ in August 1995 or 12 months after the last treatment of grazing plus a fall-applied herbicide treatment compared to 6 and 7 stems per 0.25 $m^2$ following fall-applied herbicides or season-long grazing alone, respectively. A further increase in stem density would be expected the next growing season if treatments were not resumed.

Herbicides cannot be applied to a wide area during the spring and summer at Camp Grafton South because of training exercises by Army personnel. Noxious weeds generally are treated in the fall following the training exercises. Thus, the best treatment program for this location would be to allow grazing of the leafy spurge during the training season to prevent seed-set and cause stress to the root system followed by a fall-applied herbicide treatment to increase root kill and provide longer-term control than grazing alone. Continued grazing by goats alone would probably keep the infestation down to acceptable levels once control reached 90% or better which would take about 3 years.

Herbicides applied in the fall either alone or in combination with rotational grazing provided the most rapid leafy spurge control at the Sheyenne National Grasslands (Fig. 2). Leafy spurge stem density decreased in May 1993 from an average of 20 stems per 0.25$m^2$ to 2 or less stems per 0.25 $m^2$ the year following the first treatment.

Rotational grazing alone or combined with a spring-applied herbicide treatment at the Sheyenne National Grasslands did not reduce leafy spurge stem density compared to the control until after the third year of the study (Fig. 2). These results were much different than the rapid density reduction observed with season-long grazing of leafy spurge at Camp Grafton South (Fig. 1). Derscheid et al. (1985) concluded that control of leafy spurge by grazing was best accomplished through early season and continuous intensive grazing for several years. The results of this study also indicate that continuous intensive grazing yields the best control of leafy spurge. Rotational grazing was intended to allow

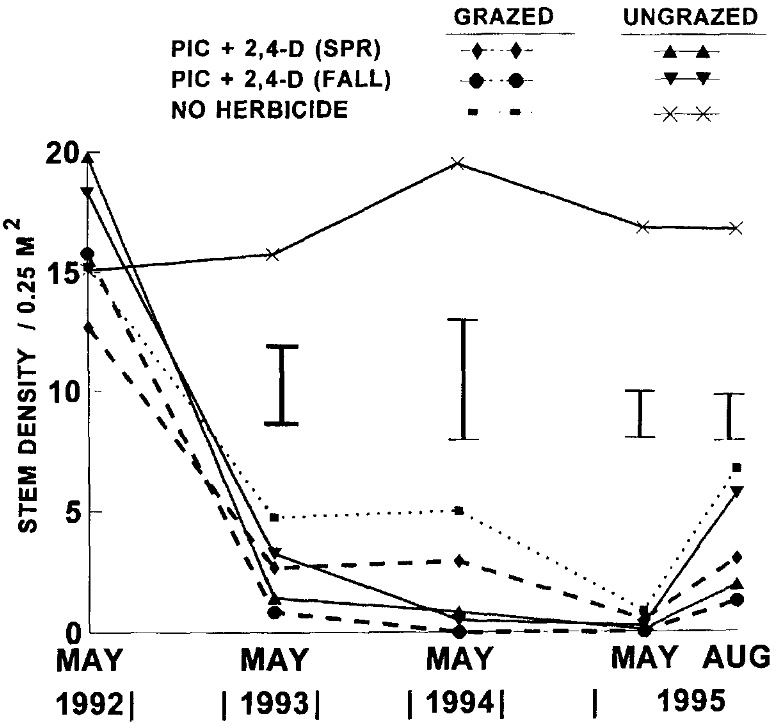


**Fig. 1. Leafy spurge control with angora goat grazing and herbicides used alone or in combination at Camp Grafton South, McHenry, N.D. Herbicides were applied and goats allowed to graze from mid May to mid August each year from 1992 through 1994 with no grazing or herbicide treatment applied in 1995. Vertical bars indicate LSD = (0.05).**

treatment of as large an area as possible with minimal damage to other forbs. Although damage to desirable shrubs and trees was minimized with rotational compared to continuous grazing, leafy spurge control was also less satisfactory.

The combination treatment of spring-applied herbicide with rotational grazing did not increase control compared to the herbicide applied alone (Fig. 2). The antagonism between spring-applied herbicides and grazing was more evident with rotational grazing compared to continuous grazing. Leafy spurge stem density after 1 year was nearly double with the herbicide plus grazing treatment compared to the spring-applied herbicide alone. Thereafter, the herbicide alone treatment provided similar or better leafy spurge control than the combination treatment.

The reason for the reduced control when the spring-applied herbicide was combined with grazing may be due to less picloram residue in the soil to maintain topgrowth control. Generally, 30% of the absorbed picloram remains in the stem and leaves and is released into the soil as the plant decays (Lym et al. 1989). Despite the dried topgrowth, the goats still grazed the leaves and top portion of the stem. Because the foliage had been removed there was little "residual" control from picloram leaching into the soil and the plants resumed regrowth more rapidly compared to those treated only with herbicides.

Herbicides applied in the fall following a rotational grazing program provided better long-term leafy spurge control than any other treatment evaluated at the Sheyenne National Grasslands

**Table 2. The effect of goat grazing alone or combined with herbicides on leafy spurge root carbohydrate and protein content under continuous grazing at Camp Grafton South, North Dakota.**

| Treatment | Rate | Sucrose[a] | | | Glucose[b] | | | Protein[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 92 | 93 | 94 | 92 | 93 | 94 | 92 | 93 | 94 |
| | (kg ha$^{-1}$) | (mg g$^{-1}$) | | | | | | | | |
| Grazed only | ... | 150 | 144 | 94 | 106 | 85 | 113 | 28 | 29 | 16 |
| Picloram+2,4-D (Fall) | 0.56+1.1 | NA[d] | 147 | 110 | NA | 130 | 92 | NA | 24 | 41 |
| Grazed (Spring)+picloram+2,4-D (Fall) | 0.56+1.1 | NA | 117 | 0[e] | NA | 72 | 0[e] | NA | 36 | NA |
| Picloram+2,4-D (Spring) | 0.28+1.1 | NA | 130 | 103 | NA | 169 | 117 | NA | 37 | 30 |
| Picloram+2,4-D (Spring)+Grazed (Fall) | 0.28+1.1 | NA | 150 | 74 | NA | 103 | 93 | NA | 29 | 17 |
| Control | ... | 153 | 125 | 113 | 186 | 186 | 134 | 48 | 56 | 70 |
| LSD (0.05) | | NS | NS | NS | NS | 57 | NS | 15 | 18 | 19 |

[a]Sucrose or water-soluble carbohydrate fraction.
[b]Glucose or water-insoluble (starch) carbohydrate fraction.
[c]Soluble crude protein.

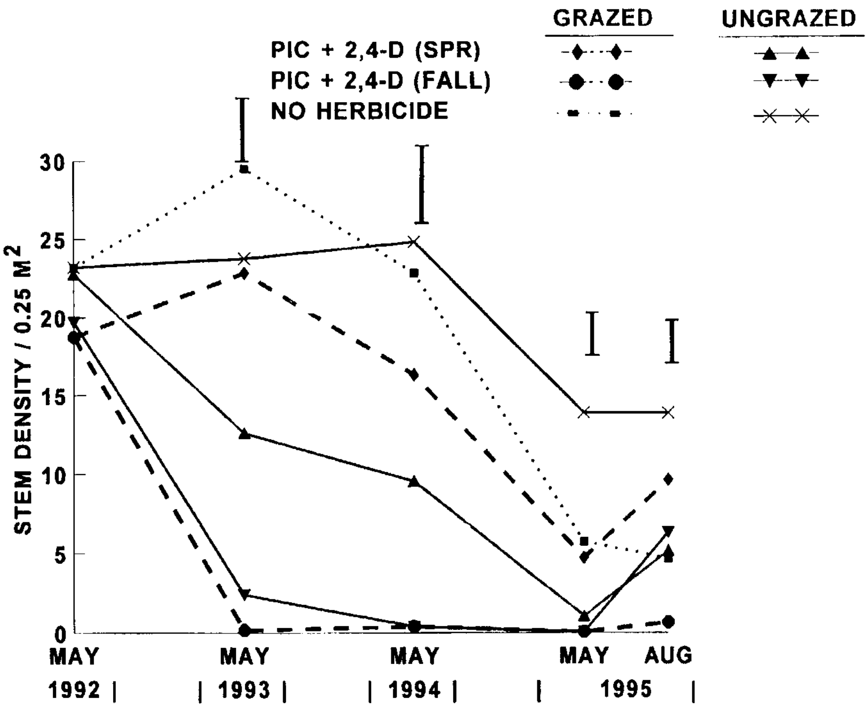


**Fig. 2. Leafy spurge control with angora goat grazing and herbicides used alone or in combination at the Sheyenne National Grasslands, Lisbon, N.D. Herbicides were applied and goats rotationally grazed from 1992 through 1994 with no grazing or herbicide treatment in 1995. Vertical bars indicate LSD = (0.05).**

(Fig. 2). Leafy spurge stem density averaged less than 1 stem per 0.25 $m^2$ 1 year after the last treatment, compared to an average of 6 stems per 0.25 $m^2$ with all other treatments.

### Root Nutrient Content

Few trends were evident for root carbohydrate content of leafy spurge controlled with herbicides and/or either grazing treatment (Tables 2 and 3). Root protein content was reduced under both grazing regimes when used alone or combined with herbicides. Protein content is considered a good indicator of plant vigor (Cyr and Bewley 1989) and for the potential of leafy spurge to overwinter (Lym and Messersmith 1993). Root carbohydrates serve as the energy source for leafy spurge to regrow following control efforts, but remain at or near average levels even when most of the root tissue has been destroyed. Thus, root protein content is a better indicator of treatment effect on the leafy spurge root system than the carbohydrate content.

Only the water-soluble (sucrose) root carbohydrates tended to decline when leafy spurge was grazed continually for 3 seasons at Camp Grafton South (Table 2). However, root carbohydrate content in the untreated control declined as well. The reason for the decline may be due to above average moisture received during the study (Table 1) that allowed vigorous competition from the grasses present. Several grass species compete well with leafy spurge and reduce its spread (Lym and Whitson 1991).

**Table 3. The effect of goat grazing alone or combined with herbicides on leafy spurge root carbohydrate and protein content under rotational grazing at the Sheyenne National Grasslands, North Dakota.**

| Treatment | Rate | Sucrose[a] | | | Glucose[b] | | | Protein[c] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 92 | 93 | 94 | 92 | 93 | 94 | 92 | 93 | 94 |
| | (kg $ha^{-1}$) | (mg $g^{-1}$) | | | | | | | | |
| Grazed only | ... | 160 | 152 | 146 | 148 | 110 | 114 | 37 | 18 | 16 |
| Picloram + 2,4-D (Fall) | 0.56+1.1 | 167 | 148 | 112 | 200 | 96 | 114 | 38 | 66 | 64 |
| Grazed (Spring) + picloram + 2,4-D (Fall) | 0.56+1.1 | 149 | 143 | 129 | 138 | 106 | 104 | 32 | 46 | 31 |
| Picloram + 2,4-D (Spring) | 0.28+1.1 | 148 | 138 | 140 | 126 | 150 | 102 | 44 | 45 | 27 |
| Picloram + 2,4-D (Spring) + Grazed (Fall) | 0.28+1.1 | 154 | 158 | 143 | 80 | 99 | 118 | 29 | 36 | 16 |
| Control | ... | 140 | 143 | 103 | 177 | 145 | 112 | 44 | 55 | 44 |
| LSD (0.05) | | NS | NS | 30 | 70 | NS | NS | NS | 22 | 23 |

[a]Sucrose or water-soluble carbohydrate fraction.
[b]Glucose or water-insoluble (starch) carbohydrate fraction.
[c]Soluble crude protein.
[d]NA = Not analyzed.
[e]Too little root material remained for analysis

At Camp Grafton South, continuous grazing alone and in combination with a herbicide treatment tended to reduce root protein content more than herbicides used alone (Table 2). Insufficient root material remained for analysis following 3 years of continuous grazing followed by a fall-applied herbicide treatment.

Root carbohydrate content generally declined under the rotational grazing regime at the Sheyenne National Grasslands even in the control (Table 3). Again the root protein content was reduced by nearly all treatments except the herbicide treatment fall-applied alone. Although rotational grazing took several years longer than continuous grazing to reduce leafy spurge topgrowth, root protein content was reduced similarly after 3 years (Tables 2 and 3).

## Conclusions

Herbicides in combination with grazing by goats provided better leafy spurge control than herbicides or grazing alone. Grazing followed by a fall-applied herbicide treatment of picloram plus 2,4-D resulted in the most rapid and long-term leafy spurge control. Leafy spurge control tended to be more rapid with continuous than rotational grazing, but control from the rotational system would be acceptable when desirable broadleaf plants can be maintained in the pasture. Leafy spurge root protein content was a better indicator of the effect of various treatments on the leafy spurge root system than the carbohydrate content.

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