IN-VITRO DRY MATTER DIGESTIBILITY OF LEHMANN LOVEGRASS (*ERAGROSTIS LEHMANNIANA* NEES) WITHIN GRAZED PATCHES AND LIGHTLY GRAZED AREAS

by

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A Thesis Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN RANGE MANAGEMENT

In the Graduate College

THE UNIVERSITY OF ARIZONA

1995

UMI Number: 1378282

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I. Acknowledgments

I am deeply indebted to Dr. George Ruyle for his instruction, patience and support through all stages of my graduate program. His advice and guidance have been invaluable in the completion of this thesis.

I appreciate the knowledge and advice I have recieved from Dr. Lamar Smith. Most importantly, I am sincerely appreciative of the professional and personal support Dr. Richard Rice has given me. He encouraged me and gave me the self-confidence to make the important changes in my professional career.

II. Dedication

So many people have profoundly influenced me. But not everyone is with me today. I dedicate this work to my father, William H. Renken, and brother, Cmdr. Ralph W. Renken. I miss them both dearly.

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V. Abstract

Cattle selectively graze grasses for green, leafy material, often restricting their foraging to localized patches surrounded by large, lightly grazed areas. A two year study was conducted on the Santa Rita Experimental Range in southern Arizona to compare the effects of heavy grazing on Lehmann lovegrass (*Eragrostis lehmanniana* Nees.) digestibility. Lehmann lovegrass was clipped from within heavily grazed patches and adjacent ungrazed areas. Green and dry plant materials were separated and analyzed for percentage in-vitro dry matter digestibility (IVDMD). Results indicated a significant difference existed in the IVDMD of the total standing crops ($p \leq 0.005$). When analyzed separately, the IVDMD for both the green and dry plant materials from the grazed patches was significantly higher ($p < .05$) than that from the ungrazed areas. Seasonal trends indicated a greater difference in digestibility during periods of active plant growth. Patch maintenance apparently maintains plants with higher forage values for grazing animals than surrounding ungrazed areas.

VI. Introduction

Lehmann lovegrass (*Eragrostis lehmanniana* Nees) is a warm season, perennial bunchgrass native to South Africa and was first introduced to Arizona in the 1930's (Cable 1971, Freeman 1979). Lehmann lovegrass seed was produced at the Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service) Plant Materials Center, Tucson, Arizona, and distributed to soil conservationists and scientists within USDA-NRCS for field plantings. The seedings in Arizona, New Mexico, and Texas were prolific. Between 1940 and 1950, Lehmann lovegrass began to spread to areas not intentionally seeded. Subsequently, continued seedings and natural spread has allowed Lehmann lovegrass to be the major grass species on approximately 145,000 ha. in Southeastern Arizona (Cox and Ruyle 1986). Because of this extensive coverage Lehmann lovegrass is an important forage resource in Southeastern Arizona.

Nutritive analysis shows that total standing biomass of Lehmann lovegrass is often marginal as cattle forage (Rice et al., 1994). However, diet studies indicate that cattle select for green, leafy material with higher amounts of crude protein and phosphorus than that available in the total standing crop (Rice et al., 1994).

In addition to selecting green, leafy plant material within the sward, cattle grazing Lehmann lovegrass rangelands largely confine grazing to heavily grazed patches. This phenomenon, known as patch grazing, occurs naturally within pastures grazed yearlong. The semidesert grassland of the Santa Rita Experimental Range (SRER) in southeastern

Arizona, rangeland dominated by Lehmann lovegrass and interspersed with mesquite, is representative of patch-grazed rangeland. The yearlong, moderately grazed pastures within the SRER are spotted with heavily grazed patches. Lehmann lovegrass plants within the heavily grazed patches, a minority of the total forage plants available, carry a high percentage of the grazing pressure (Ruyle et al., 1988).

When compared to the ungrazed or lightly grazed plants in the areas surrounding these patches, the heavily grazed plants have significantly less tiller elongation, biomass production, and subsequent residual vegetation (Ruyle et al. 1987). During the active growth period, tillers within the grazed patches were found to elongate from 6 to 14 cm. in height while the tillers of ungrazed plants grew from 18 to 29 cm. Standing green biomass increased from 13 to 26 g/m^2 within the grazed patches and 77 to 139 g/m^2 on the ungrazed areas (Ruyle et al. 1987). In addition to significant differences in total biomass, the proportion of green plant material to standing dead biomass (residual, dry plant material) remains much greater throughout the year in grazed patches compared to ungrazed or lightly grazed areas (Ruyle et al. 1987, Abu-Zanat 1989).

The difference in the green to dry plant material ratio indicates that patch maintenance may present the grazing animal with a mosaic of forage quality even though overall forage availability is greater in ungrazed areas. In-vitro dry matter digestibility is an indicator of overall forage quality reflecting the total energy available to the ruminant via microbial fermentation. The objective of this study was to evaluate nutritive quality of Lehmann lovegrass within heavily grazed patches compared to surrounding, lightly grazed areas.

VII. Literature Review

A. Patch Grazing

Cattle utilization patterns on rangelands stocked yearlong are not uniform. Some locations support heavy, repeated grazing while other areas remain lightly grazed or ungrazed (Ring et al. 1985). Commonly called patch grazing, this pattern occurs at light, moderate, and heavy stocking rates (Ruyle et al. 1988) indicating that the behavior is not easily remedied merely by changing grazing pressure. The total area of the heavily grazed patches fluctuates between grazing year (Ring et al. 1985), but the heavily grazed patches always carry the bulk of the grazing pressure (Ring et al. 1985, Ruyle et al. 1988, Norton and Johnson 1981). The likelihood of an area becoming an overgrazed patch depends upon which areas were used at the beginning of the grazing season (Ring et al. 1985). Under year-long grazing practices, repeated grazing in localized areas establishes stable, patchy utilization patterns. Areas surrounding the heavily grazed patches are very lightly grazed with use restricted to periods of grass dormancy (Ruyle et al. 1988).

Heavily grazed patch characteristics, compared to ungrazed areas, are the absence of standing dead biomass, significantly less aboveground biomass, and a significantly shorter sward height (Ring et al. 1985, Ruyle et al. 1988, Gibb 1991).

Patch utilization results from a positive feedback system where the lack of old standing biomass and the presence of succulent regrowth encourages repeated use of previously grazed areas (Ring et al. 1985). At the beginning of the grazing period, animals lightly to moderately graze certain areas while leaving other areas ungrazed. At low stocking rates, initial avoidance of certain areas may be due to areas of defecation or urination (Gibb 1991). But Ring et al. (1985) found that the ungrazed areas in the beginning of the grazing period were due to simply more forage available than the animals could consume. As the ungrazed plants matured, cattle selected regrowth on previously grazed plants. Maintenance of the grazed patches arises from the repeated defoliation of individual tillers and plants within the patch.

The degree to which a tuft is grazed depends in varying extents upon tuft size, presence or absence of moribund material, the tuft's grazing history, and tuft species and location (O'Connor 1992). Within a single species, tuft size and the degree of previous grazing consistently had the greatest influence on the likelihood of a future grazing event, with a tuft being more heavily grazed if it was large in basal diameter or had previously been heavily grazed. Tufts with less residual standing biomass were usually more heavily grazed. These preferences, relative to species identity, suggest that sward structure is an important determinant of cattle utilization (O'Connor 1992).

Patchy utilization patterns offer a selection of forage quality that is not readily apparent in the analysis of total standing biomass from a pasture. Selectivity allows animals to fulfill nutritive requirements that may not be supplied by the total standing vegetation. Many factors influence diet selection including the presence of matured standing biomass. Patch development and maintenance is considered to be a result of continuous grazing causing increased amounts of leaf material concentrated in smaller volumes, the relative absence of flowering culms and a decreased amount of moribund material (O'Connor 1992).

B. Intake

Grazing behavior and forage properties are factors that regulate the intake of grazing animals. The utility of a food to an animal is a function of both the forage quality and handling time costs (Stephens and Krebs 1986). The total time spent grazing, biting rate and bite size are behavioral variables affecting animal intake (Hodgson 1985). Sward characteristics, such as herbage available per unit of area, that influence bite size have a cascading effect upon the other two variables (Chacon et al. 1978). Under conditions in which the desired forage is sparse or difficult to obtain, cattle reduce bite size but compensate by increasing time spent grazing (Stobbs 1970) and by increasing the number of bites taken (Stobbs 1974).

The presence of residual stems affects intake on the bite level by providing a physical barrier to the grazing animal (O'Reagain and Mentis 1989, Flores et al. 1993). When eaten, stems and mature plant material are less digestible and require longer rumen retention time to be utilized by the animal. In order to be passed through the rumen, forage particles need to be reduced below a critical size (that which will pass a 1 mm screen) (Poppi 1985). A diet of less digestible forage requires increased mastication and rumen retention time; therefore, reducing forage intake.

A strong relationship exists between the physical structure of a grass and its acceptability as a forage to cattle. Selectivity of one grass species in preference over another is positively related to tuft diameter, leaf percentage, leaf height, and leaf crude protein content (O'Reagain and Mentis 1989). Patch grazing may increase the grazing efficiency of cattle by maintaining a sward of more leafy, succulent regrowth (Abu-Zanat 1989), thus reducing handling time and passage rate of the forage.

C. Digestibility

Energetic value of forages and feedstuffs is commonly divided into three components: digestibility, feed consumption, and energetic efficiency (Van Soest 1982). Each category varies in its amenability to measurement. Forage evaluation assumes that feeds and forages are variable but animal responses to estimated values are comparatively predictable. Because it is relatively easy to obtain, digestibility is analyzed more often than efficiency or intake of a forage even though efficiency and intake are more directly related to total animal responses (Van Soest 1982). The latter two components offer more inter-animal variation and the establishment of values for these components within a forage or feed is more difficult than for digestibility. Intake and efficiency are assumed to be related to the digestibility of a feed but not without exceptions (Van Soest 1982).

Total digestibility of a forage is a function of the relative amounts of soluble cell material and cell wall constituents available for degradation by bacterial, protozoal and fungal flora within the gut of ruminants. Soluble materials, such as sugars, proteins, starches and lipids, are readily fermented compared to the less soluble, structural components. Structural elements, cellulose, hemicellulose, and lignin, comprise the less soluble material of forage that require mastication and microbial degradation for sufficient particle size reduction to pass from the rumen (Poppi et al. 1985). The chemical and structural composition of ingested forage particles are the determinants of digestibility (Wilson 1994). In general, digestibility of a forage is one of the better estimations of animal intake and response (Van Soest 1982).

1. Cell wall chemistry

Structural carbohydrates, cellulose and hemicellulose, comprise 50-70% of the total dry matter in legumes and grasses. Fermentation of carbohydrates depends upon prolific microbial flora located within the ruminal gut. Peak fermentation of forage diets occurs approximately 4 - 5 hours after ingestion (Van Soest 1982). Even though pure compounds of these carbohydrates are 100% degradable by rumen microbes, lignification and inadequate rumen retention time restrict their complete digestion (Susmel and Stefanon 1993). Lignin is a nearly indigestible, non-carbohydrate polymer reinforcing plant structural integrity, located primarily in stems and leaf midribs (Wilson 1994).

Lignin is not easily defined from a chemical viewpoint. The term lignin is commonly used to describe a class of three-dimensional polymers of phenyl-propane structural units, aromatic alcohols, *p*-coumaril, coniferil, and synapil in association with the cellulose and hemicellulose components of a plant (Susmel and Stefanon 1993). The composition of lignin in plants varies with species, maturity, and plant part. Lignin composition is also highly related to the isolation technique used for evaluation (Van Soest 1982, Susmel and Stefanon 1993, Wilson 1994).

Lignins within temperate grasses are more soluble in alkali than are those within tropical grasses and within both grass categories lignin content increases with plant maturity (Van Soest 1982). The methodology for lignin determination has no specific standard, but the technique of convention is solubility in 72% sulfuric acid. However, sulfur-containing reagents add sulfur and the physical properties of the lignins are altered by strong acids (Van Soest 1982). Physical alterations of lignin occur because it is intimately bound to hemicellulose and during extraction can cause rearrangements and/or condensations of the structure (Susamel and Stefanon 1993). Therefore, the true lignin composition within a plant is difficult to determine.

Lignin is found in varying forms of high and low molecular weight matrices. Ferulic and p-coumaric acids in low molecular weight forms are identified in grasses. This low molecular weight matrix form of lignin has no effect on cell wall protection from degradation. Thus, only part of the lignin class, the lignin "core" (Van Soest 1982), affects the digestibility of forage plants. Van Soest (1982) also suggested that the term lignin be restricted to the high molecular weight matrix forms.

Electron microscopy shows cells comprising plant structural tissues, such as vascular bundles and schlerenchyma, are thick-walled with a complex of layers. These layers, from the outer structure inward, are the middle lamella, primary wall, and three layers of secondary wall (Wilson 1994). The secondary cell wall constitutes most of the wall volume. Within mature structural cells, all layers are usually lignified and are seen to be poorly digested in rumen particles or in feces (Wilson 1994).

Anaerobic fungi have been isolated from within the rumen of cattle which preferentially colonize lignified tissues and are capable of degrading lignified secondary walls (Orpin and Ho 1991). These fungi are not reliant upon surface adhesion to the forage particles but produce enzyme secreting rhizoids that permeate the secondary cell wall. However, inadequate forage retention time within the rumen also limits the digestion efficiency of the fungi.

2. Structural composition

Resistance of lignin to microbial degradation is one factor in the effect of lignin upon forage digestibility. Lignin limits the ability of ruminants to efficiently reduce forage particle size for sufficient microbial degradation. Rumen bacteria rely upon surface adhesion sites for digestion. In highly lignified plant structures (vascular and sclerenchyma), the indigestible middle lamella/primary cell wall cements adjoining cells into fibrous strands so bacteria can only access the inner wall surface via the narrow lumen of the long fibril (Wilson 1993). The thick-walled cells of these tissues are very tightly packed, reducing the ability of rumen bacteria to form close associations within their matrix, significantly reducing the overall digestibility of the plant. However, these cells comprise a small percentage of the tissue area. When cell types within a grass leaf were separated, these thick-walled cells comprised 15% of the total area but provided 61% of the cell wall mass; similarly, in stem tissue these cells made up 16% of the area and 64% of the cell wall mass (Wilson 1994). Because of their thick walls and cell density, the small contribution of these cells to total tissue area belies their effect on feed quality.

The structure of the plant cell wall changes with growth and maturation. These changes, and their resulting degree of insolubility or indigestibility, are environmentally affected (Wilson 1994). Daily air temperature can cause a 0.6 unit decrease in digestibility with each 1 °C increase. Increased temperature increases lignification and rate of maturation, therefore, decreasing the digestibility of the plant. Water stress reduces cell wall maturation, therefore plants under conditions of water stress are more digestible than rapidly maturing plants with adequate water supplies (Wilson 1994).

Thickening and lignification of cell walls, as well as a reduction in the proportion of leaves to stems, reduce the digestibility and the nutritive value of forage plants as they age. Stems are generally less digestible than leaves. Leaves, with little structural function, undergo fewer maturation changes. Cell size is fixed at an early stage in the immature plant. As maturation takes place, thickening and lignification of secondary cell layers occur with the reduction in intracellular space. Factors that influence the nutritive quality of stems are diameter and the presence or absence of pith. As stem diameter increases, lignified tissue may be more thinly distributed; therefore, a stem with a larger diameter would be more digestible than a smaller diameter stem. The presence of pith, which is usually significantly less lignified than the stem cortex, leads to a stem which is more digestible compared to a hollow stem (Van Soest 1982).

3. Rate of Digestion

The digestion rate of a forage, the quantity of dry matter that disappears per unit time with exposure to rumen flora, is an important characteristic determining the forage value to the animal. Intake partly depends upon the rate a forage can pass through the rumen and, therefore, is dependent upon structural volume; i.e., cell wall content. Overall, soluble cell constituents (sugars) ferment and pass very rapidly relative to storage carbohydrates (starches), insoluble proteins and structural carbohydrates. Plant cell wall lignification and physical accessibility to microbial attachment determines the degree to which cell walls are available for microbial digestion (Wilson 1995).

In-vitro rate of forage disappearance depends upon the relative proportions of soluble to insoluble cell constituents. Two forages of equal total digestibility may have different rates of disappearance. A forage with greater amounts of soluble cell components will digest faster than a forage comprised of more insoluble proteins and structural carbohydrates. Fermentation rates are also dependent upon adequate nitrogen and cofactor supplies for vigorous microbial flora (Van Soest 1982).

4. Foraging Behavior

The dynamics of cattle foraging behavior are influenced by a scale of effects ranging from plant chemical structure and digestibility to the topography of the landscape. The optimal foraging theory (Stephens and Krebs 1986) predicts that an animal will forage within a patch until the point at which its efforts are no longer rewarded by benefits greater than the cost of foraging. Daily forage intake by cattle is influenced by the total time spent grazing, biting rate and bite size. The quality and total availability of standing forage biomass affects these components. Plant quality is most readily defined by digestibility. Cattle selectively graze for more digestible, leafy, green forage. By maintaining heavily grazed patches the grazer is afforded the opportunity to forage within an area of immature, new plant growth.

VIII. Materials and Methods

A. Study Area

The study area is located approximately 50 kilometers southeast of Tucson, Arizona in pasture 12C of the Santa Rita Experimental Range (SRER). The terrain is flat uplands divided by shallow, dry washes located on an alluvial fan sloping from the southeast to the northwest. The range site of the area is loamy upland. Lehmann lovegrass is the dominant perennial grass species on the uplands with native grass species, including Arizona cottontop (*Digitaria californica*), cane beardgrass (*Bothriochloa barbinodis*), black grama (*Bouteloua eriopoda*), slender grama (*Bouteloua filiforma*) and green sprangletop (*Leptochloa dubia*), occurring on the slopes and wash bottoms. Interspersed shrub and cactus species include velvet mesquite (*Prosopis velutina*), ocotillo (*Foqueria splendens*), cholla (*Opuntia* spp.), and false mesquite (*Calliandra eriophylla*). Cattle grazing on the study area is year-long at moderate intensity.

The study area receives an average of 380 mm of annual rainfall. Approximately 60% of the total annual precipitation falls during the months of June through September (Martin and Reynolds 1973). Summer rainfall is highly variable spatially and temporally; usually occurring as brief, intense thunderstorms. Winter precipitation is more reliable with longer, less intense rainfall events.

The soils on the study site are gravelly loams of the Whitehouse series formed from granitic parent material from the Santa Rita mountains. The sandy loam surface horizon allows good water infiltration and takes in a lot of moisture before surface runoff occurs. An argillic horizon is located near the soil surface.

B. Vegetation Sampling

Lehmann lovegrass clippings were collected from July, 1986, to June, 1988, in association with a dissertation research project (Abu-Zanat 1989). Vegetation was collected weekly during the active growing season (late July to mid-September) and biweekly for the remainder of the year. On each sampling date (n=54), three heavily-grazed patches were randomly selected and paired with three adjacent ungrazed areas as described by Ruyle et al. (1988). Patch selection was based on the presence of grazing cattle one day previous to the sampling date (Abu-Zanat 1989). Five 0.1 m^2 plots were randomly located in each of the grazed patches and adjacent, ungrazed areas (Abu-Zanat 1989).

The sward within each plot was then harvested with hand shears at stratified heights. Five strata were defined; each stratum being 15 cm in height (stratum 1 = >60cm, 2 = 45-60 cm, 3 = 30-45 cm, 4 = 15-30 cm, 5 = ground level to 15 cm) (Figure 1) (Abu-Zanat 1989).

The harvested biomass (including stems, leaves and inflorescences) was separated into green and dead material and oven dried. Plant material was considered as dead when brown (Abu-Zanat 1989).

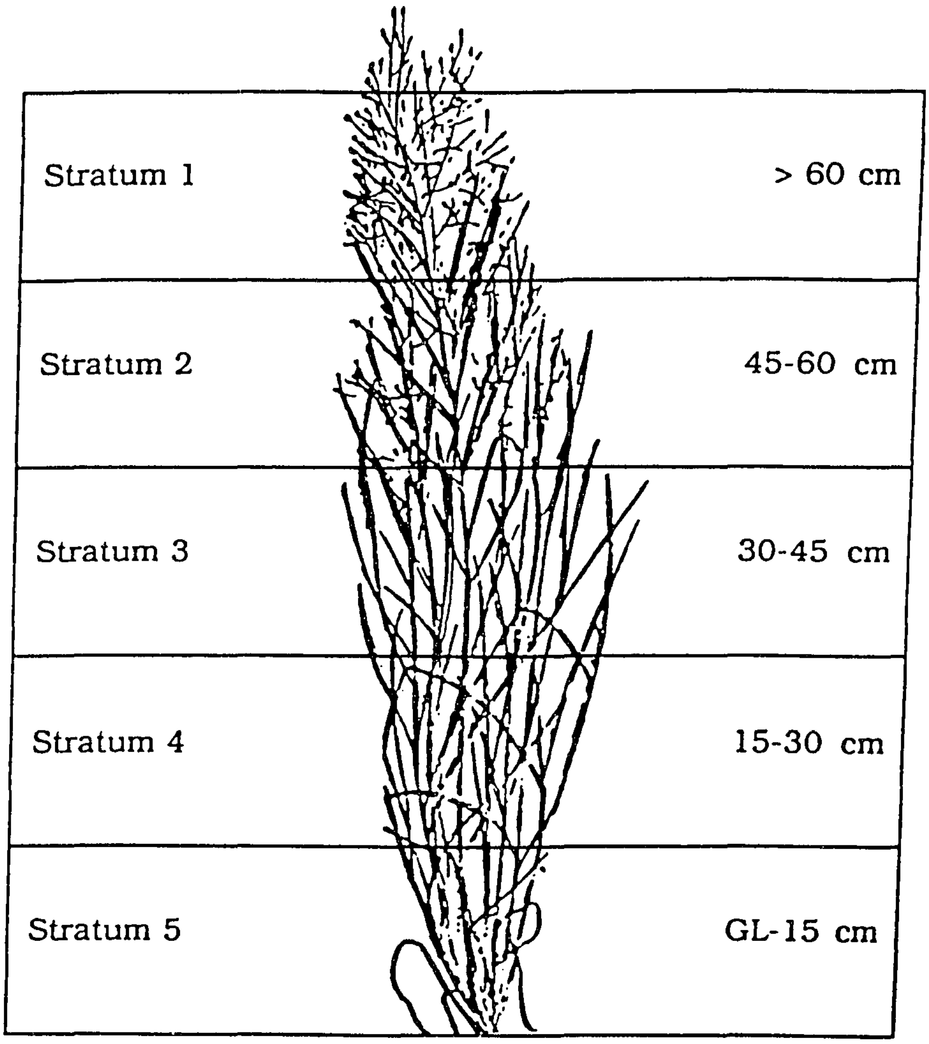

Figure 1. Harvest strata for lightly-grazed Lehmann lovegrass plants (GL: ground level) (Abu-Zanat 1989).

C. Laboratory Procedure

1. Total Digestibility

All samples collected were analyzed for in-vitro dry matter digestibility (IVDMD) as described by Tilley and Terry (1963). Due to the large numbers of samples and labor intensity required by the procedure, samples were run as a singlet for 0 hour solubility and in duplicate at 48 hour digestibility. Rumen inoculum was collected from a rumenally fistulated Holstein cow on an alfalfa/cottonseed hull diet.

Total digestibility was calculated as the dry matter loss following a 48 hour incubation and 48 hour acid-pepsin digestion.

2. Rate of Digestion

A time curve analysis of disappearance was conducted to analyze the rate of IVDMD. Incubations were stopped at defined times (0, 6, 12, 24, and 48 hours). The time curve analysis was restricted to the fifth stratum (ground level to 15 cm), the only data available from grazed patches. Samples were pooled because each sampling point lacked a sufficient sample for an entire time curve analysis (each time point in triplicate). Samples were pooled by season, green/dry, and patch type (grazed patches or ungrazed areas).

D. Statistical Analysis

Three pairs of heavily-grazed and lightly-grazed patches with five sample plots in each patch were sampled at each sampling date (54 samplings). The five plots of grass clippings collected within each patch were combined into a single replicate. Data were analyzed as whole plant digestibility (IVDMD of all strata combined) not by stratum since plant material within the grazed patches was only collected from within Stratum 5 (Figure 1). Ruyle et al. (1987), also, found that ungrazed or lightly-grazed areas contained tillers at a height greater than 30 cm. whereas heavily-grazed patches produced only tillers less than 15 cm in height. Analysis of variance with repeated measures was used to statistically analyze the data using sampling date as the sampling unit.

Table 1. Example of whole plant stratification for a single collection date (sampling unit, n = 54).

Ungrazed				Grazed			
Date	Pair	Strata	Total	Date	Pair	Stratum	Total
1	1	1		1	1	5	
		2			2	5	
		3			3	5	
		4					
		5					
	2	1					
		2					
		3					
		4					
		5					
	3	1					
		2					
		3					
		4					
		5					

IX. Results

A. Total Digestibility

The 48 hour in-vitro digestion of Lehmann lovegrass total standing crop collected from heavily grazed patches was than the total standing crop collected from adjacent ungrazed areas (Figure 2, Appendix Table 2). The overall average IVDMD percentage for grass clipped within the ungrazed area was 36.9% $\pm$ 0.3 while the overall average for the grazed patches was 39.4% $\pm$ 0.3. The difference (2.6%) was highly significant ($P \leq .0005$).

As expected, green standing vegetation had a significantly greater in-vitro dry matter digestibility compared to dry standing vegetation. The IVDMD averages for the green and dry standing vegetation were 39.7% $\pm$ 0.5 and 35.9% $\pm$ 0.4, respectively ($P \leq .0005$, Figure 3, Appendix Table 2).

Analyzed separately, the IVDMD of both the green and dry standing crop of Lehmann lovegrass was significantly higher on heavily grazed patches when compared to the biomass of separates from ungrazed areas. The overall average IVDMD for green standing crop was 38.6% $\pm$ 0.6 and 43.0% $\pm$ 0.5 from the ungrazed areas and grazed patches, respectively ($p<0.0005$; Figure 4, Appendix Table 2). The average IVDMD for dry standing crop was 35.9% $\pm$ 0.5 from the ungrazed areas and 36.1 $\pm$ 0.4 from the grazed patches ($p<0.05$; Figure 4, Appendix Table 2).

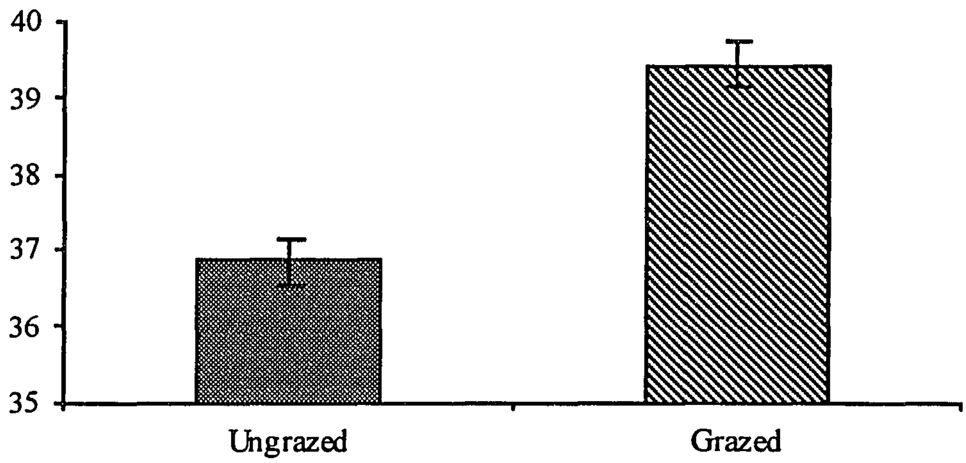

Figure 2. %IVDMD for the total standing crop of Lehmann lovegrass from ungrazed areas and heavily grazed patches.

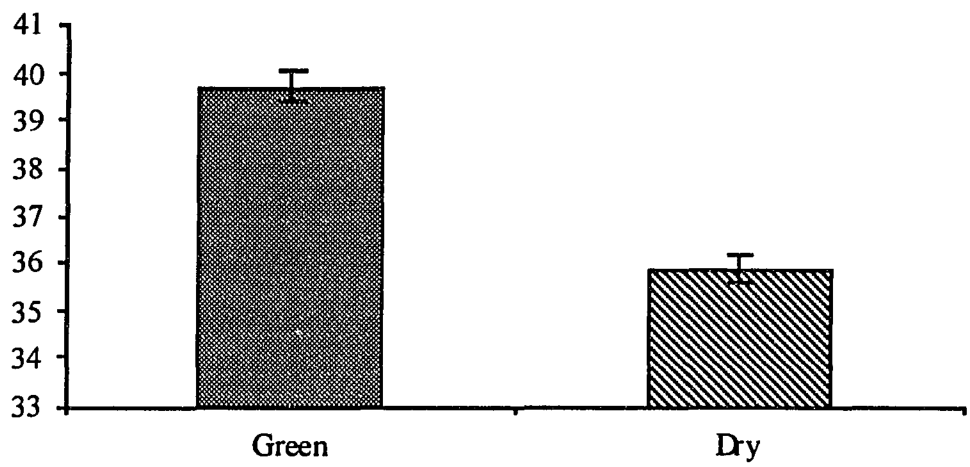

Figure 3. %IVDMD for green and dry standing crops of Lehmann lovegrass.

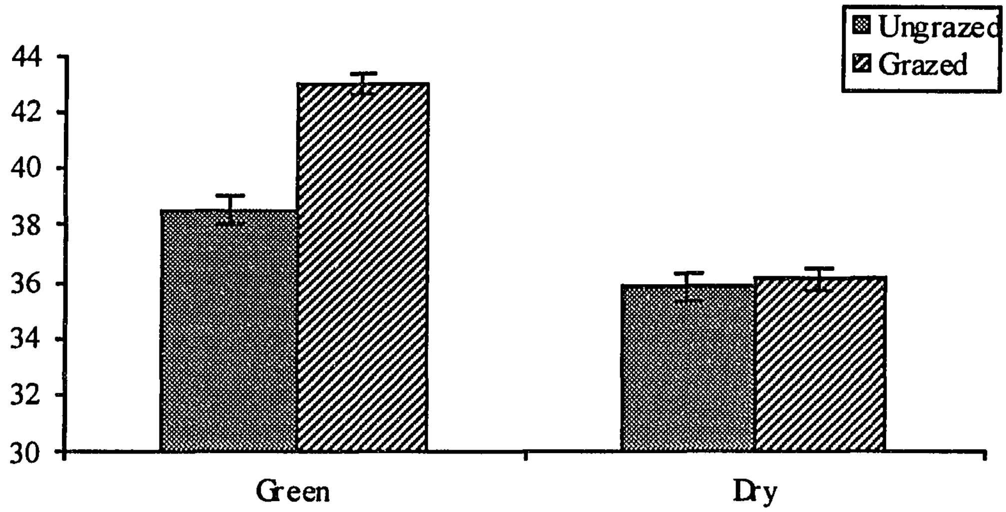

Figure 4. %IVDMD for green and dry standing crops collected from grazed patches and ungrazed areas.

Monthly differences in the digestibility of Lehmann lovegrass appeared as expected with normal plant growth and development (Figure 5, Appendix Table). In-vitro digestibility decreased from 52.3% at the initial collection in July, 1986, to 33.6% in October, 1986. Digestibility increased to 41.1% in May, 1987, before dropping to 23% during the months of June, July and August, 1987. The percentage digestibility then increased to 32.89% in September, 1987. Finally, IVDMD increased from 37.11% in March, 1988, to 44.27% in April, 1988, with another slight increase to 47.74% in June, 1988.

The total standing crop of Lehmann lovegrass within grazed patches was significantly higher in IVDMD than that from ungrazed areas during the months of September, 1986, February, March and May, 1987 (Figure 5, Appendix Table 3). The IVDMD of Lehmann lovegrass within grazed patches was higher than ungrazed areas from July to September, 1987, and also from January to March, 1988.

Green standing crop of Lehmann lovegrass was consistently higher in IVDMD compared to dry standing crop throughout the collection period (Figure 6, Appendix Table 4).

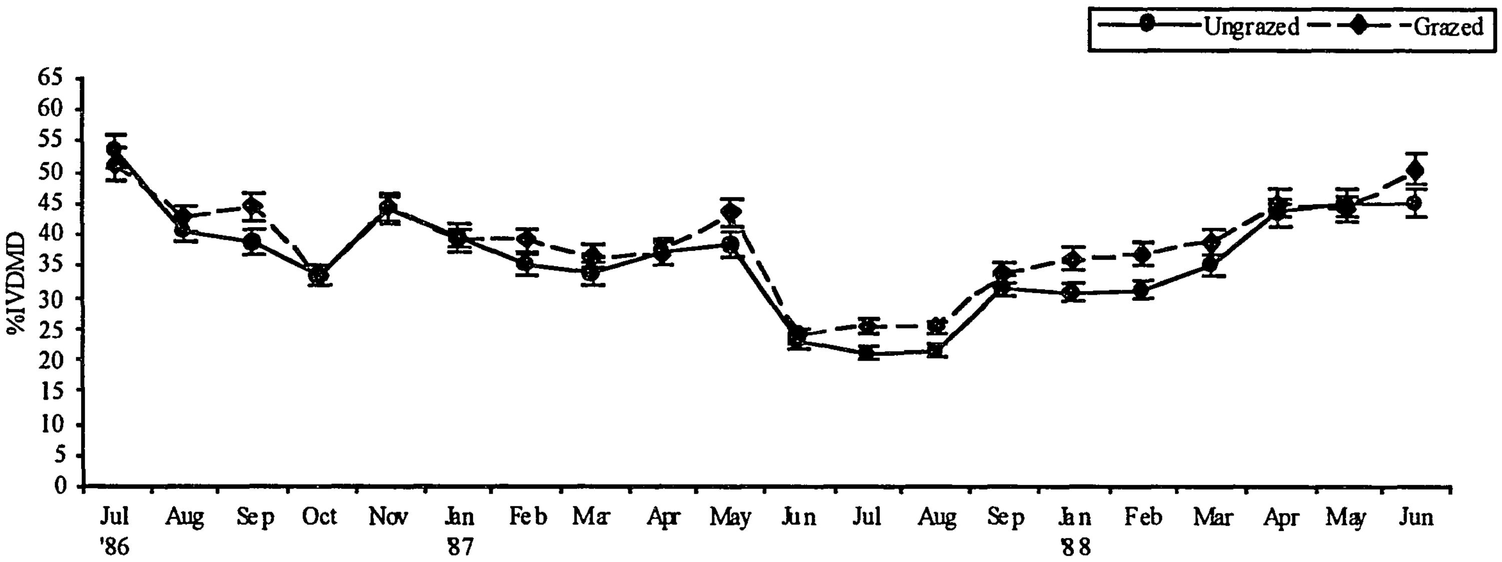

Figure 5. Monthly %IVDMD of Lehmann lovegrass standing crop from July, 1986, to June, 1988.

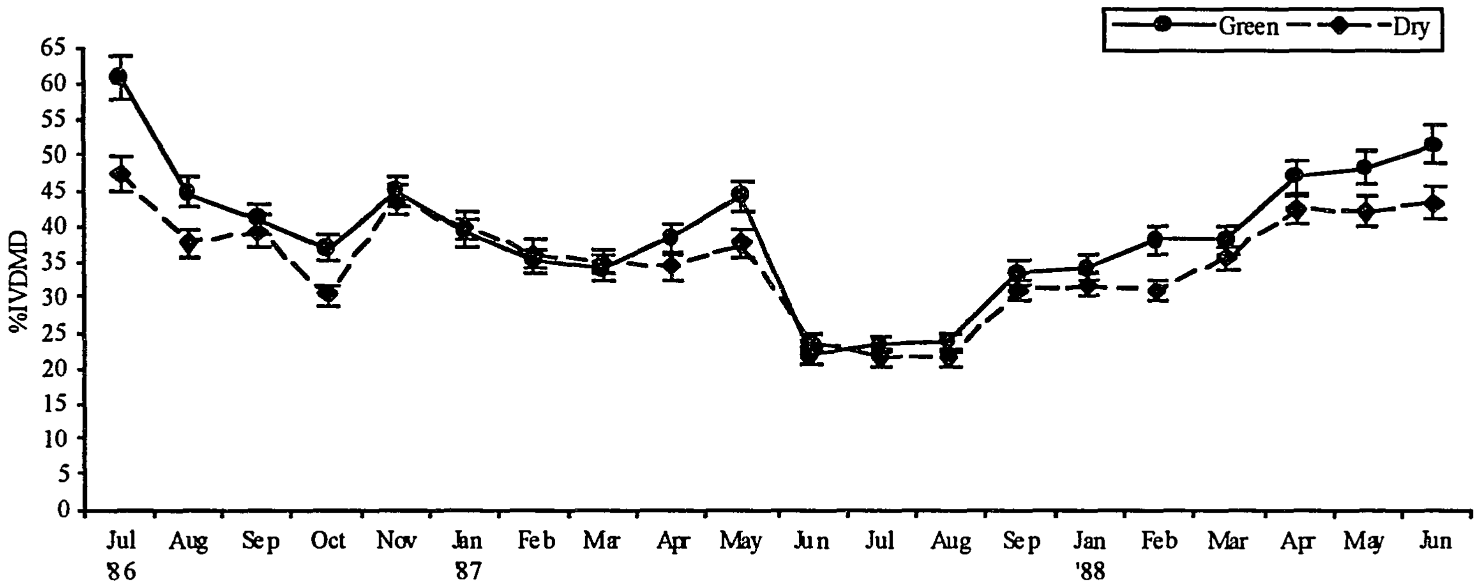

Figure 6. Monthly %IVDMD for green and dry standing crops of Lehmann lovegrass from July, 1986, to June, 1988.

The IVDMD of green standing crop on the grazed patches was higher than the green standing crop on ungrazed areas throughout the collection period except during the months of October and June, 1986, and March 1987 (Figure 7, Appendix Table 4).

The dry standing crop IVDMD of the grazed patches was higher than the dry standing crop on ungrazed areas throughout the collection period except during the months of October and June, 1986, and March, 1987 (Figure 8, Appendix Table 5).

B. Rate of Digestion

The rate of digestion by season, presented as cumulative %IVDMD over time, for green and dry standing vegetation is shown in Figure 9. The green standing vegetation was more digestible at 6, 12, and 24 hours of digestion and reached a higher 48 hour percentage in-vitro digestibility compared to the dry standing vegetation throughout all seasons.

Compared to the green biomass from ungrazed areas, the green standing vegetation from the heavily grazed patches had higher %IVDMD at 6 and 12 hours of digestion and higher 48 hour in-vitro digestibility throughout all seasons (Figure 10, Appendix Table 6).

The rate of in-vitro digestion of the spring and summer dry standing vegetation was similar for ungrazed and grazed patches (Figure 11, Appendix Table 7). During winter, the dry standing vegetation within the grazed patches was more readily digestible and had a higher 48 hour in-vitro digestibility compared to the dry standing biomass in adjacent ungrazed areas (Figure 11, Appendix Table 7).

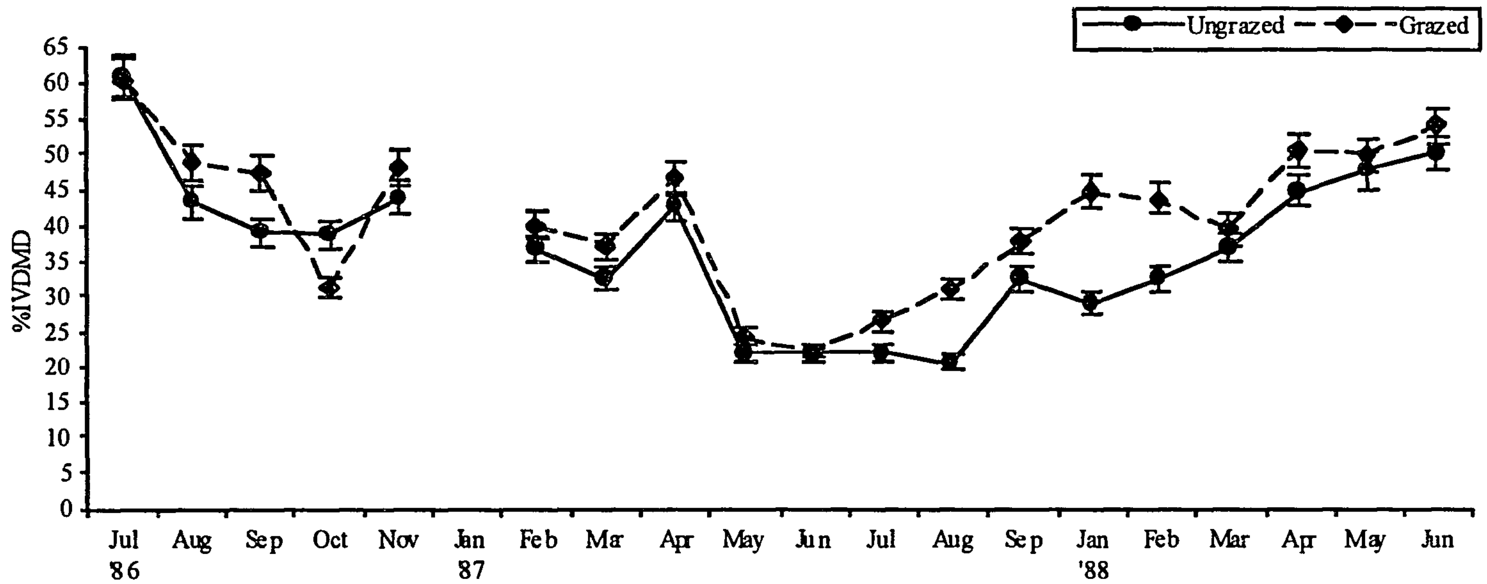

Figure 7. Monthly %IVDMD for green standing crop of Lehmann lovegrass from July, 1986, to June, 1988.

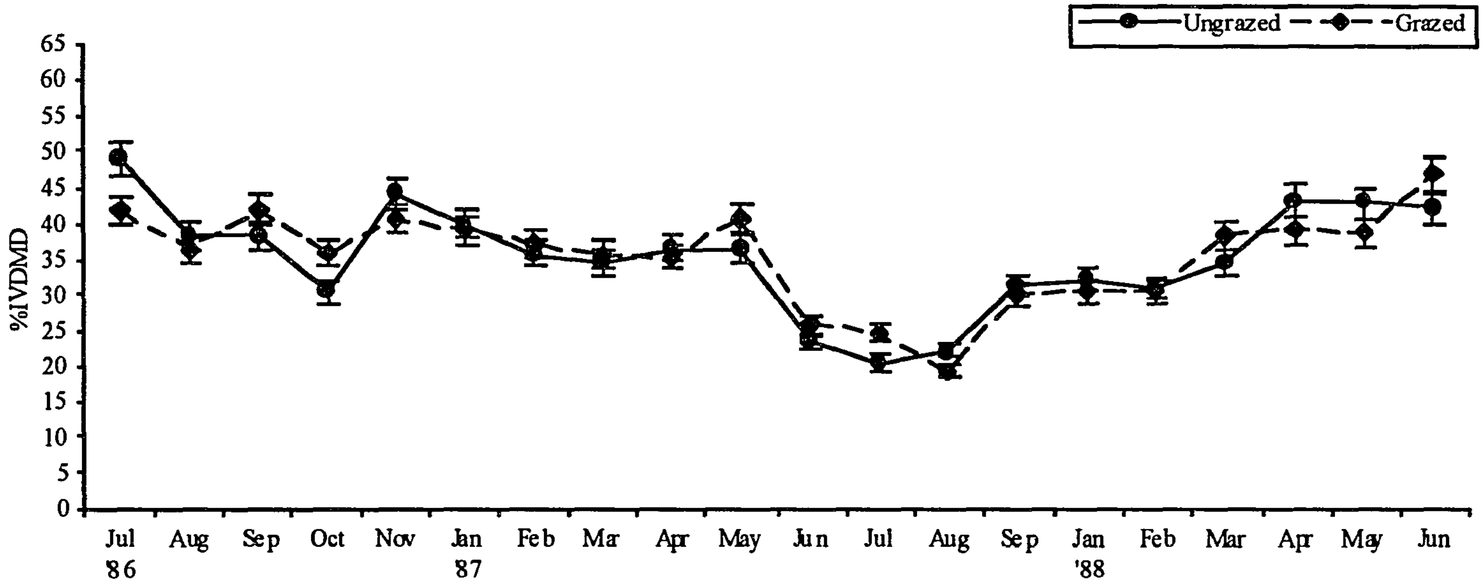

Figure 8. Monthly in-vitro dry matter digestibility for dry standing crop of Lehmann lovegrass from July, 1986, to June, 1988.

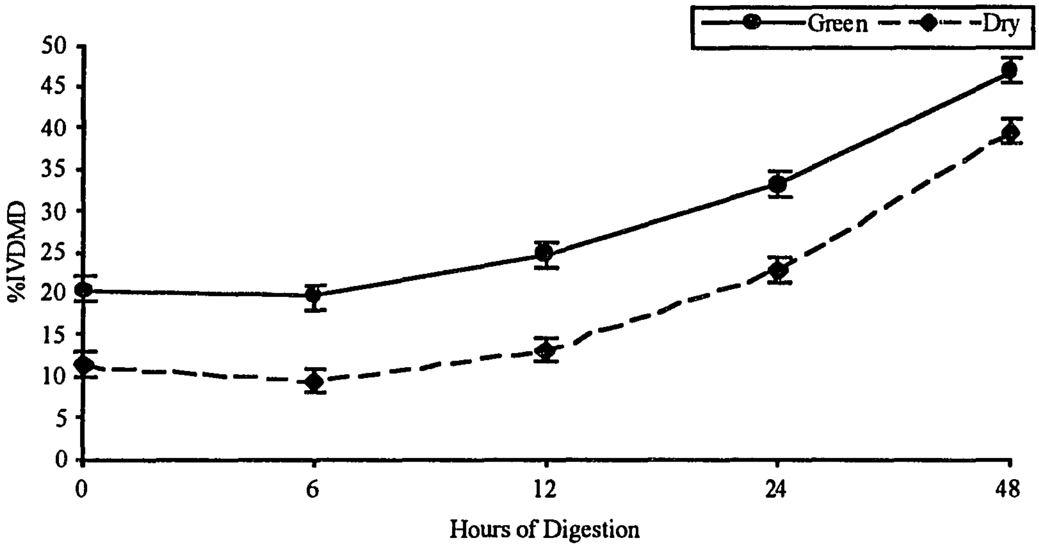

Figure 5. Cumulative IVDMD for green and dry standing crops of Lehmann lovegrass.

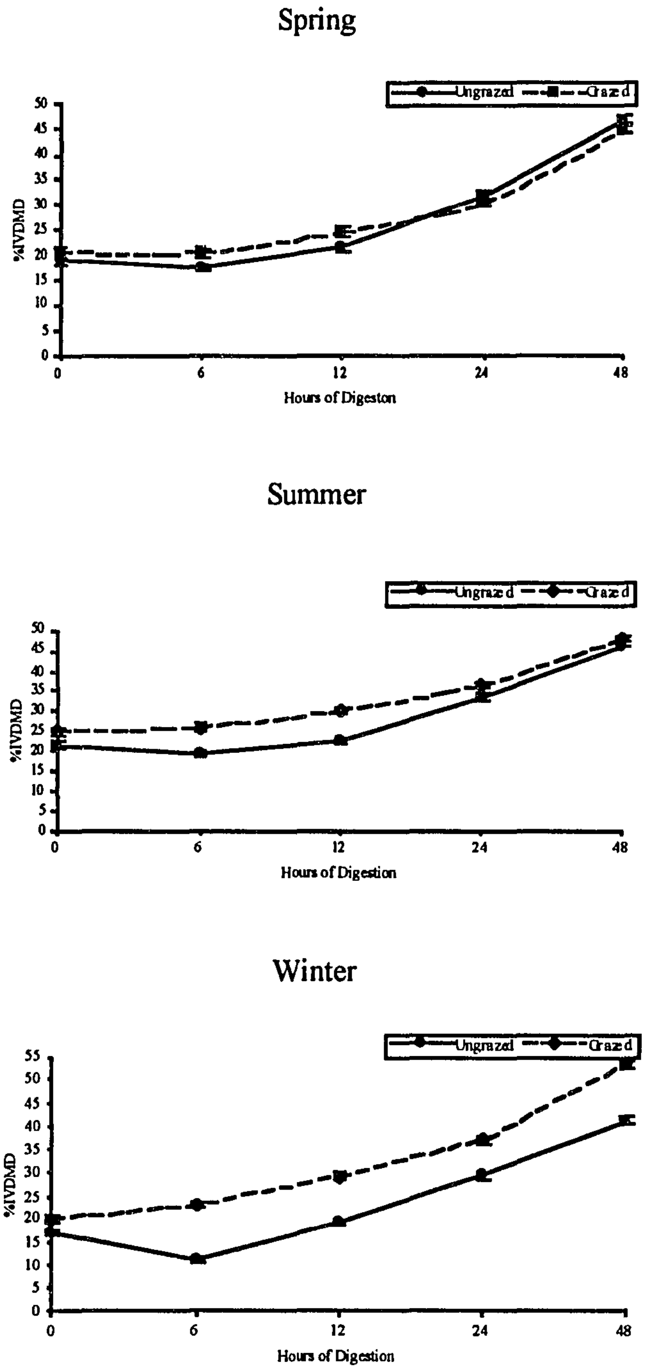

Figure 6. Cumulative IVDMD for green standing crop of Lehmann lovegrass.

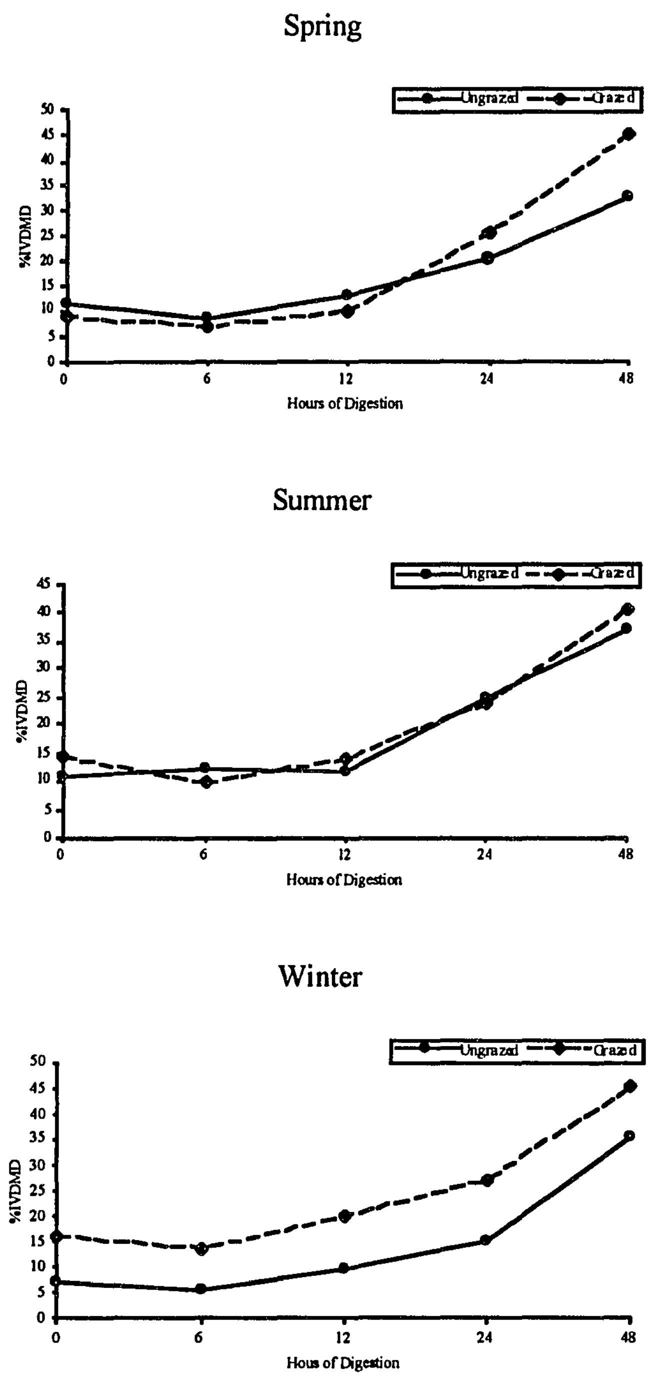

Figure 7. Cumulative IVDMD for dry standing crop of Lehmann lovegrass.

X. Discussion

A. Total Digestibility

Percentage IVDMD was significantly higher for the total standing crop of Lehmann lovegrass collected from the grazed patches as compared to adjacent ungrazed areas. Values ranged from 52% during active growth periods to 24% during plant dormancy. However, this analysis averaged the IVDMD from both the green and dry separates regardless of the actual proportions of each fraction within the total standing biomass. Abu-Zanat (1989) reported the green and dry herbage comprised 18% and 82% of the total biomass on the ungrazed patches and 46% and 54% of the standing vegetation of grazed patches, respectively. Therefore, the digestibility of the total standing crop from the ungrazed areas may be lower than that in the combined analysis. The digestibility of the total standing crop within the grazed patches would not differ greatly from the combined analysis.

The digestibility of the separates was expected to be different based upon previously published literature. Lignification associated with maturity in forage plants decreases digestibility (Cook and Harris 1950, Griffin et al. 1980, Griffin and Jung 1983, Krysl et al. 1987, and Van Soest 1982).

Accordingly, the difference in IVDMD between green and dry plant material was highly significant ($P \leq .0005$). Digestibility for the green standing crop was 39.7% $\pm$ 0.5 and dry standing crop was 35.9% $\pm$ 0.4.

Analyzed separately, the IVDMD of both the green and dry standing crop on heavily grazed patches was significantly higher than the biomass of separates from ungrazed areas. The green standing vegetation within the heavily-grazed patches was significantly more digestible (53.9% $\pm$ 0.5 and 38.6% $\pm$ 0.6, respectively; $P \leq .05$) than that from within the adjacent ungrazed areas. The difference in IVDMD of the dry standing vegetation between from grazed and ungrazed patches was also significant (36.1% $\pm$ 0.4 and 35.9% $\pm$ 0.5, respectively; $P \leq .05$).

The normal Lehmann lovegrass growth cycle is associated with the bimodal precipitation pattern (Figure 12, Appendix Table 10). Winter rains and favorable temperatures stimulate initial tiller production. A subsequent dry season follows which suspends biomass production of Lehmann lovegrass with dormant, immature tillers at the plant base. Commencement of the summer rains stimulates tiller elongation and flowering. Stem maturation and drying follows in the fall. Digestibility of the standing crop is higher during the periods of growth compared to periods of plant maturation and dormancy.

Precipitation events are reflected in the digestibility of the standing crop. Higher than average rainfall amounts recorded in June, 1986, one month prior to the collection

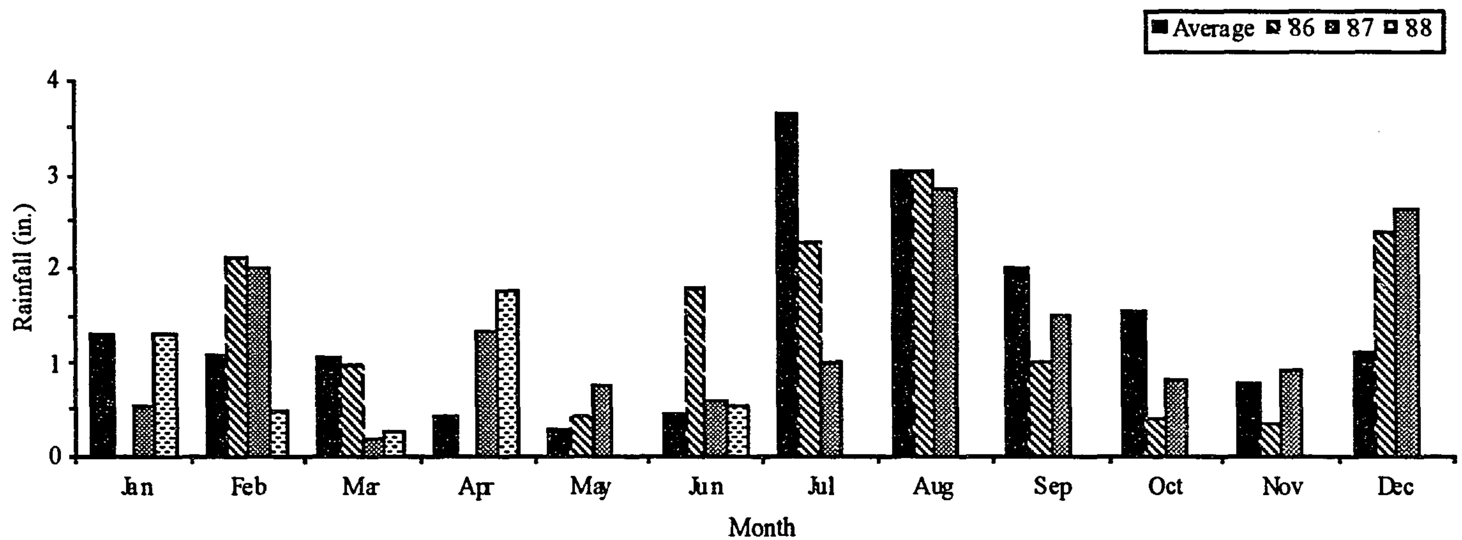

Figure 12. Current and average monthly precipitation, Pasture 12C, Santa Rita Experimental Range, from January 1986, to June, 1988.

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period, stimulated the summer plant growth, resulting in the high digestibility of plant material at the onset of the study. As plant growth and maturation proceeded, digestibility decreased. Monthly rainfall from September to November, 1986, was below average which is reflected by the decreased digestibility during that time period. Digestibility during the winter and early spring (November, 1986, to April, 1987) remains constant due to the cooler temperatures. The higher than average precipitation in April, 1987, reflects early plant growth by the slightly increased digestibility in May, 1987. The normal dry period from May to June and the unusually dry July, 1987, is reflected by the decreased digestibility in June through August, 1987. Plant growth was stimulated by the August, 1987, rainfall which is seen in the increased digestibility for September, 1987. Normal rainfall the rest of the year is reflected by the constant digestibility from January, 1988, to March, 1988. Digestibility increased slightly in April to June, 1988, from warmer temperatures and April precipitation stimulating tiller production.

Differences in digestibility of the green standing biomass from the ungrazed and grazed patches on a monthly basis is likely due to environmental differences and the influence of grazing on individual tillers. The greatest difference in digestibility of the green fraction between grazed and ungrazed patches is during the summer growing season (Figure 5.). During this period, the green biomass from the grazed patches is much more digestible than that from the ungrazed areas. The over-riding factor for this difference is probably the suspension of rapid maturation of the tillers within the grazed patches.

Grazing maintains tillers in a "younger", short-stemmed, phenological stage. Additionally, new tillers are initiated to replace those removed through grazing. The young tillers have less secondary cell wall development and greater amounts of soluble sugars than the maturing plant material within the ungrazed areas. Also, the decreased ground cover and the seemingly drier conditions in the grazed patches probably reduced the growth rate of those tillers with subsequent reductions in secondary cell wall thickening and lignification.

Additionally, plants under water stress are slowed in their mechanisms of maturation, which reduces stem growth and lignification, resulting in a higher percentage digestibility (Wilson 1994). Marked reduction in ground cover and soil surface aggregate break-down results in a drier micro-climate within the heavily grazed patches (Fuls 1992). Therefore, considering the intense, sporadic nature of the summer thundershowers and the reduced ground cover, the heavily grazed patches are probably more xeric during the primary growing period. The resulting water stress combined with continued defoliation could retard plant growth within the patches, maintaining less lignified, more leafy, and more digestible tillers.

Dry plant material within the grazed patches is also more digestible than that from the ungrazed areas throughout the year especially, after the growing season (Figure 6.). Dry plant material is no longer live, therefore, the changes in its digestibility are due to the degree of maturation prior to dry-down, and the period of time between dry-down and collection. The reduction of maturation extent induced by grazing and water limitations within the heavily grazed patches would lead to fewer stems and less lignification in the dry plant material, thus higher digestibility.

Over time, the dry standing crop decreases in digestibility due to biological degradation. Precipitation and microbial degradation leach the soluble cell contents from the dry plant material. Plant material collected soon after plant maturity and dry-down has a higher digestibility than that which has weathered. This is seen in the decreased digestibility in dry plant material collected in spring and early summer months.

B. Rate of Digestion

The green standing vegetation was more digestible after 6 and 12 hours of digestion and reached a higher 48 hour in-vitro digestibility compared to the dry standing vegetation throughout all seasons. This indicates the presence of greater amounts of soluble sugars and readily fermented starches in the green, immature plant tissue. Secondary cell wall development associated with maturation decreased the fermentation rate and subsequent rate of dry matter disappearance in the dry standing vegetation.

Compared to the green biomass from ungrazed areas, the IVDMD of green standing vegetation from the heavily grazed patches was higher at 6, 12 and 24 hours of digestion and higher after 48 hours throughout all seasons (Figure 9). The faster, higher rate of digestibility for the green biomass within grazed patches reflects the effects of patch maintenance by grazing on the suppression of plant maturation.

During the winter, dry plant material within the grazed patches was more readily digestible than that from the ungrazed areas. There was no difference in the rate of dry plant material digestibility between grazed patches and ungrazed areas in the spring and summer.

The factors that bring about the increased overall digestibility, environment and repeated grazing, also affect the rate of in-vitro digestion. More readily digestible plant material indicates less secondary cell wall thickening of tillers within the grazed patches. The greater rate and overall digestibility of the dry, winter plant material indicates the plants within grazed patches compared to ungrazed plants are less mature, have more soluble starches and less secondary cell wall thickening by the end of the growing season.

XI. Major Findings

- In-vitro dry matter digestibility of Lehmann lovegrass total standing crop within heavily grazed patches was significantly greater than that from adjacent lightly or ungrazed areas.
- Green standing vegetation was more readily digestible and had a higher total in-vitro digestibility than dry standing vegetation.
- Green and dry standing vegetation from within heavily grazed patches was significantly more digestible than from ungrazed areas.
- Patch grazing increases the availability of high quality, more digestible plant material.

XII. Management Implications

Cattle selectively graze for more digestible, leafy, green forage. The presence of residual mature grass stems does not influence the quality of the diet selected but does directly affect one component of daily forage intake, biting rate (Ruyle et al. 1995). When less digestible, residual stems are present cattle biting rate decreases but the quality of the diet selected is not affected (Rice et al. 1994). When cattle concentrate their grazing in heavily grazed patches, the quality of available forage is greater than in lightly grazed or ungrazed areas. Under yearlong stocking, patch grazing is a phenomenon which provides cattle with confined areas of higher quality forage than surrounding areas. The apparent inefficient forage usage actually may benefit livestock through improved nutrient uptake.

Forage quality can affect rumen retention time. In order for a forage particle to pass from the rumen, it must be reduced to less than 1 mm. (Poppi 1985). The higher rate of digestibility of plants within the grazed patches offer forage that more readily passes from the rumen compared to the ungrazed plants. During winter dormancy, a period of overall reduced forage quality and even nutritional stress, the dry plant material within grazed patches is more readily digestible than ungrazed dry plant material.

Patch grazing on rangelands stocked yearlong is not easily remedied. Changes in stocking rates do not affect patch dynamics; therefore, if grazing management prefers patch alleviation, implementation of rotational grazing systems are required. However, the differences in forage quality within the patches may be responsible for higher animal performance under yearlong grazing compared to animal performance within rotational grazing systems.

XIII. Appendix

Table 2. Mean ± standard error %IVDMD for green, dry, and total standing crop of Lehmann lovegrass collected from grazed patches and ungrazed areas.

	Ungrazed	Grazed	Total Standing Crop
Green	38.56 ± 0.550	43.03 ± 0.500	39.71 ± 0.460
Dry	35.87 ± 0.466	36.06 ± 0.375	35.86 ± 0.393
Total Standing Crop	36.87 ± 0.344	39.44 ± 0.293	

Table 3. Monthly average ± standard deviation %IVDMD of Lehmann lovegrass collected from grazed patches and ungrazed areas from July, 1986, to June, 1988.

Month	Ungrazed	Grazed	Total
July, 1986	53.41±5.572	51.12±4.760	52.27±5.260
August	40.71±5.032	42.55±3.457	41.63±4.533
September	38.82±5.204	44.68±3.093	41.75±5.224
October	33.51±6.309	33.61±3.364	33.56±5.006
November	44.02±6.134	44.39±3.522	44.21±4.956
January, 1987	39.76±2.777	39.14±1.969	39.45±1.969
February	35.38±5.136	39.18±2.212	37.28±4.701
March	33.93±4.155	36.35±1.173	35.14±3.260
April	37.23±5.152	36.95±2.522	37.09±4.021
May	38.44±4.625	43.72±1.887	41.08±4.436
June	22.94±5.612	23.91±1.877	23.43±4.172
July	21.07±7.089	25.52±2.242	23.29±5.669
August	21.45±6.048	24.16±3.403	23.31±5.207
September	31.80±5.747	33.99±1.888	32.89±4.377
January, 1988	40.79±4.197	36.23±3.688	33.51±4.780
February	31.22±3.572	37.04±3.413	34.13±4.540
March	35.30±3.220	38.91±0.771	37.11±2.951
April	43.76±5.434	44.78±2.828	44.27±4.319
May	45.03±4.625	44.29±2.810	44.66±3.808
June	45.01±5.510	50.46±1.788	47.74±4.901
Total	36.87±9.105	39.41±7.772	

Table 4. Monthly average ± standard deviation %IVDMD for green and dry standing crop of Lehmann lovegrass collected from grazed patches and ungrazed areas from July, 1986, to June, 1988.

Month	Green	Dry
July, 1986	60.69±1.536	47.52±4.868
August	44.81±4.018	37.59±4.952
September	41.01±7.155	39.35±3.793
October	36.94±5.296	30.37±5.804
November	44.88±4.821	43.51±7.360
January, 1987	39.18±1.041	39.84±3.305
February	35.15±2.798	36.04±6.111
March	34.21±2.340	34.88±5.008
April	38.44±2.772	34.30±5.981
May	44.12±2.093	37.53±5.465
June	22.03±3.782	24.01±6.265
July	23.49±7.747	21.52±5.509
August	24.05±7.616	21.36±4.315
September	33.40±5.037	30.97±5.536
January, 1988	34.19±6.665	31.63±3.695
February	37.98±3.684	30.78±4.467
March	37.87±2.130	35.61±3.811
April	46.92±2.112	42.29±6.915
May	48.24±3.944	41.98±4.120
June	51.37±2.966	43.26±5.421

Table 5. Monthly average ± standard deviation %IVDMD for green standing crop of Lehmann lovegrass collected from grazed patches and ungrazed areas from July, 1986, to June, 1988.

Month	Ungrazed - Green	Grazed - Green
July, 1986	60.84±1.220	60.39±1.176
August	43.40±3.382	48.77±1.522
September	39.23±6.329	47.30±2.223
October	38.62±5.004	31.32±3.029
November	43.84±3.216	48.01±3.905
January, 1987	---	---
February	36.64±4.803	39.94±2.193
March	32.50±1.416	37.07±1.308
April	42.68±0.822	46.63±1.292
May	22.00±5.854	24.28±2.241
June	22.01±3.640	22.08±2.087
July	21.99±8.066	26.49±2.384
August	20.53±7.364	31.07±0.246
September	32.32±5.041	37.72±0.656
January, 1988	28.96±3.933	44.65±0.912
February	32.33±0.451	43.64±1.321
March	36.76±2.061	39.36±0.668
April	44.76±0.744	50.51±0.409
May	47.59±4.157	49.76±1.054
June	50.12±2.916	53.87±0.393

Table 6. Monthly average ± standard deviation in-vitro dry matter digestibility for dry standing crop of Lehmann lovegrass from grazed patches and ungrazed areas from July, 1986, to June, 1988.

Month	Ungrazed - Dry	Grazed - Dry
July, 1986	48.96±4.355	41.85±1.650
August	38.31±5.062	36.34±1.011
September	38.30±3.306	42.05±1.920
October	30.40±5.322	35.91±4.576
November	44.14±8.194	40.78±1.669
January, 1987	40.04±3.769	39.14±1.121
February	35.75±6.433	37.20±2.282
March	34.65±5.702	35.63±0.865
April	36.50±6.451	35.40±2.322
May	36.39±5.880	40.80±0.944
June	23.54±7.101	25.75±0.971
July	20.38±5.786	24.54±1.960
August	22.07±4.093	19.25±2.563
September	31.31±6.384	30.26±2.225
January, 1988	32.01±4.076	30.47±1.067
February	30.88±5.095	30.44±0.777
March	34.65±3.997	38.47±0.811
April	43.26±7.764	39.05±0.212
May	43.03±4.362	38.81±0.526
June	42.23±5.824	47.06±0.830

Table 7. %IVDMD ± standard error for green and dry standing biomass of Lehmann lovegrass over time.

	0 Hr.	6 Hr.	12 Hr.	24 Hr.	48 Hr.
Green	20..49+1.11	19.57+2.03	24.58+1.80	33.09+1.30	46.81+1.67
Dry	11.47+1.40	9.47+1.22	13.03+1.52	22.74+1.77	39.35+2.10

Table 8. Seasonal %IVDMD ± standard error for green standing biomass of Lehmann lovegrass over time.

	0 Hr.	6 Hr.	12 Hr.	24 Hr.	48 Hr.
Ungrazed					
Spring	18.78±0.01	17.62±0.32	21.12±0.03	31.85±2.15	46.79±0.62
Summer	21.58±3.03	19.47±0.19	22.66±0.24	33.38±0.09	46.31±0.39
Winter	17.01±0.70	11.27±0.23	19.48±1.05	29.55±0.51	41.18±2.08
Grazed					
Spring	20.43±2.18	20.28±0.53	24.48±0.32	30.13±0.27	45.00±3.26
Summer	25.04±0.12	25.85±0.80	30.23±1.18	36.64±0.33	47.95±0.72
Winter	20.09±0.20	22.95±0.29	29.48±0.76	36.99±0.14	53.65±1.61

Table 9. Seasonal %IVDMD ± standard error for dry standing biomass of Lehmann lovegrass over time.

	0 Hr.	6 Hr.	12 Hr.	24 Hr.	48 Hr.
Ungrazed					
Spring	11.62±0.22	8.53±0.24	12.70±0.53	20.16±1.39	32.70±0.09
Summer	10.89±0.44	12.23±0.07	11.89±0.05	24.56±0.36	36.96±0.70
Winter	7.03±0.50	5.77±0.32	9.89±2.15	15.18±3.07	35.59±0.21
Grazed					
Spring					
Summer	14.40±0.77	9.85±0.05	14.12±5.47	24.10±0.35	40.62±0.35
Winter	16.23±2.17	13.47±0.74	19.84±0.54	26.99±0.84	45.23±0.25

Table 10. Current and average monthly precipitation for Pasture 12C, Santa Rita Experimental Range, January 1986 - June 1988.

Month	Current	17 yr. Average	Above/below avg.
January 1986	0.00	1.28	-1.28
February	2.12	1.06	+1.06
March	0.97	1.03	-0.06
April	0.00	0.41	-0.41
May	0.42	0.30	+0.12
June	1.79	0.44	+1.35
July	2.27	3.63	-1.36
August	3.03	3.03	0.00
September	0.98	1.99	-1.01
October	0.40	1.55	-1.15
November	0.33	0.77	-0.44
December	2.39	1.11	+1.28
January, 1987	0.54	1.28	-0.74
February	1.99	1.06	+0.93
March	0.18	1.03	-0.85
April	1.32	0.41	+0.91
May	0.76	0.30	+0.46
June	0.06	0.44	-0.38
July	1.00	3.63	-2.63
August	2.83	3.03	-0.20
September	1.50	1.99	-0.49
October	0.80	1.55	-0.75
November	0.94	0.77	+0.17
December	2.64	1.11	+1.53
January, 1988	1.27	1.28	-0.01
February	0.47	1.06	-0.59
March	0.28	1.03	-0.75
April	1.77	0.41	+1.36
May	0.00	0.30	-0.30
June	0.54	0.44	+0.10

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