



Leafy spurge (*Euphorbia Esula* L.) as a forage component for ewes and lambs
by Susan Jean Bartz

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Range Science

Montana State University

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Abstract:

Leafy spurge (*Euphorbia esula* L.) is an introduced perennial weed which is currently estimated to infest over 200,000 hectares of rangeland in Montana. Leafy spurge's extensive root system and reproductive modes make this weed extremely difficult to control. Because most methods of chemical and biological control of leafy spurge have proven to be either ineffective or too costly, it has been suggested that this weed be evaluated as a forage plant.

A research project was initiated in May of 1982 to determine the forage value of leafy spurge for sheep. Average daily gains were determined for lambs and ewes grazing different treatment pastures. Diet composition and forage intake of sheep were estimated, and production records of ewes having consumed leafy spurge were examined.

The study area consisted of nine 1.66 hectare pastures -three replications of three treatment conditions. Treatments were no spurge (control), light spurge (10-20 percent of the plant composition), and heavy spurge (>20 percent of the plant composition). Five lamb/ewe pairs were randomly assigned to each pasture. All sheep were weighed once every two weeks during the eight-week data collection period. Ten 1.5 m² utilization cages were randomly located in each pasture, and the paired plot technique was used to estimate the type and amount of forage removed.

Neither lambs nor ewes exhibited any deleterious effects due to the consumption of leafy spurge. Average daily gains (ADG's) of lambs grazing heavy spurge pastures during 1982 were higher ($P \leq .05$) than average daily gains of lambs grazing light spurge and control pastures. ADG's of lambs grazing heavy and light spurge-infested pastures during 1983 were higher ($P \leq .05$) than ADG's of lambs grazing control pastures. Estimates of forage removed and diet composition of sheep grazing the different treatment pastures showed that leafy spurge comprised 41 percent of the diet of sheep selectively grazing light spurge pastures and 55 percent of the diet of sheep selectively grazing heavy spurge pastures. Performance records showed ewes exhibited no rebreeding or lambing difficulties the season immediately following summer use of leafy spurge.

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This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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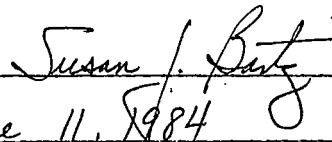
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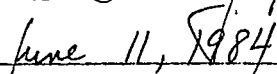
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ABSTRACT

Leafy spurge (*Euphorbia esula* L.) is an introduced perennial weed which is currently estimated to infest over 200,000 hectares of rangeland in Montana. Leafy spurge's extensive root system and reproductive modes make this weed extremely difficult to control. Because most methods of chemical and biological control of leafy spurge have proven to be either ineffective or too costly, it has been suggested that this weed be evaluated as a forage plant.

A research project was initiated in May of 1982 to determine the forage value of leafy spurge for sheep. Average daily gains were determined for lambs and ewes grazing different treatment pastures. Diet composition and forage intake of sheep were estimated, and production records of ewes having consumed leafy spurge were examined.

The study area consisted of nine 1.66 hectare pastures - three replications of three treatment conditions. Treatments were no spurge (control), light spurge (10-20 percent of the plant composition), and heavy spurge (>20 percent of the plant composition). Five lamb/ewe pairs were randomly assigned to each pasture. All sheep were weighed once every two weeks during the eight-week data collection period. Ten 1.5 m² utilization cages were randomly located in each pasture, and the paired plot technique was used to estimate the type and amount of forage removed.

Neither lambs nor ewes exhibited any deleterious effects due to the consumption of leafy spurge. Average daily gains (ADG's) of lambs grazing heavy spurge pastures during 1982 were higher ($P \leq .05$) than average daily gains of lambs grazing light spurge and control pastures. ADG's of lambs grazing heavy and light spurge-infested pastures during 1983 were higher ($P \leq .05$) than ADG's of lambs grazing control pastures. Estimates of forage removed and diet composition of sheep grazing the different treatment pastures showed that leafy spurge comprised 41 percent of the diet of sheep selectively grazing light spurge pastures and 55 percent of the diet of sheep selectively grazing heavy spurge pastures. Performance records showed ewes exhibited no rebreeding or lambing difficulties the season immediately following summer use of leafy spurge.

INTRODUCTION

Over 200,000 hectares of rangeland in Montana are currently infested with an introduced perennial weed known as leafy spurge (Euphorbia esula L.) (Noble et al. 1979). This weed possesses an extremely extensive root system which makes it difficult to control and virtually impossible to eradicate (Messersmith 1979).

Because many areas of leafy spurge infestation go ungrazed due to noxious reactions experienced by cattle ingesting this weed (Muenscher 1951), efforts have been made to find herbicidal and biological means of controlling the rapid spread of leafy spurge. Several herbicides have proven effective in controlling topgrowth for up to 3 years (Bowes and Molberg 1975; Alley 1979; Alley et al. 1983), but repeated applications, which are necessary to keep an infestation under control, are often too expensive for the average landowner to finance (Reilly and Kaufman 1979). In addition, no herbicides have been found which eradicate leafy spurge because they chemically decompose before the deep leafy spurge roots are killed (Alley 1979; Lym and Messersmith 1983). Bioagents are currently being investigated (Bruckart 1983; Carlson and Littlefield 1983).

Sheep have been successfully used to control leafy spurge (Muenscher 1930; Helgeson and Thompson 1939; Wood 1945; Johnston and Peake 1960; Bowes and Thomas 1978; Stratton 1982), but there are disagreements concerning the effects of leafy spurge on sheep (Muenscher 1930; Bakke 1936; Christensen et al. 1938; Helgeson

and Thompson 1939; Wood 1945; Johnston and Peake 1960; Bartik and Piskac 1981; Landgraf et al. 1983). If sheep are used to control leafy spurge, then its forage value must be examined.

The objectives of this study were to: 1) determine the rate of gain of lambs and ewes grazing different treatment pastures, namely no spurge, light spurge, and heavy spurge-infested pastures, 2) estimate diet composition and amount of forage removed by sheep grazing different treatment pastures, and 3) estimate the effects of consumption of leafy spurge on the rebreeding and lambing performance of ewes.

LITERATURE REVIEW

Plant Characteristics

Leafy spurge (Euphorbia esula L.) is an introduced perennial weed which is currently estimated to infest over 1 million hectares in North America and more than 200,000 hectares in Montana (Noble et al. 1979). Distribution of this weed can be largely attributed to its extremely successful modes of reproduction. Leafy spurge can reproduce and spread vegetatively from both roots and seeds. Ripe seed pods contain a special explosive mechanism which hurl seeds up to 4.6 meters (Bakke 1936). Extensive root systems, possessing propagative buds (Hanson and Rudd 1933), have been found as deep as 4.5 meters (Messersmith 1979).

Many areas of leafy spurge go ungrazed due to noxious reactions experienced by cattle ingesting this weed (Muenscher 1951). Reilly and Kaufman (1979) reported that tests conducted near Bozeman, Montana showed reductions in rangeland carrying capacity of up to 75 percent as a result of leafy spurge's ability to inhibit forage production and decrease cattle utilization of associated grasses.

Chemical Control

Control measures must be utilized on rangelands containing leafy spurge to regulate its spread and return infested areas to their original native plant composition. Therefore, efforts have been made to find herbicidal and biological means of controlling

the rapid spread of leafy spurge. Several herbicides can effectively control topgrowth of leafy spurge if applied every 1 to 3 years (Bowes and Molberg 1975; Alley 1979; Alley et al. 1983). However, there are no herbicides available which can effectively eradicate leafy spurge (Alley 1979). Initial research for chemical control involved inorganic herbicides which were effective only when high rates which sterilized the soil were used (Messersmith 1983a). These early failures established the principle that leafy spurge had a deep root system which could survive without topgrowth for three to five years or more. Modern herbicides, such as 2,4-D, dicamba, glyphosate, and picloram, are more effective than original inorganic herbicides but break down before the deep leafy spurge roots die (Lym and Messersmith 1983). Consequently, repeated annual application of herbicides is necessary to deplete deep root food reserves and inhibit root regeneration (Messersmith 1983b).

Chemical control of leafy spurge might also be hindered by variable responses of different Euphorbia species and their varieties to chemical treatments. As many as 12 different taxa have been associated with leafy spurge (Noble et al. 1979). This broad plant-ecological diversity helps to explain, in part, discrepancies in the literature regarding the effectiveness of certain control measures (Noble et al. 1979). Research is being conducted to taxonomically distinguish species and varieties of the genus Euphorbia and determine why varieties of leafy spurge

appear to respond differently to the same control measures (Nowierski 1984).

Because most chemicals must be applied every year to keep an infestation under control, it has become economically infeasible for the average rancher to finance a leafy spurge control program. Private landowners in Montana are estimated to be spending more than 2.5 million dollars annually to control leafy spurge, and a number of ranchers have weed control expenses amounting to more than their land payments each year (Reilly and Kaufman 1979).

Biological Control

Biological control of weeds involves use of a living organism to reduce the density of the target weed below the economic threshold (Harris 1979). Leafy spurge appears to be an excellent target for biocontrol because of the large number of insect species which attack Euphorbia in Europe (Harris 1979). In addition, some plant pathogens are being studied to determine their potential as biological control agents for leafy spurge (Bruckart 1983; Carlson and Littlefield 1983).

However, there are problems associated with the use of bioagents to control leafy spurge. Host specificity, survival of the bioagent in different environments, time restrictions, and economic feasibility are some limitations requiring consideration (Harris 1979). The name "leafy spurge" encompasses a diversity of taxonomic and biological plant types. This range of biotypes

and phenotypes can cause unexpected problems in developing a host-specific biological control organism. Organisms effective on one type of spurge often will not attack "other" spurges. Changes in climate or species may hinder translocation of an organism to another environment (Harris 1979; Noble et al. 1979). Some moths have been shown to defoliate leafy spurge but not enough damage has been incurred to reduce the plant's regenerative ability (Harris 1979). In addition, high rates of bioagent mortality have reduced some populations to the point where control is nonexistent (Harris 1979). A new root boring beetle has had much success reducing spurge infestations in Europe (Harris 1979), but no research has yet been conducted with this beetle in the United States. Time and money limitations must also be considered when examining the use of a bioagent to control leafy spurge. According to Harris (1979) approximately 20 years and 2 million dollars would be required to initiate and fully develop an effective biological control program.

Sheep and Leafy Spurge

There are reports that Montana ranchers have been using sheep to control leafy spurge for more than 30 years (Stratton 1982), but little research has been documented. Muenscher (1930) suggested that large areas or fields containing leafy spurge should be seeded to grass and followed by continuous close pasturing with sheep for at least 3 years. Helgeson and Thompson (1939) grazed sheep for 2 years on unmowed and mowed pastures

infested with leafy spurge and found a reduction of 68 percent (unmowed) and 31 percent (mowed) in the number of leafy spurge stalks. In addition, the total basal area of the associated bluegrass increased 179 and 212 percent in the mowed and unmowed pastures, respectively. Johnston and Peake (1960) used sheep to graze a mixed crested wheatgrass (Agropyron cristatum L.) - leafy spurge pasture. After 5 years of summer grazing the basal area of leafy spurge decreased 98 percent while the basal area of the crested wheatgrass increased 20 percent. Bowes and Thomas (1978) found that even though picloram provided control of leafy spurge for a minimum of 3 years, continuous sheep grazing gave satisfactory long-term control of leafy spurge. Vegetative portions and number of viable seeds in the soil were greatly reduced.

Although various reports have stated that sheep can be used to control leafy spurge, there is disagreement in the literature concerning the role of leafy spurge as a forage and its effects on sheep. Consideration must be given to leafy spurge's life form, production capabilities, and nutritive value.

Leafy spurge is a perennial forb which establishes early and responds readily to available moisture. New shoots have been found as tall as 15 centimeters by mid April, and plants are in full bloom by the first of June (Bakke 1936). When the soil is moist the leaves become larger and more abundant, but during water stress (i.e. - late summer) leafy spurge becomes dormant. New fall regrowth is stimulated by cooler weather and rainfall in

August or early September (Lym and Messersmith 1983). Consequently, leafy spurge maximizes its use of available moisture by producing large amounts of green succulent vegetation throughout the growing season.

The botanical and nutritive composition of sheep diets during the summer must also be evaluated when considering utilization of leafy spurge as a forage resource. Forage intake values of sheep grazing summer range also need to be evaluated to estimate relative amounts of forage removed. Cook et al. (1967) and Cook and Harris (1968) found that sheep grazing mountainous summer range readily ate grasses but generally consumed more forbs and browse. Early in the season both grasses and forbs were found to be highly palatable to sheep. As grasses decreased in palatability during late summer, forb utilization remained fairly high and was accompanied by an increase in browse consumption. Buchanon et al. (1972) found that sheep grazing high mountain range in southwestern Montana during 2 summers averaged 24 percent grass and 76 percent forbs in their diet. An earlier study by Cook et al. (1956) noted that during early summer stems comprised 60 percent of the available forage but only 34 percent of diet. Leaves comprised 40 percent of the available forage but 66 percent of the diet. This study substantiates findings of Van Dyne et al. (1980) that a major component of animal preference is the presence of green leaf material.

Van Dyne et al. (1980) also summarized data collected by Cook et al. during the summer of 1956 which estimated forage intake of sheep grazing seeded pastures in the foothills of Utah. Results of this series of grazing studies showed that wethers, averaging 59 kilograms, consumed 2.4 ± 0.77 percent their body weight in forage on a dry matter basis. This forage intake information could provide a basis for estimating forage intake of sheep grazing similar species during a similar grazing season.

There is good evidence that sheep will eat leafy spurge. Christensen et al. (1939) noted that most lambs fed leafy spurge silage did not consume much the first day, but after a few days all but two were eating enough to continue the test without apparent ill effects. Helgeson and Thompson (1939) reported that sheep ate blossoms and seeds first and later ate leaves and stems. They also noted that sheep would alternatively graze leafy spurge and grass, eating spurge rather "greedily" at times and then shifting to grass. Wood (1945) observed that sheep exhibited a decided preference for leafy spurge, even over crested wheatgrass to which they had equal access. Johnston and Peake (1960) noted that sheep preferred younger leafy spurge plants and avoided more mature plants. Landgraf et al. (1983) concluded that after a 2 to 3 week adjustment period sheep would selectively consume up to 40 to 50 percent of their diet as leafy spurge. Previous exposure to leafy spurge did not influence selection of the plant during a different grazing trial (Landgraf et al. 1983).

Although there is evidence sheep will selectively consume leafy spurge, there is disagreement in the literature concerning the effects of leafy spurge on sheep. Muenscher (1930), Christensen et al. (1938), Wood (1945), and Landgraf et al. (1983) all found that sheep exhibited no deleterious effects from consuming leafy spurge. Bakke (1936) stated that neither sheep nor cattle would eat leafy spurge because of its acrid latex, but that sheep would eat leafy spurge if starved on to it. However, no documentation was cited to validate this statement. Helgeson and Thompson (1939) found that sheep experienced no harmful effects from eating leafy spurge with the exception of a few lambs which scoured. However, no documented examination of the scoured lambs was cited to attribute this condition to consumption of leafy spurge.

Alternatively, Johnston and Peake (1960) attributed deaths of an unknown number of sheep to consumption of large mature leafy spurge plants. Post-mortem examinations indicated that leafy spurge was responsible for the poisoning losses, but these examinations were undocumented and did not explain the means by which leafy spurge contributed to the deaths. However, when sheep were put in the pasture at an earlier date and allowed to graze immature plants no losses were reported. Bartik and Piskac (1981) stated that Euphorbia esula L. and closely related species possess a poisonous white latex which affects almost all animal species, but failed to substantiate these findings as pertaining to sheep.

Although there are observations that sheep can control infestations of leafy spurge by grazing the topgrowth, there is concern that sheep may spread this weed to previously uninfested areas by passing viable seeds. Rippey et al. (1983) found that seed viability was reduced from 25 to 14 percent when seeds were exposed to a 48-hour incubation in sheep rumen fluid. Complete loss of viability occurred when seeds were exposed to an in vitro rumen and small intestine treatment. Seeds recovered from sheep manure showed germination rates ranging from 7 to 30 percent. Even though germination success was significantly lowered in seeds digested by sheep, only a small amount of viable seeds is sufficient to spread leafy spurge. Suggestions to control deposition of viable seeds to uninfested areas include heavily grazing leafy spurge before seed set to prevent seed development, or isolating sheep in a holding area for 7 days to allow for voiding of leafy spurge seed which may have retained its viability (Rippey et al. 1983).

Considerable disagreement still exists within the literature regarding the role of leafy spurge as a forage and its effects on sheep. If sheep are used to control leafy spurge, its forage value must be examined to determine whether sheep will benefit from its use as a forage.

METHODS AND PROCEDURES

Description of the Study Site

The research site was located near the western slopes of the Tobacco Root Mountains in southwestern Montana on the Ray Gillespie ranch 9.7 kilometers south of Whitehall, Montana. The research site was located in Jefferson County (Section 6, T1S, R4W) on the Jefferson River floodplain. The study area was a shallow-to-gravel range site in a 27 to 36 centimeter precipitation zone (Montana Climatological Data - 1972 - 1982) and had been seeded to tall fescue (Festuca arundinacea) in 1974. Since that time several other grass species appeared on the site, including various Agropyron spp., Kentucky bluegrass (Poa pratensis), and scattered patches of cheatgrass (Bromus tectorum) (Appendix - Table 6). In 1976 leafy spurge (Euphorbia esula) was accidentally introduced and gradually infested the area until it comprised 10 to 50 percent of the plant composition.

The rectangular experimental area measured 274 meters by 549 meters (15 hectares) and was divided into nine 1.66 hectare pastures, each measuring 61 meters by 274 meters (Figure 1). Pastures were designated on the basis of their leafy spurge composition, with three pastures of each treatment being designated by one of the following leafy spurge infestations: 1) control - no spurge (only grasses present) as a result of spraying Tordon at 0.56 kilograms per hectare, 2) light - an ocular estimate of 10 to 20 percent composition (canopy cover) of

leafy spurge, and 3) heavy - an ocular estimate of greater than 20 percent composition (canopy cover) of leafy spurge. Electric fence separated the treatment pastures.

Sheep Analyses

Forty-five ewes with single lambs were randomly selected for each research period from a range/herder operation at Montana State University's Red Bluff Research Station. Ewes were 2 to 6 year old Finn crosses which had been bred to Suffolk rams and weighed an average of 60 kilograms. Lambs averaged 70 days of age at the beginning of the study and weighed an average of 21 kilograms. Five lamb/ewe pairs were randomly assigned to each pasture during the second week of June (each summer) and allowed to selectively graze. Animals were allowed free access to trace mineralized salt and water was provided in each pasture. Fourteen days after sheep were placed in pastures both lambs and ewes were weighed. Sheep were weighed once every two weeks during the eight-week summer data collection period to monitor and compare weight gains of animals using the different treatment pastures.

Breeding and lambing records of ewes which grazed leafy spurge-infested pastures during the summers of 1982 and 1983 were examined to determine whether leafy spurge consumption caused abnormalities in production efficiency of ewes. Rebreding and lambing success, number of lambs, size of lambs, and health of newborn lambs were analyzed.

Forage Analyses

Ten 1.5 m² utilization cages were randomly located in each pasture (Figure 1). The paired plot technique was used to estimate the amount and type of forage removed (NRC 1962). Two 1 m² plots were harvested at each cage location - one inside the cage and one outside the cage. Locations of uncaged plots were randomly determined. Vegetation of each plot was harvested and separated into its leafy spurge and grass constituents. Other forbs occurred in only negligible amounts and were not included in the harvest collections. Spurge and grass samples were bagged separately and air-dried weights were determined.

Three pastures (control, light and heavy) were harvested every week beginning July 5, 1983. Paired plots were harvested from each cage location, and cages were replaced to cover harvested uncaged plots to measure regrowth of grazed plants. Beginning July 26, 1983 a second rotation of harvests was begun with three pastures, one of each treatment condition. Harvest data were used to estimate amount and type of forage removed by sheep grazing treatment pastures. Representative samples of these harvest data were analyzed to determine forage quality. Forage quality was defined on the basis of values obtained from proximate analyses of leafy spurge and grass harvests. Samples for analyses were collected during three stages of phenological development, including initial standing crop, grazed regrowth, and final standing crop. Proximate analyses were conducted following AOAC (1980) procedures to determine crude protein, ash,

acid detergent fiber (ADF), and lignin fractions of the spurge and grass samples on a percent dry matter basis.

Statistical Analyses

Data were analyzed using a randomized complete block design. One factor analysis of variance (ANOVA) was used to compare average daily gains of lambs and ewes and estimated amounts and types of forage removed by lamb/ewe pairs grazing the different treatment pastures. The statistical model for weight gains included age, time, treatment, and year as fixed sources of variation. The statistical model for forage removals included age, time, and treatment as fixed sources of variation. Means were separated using a least significant difference (LSD) test, with significance being determined at $P \leq .05$ (Steel and Torrie 1960).

Lambing performance of experimental ewes was also analyzed. Data from 1983 and 1984 lambing seasons were analyzed separately. A G-test (Sokal and Rohlf 1981) was used to test for independence between the three treatments against single and multiple births. Significance was determined at $P \leq .05$. Lamb birth weights were not analyzed because the experimental design was not adequate to allow for statistical analysis of these data.

RESULTS

The following results will present statistical analyses of sheep and forage data collected during this research project. A separate discussion section follows. Sheep data include analyses of lamb and ewe ADG's. Forage data include estimates of forage removal and diet composition of sheep, and proximate analyses of leafy spurge and grass samples. Ewe production data provide analyses of lambing performance of ewes which grazed different treatment pastures.

Sheep Weight Data

Average daily gains (ADG's) of lambs and ewes grazing different treatment pastures during the summers of 1982 and 1983 are presented in Table 1. Lambs grazing heavy spurge pastures during the summer of 1982 were found to have significantly higher ($P \leq .05$) ADG's during the first weighing period and for the entire season than lambs grazing control and light spurge pastures. Lambs grazing light and heavy spurge pastures during these two periods in 1983 were found to have significantly higher ADG's than control treatment lambs. Ewe weight data collected in 1982 showed a significant difference between ADG's of ewes grazing control and light spurge pastures during the second weighing period, and ADG's of ewes grazing light and heavy spurge pastures for the entire season were significantly higher than ADG's of control treatment ewes. A significant difference was observed

Table 1. Average daily gains (kg) of lambs and ewes grazing pastures with different proportions of leafy spurge during the summers of 1982 and 1983.

Treatment	Weighing Period			Entire Season	
	6/24-7/8	7/8-7/22	7/22-8/5		
Lambs:					
(1982)	Control	0.22 ^a	0.12 ^a	0.19 ^a	0.17 ^a
	Light	0.21 ^a	0.12 ^a	0.22 ^a	0.18 ^a
	Heavy	0.29 ^b	0.14 ^a	0.26 ^a	0.23 ^b
(1983)	Control	0.21 ^a	0.24 ^a	0.19 ^a	0.21 ^a
	Light	0.30 ^b	0.28 ^a	0.21 ^a	0.26 ^b
	Heavy	0.35 ^b	0.25 ^a	0.23 ^a	0.28 ^b
Ewes:					
(1982)	Control	-0.03 ^a	-0.22 ^a	0.00 ^a	-0.08 ^a
	Light	-0.12 ^a	-0.07 ^b	0.07 ^a	-0.04 ^b
	Heavy	-0.03 ^a	-0.17 ^{ab}	0.13 ^a	-0.02 ^b
(1983)	Control	-0.06 ^a	0.03 ^a	0.05 ^b	0.01 ^a
	Light	-0.02 ^a	0.05 ^a	-0.04 ^a	0.00 ^a
	Heavy	-0.06 ^a	0.13 ^a	0.00 ^{ab}	0.02 ^a

¹Means within the same column followed by different letters are significantly different ($P \leq .05$).

during the third weighing period in 1983 between ADG's of ewes grazing control and light spurge pastures.

Forage Data

Means of data collected during the summer of 1983 and used to estimate the amount and type of forage removed by sheep grazing different treatment pastures are listed in Table 2. A shift in diet composition was observed in the diets of sheep grazing leafy-spurge infested pastures. Sheep grazing light and heavy spurge pastures consumed more leafy spurge than grass "early" (June 28 through July 19) in the data collection period and more grass than leafy spurge "late" (July 20 through

Table 2. Estimated amounts of forage removed¹ by sheep grazing pastures with different proportions of leafy spurge during the summer of 1983.

Treatment	Pasture	Early		Late		Entire Season	
		Grass	Spurge	Grass	Spurge	Grass	Spurge
Control	1	11.2	0	16.8	0	14.0	0
	2	17.9	0	19.4	0	18.7	0
	3	33.2	0	41.6	0	37.4	0
Light	1	15.7	11.7	21.5	6.6	18.6	9.1
	2	7.6	18.2	11.9	11.4	9.7	14.8
	3	6.2	4.3	11.7	3.1	8.9	3.7
Heavy	1	9.2	17.9	9.3	13.0	9.2	15.4
	2	0	16.3	7.6	9.4	3.8	12.9
	3	2.8	0.5	15.4	7.4	9.1	4.0

¹Mean values of 10 paired plots for each pasture are expressed in kg (DM)/pasture/day of air-dried forage.

August 9) in the data collection period. Diets of sheep grazing light and heavy spurge pastures early in the season contained 52 and 61 percent leafy spurge, respectively. Diets of sheep grazing light and heavy spurge pastures late in the season contained only 31 and 49 percent leafy spurge, respectively. These decreases in leafy spurge consumption were accompanied by proportional increases in grass consumption.

Estimates of forage intake were also expressed as a percent of total live body weight per treatment. These values are listed in Table 3. Sheep grazing control pastures consumed the most total forage as a percent of live weight for the entire season while sheep grazing heavy spurge pastures consumed the least amount of total forage as a percent of live weight.

Representative samples of leafy spurge and grass harvests were examined to determine their forage quality during the summer

Table 3. Forage¹ consumed as a percent of live weight of sheep grazing pastures with different proportions of leafy spurge.

Treatment	Early		Late		Entire Season	
	Grass	Spurge	Grass	Spurge	Grass	Spurge
	----- % -----					
Control	5.0	0	6.0	0	5.4	0
Light	2.5	2.8	3.4	1.6	2.9	2.2
Heavy	1.0	2.7	2.2	2.1	1.6	2.4

¹Air-dry basis.

grazing season. Results of proximate analyses are presented in Table 4. Throughout the growing season leafy spurge contained more crude protein and lignin but less ash and acid detergent fiber (ADF) than grass. Grazed regrowth samples of both species were higher in crude protein and ash and lower in ADF and lignin than their corresponding initial and standing crops, but the magnitude of these differences was larger and more variable for leafy spurge than it was for grass.

Ewe Performance

Breeding and lambing records were monitored for ewes having grazed different treatment pastures during the summers of 1982 and 1983. Red Bluff Ranch Research Station lambing records showed that no ewes experienced rebreeding or lambing difficulties the season immediately following summer use of leafy spurge-infested pastures. Lambing performance of ewes which grazed different treatment pastures during the summers of 1982 and 1983 is presented in Table 5. No significant difference was

Table 4. Proximate analyses of leafy spurge¹ and grass² harvest samples collected at three stages of the data collection period during the summer of 1983.

		- - - Dry Matter Basis - - -				
		Crude				
Forage	Growth Stage	DM	Protein	Ash	ADF	Lignin
		- - - % - - -				
Leafy spurge:						
	Initial Standing					
	Crop	93.6	12.2	7.3	38.0	8.8
	Grazed Regrowth	93.6	20.6	9.8	23.2	4.8
	Final Standing					
	Crop	92.8	8.4	6.8	42.3	9.6
Grass:						
	Initial Standing					
	Crop	94.8	7.3	11.6	41.8	4.6
	Grazed Regrowth	94.3	11.9	13.6	36.4	3.0
	Final Standing					
	Crop	94.1	7.0	12.8	40.8	4.0

¹Mean values of samples from light and heavy spurge pastures.

²Mean values of samples from control, light, and heavy spurge pastures.

Table 5. Subsequent lambing performance of ewes which grazed treatment pastures during the summers of 1982 and 1983.

Year	Treatment	Number of Ewes	Lambs /Ewe
1982 ¹	Control	8	1.9 ^a ³
	Light	9	1.5 ^a
	Heavy	11	1.4 ^a
1983 ²	Control	13	1.5 ^a
	Light	11	1.4 ^a
	Heavy	11	1.7 ^a

¹Records were found for only 28 ewes because of culling and predation losses.

²Records were found for only 35 ewes because of culling and predation losses.

³Means within the same column followed by different letters are significantly different ($P \leq .05$).

observed among mean litter sizes of ewes which grazed different treatment pastures. All lambs were born healthy and experienced no changes in their general health which could be attributed to leafy spurge consumption by their mothers (Jordan 1984). Mean birth weights of lambs born to 1982 experimental ewes ranged from 4.4 to 4.9 kilograms. Mean birth weights of lambs born to 1983 experimental ewes ranged from 3.9 to 4.3 kilograms. Significance among birth weights of lambs born to ewes which grazed different treatment pastures was not statistically determined. Confounding factors such as breed, sex, age of ewe, and litter size would need to have been considered but were not accounted for in the experimental design.

DISCUSSION

This discussion section will examine data analyses presented in the results and attempt to explain their significance. Data will be discussed in the same order they were presented in the results section.

Season-long ADG's of experimental lambs ranged from 0.17 to 0.23 kg in 1982 and from 0.21 to 0.28 kg in 1983 (Table 1). A typical range lamb born weighing 4.5 kg and weaned 120 days later weighing 36.3 kg would have a season-long ADG of 0.26 kg (Haresign 1983). Based on these similarities ADG's of experiment lambs were considered comparable to an ADG of a lamb in a similar rangeland situation.

Significant differences were observed between season-long ADG's of experimental lambs. In 1982 season-long ADG's of heavy spurge treatment lambs were 0.05 and 0.06 kg higher than season-long ADG's of light spurge and control treatment lambs, respectively (Table 1). In 1983 season-long ADG's of light and heavy spurge treatment lambs were 0.05 and 0.07 kg higher, respectively, than season-long ADG's of control treatment lambs (Table 1). Because heavier lambs provide higher financial returns, it is important to examine what factors possibly contributed to differences between ADG's of experimental lambs.

At 2 to 4 weeks of age a lamb consumes 4 to 6 percent of its body weight as forage (Church 1980). At 8 weeks of age a lamb's stomach is physiologically developed and the same size as an

adult's (Church 1976). Experimental lambs were approximately 10 weeks old when assigned to treatment pastures and were physiologically mature enough to subsist solely on herbage (Ansotegui 1984). Lambs were observed consuming some milk, but on the basis of direct observations it was concluded that lamb diets were composed largely of forage. Milk consumption had no effect on ADG's after the first weighing period.

Environmental stress can affect ADG's. However, because all sheep were exposed to the same environmental conditions it was concluded that changes in the environment did not directly contribute to differences among treatment ADG's.

Differences among ADG's of experimental lambs were based on the quality and quantity of forage available to sheep in the treatment pastures. According to NRC requirements (1975) a 21 kg lamb needs approximately 11.7 percent crude protein in its diet to gain 0.26 kg per day. Early (June 28 through July 19) in the summer of 1983 leafy spurge contained 12.2 percent crude protein while grass contained only 7.3 percent (Table 4). Late in the summer a 32 kg lamb needs only 8.2 percent crude protein in its diet to gain 0.23 kg (NRC 1975). Mature lambs can meet their nutrient requirements by consuming larger amounts of lower quality forage. Leafy spurge furnished 8.4 percent crude protein late (July 20 through August 9) in the grazing season while grass furnished only 7.0 percent (Table 4). Leafy spurge provided a higher quality forage than grass throughout the growing season.

Estimates of forage disappearance showed that sheep in heavy and light pastures selectively consumed part of their diet as leafy spurge (Table 2). Sheep grazing control pastures consumed only grass. Consequently, higher ADG's of lambs grazing spurge pastures were attributed to the availability and selective consumption of a higher quality diet. Differences were observed among season-long ADG's of ewes in 1982 (Table 1), but the magnitude of these ADG's and their corresponding treatment differences were not considered large enough to be deemed biologically significant.

Estimated amounts of forage removed by experimental sheep suggested a shift in diet composition of sheep grazing leafy spurge - infested pastures. Early in the season a larger portion of sheep diets consisted of leafy spurge. Late in the season more grass was proportionally consumed (Table 2). This shift in diet composition corresponds closely to the phenological development and production capabilities of leafy spurge. Leafy spurge establishes and produces large amounts of green, succulent leaf material early in the growing season (Bakke 1936). The exhibited preference of sheep for leafy spurge early in the season may be directly related to the presence of large amounts of this more succulent vegetation. McClymont (1967) noted that studies on grazing sheep have shown animals will select forages with high nutritional values. Leaves will be selected over stems, green material over dead material, and young leaves over old leaves (McClymont 1967). Sheep were observed consuming all

the topgrowth of young leafy spurge plants but they selected only leaves and blossoms of more mature plants. Late in the season, after leafy spurge had been heavily grazed and only bare, woody stems remained, increased consumption of grass was observed. If an animal is unable to satisfy its food needs with preferred species it may consume forage previously rejected (McClymont 1967). Sheep may have selectively consumed more grass late in the season to avoid consuming woody stalks of mature leafy spurge plants.

Forage intake was expressed as a percent of total live body weight per treatment (Table 3). Sheep grazing control pastures consumed more forage as a percent of live weight than sheep grazing spurge pastures (Table 3). Differences between intake values were attributed to differences in quality of available forage. This report will base its definition of forage "quality" of leafy spurge and grass on data derived from proximate analyses of these forages (Table 4). Only the forage qualities of leafy spurge and grass samples collected during this study will be compared.

High-quality forages are generally more digestible than low-quality forages and pass through the digestive tract more rapidly (NRC 1975). Animals may eat more biomass but actually require smaller amounts of high-quality forage to meet their nutritive needs. Low-quality forages pass through the digestive tract slowly, but animals actually need to consume larger quantities to meet their nutritional requirements (Church 1980). Leafy spurge

contributed substantial amounts of protein to sheep diets but may also have contributed to lower intake values by slowing digestion rates with its high lignin content (Table 4). Sheep grazing control pastures needed to consume more total forage to meet their nutrient requirements. Grass contained less protein than leafy spurge but sheep could eat more of it because its low lignin content facilitated digestion.

Forage intake values for all treatments were comparatively higher than values derived from similar documented summer grazing experiments (Cook et al. 1956). One factor possibly contributing to these dissimilarities was the use of an agronomic technique instead of a direct approach to estimate the amount and type of forage removed from the treatment pastures. Another factor which must be considered was the increasing forage consumption by lambs. Research has shown that herbage consumption increases proportionally with decreased milk consumption and increasing body weight (Penning and Gibb 1979). Early in the season lambs were consuming only small amounts of forage because of their small body size. As the season progressed, however, lambs consumed greater amounts of forage to keep up with proportional increases in their body size. To gain an average of 0.23 kg per day a 32 kilogram replacement lamb must consume 4.9 percent its body weight as forage - almost twice as much forage as a ewe on a maintenance ration (NRC 1975). This increase in forage consumption by lambs possibly contributed to high experimental intake values. During the season grazing pressure increased from

5 animal units per pasture to approximately 7.5 animal units per pasture.

Proximate analyses of leafy spurge and grass samples showed that leafy spurge consistently maintained a higher nutrient content than grass. Leafy spurge's high crude protein levels were attributed to the characteristic high crude protein content of forbs and the extensive leaf production of this species. Leafy spurge's high lignin content was attributed to its woody stem and possible contamination of the lignin fraction by the milky latex in spurge. Leafy spurge also contained a lower ADF fraction than grass during most of the summer, and ash fractions for both forages were considered adequate to meet nutritional requirements.

The magnitude of difference in nutrient levels between growth stages of both forages was considered important. Grazed regrowth samples of both forages possessed higher nutrient levels than corresponding initial and final standing crops. Regrowth samples consisted of young succulent vegetation which contained high amounts of protein and ash and low amounts of ADF and lignin. Differences in nutrient levels between growth stages were generally larger for leafy spurge, indicating that leafy spurge could produce higher quality forage than grass early in the season even after being grazed. Late in the season, however, leafy spurge's forage quality dropped dramatically. Grass maintained a fairly consistent forage quality during the

entire season and consequently provided a better forage than spurge late in the season.

Changes in forage values of leafy spurge and grass closely coincided with their presence in diets of sheep grazing leafy spurge pastures. Early in the season when leafy spurge provided a higher quality forage than grass it composed a higher percentage of sheep diets. As leafy spurge matured its forage value declined and sheep consumed more grass.

Lambing records of experimental ewes were examined to see whether consumption of leafy spurge might adversely affect subsequent lambing performances. All bred ewes delivered healthy lambs. Lamb birth weights were considered average (Jordan 1984). Birth weights of lambs born to experimental ewes were not statistically analyzed because too many variables (which needed to be considered) were not accounted for in the experimental design.

Litter sizes of ewes which grazed different treatment pastures were analyzed (Table 5). No significant differences were found between mean litter sizes of control treatment and spurge treatment ewes. It was concluded that consumption of leafy spurge by experimental ewes the summer prior to being bred did not adversely affect their subsequent lambing performances.

Although leafy spurge has been classified as a noxious weed results from this study indicate that leafy spurge can be classified as a forage for sheep. Sheep selectively consumed as much as 55 percent of their diet as leafy spurge and exhibited no

harmful side effects. Helgeson and Thompson (1939) attributed the presence of scours in a few lambs to consumption of leafy spurge. Johnston and Peake (1960) attributed the deaths of an unknown number of sheep to poisoning resulting from consumption of mature leafy spurge plants. In this study sheep were allowed to selectively consume leafy spurge throughout its phenological development and no deaths or sickness were recorded. ADG's of spurge treatment lambs were comparable to those of control treatment lambs, and spurge treatment ewes produced lambs comparable in size and number to lambs of control treatment ewes. On the basis of these results leafy spurge was considered a good if not better forage for sheep than grass.

SUMMARY

Because considerable disagreement exists within the literature regarding the role of leafy spurge as a forage and its effects on sheep, a research project was initiated in May, 1982 to determine its forage value. Lamb/ewe pairs were randomly assigned to treatment pastures containing no spurge (control), light spurge, or heavy spurge and allowed to freely graze during the summers of 1982 and 1983. Utilization cages and the paired plot technique were used to estimate the amount and type of forage removed by sheep. Sheep weight gains were recorded and ewe performance records were examined to estimate the nutritional contribution of leafy spurge to sheep diets.

Neither lambs nor ewes exhibited any deleterious effects resulting from consumption of leafy spurge. ADG's of spurge treatment lambs were found to be comparable to and, in some cases, higher than ADG's of control treatment lambs. Sheep selectively consumed from 40 to 60 percent of their diet as leafy spurge. Leafy spurge consistently provided a higher quality forage than grass. Production capabilities of ewes which consumed leafy spurge the summer immediately prior to being bred showed no abnormalities in subsequent lambing performance. All bred ewes produced healthy lambs.

Results of this study indicate that leafy spurge can be classified as a good forage for sheep. Throughout the growing season leafy spurge provided a higher quality forage than grass.

Sheep selectively consumed a large portion of their diet as leafy spurge and experienced no harmful side effects from consuming leafy spurge throughout its phenological development.

Future research on sheep use of leafy spurge might include more extensive examinations of viability of leafy spurge seeds passed by sheep. If sheep are to be used to control the spread of leafy spurge it is important to prevent transport of viable seeds to uninfested areas. Also, as different varieties of leafy spurge are taxonomically identified it might prove beneficial to determine their corresponding forage potentials.

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APPENDIX

Table 6. Species composition¹ of the nine treatment pastures.

Scientific Binomial	Common Name	Pastures								
		1 C	2 L	3 C	4 L	5 H	6 C	7 H	8 H	9 L
Grasses:										
<u>Alopecurus pratensis</u>	meadow foxtail	2	1	1	3	2	1	6	3	15
<u>Agropyron repens</u>	quackgrass	2						1		
<u>Agropyron smithii</u>	western wheatgrass	4	7	3	13	15	11	6	6	2
<u>Agropyron spicatum</u>	bluebunch wheatgrass	3	1	3						
<u>Agropyron trichophorum</u>	pubescent wheatgrass				1					
<u>Agrostis</u> spp.					1			1		
<u>Bromus inermis</u>	smooth brome	1								
<u>Bromus tectorum</u>	cheatgrass brome	3	1	9	15	28	32	36	15	10
<u>Dactylis glomerata</u>	orchardgrass			1		1		1		5
<u>Festuca arundinacea</u>	tall fescue	68	59	57	37	15	37	21	33	49
<u>Hordeum jubatum</u>	foxtail barley	2	1	7	1	3	1	2	1	1
<u>Poa pratensis</u>	Kentucky bluegrass	9	12	9	5	8	10	3	13	4
<u>Stipa comata</u>	needleandthread	1			1					
	Total	95	82	90	77	72	92	77	71	86
Grasslike Plants:										
<u>Carex</u> spp.	sedge	2	2	7	3	2	7	1	5	3
Forbs:										
<u>Asclepias</u> sp.	milkweed			1						
<u>Cirsium canadensis</u>	Canada thistle		1	1	4	1	1		3	
<u>Equisetum</u> spp.	horsetail	3	1	1	1			1	1	1
<u>Euphorbia esula</u>	leafy spurge		13		15	22		21	20	10
<u>Melilotus officinalis</u>	yellow sweet clover		1							
	Total	3	16	3	20	23	1	22	24	11
Half-Shrubs:										
<u>Artemesia frigida</u>	fringed sagewort					3				

¹Species composition was determined by three 50-point step/point transects randomly located in each pasture. Data collected by Hatfield (1982). Values are expressed as a percent of the total composition.

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