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Recovery rate of Lehmann lovegrass (*Eragrostis lehmanniana* Nees.) in a simulated short duration grazing system

Douds, George Allen, M.S.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

RECOVERY RATE OF LEHMANN LOVEGRASS (*ERAGROSTIS LEHMANNIANA* NEES.) IN A SIMULATED SHORT DURATION GRAZING SYSTEM

by

George Allen Douds

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APPROVAL BY THESIS COMMITTEE

This thesis has been approved on the date shown below:

George B. Ruyle
Associate Research Scientist
Range Management

Aug 11, 1994
Date

E. Lamar Smith
Associate Professor of Range Management

Aug 9, 1994
Date

Phil R. Ogden
Professor of Range Management

Aug 9, 1994
Date

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ABSTRACT

A nearly monospecific stand of Lehmann lovegrass (*Eragrostis lehmanniana* Nees.) was grazed by cattle during two summer growing seasons to simulate short duration grazing. Grazing treatments were timed to coincide with preboot, boot to early inflorescence and hard seed phenological stages. During each treatment, grazing intensity on individual plants included heavy, moderate or light intensities.

In 1990 maximum regrowth occurred when plants were grazed during boot to early inflorescence and at a light grazing intensity. In 1991, plants grazed during preboot or boot to early inflorescence and at a light or moderate intensity produced higher regrowth amounts than the other treatments.

Plants grazed during boot to early inflorescence recovered significantly faster than plants grazed during preboot in 1990 and 1991. In 1990 lightly grazed plants recovered biomass faster than plants grazed at heavier intensities. In 1991 plants grazed at light and moderate grazing intensities recovered significantly faster than heavily grazed plants. Heavily grazed plants never produced enough regrowth to resemble moderately or lightly grazed plants within one growing season.

INTRODUCTION

Lehmann lovegrass was introduced into Arizona in the 1930's primarily for the purpose of reseeding denuded rangelands. The grass has been seeded on approximately 69,000 ha, spread to dominate over 145,000 ha and has become the primary forage source on many southeastern Arizona rangelands (Cox and Ruyle 1986).

Limited research projects have studied ways to manage the plant in order to improve cattle production and maintain vigorous stands. In practice there have been many grazing regimes applied to utilize this plant. One of these is short duration grazing (SDG). Short duration grazing entails the movement of high densities of livestock through pastures for short periods of time. Proponents of this method feel that benefits such as hoof action, uniform plant utilization, potentially higher stocking rates and flexibility in the timing of grazing will improve production and profitability (Savory 1978).

One premise for SDG is that "one can only observe the most severely grazed plants of whatever species and consider them recovered when they resemble an ungrazed plant alongside them under virtually identical conditions and health" (Savory 1988). Quite often when using a SDG, pastures are grazed two or more times during a growing season. It is commonly thought that this visual method will determine whether or not a plant has recovered from past grazing and can now be grazed again without harm. A visual identification of plant recovery would be a very useful management cue.

This study was initiated to simulate short duration grazing during the active growing season, determine how useful visual estimations of plant recovery are and estimate appropriate recovery periods for Lehmann lovegrass after grazing.

The study examined the effects of grazing at different phenological stages and different intensities within the stages on Lehmann lovegrass regrowth amounts and rates during the growing season. The primary aim was to determine whether or not the recovery amounts and rates varied among plants defoliated at different phenological stages and grazing intensities.

LITERATURE REVIEW

Lehmann Lovegrass

Since its introduction from South Africa in the early 1930's, Lehmann lovegrass (Eragrostis lehmanniana Nees.) has been sown throughout the southwestern United States and northern Mexico. The grass seems best adapted to southeastern Arizona, and major stands are now present there (Cox and Ruyle 1988).

The geographical region of its origin has elevations ranging from about 1,175 m to 1,350 m and about 80% of the precipitation falls during the late spring early summer. Mean annual precipitation is between 225 mm to 395 mm and temperatures range from a mean minimum of 0-19°C to a mean maximum in the summer of 18 to 34°C (Cox and Martin 1988; Cox and Ruyle 1988).

Areas of southern Arizona where Lehmann lovegrass is found have much of the same attributes as South Africa. Elevations typically range from 775 m to 1540 m. The annual precipitation varies from 275 mm to 500 mm with the majority falling in the summer (150-220 mm). The mean minimum temperatures vary from -4°C to 20°C and the mean maximum temperatures vary from 13 to 38°C (Cox and Martin 1988; Cox and Ruyle 1988).

Besides the similarities between South Africa and southern Arizona the success of Lehmann lovegrass can also be attributed to the way in which it reproduces. At the Plant Material Center, Tucson, Arizona field seed production has been estimated to be about 50 kg/ha in good rainfall years (Crider 1945). Seed sizes range from 1-1.6 mm in length and 0.5-0.8 mm in width (Wright and Brauen 1971) with over 13 million seeds per kilogram.

Lehmann lovegrass seeds have been sown on many different soil types in the southwest. Cox and Martin (1984) collected soils that have the textural characteristics commonly found in these desert regions. They concluded that on these soils Lehmann lovegrass must be surface sown and will not emerge when planted at a depth of 0.5 cm or greater. Lehmann lovegrass germinates best on soils that have a small clay fraction and a high sand content. Cox et. al. (1983) also found that Lehmann lovegrass seedlings emerge when seeds were planted near the surface in sand, loamy sand and sandy loam soil; seedlings did not emerge in silt loam and clay loam soils, regardless of planting depth.

Lehmann lovegrass seeds have certain germination requirements. Knipe (1967) concluded that Lehmann lovegrass seeds germinated best (under controlled conditions) at a constant temperature of 60°F (15.5°C) and 100% percent relative humidity. Other researchers found that the seeds germinated best at 25 to 35°C (Wright 1973). Mechanical scarification of different strains of Lehmann lovegrass increased total germination as well as the germination rate (Hardegree and Emmerich 1991). Laboratory germination is also enhanced by chemical scarification, moist pre-chilling, and various sequences of wetting and drying (Wright 1973, Haferkamp and Jordan 1977). Lehmann lovegrass germinates best when exposed to red light and at an alternating temperature of 16 hours at 15°C and 8 hours at 38°C (Roundy et. al. 1992).

The survival of the seedling seems to mainly be driven by competition for moisture. If the radicle does not penetrate the soil surface within 48 hours to take advantage of soil moisture the seedling will perish (Cox and Martin 1984). Lehmann lovegrass seedlings are inhibited by moisture stress making them unable to tolerate drought (Knipe and Herbel 1960, Tapia and Schmutz 1971). A major advantage of Lehmann lovegrass seeds is that they are very quick to sprout; thus, able to take advantage of the limited soil moisture to become established (Tapia and Schmutz 1971). Hardegree and

Emmerich (1991) point out that this is an advantage as long as seeds are not limiting.

Lehmann lovegrass tends to be low in palatability as a cattle forage species (Cable 1971, Fourie and Roberts 1977, Voigt et. al. 1986). Low palatability is partly due to coarse stubble and residual stems. One study found that the presence of these residual stems impaired cattle grazing by increasing the times between bites, thus decreasing the biting rates when compared to bites taken where the stem were absent (Ruyle et. al. 1987). Rice et. al. (1991) found that removal of residual stems prior to the growing season resulted in higher protein and phosphorus in current green herbage. However, the removal of residual stems did not affect the dietary nutrient composition of grazing cattle. The grazing steers were able to select the more nutritious herbage with or without the residual stems.

Another way that cattle avoid residual stems is by patch grazing. Patch grazing results when an area is repeatedly grazed and, therefore, contains almost no residual stems. This phenomenon is observed in dense stands of Lehmann lovegrass. Cattle will travel faster and take fewer, slower bites where Lehmann lovegrass plants maintain an abundance of residual vegetation compared to grazed patches where residual stems were reduced (Ruyle et. al. 1988a).

Ruyle et. al. (1988b) looked at the grazed patches even further. They found that as stocking rates increased the patchy pattern of cattle grazing was not disrupted until extremely heavy rates were attained. Throughout the duration of this study over 75% of the grazing occurred in previously grazed patches. Within these patches only 18% of the defoliated tillers were regrazed within one growing season. At each defoliation event an average of 72% of tiller biomass was removed regardless of stocking rate.

Lehmann lovegrass copes with defoliation by originating leaves in the crown rather than from recently defoliated tillers, and new tillers frequently elongate horizontally within the crown and beneath a coarse stubble of defoliated tillers (Cox et al. 1990). Lehmann lovegrass also has a higher ratio of reproductive to vegetative culms when clipped, thus allowing it to set more seeds (Giner-Mendoza 1986). Culms provide support and photosynthesis and may remain green for 9-12 months (Cox et al. 1990).

Giner-Mendoza (1986) found that clipping Lehmann lovegrass at a 5 cm height above the growth medium removed 100% of the leaves and sheaths and 90% of culms. As

Lehmann lovegrass regrew, the leaf area of non-defoliated grass plants was four times greater than defoliated plants at week 2, three times at week 4 and 6, and two times at week 8 (Cox et al. 1991). At the end of the study, the total above ground biomass production was five times greater for the unclipped plants than for the clipped plants.

The roots seemed to be the part of the plant least affected by defoliation. Total root production was statistically similar for clipped and unclipped plants; however, a slight reduction in total root production was noted for clipped plants (Giner-Mendoza 1986). The reasons for this slight decrease, as opposed to the large decrease in root production noted in other grass species, are hypothesized to be the ability of Lehmann lovegrass culms to remain green and to photosynthesize after defoliation. The remaining photosynthetic material may allow the plant to be less dependent on stored root reserves (Cox et al. 1991).

General Plant Responses to Defoliation

The ability of individual plants to recover from defoliation is of major importance for those concerned with managing grazing systems. Researchers in the past have looked at many characteristics of plants to determine the effects of defoliation. Various estimates of the plants productivity have been used such as tillering, herbage yield and root characteristics to compare grazed and ungrazed situations.

Additionally, when the above ground portion of the plant is removed, the roots are also affected. The reduction in photosynthetic material decreases the rate and amount of root growth. For example in a greenhouse study with little bluestem (Andropogon scoparius), Jameson and Huss (1959) found that root weights were reduced by removal of leaves or stems. In another study Biswell and Weaver (1933) found the average volume of roots from clipped prairie sods were 11.7 percent of that of the controls, and the average dry weight was 10.1 percent of the controls.

Defoliation also affects tillering. There are conflicting reports in the literature as to whether defoliation increases or decreases the amount of tillering. Working with crested wheatgrass (Andropogon cristatum), Cook and Stoddart (1953) found that defoliation which removes the apexes of elongating stems stimulates the emergence of tillers. Other studies reviewed by Troughton (1957) found that as the amount of tissue removed increases, the amount of tillering decreases. The methods were not defined well enough to deduce the kinds and amounts of material removed.

The time and amount of defoliation are both important to the plant responses to grazing. Miller and Donart (1979), working with black grama (Bouteloua eriopoda (Torr.) Torr.) and mesa dropseed (Sporobolus flexuosus (Thurb.) Rybd.), found that clipping during the vegetative stage had little apparent effect on vigor. Clipping at any other stage in the growing season negatively affected the plants vigor. In another study Pearson (1964) found that Poa spp., needle and thread (Stipa comata Trin. & Rupr.), and Indian ricegrass (Oryzopsis hymenoides (R. & S.) Ricker) were most affected by defoliation during the mid-growing season as opposed to earlier or later in the year.

Hazell (1965) mowed prairie grasses big bluestem (Andropogon gerardi Vitman), little bluestem (Andropogon scoparius Michx), Indiangrass (Sorghastrum nutans (L.) Nash), and switchgrass (Panicum virgatum L.). Mowing late in the fall was more detrimental to the other species of grass than to Indiangrass. There was a decrease in the number of little bluestem, big bluestem, and switchgrass plants and an increase in forbs in a pasture that was mowed in the late fall. On the other hand, clipping of little bluestem, big bluestem, and Indiangrass, at seed ripened stage or later, increased yields and tillering of those plants (Vogel and Bjugstad 1968). The most detrimental times of the season to clip these three species was between floral initiation and anthesis.

Intensity of defoliation also affects the plant's regrowth. Davis (1960) grew reed canarygrass (Phalaris arundinacea L.) and found that as the intensity of defoliation increased the subsequent regrowth decreased. Clipping of a tufted annual grass in India yielded similar results (Singh and Mall 1976). Andropogon pumilus Roxb. produced the most herbage when clipped to a height of 15 cm and when it was clipped to a height of 10 cm and 5 cm there was a substantial decrease in yields.

Blaisdell and Pechanec (1949) looked at the effects of herbage removal on bluebunch wheatgrass (Agropyron spicatum (Pursh) Scribn.). Bluebunch wheatgrass was most severely affected by defoliation after the date when substantial regrowth is impossible and after maturity. Regrowth later in the growing season was limited by the availability of moisture.

Most grasses are affected in some way when above ground photosynthetic materials are removed. In grass species certain attributes such as root growth, carbohydrate reserves, tillering, recovery rate and forage yield will be affected by defoliation. These attributes will be affected to varying degrees within each grass species. Other factors such as soils, climate, nutrients, light, competition and the time of defoliation must be considered to understand the effects of defoliation on grass plants (Aberda 1957).

METHODS

Study Location

This study was conducted at the Santa Rita Experimental Range (SRER) located about 50 km south of Tucson, Arizona. The majority of the range is on alluvial deposits with soils consisting of Aridisols, Mollisols, and Entisols in a mosaic pattern (Clemmons and Wheeler 1970). The elevation ranges from 868 m in the extreme northwest corner to 1524 m at the southeast corner. The average annual precipitation estimate is 366 mm, 56% of which falls as rain during the months of July through September (Anable 1990).

The study site is located at the southeast end of the range. The elevation on the site ranges from 1036 m to 1066.5 m. The average annual precipitation (1972-1990) at the rain gauge located in this pasture is 416 mm (16.36 in). The soils are classified as Whitehouse gravelly loam. Dominant vegetation includes Lehmann lovegrass (_Eragrostis_ _lehmanniana_ Nees), mesquite (_Prosopis_ _juliflora_ Swartz) and the half-shrub, false mesquite (_Calliandra_ _eriophylla_ Benth.).

Study Design

The experiment was conducted in a 12 ha enclosure erected within the pasture known as 12c. Electric fences separate the twenty-four, .35 ha plots from one another within the enclosure. Twelve of these plots were used for this study. Vegetation within the enclosure is nearly a monoculture of Lehmann lovegrass.

Treatments, replicated four times, were randomly assigned to each plot. Main treatments consisted of grazing by cattle at three specific phenological stages of Lehmann lovegrass: preboot, boot to early inflorescence and hard seed (Figure 1).

Treatments were applied by allowing 4 to 5 steers to graze the plots to achieve approximately 40-60% utilization of Lehmann lovegrass, estimated visually. After the steers were removed, 30 individual Lehmann lovegrass plants were flagged in each plot. Ten plants were selected in each of three stubble height classes. The stubble height classes were: light (L) greater than 15 cm stubble height (30% or less utilization), moderate (M) 5-15 cm (30-70% utilization) and heavy (H) less than or equal to 5 cm (70% or greater utilization) (Shmutz 1963, Ruyle et. al. 1988). The plants were selected by this criterion immediately after the animals were removed from the plot.

12	3a (1b)
11	2b (2d)
10	3d (3d)
9	2d (1a)
8	3c (3b)
7	2a (3a)
6	3b (2c)
5	1a (2a)
4	2c (1c)
3	1c (3c)
2	1d (2b)
1	1b (1b)

Figure 1: Pasture assignment of treatment applied during 1990 and 1991 (in parentheses). Numbers on the left are the pasture numbers. Numbers on the right are the treatments; 1 is grazing during preboot, 2 is grazing during boot to early inflorescence, and 3 is grazing during hard seed. Letters on the right are the replications.

Because a non-destructive biomass sampling technique was required, regrowth of these grazed plants was estimated by using a reference unit method (Hutchinson 1972, Schmutz 1963). Reference units were constructed with representative Lehmann lovegrass plants from the immediate area. These sample plants were pulled from the soil, the roots were cut off and dead material was removed. The above ground portion of the plant was then cut to a specific height and immediately weighed. Reference plants were classified by basal diameters of 1-4 cm. Three to four plants from each basal diameter class were glued to a piece of cardboard with their respective weights written beside each plant and covered with a thick piece of clear plastic. These reference units were allowed to air dry and were used throughout the study.

Before regrowth was estimated each Lehmann lovegrass plant that was selected as a treatment plant was measured to place it in a basal diameter class. The basal diameter reference class that corresponded to the individual treatment plant was then used for the duration of the study. After basal diameters were determined, regrowth was estimated by comparing each treatment plant with the appropriate reference plants. Data were collected at weekly intervals until the plants ceased active growth.

Statistical Analysis

Data were analyzed using analysis of variance. Main effects included grazing intensity and phenological stage, when grazed. Analysis was done on regrowth after one month and maximum regrowth by subtracting the week one value from the week four value and by subtracting week one from the week with the highest total standing green herbage value, respectively. An analysis of variance was then performed on the resulting data.

The measurements on individual plants were regressed using a quadratic function. The quadratic function closely matches the growth curve observed in most plant species. The growth curve's slope increases at first and then levels out or drops off.

After fitting regression curves, slopes at time zero were analyzed. Slopes at time zero are a good estimate of the of the rate of growth immediately following grazing. The first derivative of a quadratic function will result in the slope of the function given below:

$$y = a + bx + cx^2 \tag{1}$$

slope = rate = b + 2cx <*first derivative*>

slope @ 0 = b + 2c(0)

slope @ 0 = b .

After solving for the first derivative at time zero the linear portion of the function is the recovery rate for each plant.

Tukey's standardized range test identified the treatment and intensities that had recovery rates significantly higher or lower than each other.

RESULTS

Precipitation

The total annual precipitation for 1990 was greater than the average annual precipitation (1972-1990), and the total precipitation for 1991 was less than the annual precipitation (Figure 2). During the summer of 1990 and 1991, growing season precipitation was 157% and 49% of the average, respectively. Total yearly precipitation in 1990 was greater than 1991 (Figure 3).

Regrowth Amounts

In 1990, thirty days after grazing, regrowth of Lehmann lovegrass was the same for plants grazed during the preboot and boot to early inflorescence phenology stages, (3.2 versus 3.5 grams, respectively) (Appendix Table A3). In 1991 grazing during the preboot stage resulted in a larger amount of regrowth, than grazing during boot to early inflorescence stage (1.3 versus 0.6 grams, respectively) (Appendix Table A11).

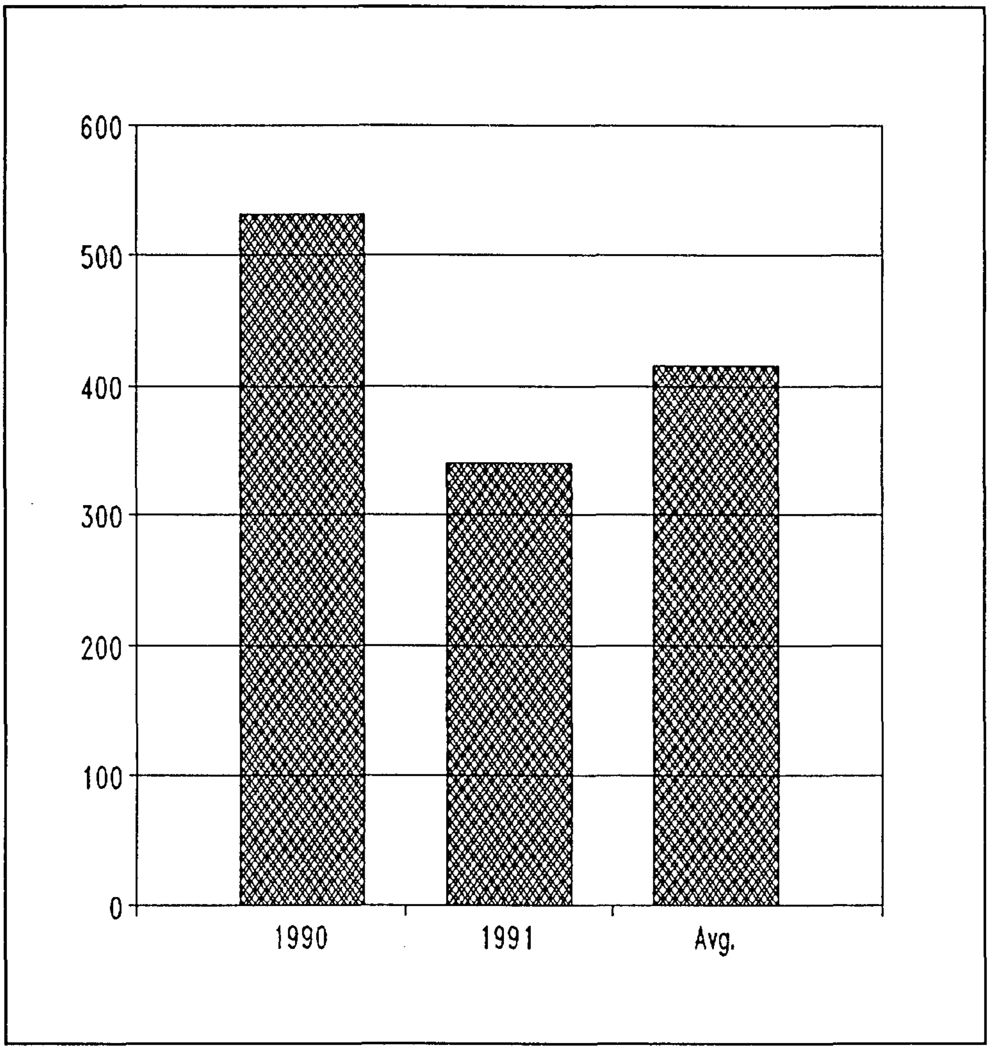

Figure 2: Total annual precipitation (mm) at the Santa Rita Experimental Range for rain gauge 41 during 1990 and 1991 and average annual precipitation from 1972-1990.

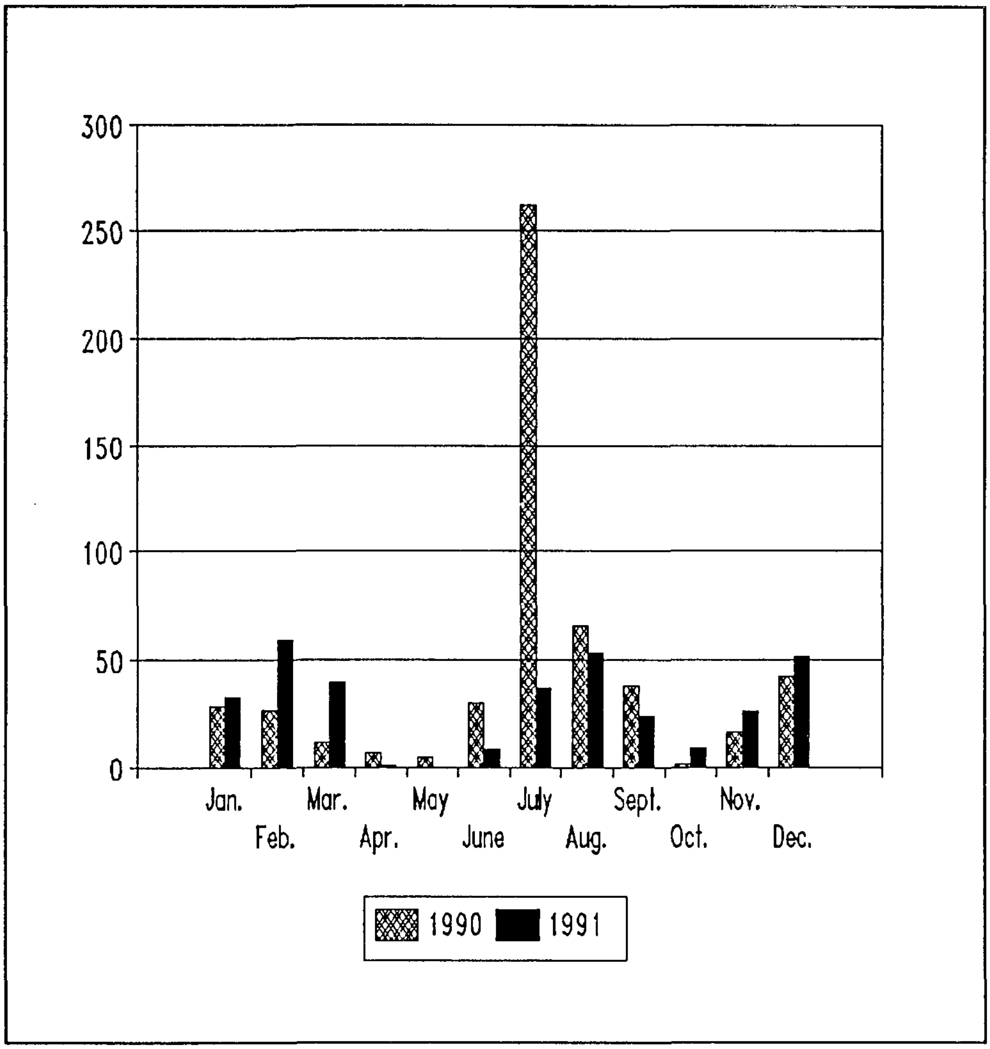

Figure 3: Monthly total precipitation (mm) for 1990 and 1991 from rain gauge 41 at the Santa Rita Experimental Range

Grazing intensity also affected maximum regrowth produced by Lehmann lovegrass (Tables 1 and 2). In 1990, at an alpha level of 0.17, plants grazed lightly during the boot to early inflorescence stage produced more regrowth than moderately or heavily grazed plants at that phenology. For plants grazed during the preboot growth stage, heavily grazed plants produced more regrowth than either lightly or moderately grazed plants. The amount of regrowth observed for plants grazed during the hard seed stage was negligible for all grazing intensities (Table 1).

During the 1991 growing season, plants grazed during the preboot growth stage produced more regrowth at a light intensity than heavily and moderately grazed plants (Table 2). Plants grazed during the boot to early inflorescence growth stage produced more regrowth at a moderate grazing intensity than heavily and lightly grazed plants.

Comparison of standing herbage after grazing and regrowth amounts at the end of the growing season followed similar patterns for both years (Figures 4 through 9). Regardless of the phenological stage when grazed, heavily grazed plants did not recover enough regrowth to resemble moderately or lightly grazed plants. Likewise moderately grazed plants did not recover enough aboveground regrowth

Table 1: Maximum regrowth of Lehmann lovegrass grazed at high, moderate and light grazing intensities and at different phenological stages during the 1990 growing season.

Phenology Stage	**Grazing Intensity**			
	Heavy (g)	Moderate (g)	Light (g)	Mean (g)
Preboot	4.00 a[1], 1[2]	3.38 b,1	3.59 b,1	3.65
Boot to Early Inflorescence	3.86 a,1	3.59 b,1	4.98 c,2	4.14
Hardseed	0.02 b,2	0.04 b,2	0.13 b,3	0.06
Overall Mean for each grazing intensity (g)	2.66	2.34	2.60	

[1]Means in a row followed by the same letter are not different at p = 0.1.
[2]Means in a column followed by the same number are not different at p = 0.1.

Table 2: Maximum regrowth of Lehmann lovegrass grazed at high, moderate and light grazing intensities and at different phenological stages during the 1991 growing season.

Phenology Stage	**Grazing Intensity**			
	Heavy (g)	Moderate (g)	Light (g)	Mean (g)
Preboot	1.08 a[1],1[2]	1.73 b,1	2.31 c,1	1.70
Boot to Early Inflorescence	0.39 a,2	0.91 b,2	0.78 b,2	0.69
Hardseed	0.06 a,3	0.08 a,3	0.03 a,3	0.05
Overall Mean for each grazing intensity (g)	0.51	0.90	1.04	

[1]Means in a row followed by the same letter are not different at $p = 0.1$.
[2]Means in a column followed by the same number are not different at $p = 0.1$.

to match the appearance of lightly grazed plants by the end of the growing season. Even though regrowth amounts were greater in 1990 than 1991 for the plants grazed earlier in the season, those defoliated during the hard seed stage recovered negligible amounts of regrowth (Tables 8 and 9).

Regrowth Rates

Analysis of the quadratic regression revealed a significant difference between the recovery rates for plants grazed at preboot, 0.19 $g \bullet wk^2$ and 0.10 $g \bullet wk^2$, and boot to early inflorescence, 0.39 $g \bullet wk^2$ and 0.14 $g \bullet wk^2$, in both 1990 and 1991, respectively (Appendix Tables A6 and A14). In both years boot to early inflorescence had a higher recovery rate than either preboot or hardseed (Figures 10 through 15). Also there was a significant difference in the recovery rates for the three intensity levels for both 1990 and 1991. Lightly grazed plants which had a mean recovery of 0.46 $g \bullet wk^2$ and 0.16 $g \bullet wk^2$ for 1990 and 1991, respectively, recovered faster than moderately or heavily grazed plants (recovery rates of 0.23 and 0.12 $g \bullet wk^2$ for moderately grazed plants and 0.20 and 0.07 $g \bullet wk^2$ for heavily grazed plants).

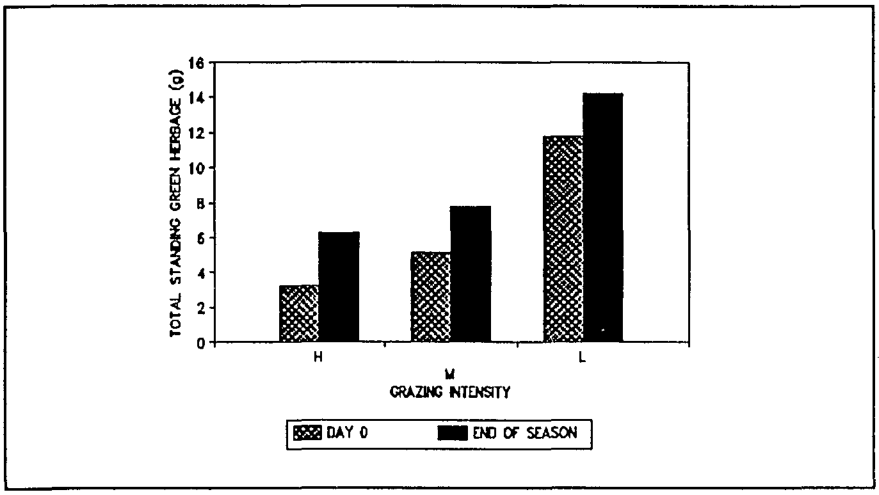

Figure 4: 1990 total standing green herbage left after grazing and after regrowth at heavy, moderate, and light intensities during the preboot growth stage.

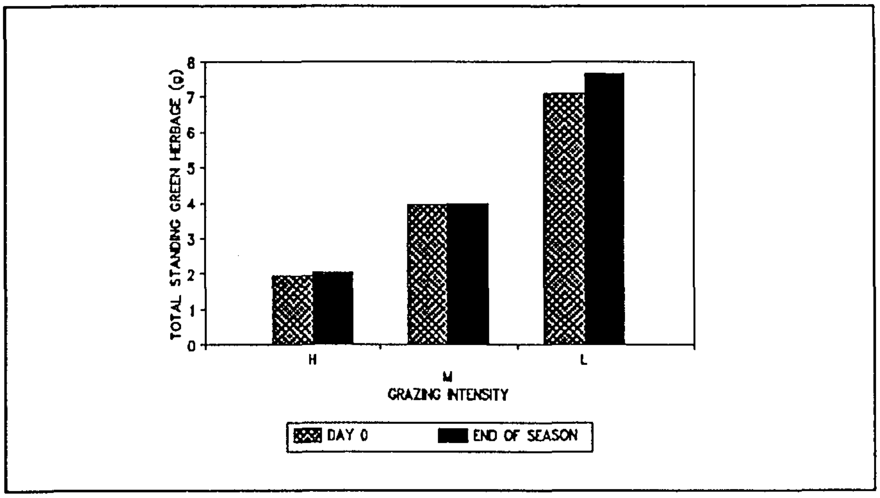

Figure 5: 1991 total standing green herbage left after grazing and after regrowth at heavy, moderate and light intensities during the preboot growth stage.

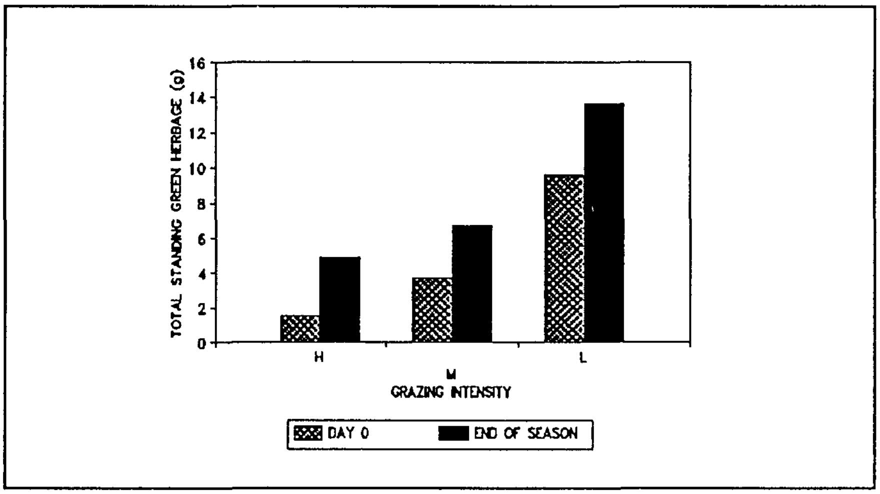

Figure 6: 1990 total standing green herbage left after grazing and after regrowth at heavy, moderate, and light intensities during the boot to early inflorescence growth stage.

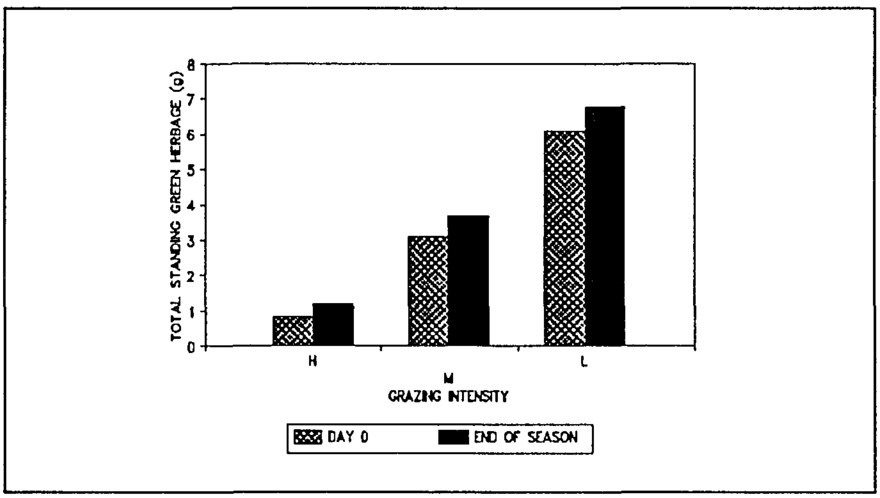

Figure 7: 1991 total standing green herbage left after grazing and after regrowth at heavy, moderate and light intensities during the boot to early inflorescence growth stage.

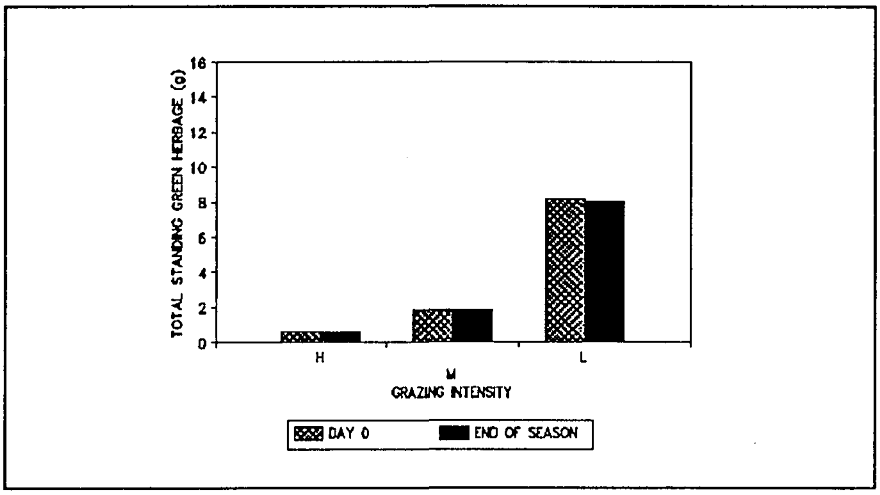

Figure 8: 1990 total standing green herbage left after grazing and after regrowth at heavy, moderate, and light intensities during the seed set growth stage.

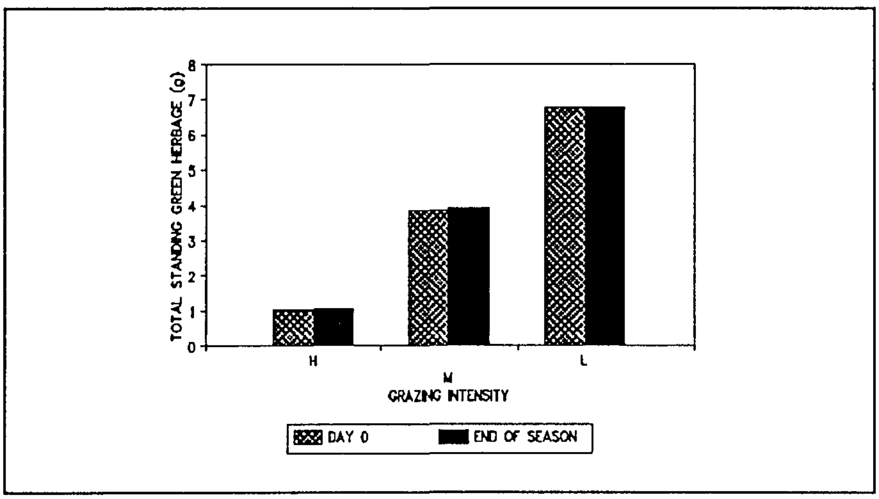

Figure 9: 1991 total standing green herbage left after grazing and after regrowth at heavy, moderate and light intensities during the seed set growth stage.

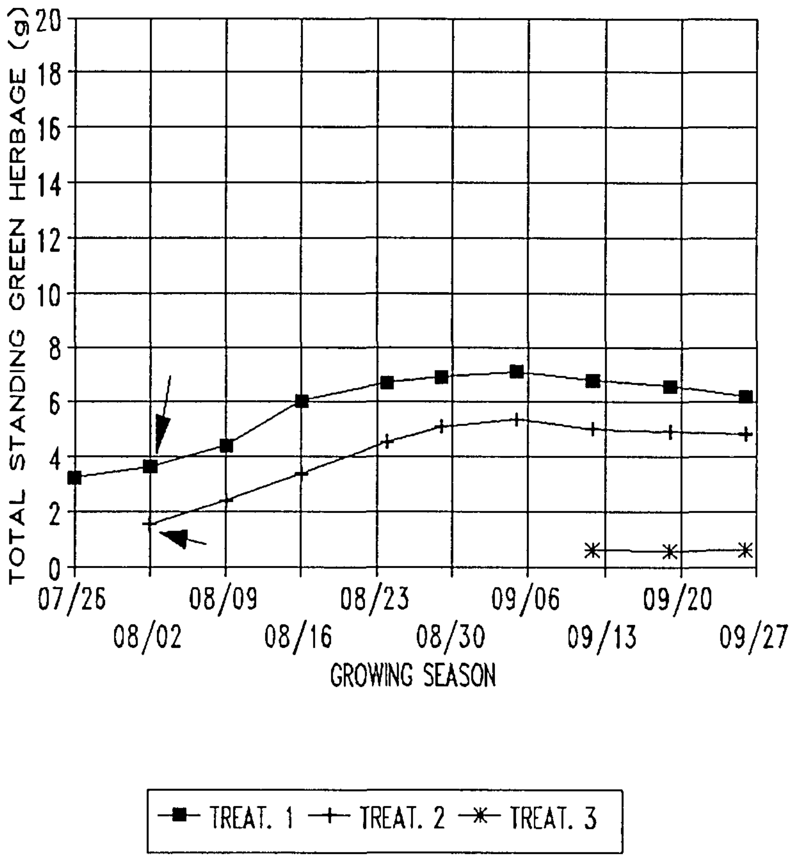

Figure 10: Weekly above ground biomass for heavily grazed Lehmann lovegrass plants during 1990. Initial date is one week after grazing. Treatment 1 is grazing during preboot, treatment 2 is grazing during boot to early inflorescence and treatment 3 is grazing during hard seed. Arrows indicate the point at which the slope was determined for the quadratic equation.

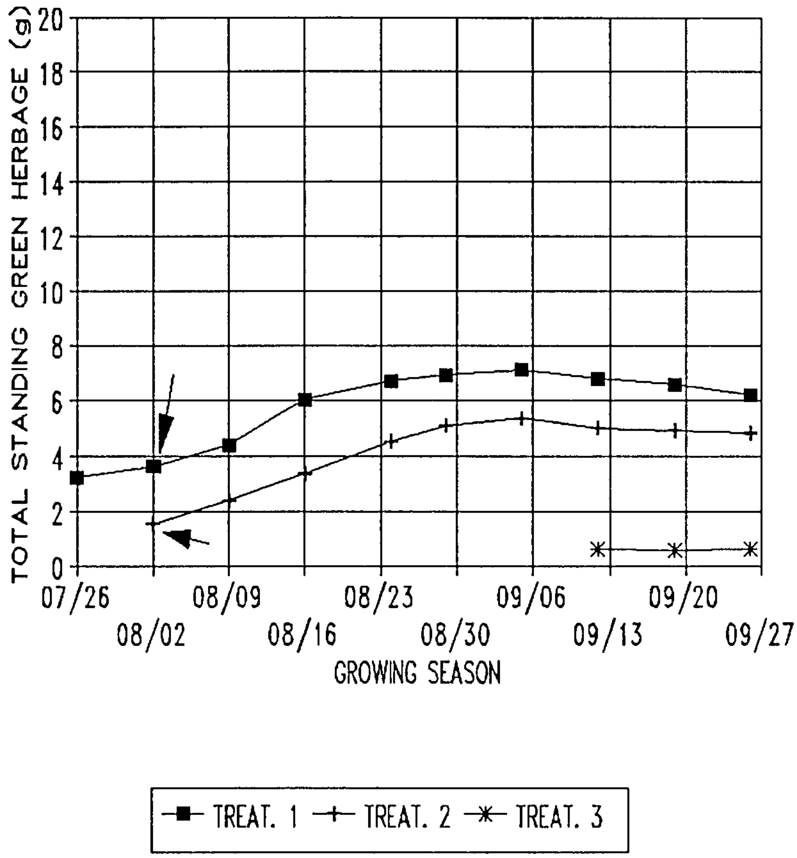

Figure 11: Weekly above ground biomass for moderately grazed Lehmann lovegrass plants during 1990. Initial date is one week after grazing. Treatment 1 is grazing during preboot, treatment 2 is grazing during boot to early inflorescence and treatment 3 is grazing during hard seed. Arrows indicate the point at which the slope was determined for the quadratic equation.

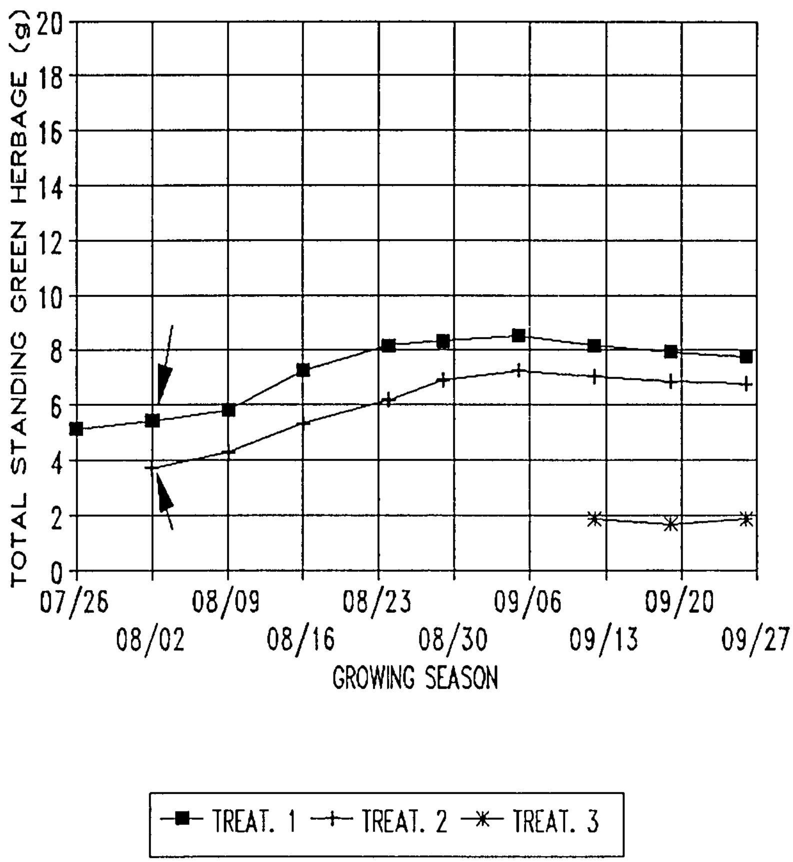

Figure 12: Weekly above ground biomass for lightly grazed Lehmann lovegrass plants during 1990. Initial date is one week after grazing. Treatment 1 is grazing during preboot, treatment 2 is grazing during boot to early inflorescence and treatment 3 is grazing during hard seed. Arrows indicate the point at which the slope was determined for the quadratic equation.

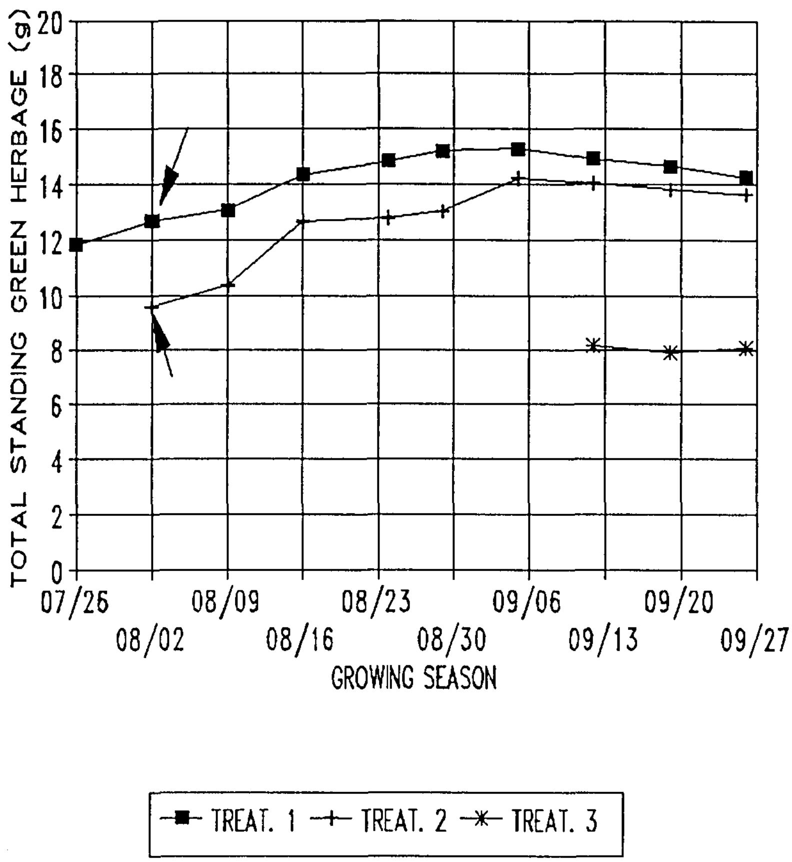

Figure 13: Weekly above ground biomass for heavily grazed Lehmann lovegrass plants during 1991. Initial date is one week after grazing. Treatment 1 is grazing during preboot, treatment 2 is grazing during boot to early inflorescence and treatment 3 is grazing during hard seed. Arrows indicate the point at which the slope was determined for the quadratic equation.

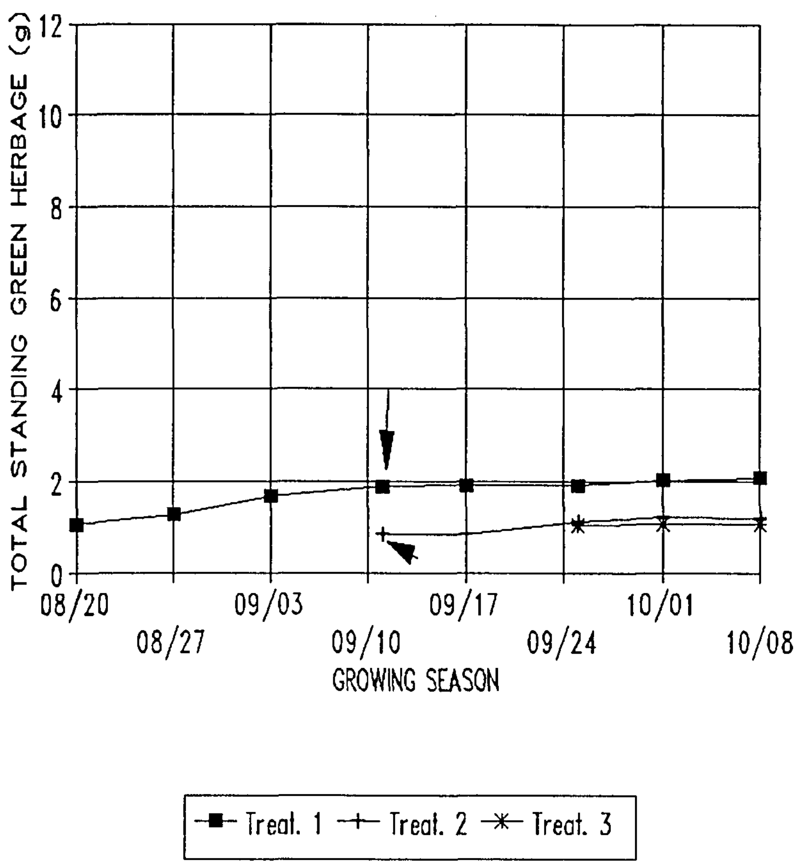

Figure 14: Weekly above ground biomass for moderately grazed Lehmann lovegrass plants during 1991. Initial date is one week after grazing. Treatment 1 is grazing during preboot, treatment 2 is grazing during boot to early inflorescence and treatment 3 is grazing during hard seed. Arrows indicate the point at which the slope was determined for the quadratic equation.

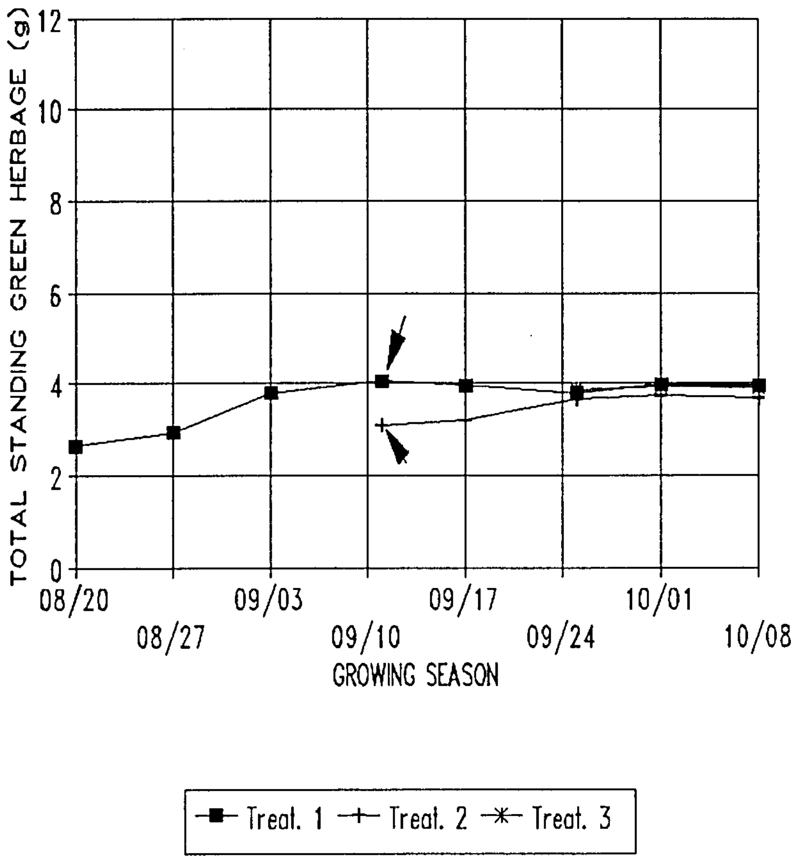

Figure 15: Weekly above ground biomass for lightly grazed Lehmann lovegrass plants during 1991. Initial date is one week after grazing. Treatment 1 is grazing during preboot, treatment 2 is grazing during boot to early inflorescence and treatment 3 is grazing during hard seed. Arrows indicate the point at which the slope was determined for the quadratic equation.

In 1990 there was an interaction between timing of grazing and intensity of the grazing ($p < 0.0001$, Appendix Table A6). In some cases of measurement error, the regression analysis in 1990 produced some unusual curves while trying to account for the reduction in total standing green herbage. These odd regressions may have created the regression interaction terms which are significant in the regression analysis but not in the repeated measures model. In 1991 there was not a significant interaction between intensity and treatment ($p < 0.5010$, Appendix Table A14).

Tukey's studentized range test also revealed a significant difference in recovery rates between plants grazed at preboot and boot to early inflorescence phenology stages. Plants grazed during the boot to early inflorescence phenology stages had the highest rate of total standing green herbage regrowth in both years (Appendix Tables A8 and A15). Moderately and heavily defoliated plants recovered from grazing at similar rates in 1990 but had a lower rate of regrowth than lightly grazed plants. Lightly grazed plants had the highest recovery rate. In 1991 lightly and moderately grazed plants had similar recovery rates, but both had significantly higher regrowth rates than heavily grazed plants.

DISCUSSION

In 1990 the precipitation was above average during the growing season. Plant recovery from defoliation was probably not limited due to moisture during this season. Grazed plants began regrowth very quickly after being grazed. Lehmann lovegrass typically responds very quickly when growing conditions are favorable.

In 1991 rainfall was below average during the growing season. The rain that did fall was of very short duration and occurred during hot days. Evapotransporation was high which probably limited soil moisture.

Lehmann lovegrass plants grazed at different phenological stages and intensities within each stage did not respond to defoliation in the same manner. In 1990, plants grazed during preboot and boot to early inflorescence produced the same amount of regrowth after thirty days, but plants grazed at preboot had more total standing green herbage. There was also no difference in the amount of regrowth produced over the entire growing season when grazed at a heavy, moderate and light grazing intensity. However, with a larger alpha, plants grazed during the boot to early inflorescence growth stage and at a light grazing intensity produced more regrowth than plants grazed at moderate or heavy intensities.

Plants grazed at preboot in 1991 produced more and had more total standing green herbage at the end of the growing season than plants grazed at the boot to early inflorescence stage. Plants grazed during the preboot phenology growth stage at light and moderate intensities produced more regrowth than plants grazed at heavy intensities. Lightly and moderately grazed plants during the boot to early inflorescence stage produced a greater amount of regrowth than heavily grazed plants.

Lehmann lovegrass recovered faster from defoliation when it was grazed during the boot to early inflorescence phenological stage as opposed to the preboot stage in both 1990 and 1991. Lehmann lovegrass also had a faster recovery rate during both years when grazed at light intensities. One of the reasons the lightly grazed plants recovered more quickly, could be due to the remaining leaf area. Plants grazed more severely have reduced leaf areas, thereby reducing light interception for photosynthesis. Growth rates coincide with light interception levels up to a saturation point. Leaf areas seemed to be higher for Lehmann lovegrass when the plants are grazed lightly and during the boot to early inflorescence stage as compared to plants that are heavier defoliated and at a less mature phenology.

However, regardless of the grazing treatment, heavily grazed Lehmann lovegrass plants did not recover sufficient regrowth to resemble moderately or lightly grazed plants within one growing season. Moderately grazed plants did not recover enough above ground biomass to compare to the lightly grazed plants. The visual recovery cue was not useful due to the limited regrowth patterns of grazed plants.

The effects of defoliation on the plant growth the subsequent year was not investigated. The recovery of grazed Lehmann lovegrass plants may not be complete for the next few growing season. Meuggler (1975) found that it took Idaho fescue and bluebunch wheatgrass more than six years to fully recover from severe clipping. Cook and Child (1971) also found that the productivity and vigor of plants subjected to only moderate defoliation in the spring of the year were significantly different from plants in the control group after seven years of rest. These studies may suggest that heavily or moderately grazed Lehmann lovegrass plants may take more than a growing season to fully recover from defoliation.

However, Cox (1991) found little impact on Lehmann lovegrass root growth after defoliation. Elmi (1981) found that both periodic and continuous grazing had little affect on the number of new roots of Lehmann lovegrass, but grazed plants did produce significantly more roots than ungrazed plants.

Competition between Lehmann lovegrass plants may also effect plant recovery from grazing. Studies have shown competition to decrease plant production (Mueggler 1972). However, research done at the SRER (Andrade 1979) found that clipping sideoats grama and surrounding plants or not clipping surrounding plants had no measurable effect on the production. With the lack of any research as to how Lehmann lovegrass competes within its monoculture it is hard to determine just how much influence competition had on the recovery rates.

MAJOR FINDINGS

1. With adequate moisture, Lehmann lovegrass produces maximum regrowth in approximately thirty days subsequent to defoliation regardless of the intensity or timing of grazing.

2. Lehmann lovegrass plants lightly grazed during the boot to early inflorescence phenological stage had higher regrowth rates and regrowth amounts than plants grazed at any other phenological stage or intensity.

3. Heavily and moderately grazed plants will not recover enough standing biomass to resemble a lightly grazed plant within one growing season.

Management Implications

Grazing Lehmann lovegrass lightly after the boot stage and before seed set allowed plants to recover their maximum above ground biomass during the growing season.

In a short duration grazing cell, cattle should be moved through quickly during the growing season to achieve short grazing periods before the boot to early inflorescence phenology stage. Marking heavily grazed plants and relying on visual estimates of recovery will not likely allow regrazing during the current growing season. If it is necessary to graze pastures twice during the summer growing season, the rotation should be set up so that the same pasture is not regrazed any earlier than 30 days after the initial grazing. These recommendations will allow Lehmann lovegrass to produce maximum levels of total standing green herbage within the current growing season.

Further research on the influence of grazing on Lehmann lovegrass should consider the following criteria (Caldwell 1984): (1) studies should be conducted with plants in a realistic competitive environment, (2) parameters of productivity and vigor should be truly indicative of productive potential and competitive position in the community, and (3) defoliation effected by clipping should correspond to approximate patterns of timing and defoliation of individual plants by grazing animals.

APPENDIX A

Tabular Data

Table 1: Results of general linear models procedure for repeated measures analysis of variance tests for differences in growth patterns among the plants grazed in various growth stages during 1990.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	1	1800.266139	1800.266139	14.85	0.0002
INTENS	2	25113.133371	12556.566686	103.58	0.0001
INTENS*TREAT	2	11.778944	5.889472	0.05	0.9526
Error	229	27759.576927	121.220860		

Table 2: Randomized block analysis of variance on the amount of regrowth (g) of Lehmann lovegrass (1990), after 30 days. Includes treatment grazed at hardseed.

1990	df	Sum Square	Mean Square	F Value
BLOCK	3	12.80	4.27	2.91
TREAT	2	89.70	44.85	30.64
LEVEL	2	4.42	2.21	1.51
INT	4	-3.45	-0.86	-0.59
TOTAL		138.61		
ERROR	24	35.14	1.46	
TOTAL	35			

Alpha = 0.05

Table 3: Production (g) of Lehmann lovegrass plants grazed at the preboot and boot to early inflorescence phenological stages after a thirty-day regrowth period during 1990. Treatment 1 is plants grazed during the preboot phenology growth stage. Treatment 2 is plants grazed during the boot to early inflorescence growth stage.

	Treat. 1		Treat. 2	
Mean	3.194		3.491	
Std.Dev.	3.105		3.270	
	L.C.L.	U.C.L.	L.C.L.	U.C.L.
	0.088	6.299	0.221	6.762

t= -0.72, df= 238, p= 0.47

Table 4: Production (g) of Lehmann lovegrass grazed at heavy (H), moderate (M), and light (L) intensities after a thirty-day regrowth period during 1990. Treatment 1 is plants grazed during the preboot phenology growth stage. Treatment 2 is plants grazed during the boot to early inflorescence growth stage.

	Trt. 1			Trt. 2		
	H	M	L	H	M	L
Mean	3.431	2.937	3.062	3.562	3.200	3.412
Std.Dev.	2.701	2.038	4.105	2.079	2.626	4.754

Trt. 1; F= 0.17, df= 2/117, p= 0.8408
Trt. 2; F= 0.26, df= 2/117, p= 0.7743

Table 5: ANOVA on linear coefficient from quadratic fit for all individual plants (1990). Only positive slopes selected.

Source	DF	Type I SS	Mean Square	F Value	Pr > F
TREAT	1	2.05595164	2.05595164	61.83	0.0001
INTENS	2	2.72297584	1.36148792	40.95	0.0001
INTENS*TREAT	2	1.90805597	0.95402799	28.69	0.0001

Table 6: Tukey's Studentized Range Test (HSD) for determining the relationships of the slopes (g•wk^2) at time zero for the treatments in 1990. Treatment 1 is plants grazed during the preboot phenology growth stage. Treatment 2 is plants grazed during the boot to early inflorescence growth stage.

Tukey Grouping	Mean	N	TREAT
A	0.38540	120	2
B	0.19492	110	1

Means with the same letter are not significantly different.
Alpha= 0.05 df= 224 MSE= 0.033251

Table 7: Tukey's Studentized Range Test (HSD) for determining the relationships of the slopes ($g \bullet wk^2$) at time zero for light (L), moderate (M), and heavy (H) grazing intensities in 1990.

Tukey Grouping	Mean	N	INTENS
A	0.46295	74	L
B	0.23154	78	M
B	0.19706	78	H

Means with the same letter are not significantly different.
Alpha= 0.05 df= 224 MSE= 0.033251

Table 8: Analysis of variance on the maximum regrowth of Lehmann lovegrass plants grazed during 3 different phenological stages at heavy, moderate and light grazing intensities during the 1990 growing season.

Preboot	Grazing Intensity	Heavy	Moderate	Light
	Regrowth Amount (g)	4.00	3.38	3.59
	S.D.	0.90	0.61	2.54
	S.E.	0.45	0.30	1.27
	P Value	0.822		
Boot to Early Inflorescence	Grazing Intensity	Heavy	Moderate	Light
	Regrowth Amount (g)	3.86	3.59	4.98
	S.D.	0.99	0.72	1.27
	S.E.	0.50	0.36	0.64
	P Value	0.17		
Hard Seed	Grazing Intensity	Heavy	Moderate	Light
	Regrowth Amount (g)	0.02	0.04	0.13
	S.D.	0.02	0.07	0.25
	S.E.	0.01	0.04	0.12
	P Value	0.58		

Table 9: Results of general linear models procedure for repeated measures analysis of variance tests for differences in growth patterns among the plants grazed in various growth stages during 1991.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	1	166.5260049	166.5260049	4.00	0.0468
INTENS	2	5987.9911141	2993.9955571	71.86	0.0001
INTENS*TREAT	2	15.4332190	7.7166095	0.19	0.8311
Error	228	9499.4902238	41.6644308		

Table 10: Randomized block analysis of variance on the amount of regrowth (g) of Lehmann lovegrass (1991), after 30 days. Includes treatment grazed at hardseed.

1991	df	Sum Square	Mean Square	F Value
BLOCK	3	2.90	0.97	5.22
TREAT	2	10.74	5.37	28.97
LEVEL	2	-0.28	-0.14	-0.77
INT	4	1.65	0.41	2.22
TOTAL		19.46		
ERROR	24	4.45	.196	
TOTAL	35			

Alpha = 0.05

Table 11: Production (g) of Lehmann lovegrass plants grazed at the preboot and boot to early inflorescence phenological stages after a thirty-day regrowth period during 1991. Treatment 1 is plants grazed during the preboot phenology growth stage. Treatment 2 is plants grazed during the boot to early inflorescence growth stage.

	Treat. 1		Treat. 2	
Mean	1.256		0.554	
Std.Dev.	1.747		0.825	
	L.C.L.	U.C.L.	L.C.L.	U.C.L.
	-0.486	2.999	-0.271	1.379

t= 3.99, df= 238, p= 0.0001

Table 12: Production (g) of Lehmann lovegrass grazed at heavy (H), moderate (M), and light (L) intensities after a thirty-day regrowth period during 1991. Treatment 1 is plants grazed during the preboot phenology growth stage. Treatment 2 is plants grazed during the boot to early inflorescence growth stage.

	Trt. 1			Trt. 2		
	H	M	L	H	M	L
Mean	0.950	1.300	1.861	0.362	0.600	0.695
Std.Dev.	0.937	1.826	2.134	0.617	0.768	0.995

Trt. 1; F= 1.80, df= 2/117, p= 0.1693
Trt. 2; F= 1.92, df= 2/117, p= 0.1510

Table 13: ANOVA on linear coefficient from quadratic fit for all individual plants (1991). Only positive slopes selected.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TREAT	1	0.07347562	0.07347562	5.85	0.0166
INTENS	2	0.22431012	0.11215506	8.93	0.0002
INTENS*TREAT	2	0.01743509	0.00871754	0.69	0.5010

Table 14: Tukey's Studentized Range Test (HSD) for determining the relationships of the slopes (g•wk^2) at time zero for the treatments in 1991. Treatment 1 is plants grazed during the preboot phenology growth stage. Treatment 2 is plants grazed during the boot to early inflorescence growth stage.

Tukey Grouping	Mean	N	TREAT
A	0.13876	93	2
B	0.09729	97	1

Means with the same letter are not significantly different.
Alpha= 0.05 df= 184 MSE= 0.012565

Table 15: Tukey's Studentized Range (HSD) Test for determining the relationships of the slopes ($g \bullet wk^2$) at time zero for light (L), moderate (M), and heavy (H) grazing intensities in 1991.

Tukey Grouping	Mean	N	INTENS
A	0.15735	63	L
A	0.12126	67	M
B	0.07172	60	H

Means with the same letter are not significantly different.
Alpha= 0.05   df= 184   MSE= 0.012565

Table 16: Analysis of variance on the maximum regrowth of Lehmann lovegrass plants grazed during 3 different phenological stages at high, moderate and light grazing intensities during the 1991 growing season.

Preboot	Grazing Intensity	Heavy	Moderate	Light
	Regrowth Amount (g)	1.08	1.73	2.31
	S.D.	0.41	0.62	0.76
	S.E.	0.21	0.31	0.38
	P Value	0.05		
Boot to Early Inflorescence	Grazing Intensity	Heavy	Moderate	Light
	Regrowth Amount (g)	0.39	0.91	0.78
	S.D.	0.22	0.40	0.32
	S.E.	0.11	0.20	0.16
	P Value	0.10		
Hard Seed	Grazing Intensity	Heavy	Moderate	Light
	Regrowth Amount (g)	0.06	0.08	0.03
	S.D.	0.05	0.06	0.05
	S.E.	0.03	0.03	0.03
	P Value	0.45		

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