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**GRAZING SYSTEMS FOR DIRECT-SEEDED
ALFALFA PASTURES**

presented by

Michael Lynn Schlegel

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of the requirements for

M.S. degree in Animal Science

A handwritten signature in cursive script, reading "Steven Rust", written over a horizontal line.

Major professor

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GRAZING SYSTEMS FOR DIRECT-SEEDED ALFALFA PASTURES

By

Michael Lynn Schlegel

A THESIS

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

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ABSTRACT

GRAZING SYSTEMS FOR DIRECT-SEEDED ALFALFA PASTURES

By

Michael Lynn Schlegel

A four-year study was conducted to determine the effects of grazing method and stocking rate on animal and plant productivity of alfalfa pastures; to compare the forage productivity of pasture systems to a mechanically harvested system, to ascertain the effect of grazing system on subsequent cattle performance fed concentrate diets; to determine intake of steers grazing alfalfa; and to calculate a net energy value for alfalfa pasture. Ten pasture plots (.76 ha) were divided into 2 replicates of 5 pastures each. Five treatments were assigned to each replicate of 5 pastures. Treatments were 1) 4 paddocks-low stocking rate, 2) 4 paddock-high stocking rate, 3) 13 paddock-low stocking rate, 4) 13 paddock-high stocking rate, and 5) mechanical harvest. Grazing method did not affect daily gains or gain/ha. High stocking rates decreased ($P < .05$) daily gains, but increased ($P < .01$) gains/ha in the third and fourth year. Daily organic matter intake of grazing steers was estimated to be 3.84 kg/d.

**Dedicated to my parents,
Kay and Sid Schlegel**

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LIST OF ABBREVIATIONS

13-H	13 paddocks, high stocking rate
13-L	13 paddocks, low stocking rate
4-H	4 paddocks, high stocking rate
4-L	4 paddocks, low stocking rate
ac	acre
ADG	average daily gain
AST	aspartate transaminase
BCP	Bovine Congenital Protoporphyria
bu	bushel
BW	body weight
°C	degree Celsius
cm	centimeter
CP	crude protein
Cr	chromium
CR	chromium predicted fecal output
CR-15D	chromium predicted fecal output and forage digestibility increased 15%
CR-D	chromium predicted fecal output and forage digestibility
d	day
DM	dry matter
DMD	dry matter degradation
DMI	dry matter intake
EPP	Erythropoietic Porphyria
g	gram
GLM	General linear model
GM	grazing method
h	hour
ha	hectare
IBR	Infectious Bovine Rhinotracheitis
IU	International unit
IVDMD	in vitro dry matter digestibility
IVOMD	in vitro organic matter digestibility
kg	kilogram
km	kilometer
L	liter
LWG	live-weight gain
m	meter

Mcal	megacalorie
mg	milligram
MH	mechanical harvest
mm	millimeter
N	nitrogen
NDF	neutral detergent fiber
NE _g	net energy for gain
NE _m	net energy for maintenance
nm	nanometer
NSC	non-structural carbohydrates
OBS	observation date
OM	organic matter
OMI	organic matter intake
OP	occupation period
P	probability
PI ₃	Parainfluenza 3-Virus
r	simple correlation coefficient
r ²	simple coefficient of determination
RP	rest period
SDH	sorbitol dehydrogenase
SED	standard error of the difference
SEM	standard error of the mean
SR	stocking rate
TC	total fecal collection
TC-15D	total fecal collection and forage digestibility increased 15%
TC-D	total fecal collection and forage digestibility
TDN	total digestible nutrients
UDP	undegradable protein
UV	ultra violet
VFA	volatile fatty acid
wt	weight
x	multiplied by
yr	year

CHAPTER 1: INTRODUCTION

In recent years, grazing of livestock has regained its popularity. Recommendations by animal scientists in the 1960's and early 1970's moved cattle indoors for improved animal performance. Although, confinement operations have lead to concerns over handling animal waste, animal health, and nutrient runoff. In addition, urban sprawl has been increasing in agricultural areas, compelling agricultural practices to become more urban and environmentally friendly. This may mean adapting agricultural practices that reduce odor, protect ground water, prevent soil erosion and emphasize animal welfare. Pasture systems may meet these demands.

Alfalfa, Michigan's most productive forage for harvested feedstuffs, may be an ideal grazing forage as well. Over 485 thousand hectares of alfalfa are grown in Michigan annually (Michigan Agricultural Statistics Service, 1992). Alfalfa has been regarded as a superior forage crop in terms of quality, palatability and yield potential (Van Keuren and Marten, 1972).

Animal production from alfalfa pastures has ranged from 392 kg/ha in heifers (Marten et al., 1987) to 783 kg/ha in lambs (Marten et al., 1990). More recently, studies in Kentucky have shown live-weight gains from 535 to 820 kg of beef produced per hectare on rotationally stocked alfalfa pastures (Burris et al., 1993). This level of production may allow alfalfa to compete with cash crops grown in Michigan.

Until recently, most alfalfa grazing system research has been done in New Zealand and Australia. There is a paucity of information on the correct methods for optimal management of grazed alfalfa pastures in the United States. Of major concern when developing a grazing system is plant survival. Under continuous stocking, alfalfa stands are not maintained (Brownlee, 1973; Van Keuren and Matches, 1988), therefore, a rotational stocking method must be employed. Selection of an adequate rest period, occupation period and stocking rate are critical to the maintenance of plant populations.

To ensure a profitable enterprise, an estimate of the productivity of the pasture is needed. In a pen feeding situation, the intake and gain of an animal can be used to determine the energy value of the feed consumed. The intake of grazing cattle is difficult to determine. Knowing the intake of grazing animals would allow the producer to determine stocking rates based on intake and expected forage production. In addition, energy intake could be determined and gain predicted.

For alfalfa pasture systems to be readily adopted, the systems must be economically competitive with traditional production systems in Michigan. The intent of this thesis is not to determine the economical viability of such an enterprise, but to determine the methods and management practices needed to successfully manage a productive alfalfa pasture system. The objectives of this thesis were:

- 1) to determine the effect of grazing method and stocking rate on animal and plant productivity of alfalfa pastures;
- 2) to compare the forage presentation of a pasture system to a mechanically harvested system;

- 3) to ascertain the effect of grazing systems on subsequent performance of cattle fed high concentrate diets;
- 4) to determine the intake of steers grazing alfalfa; and
- 5) to calculate a net energy value for alfalfa pasture.

Chapter two reviews literature on grazing systems, the use of alfalfa as a pasture crop, bloat, predicting intake of grazing animals, and photosensitivity. Studies to answer objectives one through three are discussed in chapter three. Chapter four discusses the experiment design to address objectives four and five. Based on the first two years of this study, the economic impact and feasibility of an alfalfa grazing system was summarized in a companion thesis by Wachenheim (1991).

A drawback to grazing experiments is the uncontrollable environment. Annual variations in rainfall, temperature, and weed and pest infestation can affect the production of forage and the efficiency of animal gains. One such anomaly occurred in the first year of the experiment. Holstein steers exhibited photosensitivity unexpectedly during the first 24 days of the experiment. Chapter five attempts to characterize the photosensitivity condition observed and determine a possible origin of the photodynamic agent.

CHAPTER 2: LITERATURE REVIEW

GRAZING METHODS

Grazing management is "the manipulation of animal grazing in pursuit of a defined objective" (The Forage and Grazing Terminology Committee, 1991). Defined grazing procedures or techniques are known as the grazing method, and one or more methods make up a grazing system. Terms used to describe grazing and methods are in accordance with The Forage and Grazing Terminology Committee (1991) and appear in Appendix A. The basic grazing methods include continuous stocking, rotational stocking, strip grazing, first and last grazers, stockpiling and variations thereof (Figure 2.1).

Continuous stocking

Continuous stocking has been referred to as continuous grazing. The former is the preferred term because animals do not graze continuously (The Forage and Grazing Terminology Committee, 1991). With continuous stocking, livestock graze a given area of land without subdivision throughout a grazing season. The forage does not receive defined rest periods (Whittier and Schmitz, 1990). Advantages of continuous stocking include low input costs (i.e. fencing, watering facilities), low labor requirements and requires fewer management decisions (Matches and Burns, 1985). Disadvantages of

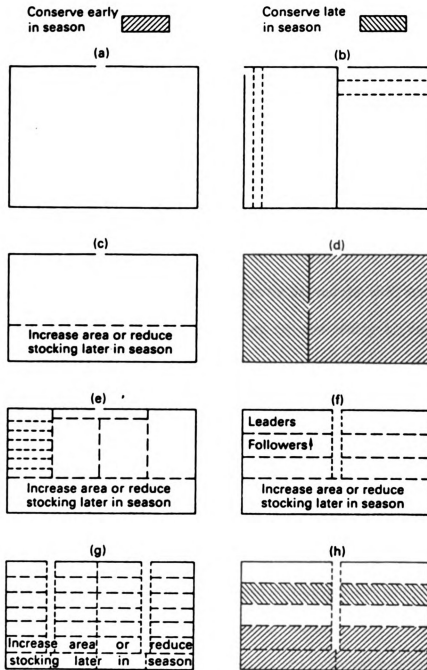


Figure 2.1. Outline of grazing systems. (a) continuous stocking; (b) strip grazing (alternative methods); (c) intensive continuous stocking; (d) integrated grazing and conservation; (e) rigid rotational grazing; (f) leader and follower rotational grazing; (g) daily rotational paddocks; (h) flexible rotational paddocks.

Permanent fence _____, semi-permanent - - - -, movable fence (Holmes,1989).

continuous stocking are poor grazing distribution and no control over the frequency of forage defoliation. This allows unpalatable plants to proliferate in under-grazed areas and the loss of palatable plant species in over-grazed areas (Dodds et al., 1985; Smetham, 1990).

Rotational stocking

Rotational stocking is "a grazing method which utilizes recurring periods of grazing and rest among two or more paddocks in a grazing management unit throughout the period when grazing is allowed" (The Forage and Grazing Terminology Committee, 1991). The number of paddocks is determined from the desired rest (RP) and occupation (OP) periods and is calculated by dividing RP by OP and adding 1 (Voisin, 1988). Advantages of rotational stocking include improved plant persistence, timely forage utilization, the opportunity to conserve excess forage (Matches and Burns, 1985), increased forage quality, increased stocking rate (SR), decreased selective grazing, and decreased weed infestation (Smetham, 1990). Responses in animal performance from rotational stocking are mixed (Table 2.1.). Caution must be used in interpreting the data in Table 2.1. In all but one experiment, SR of the rotational system was greater than the continuous system. Stocking rates were determined utilizing put-and-take procedures or increased according to expected improvements in forage yield. In either case, production/ha is confounded with SR. Disadvantages of a rotational stocking system are that it requires a greater capital investment and a higher degree of management than a continuous stocking system (Matches and Burns, 1985).

Table 2.1. Effect of rotational grazing on live-weight gain and gain per hectare when compared to continuous grazing

Forage species	Grazing system	Stocking rate, steers/ha	Grazing period, d	ADG, kg/d	Gain/ha, kg	Reference
Tall Fescue	Rotation, low stubble			.71 (+6.0) ^a	488 (+5.6) ^a	Aremu and Essig, 1992
	Rotation, high stubble			.71 (-6.6)	397 (-8.1)	
Tall Fescue	2 pad. rotation	3.0	165	.72	342	Schmitz et al., 1989
	3 pad. rotation	3.0	165	.65 (-9.7) ^b	307 (-10.2) ^b	
	6 pad. rotation	3.7	165	.60 (-16.7)	369 (+7.9)	
	12 pad. rotation	4.4/3.0 ^c	165	.59 (-18.1)	353 (+3.2)	
Ryegrass-clover	15 pad. rotation	4.5 (+26) ^a	187	1.01 (-3.8)	834 (+26.4)	Mooso et al., 1990
'Tifton' Bermudagrass	10 pad. rotation	6.7 (+43)	166	.65 (-7.1)	913(+29.7)	Tharel, 1989
'Midland' Bermudagrass	10 pad. rotation	8.4 (+42)	166	.64 (-17.9)	721 (+19.4)	
Common Bermudagrass	10 pad. rotation	5.9 (+26)	166	.59 (-3.3)	549 (+13.2)	
Limpograss	Rotational ^d	6.7 (+24)	168	.4(+21.2)	461 (+34.0)	Sollenberger et al., 1989
Bahiagrass	Rotational ^d	5.2 (+0)	168	.38 (+0)	318 (-14.1)	
Fescue-ryegrass	8 pad. rotation	7.2 (+16)	67 (+3.1) ^a	.88 (-15.4)	414 (-.5)	McGill et al., 1989

^a Values in parentheses are the percent increase or decrease compared to continuous grazing in the same experiment

^b Values in parentheses in Schmitz et al., 1989 study are compared to the 2 paddock rotation with the experiment

^c First 65 days stocking rate was 4.4 steers/ha; the last 100 days the stocking rate was 3.0 steers/ha

^d The rotational system was compared to the continuous in the same year

Strip grazing

Strip grazing "confines animals to an area of grazing land to be grazed in a relatively short period of time, where the paddock size is varied to allow access to a specific land area" (The Forage and Grazing Terminology, Committee, 1991). This method is closely related to rationed grazing described by Voisin (1988), where animal graze a variable area of land based on the animal's requirements and forage production. The main limitation of this method is the need for a greater intensity of management, and a manager to be able to coordinate both the animal and forage production (Matches and Burns, 1985). Strip grazes does increase forage utilization and decreases the waste of forage from trampling (Matches and Burns, 1985; Smetham, 1990).

First and last grazers

The first and last grazing method allows the producer to divide the animals into two groups based on differing nutrient requirements. The animals with the highest nutrient requirements graze a paddock first followed by the second lower-nutrient-requiring animals which graze the residue left by the first group. This method is also referred to as creep or forward grazing, where young animals graze ahead of their dams on pastures of higher quality (Matches and Burns, 1985; Blaser et al., 1986).

Stockpiling

The concept of stockpiling is "to allow forage to accumulate for grazing at a later period" (The Forage and Grazing Terminology Committee, 1991). Forage accumulates and is grazed during periods of little or no pasture growth (Blaser et al., 1986). The

most common practice is to stockpile forage for fall or winter grazing. Tall fescue has been shown to be the preferred forage for stockpiling in the transition zone of the United States (southern Illinois and Ohio south to northern Mississippi and Georgia, eastern Oklahoma east to the Piedmont in Virginia and the Carolinas; Thompson et al., 1993). Few legumes can be stockpiled because leaves are lost due to disease, maturation or frost in the fall, but, sainfoin and birdsfoot trefoil may have potential. Although, forage yield increases with stockpiling; forage quality decreases (Matches and Burns, 1985).

THE USE OF ALFALFA AS A PASTURE CROP

Origin and Development

According to Smith et al. (1986), "alfalfa is the oldest crop grown solely for forage". Alfalfa (*Medicago sativa*) originated in the mountainous region east of the Mediterranean in southwestern Asia. The earliest account of alfalfa is in 700 BC from a Babylonian text, and called aspasti, meaning best fodder (Smith et al., 1986).

Alfalfa culture was advanced by the Medes, Persians, Romans, Arabs and Moors as each invaded Europe (Smith et al., 1986; and Barnes and Sheaffer, 1985). Alfalfa was brought to the Americas by Cortez around 1540 AD and cultivated in Mexico. The use of alfalfa spread throughout South America with the Spanish conquest of the New World. The introduction of alfalfa into California coincided with the Gold Rush of 1848. Ships sailing around Cape Horn of South America picked up the 'Spanish alfalfa' in route. From California, alfalfa spread eastward, and was widely grown in the states west of the Missouri river by 1900 (Smith et al., 1986).

Colonists introduced alfalfa into the eastern United States around 1736, but the alfalfa was less productive than in the west due to acidic soils, lack of basic nutrients, less solar radiation and winter losses (Smith et al., 1986; and Barnes and Sheaffer, 1985).

Growth characteristics

Alfalfa is a herbaceous perennial legume with pinnately trifoliate leaves alternately arranged on the stem. Mature plants have 5 to 25 stems and normally 60 to 90 cm in height. The crown is first formed at the cotyledon node, at or beneath the surface of the soil. Secondary and tertiary buds, and development of the stem occur at this node and other basal nodes. Following harvest, growth can occur from crown or axillary stem buds depending on cutting height and plant type. Alfalfa utilizes a taproot which penetrates the soil 7 to 9 m and may be branched (Barnes and Sheaffer, 1985). Smith et al. (1986) lists several characteristics of an ideal alfalfa variety for the northern temperate region which include;

1. High yield capacity
2. Forage of high quality, that is, leafy and fine stemmed
3. Strong survival value with respect to winter injury and resistance to bacterial wilt
4. Resistance to leaf, stem, root and crown diseases
5. Rapid recovery after cutting
6. Resistance to insect pests
7. Strong, vigorous establishment
8. Good competitive capacity and drought tolerant, particularly during the first season
9. Broad and submerged crown
10. Branching root system
11. Persistence under grazing
12. Low animal bloat potential when grazed
13. Prolific seed producer

Continuous stocking

Continuous stocking causes the rapid decline of alfalfa stands in the North Central United States (Van Keuren and Matches, 1988). In Australia, Brownlee (1973) demonstrated a loss of alfalfa within three months with continuous stocking. The decline of alfalfa with continuous grazing occurs due to frequent defoliation resulting in the decreased accumulation of non-structural carbohydrate (NSC) reserves in the roots. Plants that do not accumulate NSC, fail to regrow (Blaser et al., 1986). In addition, continuous stocking may increase plant susceptibility to stressors such as drought or flooding leading to increased loss of plants (Leach, 1978). Decreasing the SR to prevent regrazing of alfalfa is not practical because the highly palatable alfalfa will be selectively grazed (Leach, 1978). For continuous stocking to be successful, a new type of alfalfa needs to be developed which produces a continuous succession of new shoots (Leach, 1978). A new cultivar of alfalfa, Alfagraze, which does survive successive defoliation is being developed in Georgia (Brummer and Bouton, 1991). Grazing tolerant cultivars are characterized by decumbent growth, thin stems and low yields. Alfagraze combines the high yield trait from the hay-type cultivars with the high stem numbers of grazing-type cultivars (Brummer and Bouton, 1992). One reason Alfagraze persists under continuous stocking is its ability to maintain higher stores of NSC.

Rotational stocking

Studies by Ittner et al. (1954) determined soiling (green chopping) and strip grazing produced 69% and 39% more beef/ha than a 4-paddock rotational stocking system. Meyer et al. (1956), using the same treatments as Ittner et al. (1954), confirmed

that strip grazing and soiling produced 3 to 7% and 29 to 57% more live-weight gain/ha than a rotational stocking system. Since traditional grazing-type alfalfas do not persist under continuous stocking, rotational stocking must be practiced. Important considerations with rotational stocking include: occupation period (OP), rest period (RP), and their relationship to plant growth, development, weather, and severity of grazing. Rest period is of primary importance (Leach 1978).

Rest period

The RP is the period of time that a specific land area is allowed to rest between the end of one OP and the start of the next OP (Voisin, 1988; The Forage and Grazing Terminology Committee, 1991). The RP allows the plant to produce new vegetation, thereby, increasing its photosynthetic capacity and regenerate the loss of NSC used for the initial regrowth (Blaser et al., 1986). With adequate rest periods, alfalfa can tolerate grazing activity. In Utah, alfalfa persisted nine years with a 35 or 42-d RP (Bateman and Keller, 1956, as referenced by Van Keuren and Matches, 1988) and a 36-d RP provided the greatest persistence in New Zealand (Iversen, 1967). O'Connor (1970) concluded that the RP should be from 36 to 54 d, but 18 d was not sufficient as total forage yield, alfalfa yield and stand density were decreased. McKinney (1974) determined a minimum RP of 39 d during the summer and 56 d in the winter was required to maintain stands in Australia. Alfalfa did not persist with a 21-d RP in Canada (Wilson and Clark, 1961) nor a 14-d rest in England (Davis, 1947).

Jason (1974) observed similar lamb gains when grazing was started early in the spring by decreasing grazing cycle and RP. Southwood and Robards (1975) also

reported similar gains of lambs grazed with short RP in the spring. If animal requirements dictate a decreased RP, the drop in forage production will be short-term and if the RP is returned to 35 to 42 d, little long-term damage will occur (Jason, 1975b; Douglas and Wilkinson, 1976).

Occupation period

Iversen (1967) recommends a short OP (4 d) and a high stocking density than leaves less than 5 cm of residual DM and allows a 36-d RP. Although in Australia, Leach (1979) demonstrated alfalfa survival was decreased with a 4-d OP than when grazed 8 or 16 d. The longer OP is also supported by work published by O'Connor (1970) in which, a 12-d OP increased forage production as compared with a 6, 18 or 24-d OP each with a 36-d RP. Although earlier work by O'Connor (1970) determined 6 or 18-d OP was not different than the 12-d OP. With a very short OP, 2 to 4 d, there is a lag of regrowth because basal shoots are immature (Jason, 1975a). When the OP is increased, basal shoots have time to develop allowing regrowth to begin as grazing continues. With very long OP, the early developing shoots are topped and the plant must rely on slower growing shoots which reduces regrowth rate and overall forage production (Jason, 1975a)

Competition from grass was greatest with a 4-d OP (Leach, 1979). In agreement with that study, a 14-d OP as compared with a 3-d OP reduced grass infiltration (O'Connor and Vartha, 1968). Douglas (1986) suggested that a longer OP for alfalfa prevents competition from faster-growing plants during the lag phase of growth following

defoliation. Grazing competing species until alfalfa buds develop, gives alfalfa the competitive edge, therefore allowing a shorter OP.

Plant maturity can be a determining factor in selecting an optimum OP. Jason (1975a) investigated the effect of maturity and OP on basal shoot development from the crown and determined that as maturity of the plant increased, OP should decrease. Basal shoots are absent at the immature mid-vegetative stage. As the plant matures through flowering, the number and size of the basal shoots increases, which decreases the lag time of regrowth (Jason, 1975a).

Stocking rate

Live-weight gains per animal decrease with increasing SR but gains per unit land area follow a quadratic relationship (Douglas, 1986; Figure 2.2). Therefore, a compromise must be made to achieve acceptable individual animal gains and desirable land area yields (Douglas, 1986). In the evaluation of SR, Thompson et al. (1976) concluded that rates above 12 ewes/ha decreased rotationally-stocked alfalfa stands. In support of the Thompson et al. (1976) study, Reeve and Sharkey, (1980) demonstrated a decline in alfalfa in rotationally-stocked alfalfa pastures with SR above 12.4 ewes/ha, but alfalfa was maintained at rates of 7.4 and 9.9 ewes/ha. Studies by Joyce and Brunswick (1977) and Marsh and Brunswick (1978) illustrate the effect of SR on ADG and gain/ha of steers grazing alfalfa and an alfalfa-prairie grass pasture (Table 2.2). The results from these studies clearly demonstrate the negative impact SR has on individual animal weight gains, but is offset by an increase in production/ha. Marten and Jordan (1972)

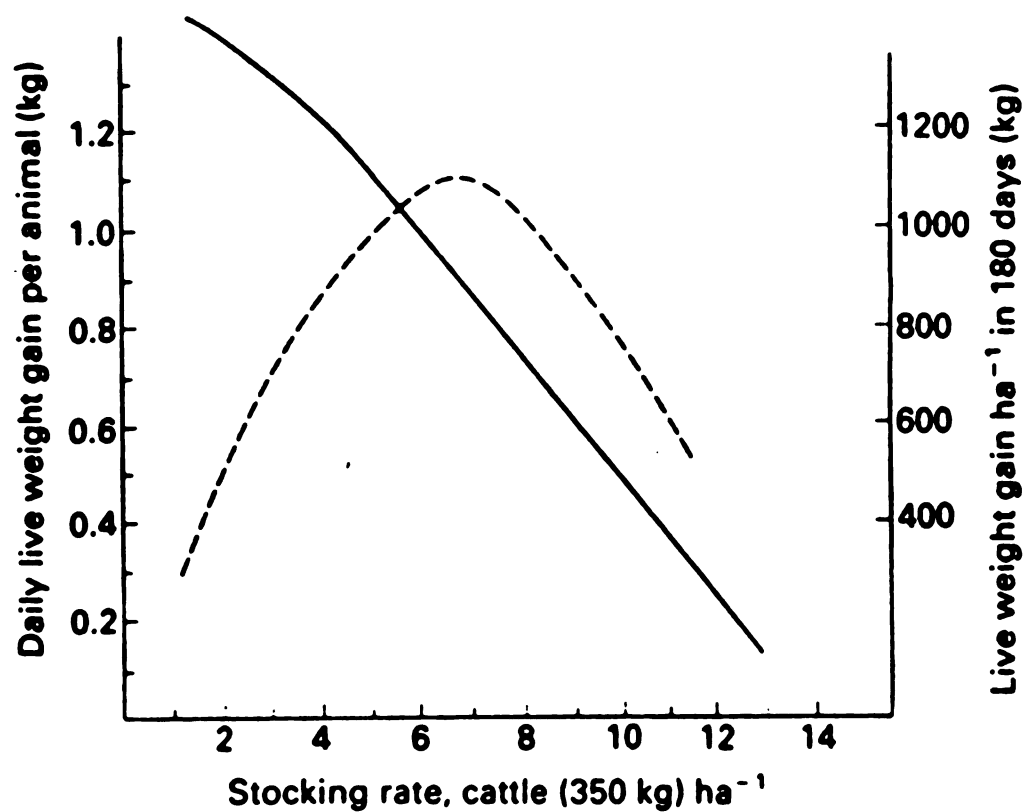


Figure 2.2. Relationship between stocking rate and live-weight gain per animal and per ha (based on average conditions with 200 kg N ha⁻¹): daily live-weight gain per animal —, live-weight gain per hectare - - - - . (adapted from Holmes, 1989).

Table 2.2. Effect of stocking rate on performance of animals grazing alfalfa

Location	Year	Livestock species (wt, kg)	Grazing method	Stocking rate steers/ha	Grazing season	ADG, kg	Gain/ha, kg	Reference
Taupo region, New Zealand	1975 to 1976 1 yr study	steers	15 paddock rotation	3.7	179	.97	642	Joyce and Brunswick, 1977
				5.0	179	.81	725	
				7.7	179	.67	923	
			15 paddock rotation, alfalfa with prairie grass	3.7	179	1.01	669	
				5.0	179	.85	761	
				7.7	179	.64	882	
Taupo region	1976 to 1977 1 yr study	steers (204)	15 paddock rotation	5.0	130	1.23	801	Marsh and Brunswick, 1978
				6.7	130	1.02	886	
				10.0	130	.65	839	
			15 paddock rotation, alfalfa with prairie grass	5.0	130	1.13	737	
				6.7	130	.92	797	
				10.0	130	.64	835	

suggest that to set the SR regardless of the yield potential of a pasture is unwise since this can cause over- or understocking of specific treatments. Studies by Marten and Jordan (1972) did not show a difference in animal production/ha between put-and-take stocking and set stocking, but the researchers had previous yield information to predict pasture yield to select the appropriate SR.

Animal performance

Dougherty et al. (1990) reported beef cattle gains of up to 1.36 kg/d are possible on a rotationally-stocked alfalfa pasture. Studies from Australia and the United States (Table 2.3) do not support the superior gains suggested by Dougherty et al. (1990), but gains from .9 kg to 1.2 kg/d are documented on alfalfa (Joyce and Brunswick, 1977; Marsh and Brunswick, 1978; Reardon, 1980) in Australia. Forage utilization is a major factor in determining gain potential (Joyce and Brunswick, 1977; Marsh and Brunswick, 1978). Joyce and Brunswick (1977) determined that a 70% forage utilization in the spring would produce 1 kg/d live-weight gain, but to achieve the same performance in the summer, only 27% utilization is permitted. Similarly, Marsh and Brunswick (1978) reported that a spring forage utilization of 86% achieved 1 kg/d beef gains but the same utilization in the summer produced only .47 kg/d gains. This difference in optimum utilization is due to the decrease in the nutrient quality through the grazing season and not total intake of the animal (Marsh and Brunswick, 1978; and Reardon, 1980). Reardon (1980) determined that cattle given a daily forage allowance of 4 kg/d per 100 kg BW did not have increased live-weight gains compared to cattle receiving 3 kg/d per 100 kg BW. For rapid growth rates of cattle, the OP should allow only the leaves and

Table 2.3. Summary of alfalfa grazing studies in the United States

Location	Year	Livestock species (wt, kg)	Grazing method	Stocking rate animal/ha	Grazing season, d	ADG, kg	Gain/ha, kg	Reference
Alabama	1982, 1983, 1984	steer (225)	3 paddock rotation	3.3	163	.98	533	Schmidt et al., 1985
California	1952 to 1953 (1 yr study)	steer (247)	4 paddock rotation	3.4	168	.82	467	Itner et al., 1954
		steer (245)	strip grazed	4.5	168	.86	650	
California	1 yr study	steer (217)	4 paddock rotation	4.3	155	.88	588	Meyer et al., 1956
		steer (218)	strip grazed	5.1	155	.77	604	
	1 yr study	steer (249)	8 paddock rotation	7.2	132	.81	772	
		steer (256)	strip grazed	8.5	132	.74	828	
Georgia	1983, 1984	steer (266)	3 paddock rotation	3.9	103	.83	317	Hoveland et al., 1988
Kentucky	1990, 1991	steers (300)	8 paddock rotation	6.2	133	.80	668	Burris et al., 1993
Minnesota	1983, 1984	heifers (268)	3 paddock rotation	6.4	92	.67	392	Marten et al., 1987
Minnesota	1985, 1986, 1987	lambs (29)	3 paddock rotation	49	75	.22	784	Marten et al., 1990

the tops of stems to be grazed (Christian et al., 1970, McKinney et al., 1970). A major factor affecting animal performance is intake of digestible DM (McGraw and Marten, 1986). A decrease in animal gains follows a decrease in stem digestibility (Fletcher, 1976).

Nutrient quality

The nutritive quality of forage is high at immature stages of growth and then declines with increasing maturity (McGraw and Marten, 1986). Leaves contain high concentrations of IVDMD and CP and only exhibit a slow loss of quality as the plant matures (Christian et al., 1970; Fletcher, 1976; McGraw and Marten, 1986). In contrast, stems lose significant digestibility as the plant matures. Marten et al. (1987) determined that alfalfa had lower IVDMD than cicer milkvetch and birdsfoot trefoil, but greater than sainfoin. Alfalfa's CP content was similar to birdsfoot trefoil and cicer milkvetch and greater than sainfoin. The authors suggested that cicer milkvetch and birdsfoot trefoil may be good alternatives to alfalfa but cicer milkvetch is very unpalatable (Marten et al., 1987). McKinney (1974) suggests that if RP is too long, the alfalfa's leaf-stem ratio decreases which decreases the quality per unit yield of alfalfa.

Alfalfa - grass pastures

Alfalfa-grass mixtures produce greater individual ADG, more weight gain per land area and have greater carrying capacity than grass alone (Van Keuren and Matches, 1988), although one problem with an alfalfa-pasture is finding a cool-season grass that has compatible growth characteristics. Most cool-season grasses do not persist under

alfalfa harvest schedules, are too competitive with alfalfa, or not palatable to the grazing animal (Jung et al., 1982). Orchardgrass, smooth brome grass, ryegrass and tall fescue are the most common cool-season grasses seeded with alfalfa (Rather and Harrison, 1944; Van Keuren and Heinemann, 1958; Hubbard and Nelson, 1964; Cooke et al., 1965; and Jung et al., 1982). Smooth brome grass was the preferred addition to alfalfa when compared to intermediate wheatgrass under rotational stocking, but an alfalfa-intermediate wheatgrass mixture was preferred when the pasture was continuously stocked (Cooke et al., 1965). In a study by Jung et al. (1982), alfalfa-ryegrass produced more protein/ha than alfalfa-orchardgrass pastures.

Over a 3-yr period, alfalfa-orchardgrass and alfalfa-tall fescue mixtures produced 52% more weight gain/ha than the grasses alone (Van Keuren and Heinemann, 1958). When the two mixtures were compared, the alfalfa-orchardgrass pasture was found to be more productive in terms of animal performance. A summary of alfalfa-grass grazing studies is presented in Table 2.4.

BLOAT

Bloat as defined by Howarth (1975), "results from a failure in eructation of gases produced by microbial fermentation in the rumen". Bloat occurs in two forms, frothy and free-gas bloat. Frothy bloat refers to gas trapped in tiny bubbles which cannot be eructated. Free-gas bloat denotes the separation of the gas, which cannot be eructed, from the rumen (Howarth, 1975). Howarth (1975) further classifies bloat as legume pasture bloat, legume hay bloat, high concentrate bloat and free-gas bloat.

Table 2.4. Summary of alfalfa-grass grazing studies in North America

Location	Year	Livestock species (wt, kg)	Grazing method	Stocking rate, animal/ha	Grazing season,d	ADG, kg/d	Gain/ha, kg	Reference
Alberta	1975, 1976, 1977, 1978	steers	23% alfalfa, 52% bromegrass, 25% creeping red fescue continuous	1.97	93	.91	167	Walton et al., 1981
			4 paddock rotation	2.42	98	1.09	258	
Iowa	1982, 1983, 1984, 1985, 1986	steers	alfalfa, smooth bromegrass, orchardgrass 2 paddock rotation	440 steer d/ha ¹		.79	315	Barnhart et al., 1987
Iowa	1986	steers (271)	alfalfa, smooth bromegrass, orchardgrass 6 paddock rotation	432 steer d/ha ¹		.80	345	Wedin et al., 1987
Michigan	1940, 1941	ewes / lambs	alfalfa-smooth bromegrass continuous	14.4/11.8 ²	95/79 ²		57/197 ² (254) ³	Harrison et al., 1941
			4 paddock rotation	14.3/12.1 ²	95/79 ²		41/216 ² (257) ³	

¹Stocking rate not available

²Ewe values listed first followed by values for lambs

³Total gain per hectare

Legumes such as alfalfa, red clover, white clover, ladino clover, sweet clover and alsike clover have been shown to cause bloat (Howarth, 1975). Subterranean clover has moderate bloat potential (Howarth, 1975) and birdsfoot trefoil, crownvetch, sainfoin (Howarth, 1975, Marten et al., 1987) and cicer milkvetch (Marten et al., 1987) are non-bloat provocative legumes. Legumes are primarily associated with bloat, but bloat can occur in cattle grazing lush, rapidly-growing grass pastures as well (Reid and Johns, 1957). Legume pasture bloat will be discussed further in this section. For a complete review of bloat, see reviews by Howarth (1975), Clark and Reid (1974), or "Bloat " a symposium held at the University of New England, Armidale, N.S.W. Australia (Leng and McWilliam, 1973).

Grazing animals develop bloat through the interaction between the plant, animal, rumen microbes and the environment (McClymont, 1973). Soluble leaf proteins are responsible for foam stabilization and bloat in pasture legumes (Jones and Lyttleton, 1972). These authors reported a positive correlation between fraction I protein and the severity and incidence of bloat. Fraction I protein is the major protein in leaf tissue (Jones and Lyttleton, 1972), and accounts for 3.4 to 6.8% of the leaf tissue (Miltmore et al., 1970). Miltmore and co-workers (1970) defined the threshold of fraction I protein which produces bloat to be 1.8%. Plants below this threshold are non-bloat provocative. Non-bloat provocative legumes, such as those mentioned previously, contain less than 1.5% fraction I protein. Saponins, glycosides and pectins, are interrelated with the bloat-producing capabilities of fraction I proteins, and bloat-provocative legumes contain larger amounts of saponins than non-bloat provocative legumes (Cheeke, 1971).

The identification of genetic factors that may predispose animals to bloat susceptibility are difficult to determine (Mendel and Boda, 1961). Factors which may be important in reducing bloat include: salivary flow, salivary composition, ruminal fluid transfer, rumen motility, gas production, microbial population, rate of eating, rumen pH, and rate of nitrogen metabolism (Clarke and Reid, 1974). Clark and Reid (1970) have determined that animals with low susceptibility eat 1.5 times faster and have greater salivary flow than animals with high susceptibility. Clark and Reid (1970) concluded that large microbial populations are associated with greater incidence of bloat in highly-susceptible animals. In addition, McIntosh and Cockrem (1977) showed that the absence of specific salivary proteins may contribute to decreased susceptibility of bloat.

There are no reports or studies on the adaptability of cattle to bloat-provocative legumes. Howarth (1975) stated that bloat can occur any time on dry forage, warm days and at full bloom; therefore, the occurrence of bloat is difficult to predict. Prevention of bloat includes the use of non-bloat provocative legumes, use of a grass-legume pasture mixtures, and filling cattle with dry feed before grazing bloat-provocative legumes (Howarth, 1975). Even though an alfalfa-grass pasture was used in a study by Van Keuren and Heinemann (1958), six animals died of bloat during the three-year evaluation.

Other approaches deal with spraying bloating pastures with oils or antifoaming agents (Van Keuren and Matches, 1988) and feeding poloxalene to cattle. Poloxalene is a synthetic, water-soluble detergent-type compound (Heath et al., 1985) which has been shown to be 100% effective in reducing bloat (Bartley et al., 1983, Katz et al., 1986). Ionophores such as monensin and lasalocid are not as effective in reducing bloat

as poloxalene, but have been demonstrated to reduce bloat 41 to 73% and 12-30%, respectively (Bartely et al., 1983, Katz et al., 1986).

INTAKE AND ITS PREDICTION IN GRAZING ANIMALS

Animal performance in a grazing environment can be enhanced through increased intake or efficiency of digestion and metabolism. The understanding of what controls feed intake in ruminants is limited (Grovum, 1988). Feed intake is controlled through physiological, physical, chemical, and environmental factors (Arnold, 1970; Campling, 1970). Physiological and chemical factors generally are more important in controlling intake of high concentrate diets (Grovum, 1988). Physical characteristics of the diet may limit the intake of roughages. Environmental factors associated with the grazing environment such as temperature, shade, forage availability and height of the pasture also influence intake.

Physiological and chemical factors affecting intake regulation

The control of energy balance and feed intake is associated with functions of the central nervous system. In particular, the hypothalamus is the region of the brain which controls feeding (Baile and Mayer, 1970). Removal of the ventromedial area of the hypothalamus produces obesity through hyperphagia (Hetherington and Ranson, 1942; Mayer et al., 1955). In contrast, ablation of the lateral areas of the hypothalamus causes aphagia and adipsia (lack of eating and thirst, Baile and Mayer, 1968). Receptors for temperature, glucose and osmolarity have been found to be important in the control of feeding in monogastrics (Baile and Mayer, 1970). Baile and Mayer (1968) reported an

increase in feed intake of satiated goats when the hypothalamus was cooled but concluded, this mechanism would not be a primary controller of feed intake. Neuronal cells which only respond to changes in glucose concentrations have been found in the ventromedial hypothalamus of monogastrics (Anand et al., 1964). It is unlikely that glucose is a signal for intake in ruminants because glucose concentrations are low and change little (Baile and Mayer, 1970). Therefore, volatile fatty acid (VFA) concentrations, an important source of energy in ruminants, may have a role.

Baile and Mayer (1970) list three characteristics which may suggest that volatile fatty acids contribute to the control of feed intake: 1) VFA are produced in the reticulo-rumen and are absorbed prior to entering the abomasum, 2) rates of VFA production and absorption are closely correlated to feeding behavior, and 3) the intraruminal injection of VFA decrease intake of cattle, sheep and goats. Intraruminal infusion of acetate and propionate, but not butyrate, decreased feed intake (Baile and Mayer, 1969). Acetate decreased intake more when infused into the dorsal rumen as compared with the jugular vein. This suggests receptors for acetate are present in the dorsal rumen. Baile and Mayer (1970) suggest a different mechanism with regards to propionate. Feed intake is decreased with infusion of propionate into the ruminal vein, but not the carotid artery, which implies, propionate receptors are present in the portal system.

Physical factors of the animal affecting feed intake

Physical factors are thought to play a role in determining the intake of roughages (Grover, 1988). Factors reported to influence intake of forages are palatability, rumen fill and capacity, rate of digesta disappearance, and distension of the abomasum and

intestine (Arnold, 1970, Campling, 1970). Palatability is the first determinant of what a moderately hungry animal will eat. Palatability includes smell, taste, flavor, and texture of the forage (Grovm, 1988). As the variety of feed decreases due to high grazing pressure or drought, the animals are less able to satisfy their needs from preferred species; and species, which were rejected previously, are consumed (McClymont, 1967).

Campling and Balch (1961) demonstrated that rumen fill affects feed intake. Addition of esophageal masticates into a fistulated cow decreased intake and removal of ingested feed increased intake to a point when fatigue from mastication limited intake. In addition, the size and weight of the empty reticulo-rumen is directly associated with voluntary intake of cattle and sheep (Balch and Campling, 1962). The growing fetus and abdominal fat will also influence rumen capacity and therefore intake (Campling, 1970).

The rate of disappearance of digesta from the reticulo-rumen is also associated with voluntary intake. Factors which influence the rate of digesta flow include: 1) the efficiency of chewing during eating and rumination, 2) the rate of digestion within the rumen, and 3) the propulsion activity of the gut and transfer of roughage residues (Campling, 1970). As the rate of digesta disappearance increases, rumen fill decrease and allows greater intake.

Burlison and Hodgson (1985) determined that bite size, depth of biting, and volume of each bite by sheep were positively correlated to sward height. Penning et al., (1984) showed that swards less than 3 cm in height decreased the intake of ewes by 50% as compared to ewes grazing pastures 6, 9, or 12 cm in height.

Environmental factors affecting feed intake

Forage allowance has a curvilinear relationship with intake of calves, and beef or dairy cows (Minson, 1990). As the allowance of forage becomes less than twice the maximum intake there is a decrease in the amount of forage eaten (Ernst et al., 1980 as referenced by Minson, 1990). Maximum intake of immature temperate forages was achieved when cows left a 8 to 10 cm stubble height. When the cows were forced to graze down to 5 cm, intake was reduced 10 to 15% (Ernst et al., 1980 as referenced by Minson, 1990). Beef calves provided a daily forage allowance of 30 g DM/kg BW had an 18% lower intake than calves provided an allowance of 90 g DM/kg BW (Jamieson and Hodgson, 1979 as referenced by Minson, 1990). The lower forage allowance resulted in a lower residual stubble height and decreased OM digestibility. The effects of forage allowance on intake are similar for steers between 5 and 18 months of age (Minson, 1990). Forage allowance is partly determined by SR. Zoby and Holmes (1983) reported that animals on high-stocked spring pastures consumed 32% less forage than animals on low-stocked pastures. The same trend continued through the summer, but the magnitude of the difference narrowed and was not statistically significant in the summer.

Ingestive behavior

Forage intake is the result of grazing time, the rate of biting, and size of each bite (Minson, 1990). The final outcome of prolonged grazing or any physical activity is fatigue. When pasture density decreases, bite size also decreases. To overcome the decrease in bite size, the rate of biting and the duration of biting increases. The

maximum duration of grazing is about 13 h/d even on sparse pastures (McClymont, 1967). Consequently, the possibility exists that an animal may reach the point of fatigue before the consumption of adequate energy to maintain live-weight gain near 1 kg/d.

Stocking rate was determined by Zoby and Holmes (1983) to influence grazing behavior. Especially in the spring, animals in the high stocked pastures had increased grazing times, bite frequency and total bites/d when compared to the low stocked counterparts. As mentioned above, herbage allowance was decreased in the high stocked pastures. This explains why the animals on the high stocked pastures behavior changed, but still was not sufficient to compensate for the decrease in forage availability.

Intake prediction

There are several questions that Leaver (1982) proposed that still remain unanswered about intake and efficiency of grazing. How much are grazing animals consuming? Do differences in intake explain the differences in animal performance on different forages? Does intake reflect ease of forage prehension and mastication? Can these physical properties of the plant be changed?

The absence of techniques to accurately determine the intake of grazing animals has slowed the progress of forage utilization. Agronomists have concentrated on factors that can be easily measured such as yield per hectare, longevity, and winter survival, but little progress has been made in improving intake of pastures (Leaver, 1982).

Direct measurements of the intake of grazing animals are very difficult. Therefore, indirect methods are utilized. These include pasture based methods, use of

internal and external markers, changes in animal weight, calculations based on animal performance, and ingestive behavior (Leaver, 1982).

Pasture based methods

Changes in forage mass utilizes the same principles as for pen-feeding where intake is measured by difference:

$$\text{Forage intake} = \text{forage offered} - \text{forage refused (Meijs et al., 1982)}.$$

Forage mass is determined at the beginning and the end of a grazing event. The difference is the apparent quantity of forage consumed by the grazing animal. Non-destructive methods to measure forage mass include, height and(or) density measurements, and non-vegetative attributes such as capacitance (Meijs et al., 1982).

The key to achieve reliable intake estimates is to reduce possible systematic error in measuring the difference in forage mass. When using non-destructive techniques, systematic and random errors may occur when applying the regression equations derived from the sampling method (e.g., canopy height) and herbage mass (Meijs et al., 1982).

Use of internal and external markers

Internal markers are natural constituents of the plant that are not digested or absorbed (Pond et al., 1987). Internal markers include: the use of nitrogen in a fecal nitrogen index; and the concentration of lignin, chromogen, acid insoluble ash, or indigestible fiber as it passes through the animal. The difference in concentration of the

internal marker between the consumed forage and the feces allows calculation of the digestibility of the forage. The amount of indigestible residue is divided by the indigestibility value to obtain the intake of the animal. Intake or digestibility of animals consuming the pasture can then be calculated from regression equations (Cochran et al., 1987) based on pen fed animals.

Like internal markers, external markers should not be digested or absorbed. External markers can be fed, drenched or given as a bolus. Examples of external markers include: chromic oxide, ferric oxide, silver sulfide, polyethylene glycol, preparations of chromium, cobalt, hafnium, and rare earth metals (Pond et al., 1987). External markers are used to determine fecal output, and with DM indigestibility, can determine DMI using the following formula (Pond et al., 1987):

$$\text{Intake (g/d)} = \text{DM output of feces (g/d)} \div [1 - (\% \text{ DM digestibility} \div 100)].$$

Changes in animal weight

Intake can be calculated from animal performance. Based on the energy requirements for maintenance, the gain of grazing animals, and energy concentration of the forage (Baker, 1982), intake can be calculated by:

$$\text{Forage intake} = \text{Energy for maintenance and gain} \div \text{Forage energy concentration} .$$

Changes in animal weight over short-term periods have been investigated as a method to determine intake. At the Oklahoma Agricultural Experiment Station, steers were fitted

with 'bovine boots', load cells under each hoof to measure weight changes (Horn and Miller, 1979).

Calculations based on ingestive behavior

The use of ingestive behavior to calculate intake requires determination of grazing time, rate of biting during grazing and forage intake per bite, thus:

$$\text{Intake} = \text{grazing time} \times \text{rate of biting} \times \text{forage intake per bite (Hodgson, 1982)}.$$

As discussed by Meijjs et al. (1982), the best procedure to estimate intake is one which produces sufficiently precise estimates with the least cost.

PHOTOSENSITIVITY

Photosensitivity is the sensitization of the superficial layers of lightly pigmented skin to sunlight (Clare, 1955; Johnson, 1986; Scott, 1988) and is an abnormal reaction requiring the presence of a photodynamic agent (Clare, 1952). Photosensitivity differs from sunburn in that sunburn is a normal reaction of unprotected skin and occurs from the overexposure to ultraviolet rays from the sun (Clare, 1952). Photosensitivity develops from photodynamic compounds in the skin, which when excited by sunlight, damages the cells in the vicinity (Scott, 1988). The effective light in photosensitivity is determined by the absorption spectrum of the photodynamic agent and extends into the visible light region, wavelengths greater than 320 nm (Clare, 1952). Photosensitivity has

been categorized into four groups: primary, hepatogenous, aberrant pigment metabolism, and photosensitization of unknown origin (Clare, 1955; Johnson, 1986; Scott, 1988).

Primary photosensitivity

Primary photosensitization is due to ingestion of a photodynamic compound which enters the blood unchanged and causes a reaction in the skin (Clare, 1955, Scott, 1988). Plants containing a phototoxin and chemicals which cause primary photosensitivity when ingested are presented in Table 2.5. Primary photosensitivity is the only true form of photosensitivity. In animals diagnosed with hepatogenous photosensitivity or aberrant pigment metabolism, photosensitivity is a secondary condition developed from liver damage or aberrant heme synthesis (Clare, 1952).

Hepatogenous photosensitivity

Hepatogenous photosensitivity is the most common form of photosensitivity among ruminants (Scott, 1988). Hepatogenous photosensitivity is a secondary condition due to liver damage which decreases the excretion of phylloerythrin in the bile (Clare, 1955; Scott, 1988). Phylloerythrin is derived from the anaerobic breakdown of chlorophyll by microorganisms in the rumen and lower gastrointestinal tract. Hepatogenous photosensitivity can result from liver damage associated with ingestion of plants, molds and chemicals (Table 2.6) and can be induced experimentally via surgical ligation of the bile duct to impair normal bile flow (Glenn et al. 1964).

Ingestion of a hepatotoxin is the primary cause of hepatogenous photosensitivity (Cornelius et al., 1965), but a rare genetic defect in Southdown and Corriedale sheep can

Table 2.5. Cause of primary photosensitivity

Source	
Plants	
Bishop's weed <i>Ammi majus</i>	Rain Lily <i>Cooperia pedunculata</i>
Buckwheat <i>Fagopyrum esculentum</i>	St. John's Wort <i>Hypericum perforatum</i>
Burr trefoil <i>Medicago denticulata</i>	Spring parsley <i>Cymopterus watsonii</i>
Dutchmans breeches <i>Thamnosma texana</i>	Wild carrot <i>Daucus carota</i>
Perennial ryegrass <i>Lolium perenne</i>	
Chemicals	
Acridine dyes	Rose bengal
Acriflavines	Sulfonamides
Eosin	Tetracyclines
Methylene blue	Thiazides
Phenothiazine	

Adapted from Scott, 1988

Table 2.6. Causes of hepatogenous photosensitivity

Source	
Plants	
Alecrim	Lechuguilla
<i>Holocalyx glaziovii</i>	<i>Agave lecheguilla</i>
Bog asphodel	Millet, panic grass
<i>Nartheceum ossifragum</i>	<i>Panicum</i> spp.
Burning bush, fireweed	Ngaio tree
<i>Kochia scoparia</i>	<i>Myoporum</i> spp.
Caltrops	Ragworts
<i>Tribulus terrestris</i>	<i>Senecio</i> spp.
Coal-oil brush, spineless horsebush	Rape, kale
<i>Tetradymia</i> spp.	<i>Brassica</i> spp.
Crotalaria, rattleweed	Sacahuiste
<i>Crotalaria</i> spp.	<i>Nolina texana</i>
Ganksweed	Salvation Jane
<i>Laispermum bipinnatum</i>	<i>Echium lycopsis</i>
Heliotrope	Tarweed, fiddle-neck
<i>Heliotropium europaeum</i>	<i>Amsinckia</i> spp.
Kleingrass	Vervain
<i>Panicum coloratum</i>	<i>Lippa rehmanni</i>
Lantana	
<i>Lantana camara</i>	
Mycotoxicoeses	
<i>Anacystis (Microcystis)</i> spp. (blue-green algae in water)	<i>Periconia</i> spp. (on Bermudagrass)
<i>Aspergillus</i> spp. (on stored feeds)	<i>Phomopsis leptostromiformis</i> (on lupines)
<i>Fusarium</i> spp. (on moldy corn)	<i>Pithomyces chartarum</i> (on pasture, especially rye)
Infection	
Leptospirosis	Parasitic liver cyst (flukes, hydatids)
Liver abscesses	Rift Valley fever
Neoplasia	
Hepatic carcinoma	Lymphosarcoma
Chemical	
Carbon tetrachloride	Phenanthridium
Excess copper	Excess phosphorus

Adapted from Scott, 1988

produce hepatogenous photosensitivity as well. An autosomal recessive trait in Southdown sheep produces congenital hyperbilirubinemia and photosensitivity (Hancock, 1950). The defect impairs the ability of the liver to remove plasma bilirubin (Gronwall, 1970; McGavin et al. 1972) and decreases the excretion of bilirubin and phylloerythrin in the bile (Cornelius et al., 1986; McGavin et al., 1972). The ovine kidney is capable of excreting phylloerythrin but in the case of congenital hyperbilirubinemia, renal damage occurs which inhibits phylloerythrin excretion (McGavin et al., 1972). The excess circulating phylloerythrin causes green discolorization of the teeth, periosteum, fascia, serosa, and mucous membranes. The elevated plasma bilirubin causes yellow discoloration of the inner lining of the aorta and endocardium (McGavin et al., 1972). Livers of affected sheep appear normal unlike the condition observed in the Corriedale sheep where a dark brown to black discoloration of the liver occurs (Cornelius et al., 1965).

The condition in Corriedale sheep, inherited by an autosomal recessive gene, impairs the excretion of bilirubin and phylloerythrin (Gronwall, 1970; Blood et al., 1983). Affected lambs appear normal until grazing or consumption of a chlorophyll-containing diet (Clare, 1955). Photosensitivity in both breeds is lethal if the chlorophyll diet or sunlight is not removed (Clare, 1955; Cornelius et al., 1965). Mutant Southdowns if surviving photosensitivity will die of renal failure (McGavin et al., 1972).

Aberrant pigment metabolism

The third form of photosensitivity is aberrant pigment metabolism. This condition is a result of the accumulation of porphyrins in the blood and body tissues due to

aberrant porphyrin synthesis (Scott, 1988). Bovine congenital protoporphyria (BCP) and bovine erythropoietic porphyria (EPP, pink tooth) are both examples of photosensitivity due to aberrant pigment metabolism. Bovine erythropoietic protoporphyria, originally thought to affect Limousin cattle only (Fraser, 1986), has been shown to affect the Blonde d'Aquitane breed as well (Schelecher et al., 1991). Bovine erythropoietic protoporphyria is characterized by the accumulation of protoporphyrins in the blood due to the decreased activity of ferrochelatase (Schelecher et al., 1991, Ruth et al., 1977, Sassa et al., 1981; Figure 2.3), the enzyme which adds the ferrous ion to protoporphyrin IX to form heme (Rawn, 1989.). This rare condition is inherited as a simple autosomal recessive trait unlike the similar condition in humans which is inherited as an autosomal dominant trait (Ruth et al., 1977). Homozygous animals have 10% and heterozygous animals have 50% of the normal ferrochelatase activity, respectively (Sassa et al., 1981).

Bovine congenital porphyria, as EPP, is inherited as an autosomal recessive trait (Wass and Hoyt, 1965) and affects both sexes (Ellis et al. 1958). The condition has been diagnosed in Hereford (Railsback, 1938), Holstein-Friesian (Ellis et al., 1958), Jamaica Red and Black (Nestel, 1958), and Shorthorn, (Fourie, 1936; Amoroso et al., 1957), breeds. Uroporphyrin I and coproporphyrin I, are the photodynamic agents (Clare, 1952), and accumulate in the blood and body (Rhode and Cornelius, 1958) due to a depressed function of uroporphyrinogen III cosynthase (Levin, 1968; Romeo and Levin, 1969).

Uroporphyrin I and coproporphyrin I are not intermediates in the biosynthesis of protoporphyrin IX. Uroporphyrin I and coproporphyrin I are products of the oxidation

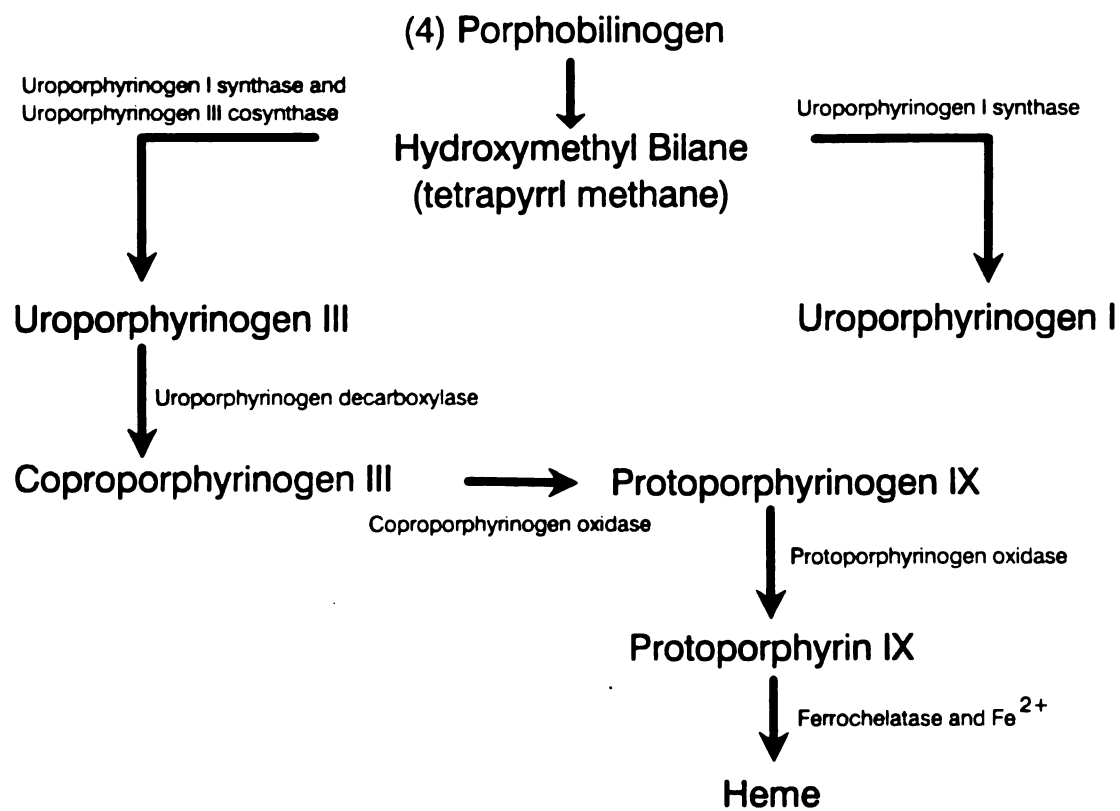


Figure 2.3. Biosynthesis of heme from porphobilinogen (Rawn, 1989).

of uroporphyrinogen I and its decarboxylated derivative coproporphyrinogen I (Romeo and Levin, 1969). Uroporphyrinogen I is formed from the monopyrrole compound porphobilinogen by uroporphyrinogen I synthase, but in the presence of uroporphyrinogen III cosynthase, uroporphyrinogen III is produced (Romeo and Levin, 1969). Uroporphyrinogen III is converted to protoporphyrin IX and then to heme by the enzyme ferrochelatase (Romeo and Levin, 1969).

The accumulation of uroporphyrin I and coproporphyrin I produces a discolorization of the teeth and bones, which vary from pinkish-red to mahogany, hence the name "pink-tooth"; and affected animals excrete reddish-brown urine (Ellis et al. 1958). Animals with EPP or BCP will exhibit photosensitivity if not protected from the sun and will be unthrifty (Ellis et al., 1958).

Photosensitization of unknown origin

When photosensitization occurs and the causative agent cannot be determined as primary, hepatogenous or aberrant pigment metabolism, the agent is classified as unknown (Clare, 1955; Johnson, 1986, Scott, 1988). Reports of photosensitivity often occur when common pasture plants are grazed. These include alfalfa (*Medicago sativa*), clovers (*Trifolium spp.*), vetches (*Vicia spp.*), and oats (*Avena sativa*; Clare, 1955; Johnson, 1986; Scott, 1988). Frequently, cases occur when cattle are grazing lush pastures (Scott, 1988) or when fed water-damaged alfalfa hay (Putnam et al., 1986).

Clinical signs and treatment

Clinically, photosensitive animals show photophobia and may rub the ear, eyelids and muzzle. Lesions are usually confined to lightly pigmented skin exposed to sunlight. In severe cases, black pigmented skin may be affected. The skin becomes inflamed and swollen. If not prevented at this stage, the affected area develops lesions. The lesions are characterized by serum exudation, scab formation and skin necrosis. The ears, face, back, base of tail, vulva, udder and coronets are the most common sites of lesions. In the case of aberrant pigment metabolism, photodermatitis is the predominant clinical sign. In addition to photodermatitis, cattle with EPP exhibit teeth varying in color from light pink to mahogany, with reddish-brown urine (Fraser, 1986). Treatment of photosensitivity involves:

1. Remove animals from sunlight (Fraser, 1986).
2. Prevent reexposure to the photodynamic agent (i.e. decrease the amount of high chlorophyll feeds; change feed and pasture, remove moldy hay, etc.; Fraser, 1986).
3. Treat symptomatically with antibiotics and corticosteroids. (Manning, 1984)
4. Secondary skin infections should be treated and fly strike prevented (Fraser, 1986).
5. Animals with congenital photosensitivity and carriers should not be used for breeding (Scott, 1988).

Skin lesions will heal even after severe necrosis. Productivity of affected animals is influenced by the site and severity of the lesions (Fraser, 1986).

CHAPTER 3: EVALUATION OF GRAZING METHODS AND STOCKING RATES OF ALFALFA PASTURES ON ANIMAL AND PLANT PRODUCTIVITY

SUMMARY

A four year study was conducted to determine the effects of grazing method and stocking rate on animal and plant productivity of alfalfa pastures, to compare the forage presentation of a pasture system to a mechanical harvested system, and to ascertain the effect of grazing system on subsequent performance of steers fed a high concentrate diet. Ten pasture plots (.76 ha) were seeded in 1988 with alfalfa. Plots were divided into 2 blocks of 5 pastures each. Two grazing methods, 4 or 13 paddocks, at two stocking rates (SR), 5.5 and 9.5 steers/ha, and a mechanically harvested systems were evaluated. Pastures were managed to allow a 36-d rest period with an average grazing season of 110 days. Following the grazing season, steers were placed in a feedlot and fed a corn silage-high moisture corn diet for an average of 211 d. In each year, steers from high SR systems had lower pasture ADG ($P < .02$) than steers from low SR systems. In 1989, low SR systems produced 104% greater ($P = .07$) live-weight gain/ha than high SR systems. Thirteen paddock high SR systems in 1990 tended ($P < .10$) to produce more live-weight gain/ha than 4-paddock high SR systems, but similar to the 4- and 13-paddock low SR systems. In 1991 and 1992, after a 25% decrease in the high SR, high SR systems produced 24% greater live-weight gain/ha than low SR systems. Forage

presentation was similar for the mechanical harvest and the grazing systems in 1989 and 1990, but in 1991, the mechanical harvested system had 42% less ($P < .05$) forage presentation than the grazing systems. Low SR steers entered the feedlot heavier ($P < .01$), and had greater ($P < .06$) live-weights after 48 to 64 d. Weight gain and feed conversion efficiency were similar after 211 d in the feedlot. Increasing paddock number did not improve live-weight gain/ha or forage presentation. Optimum SR was between 5.3 and 7.9 steers/ha.

INTRODUCTION

Alfalfa is the most productive forage produced in Michigan with 485,000 ha grown annually (Michigan Agricultural Statistics Service, 1992). Alfalfa is regarded as a superior forage crop in terms of quality, palatability, and yield potential (Van Keuren and Marten, 1972). In recent years, alfalfa has been considered as a pasture crop. Production of 392 kg/ha (Marten et al., 1987) and 783 kg/ha (Marten et al., 1990) have been reported for grazing heifers and lambs, respectively. More recently, studies in Kentucky has shown gains from 535 to 820 kg of beef produced/ha with rotational stocking of alfalfa (Burris et al., 1993).

Alfalfa stand persistence is not maintained with continuous stocking (Cooke et al., 1965; Brownlee, 1973; Van Keuren and Matches, 1988); therefore, a rotational stocking system must be implemented. McKinney (1974) determined that alfalfa stands were maintained and more profitable with 2 or 4-paddocks than 6 or 12-paddocks or continuous stocking. With an alfalfa based pasture, Smith (1970) demonstrated the decrease of the alfalfa component of the pastures with continuous stocking as compared

with a 3 or 4-paddock system, and in Utah, an alfalfa pasture persisted 9 yr with rotational stocking (Bateman and Keller, 1956 as referenced by Van Keuren and Matches, 1988).

There has been no consensus on the OP needed to maintain alfalfa in pastures. Iversen (1967) and Jason (1975a) recommend a 2 to 4-d OP, whereas Leach (1979) recommends 8 to 16 d. The RP to maintain alfalfa in the pasture has been determined to be between 35 to 54 d (Bateman and Keller, 1956 as referenced by Van Keuren and Matches, 1988; Iversen, 1967; O'Connor, 1970).

The goal of this study was to develop methods and management practices needed to successfully manage a productive alfalfa pasture system. Therefore the objectives of this study were to determine the effect of two grazing methods and two stocking rates on animal and plant productivity of alfalfa pastures, to compare the forage productivity of a pasture system to a mechanically harvested system, and to ascertain the effect of the grazing systems on subsequent cattle performance fed high concentrate diets. To accomplish these objectives, a direct-seeded alfalfa field was subdivided into ten pasture plots, and two grazing methods with two SR were evaluated.

MATERIALS AND METHODS

This study was conducted under the approval of the Michigan State University All-University Committee on Animal Use and Care (AUF # 8/88-321-01). The study was initiated in the summer 1988 and continued through the spring of 1993. In August 1988, 8 ha were direct-seeded with alfalfa variety WL 225 (17 kg/ha). Prior to seeding, the previous wheat field stubble was plowed, treated with Eptam (2.4 L/ha) and fertilized

with 290 kg/ha of potash (0-0-60). The soil consists of Capac loam, Sisson fine sandy loam, and Riddles-Hillsdale sandy loams. These soils are within the Marlette-Capac-Owosso association, which are nearly level to rolling, well drained to somewhat poorly drained loam soils (USDA, 1979).

The 8 ha were seeded in 1988 and divided into 10 pasture plots (.76 ha/plot, Figure 3.1). Four hectares, contiguous to the 8 ha was seeded to alfalfa variety Big Ten in 1987 and subdivided into two pasture plots (.76 ha/plot) and a supplemental pasture. Each pasture plot was surrounded by a double strand of 20 gauge electrified wire (Kiwi Fence Systems, Inc., Waynesburg, PA; Table 3.2). The pasture plots were further subdivided utilizing electrified polytape (Kiwi Fence Systems, Inc., Waynesburg, PA) into 4 or 13 paddocks (Table 3.2). The 10 pasture plots in the 8 ha field were divided into two replicates of five pastures each, and used to evaluate grazing methods and stocking rate. The additional pasture plots in the 4 ha field (plots 11 and 12) were used to determine the intake of grazing Holstein steers and a net energy value for grazed alfalfa (Chapter 4).

A mechanical harvest system was compared to the four grazing systems. The grazing systems were comprised of two grazing methods (GM), a traditional four-paddock rotation and a more intensive 13-paddock rotation, each at a low and high SR. The mechanically harvested plots were assigned to the plots 5 and 10 because these contained low lying areas. The four grazing systems were randomly assigned within the remaining four plots per replicate. The five treatments were as follows: 1) 4 paddocks-low SR, (4-L); 2) 4 paddocks-high SR (4-H); 3) 13 paddocks-low SR (13-L); 4) 13 paddocks-high SR (13-H); and 5) a mechanical harvest system (MH).

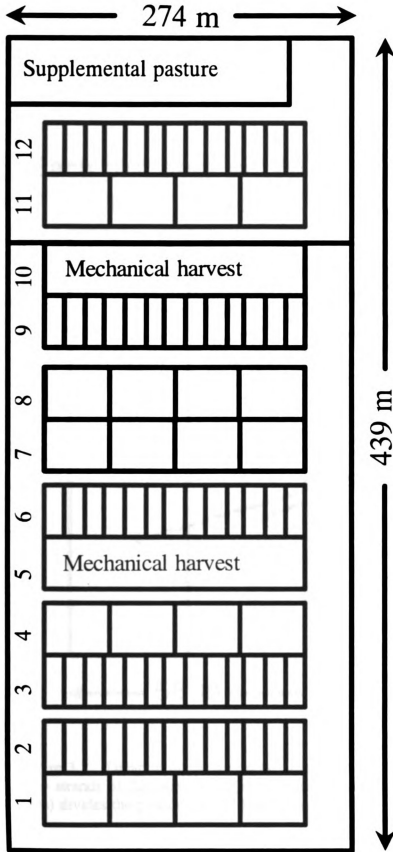


Figure 3.1. Alfalfa grazing experiment design. Twelve hectares were divided into 12 plots (.76 ha) plus a supplemental pasture. Plots 1 to 10 were used to evaluate grazing methods and stocking rates. Treatment assignments were 4-L (plots 1,7), 4-H (plots 4,8), 13-L (plots 2,9), and 13-H (plots 3,6). Plots 11 (4-H) and 12 (13-H) were used to determine intake of grazing steers.

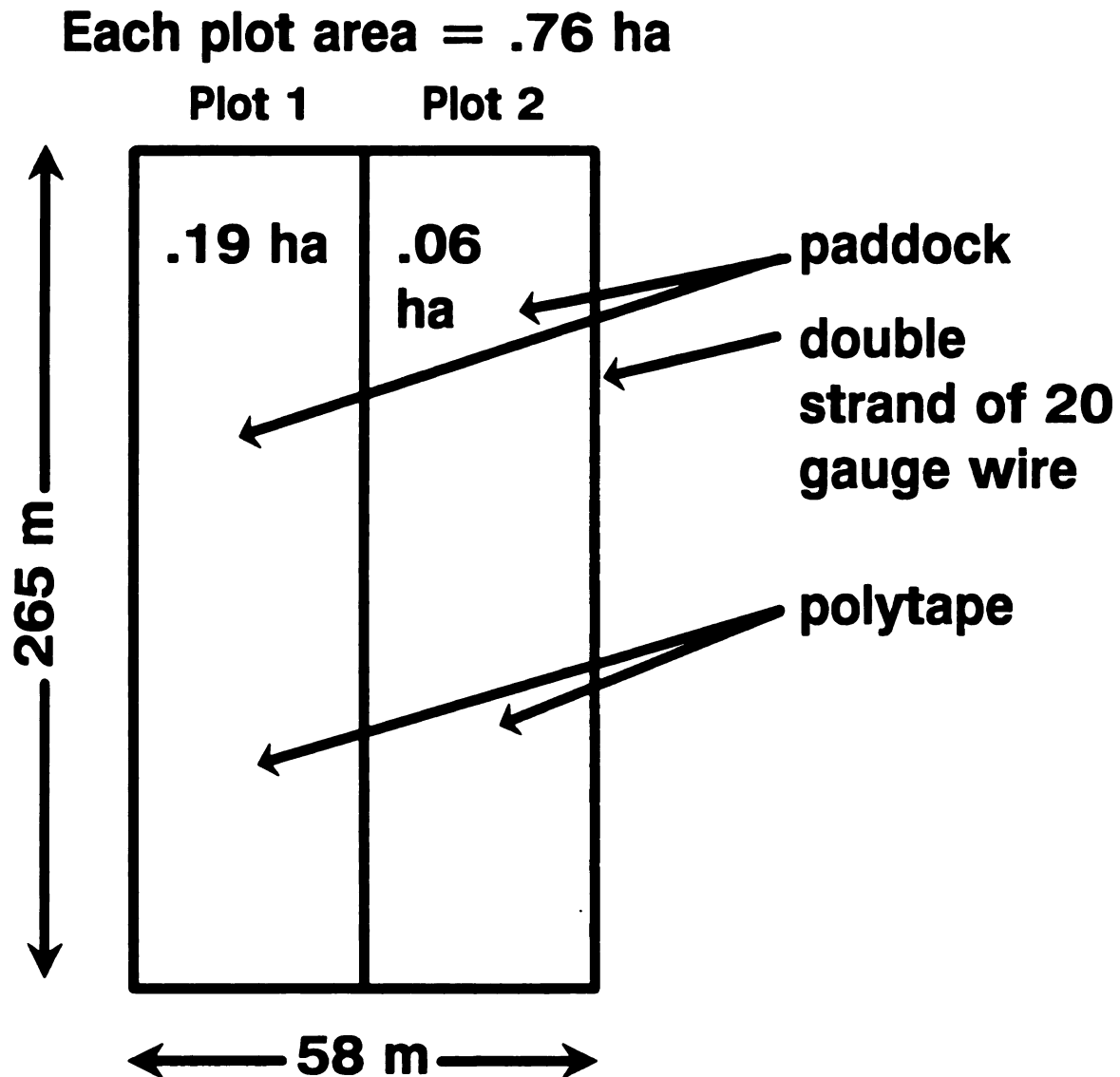


Figure 3.2. Diagram of pasture plots. Each plot is 29 x 265 m to equal .76 ha. Two strands of 20 gauge wire (heavy lines) separates each plot. Polywire (light lines) divides the plot into 4 or 13 paddocks.

Occupation periods were 12 and 3 d per paddock for the 4 and 13-paddock GM, respectively. Grazing cycles, were 48 and 39 for the 4 and 13-paddock methods. As a result, each paddock was allowed a 36-d RP between grazing events. The initial SR were set at 7.9 steers/ha (1885 kg/ha) and 15.8 steers/ha (3770 kg/ha) for the low and high SR, respectively. The SR resulted in 4 and 8 steers per pasture plot.

Year 1: 1989

Seventy-two Holstein steers (239 kg) were received between April 15 and 20. The steers were weighed, ear tagged, dehorned, vaccinated against IBR, PI₃, and treated for parasites with ivermectin (MSDAGVET, Rahway, NJ). Steers were fed a corn silage-hay diet from arrival date to May 11. An alfalfa haylage diet was fed from May 11 to 20. The haylage diet was supplemented with a poloxalene (SmithKline Beecham, West Chester, PA)-mineral mix (Table 3.1). The expected intake of mineral supplement 227 g steer⁻¹ d⁻¹.

Table 3.1. Ingredient composition of poloxalene-mineral mix

Ingredient	Percent in supplement
Dicalcium phosphate	26
Magnesium oxide	26
Trace mineral salt	26
Poloxalene	12
Selenium 200	<u>10</u>
Total	100

Steers were implanted with estradiol-17 β (ELANCO, Indianapolis, IN), weighed full, and blocked by weight into two groups (218 kg, 260 kg) on May 17. Steers within blocks were randomly allocated to the four grazing systems. On May 19, steers were weighed and tagged with a fly repellent ear-tag (Coopers Animal Health Inc., Kansas City, KS). Steers in block one, plots 1 to 4, were sorted into systems groups on May 19, fed alfalfa haylage and supplement; and transported .8 km to the pasture site. Steers assigned to block two, plots 6 to 9, were sorted by treatment and taken to the pasture site on May 20. The start of the blocks was staggered to allow ease of sample collection. Before transport to pasture, steers were allowed to consume alfalfa haylage and poloxalene-mineral mix to appetite to minimize bloat problems. Steers had ad libitum access to mineral-poloxalene mix and water while on pasture plots.

Cycle 1: pasture management

To prevent forage from becoming mature, the OP of the paddocks was decreased to 8 and 2 d for the 4 and 13-paddock systems, respectively, during the first grazing cycle. Stocking rate was maintained at the original levels. For the first cycle, the RP was 24 d.

Every 2 or 8 d, steers were moved to a new ungrazed paddock during the morning. On June 1, excessive rainfall resulted in severe trampling damage in the occupied paddocks and cattle were moved to a new paddock 1 d earlier than scheduled.

Alfalfa weevils presented a problem early in the grazing season. To prevent further weevil damage, paddocks grazed before June 9 were sprayed with 1.4 L of Sevin

insecticide (Carbaryl [1-naphthyl N-methyl carbamate], RHÔNE-POULENC AG COMPANY, Research Triangle Park, NC).

By June 13, it was obvious the SR was too high for the forage available and the SR were decreased by 33% to 5.3 and 10.5 steers/ha for the low and high SR, respectively. Concurrently, 21 steers developed symptoms of photosensitivity. These steers were part of the 37 steers removed to reduce the SR. In order to maintain pre-established RP, cattle were removed from the experimental plots for a brief period. On June 13, steers in the 13-paddock GM (plots 2,3,6,9) were removed to supplemental pasture. Steers from the 4-paddock GM were removed on June 15 (plot 4) and 21 (plots 1,7, and 8).

From June 21 to June 26, all steers (plots 2,3,6,9) were grazing supplemental pasture. On June 26, steers were placed in a holding pen and fed alfalfa hay (2.3 kg DM/steer), watered and provided access to the poloxalene-mineral mix. The steers were removed from feed and water at 1600 h. After a 16 h shrink, steers were weighed (June 27, d 38), fed hay, sorted and placed onto the originally assigned pasture plots, beginning the second grazing cycle.

Cycle 2 and 3: pasture management

The OP during the second and third grazing cycles was increased to the original 3 and 12 d. Stocking rates were maintained at 5.3 and 10.5 steers/ha. Forage availability was determined daily by visual estimation of forage stubble height. Steers were removed to supplemental pasture, comprised primarily of alfalfa, when the forage

stubble was below 10 cm. Once moved to supplemental pastures, steers remained there until the scheduled move to the next paddock.

In August, steers from two pasture plots 4 and 8 (4-H) were removed for lack of forage. Since supplemental pastures were depleted, steers were fed hay. Prior to reentry into assigned pasture plots, steers were provided alfalfa hay and placed onto supplemental pasture. Approximately 4 h later, 4 steers died from bloat.

Steers were weighed full on d 63 and 87. At the conclusion of the 1989 trial (August 29), steers were removed from pasture (d 102), held off feed and water 16 h and weighed. To calculate overall daily gain from a full initial weight and a shrunk final weight, the shrunk weight was divided by .96, assuming a 4% shrink.

To determine gain/ha for each pasture plot, ADG was multiplied by SR and the number of days on pasture. Days on pasture is the number of days the steers spent on the experimental plots. Days on pasture does not include days spent on supplemental pasture. This procedure was used to determine gain/ha for each year.

Year 2: 1990

Forty-eight Holstein steers (232 kg) were received on March 7. Steers were weighed, ear-tagged, vaccinated against IBR, PI₃ and treated for parasites with ivermectin (MSDAGVET, Rahway, NJ). A corn silage-hay diet was fed from March 7 to May 7,. As in Year 1, steers were fed an alfalfa haylage diet one week (May 7 to May 14) prior to grazing and received poloxalene-mineral supplement 3 d (May 11 to May 14) before initiation of the grazing trial.

On May 13 steers were weighed, blocked by weight into two groups (225 kg, 240 kg) and randomly allocated to the four grazing systems within a weight block. Steers were weighed on May 14, implanted with estradiol-17 β (ELANCO, Indianapolis, IN), tagged with a fly repellant ear-tag (Coopers Animal Health Inc., Kansas City, KS) and sorted into system groups. Having been fed haylage and supplement, the steers were transported .8 km to the pasture site.

Cycle 1: pasture management

Prior to grazing (April 26), the alfalfa pasture was fertilized (0-17-34 with .5% boron) with 1254 kg/ha according to a soil test taken the previous fall. Cycle 1 was accelerated as in year 1 for similar reasons. Unlike year 1, the OP were not the same but increased with each subsequent paddock. The OP for the four-paddock system were 4, 8, 12, and 12 d for paddocks 1 through 4, respectively. This system resulted in a 32-d RP for paddock 1. The 13-paddock system utilized OP of 2 d for the first 6 paddocks and 3 d for the remaining 7 paddocks. The accelerated system for the 13-paddock system provided a 31-d RP for paddock 1. Stocking rates were set at 5.3 and 10.5 steers/ha (1161 and 2322 kg/ha) for the low and high SR, respectively. Paddocks were grazed in numerical order for the first and subsequent grazing cycles.

Cycle 2 and 3: pasture management

Unlike the first year, the pastures had sufficient regrowth after the first grazing cycle to continue with the second and third cycle uninterrupted. Occupation periods were maintained at 12 and 3 d for the 4 and 13-paddock GM, respectively. Steers were

moved to new paddocks every 3 or 12 d. When forage availability became limiting, steers were removed to supplemental pastures, with the same criteria mentioned previously, until the next scheduled move.

Steers were weighed full on June 8, (d 25) and every 24 d (d 49, 73, and 97), thereafter. On August 30, (d 108) steers were removed from pasture and weighed on two consecutive days. The steers were then placed on an alfalfa haylage diet for 7 d and weighed to equalize rumen fill.

On June 2, the poloxalene content of the mineral mix was decreased to 6% due to decreased possibility of bloat. Trace mineral salt, dicalcium phosphate, and magnesium oxide each increased to 28%. The poloxalene content of the supplement was returned to 12% on July 24 to prevent bloat because of low forage availability and immaturity of the alfalfa.

Year 3: 1991

Forty Holstein steers were received from April 23 through May 6. Steers were processed upon arrival as before and fed a corn silage-hay diet. Cattle received on May 6 were placed directly on an alfalfa haylage diet. The poloxalene-mineral mix was added to the haylage diet as in the previous years from May 6 to 13. On May 9, steers were implanted with estradiol-17 β (ELANCO, Indianapolis, IN), received a fly repellent ear-tag (Coopers Animal Health Inc., Kansas City, KS), weighed full to block the steers into two weight groups (216 kg, 258 kg) and randomly assigned to plots. As in year 1 and 2, initial steer full-weights were determined on two days (May 11 and 13) during the week of adaptation to an alfalfa haylage diet. Steers were transported .8 km to pasture

on May 13 after being offered alfalfa haylage and poloxalene-mineral supplement. Steers had ad libitum access to water and poloxalene-mineral supplement while on pasture.

Cycle 1: pasture management

Prior to grazing, the pastures were fertilized with 225 kg/ha of potash (0-0-60) according to a soil test. Grazing of paddocks was accelerated as in the previous two years. The accelerated scheme followed the schedule utilized in year 2. Problems with the electric fence resulted in a loss of 6 and 3 d in cycle 1 of the 4 and 13-paddock GM, respectively. This change in the calculated rotation resulted in RP of 26 and 29 d for the 4 and 13-paddock GM, respectively during the first grazing cycle. Stocking rates were 5.3 and 7.9 steers/ha (1186 and 1874 kg/ha) for the low and high SR. The high SR was reduced compared with the two previous years. The decrease in SR was an attempt to increase the steer ADG and gain/ha as compared with the low SR.

Cycle 2 and 3: pasture management

Occupation and rest periods were the same as year 2. Visual appraisal was made each day to determine forage adequacy. Forage was adequate throughout 1991 and steers did not require supplemental pasture. Steers were weighed on June 6 (d 24), August 2 (d 81) and at the conclusion of the grazing season September 2 (d 122). Following pasture removal, steers were placed on the standard alfalfa haylage diet for 7 d as in year 2, and weighed on two consecutive days, September 9 and 10.

Year 4: 1992

Forty Holstein steers (265 kg) were received on April 19. Steers were processed at arrival as before and fed a corn silage-hay diet until May 5. From May 5 to 12, steers were fed the adjustment diet of alfalfa haylage and poloxalene-mineral mix prior to the grazing season. Steers received an estradiol 17- β implant (ELANCO, Indianapolis, IN) and a fly repellent ear-tag (Coopers Animal Health, Inc., Kansas City, KS), weighed, grouped into two weight blocks (249 kg, 281 kg) and randomly assigned to plots. On May 13, steers were weighed, fed alfalfa haylage and supplement, and transported .8 km to the pasture site. Steers had ad libitum access to water and poloxalene-mineral mix while on pasture. Stocking rates were as in year 3, 5.3 and 7.9 steers/ha (1324 and 2093 kg/ha). Steers were weighed on June 10 (d 28), July 8 (d 56), and September 8 and 9 (d 118, 119).

Cycle 1,2 and 3: pasture management

Unlike the three previous years, the first grazing cycle was not accelerated. This was due to the cool weather which retarded the growth of the pasture. Therefore the 12 and 3 d OP for the 4 and 13-paddock GM, respectively, were maintained throughout cycle 1,2 and 3. Steers were weighed off pasture on September 8 and 9 (d 118, 119) and fed the standard alfalfa haylage and poloxalene-mineral mix diet for seven days. After the post-adaption period, steers were weighed on two consecutive days September 15 and 16. A summary of grazing season, SR and initial weights used in each year is presented in Table 3.2.

Mechanical Harvest

The MH plots, 5 and 10, were harvested as haylage in 1989 and 1990. First cuttings were made on June 7 and May 30, and second cuttings on August 9 and July 30

from 1989 and 1990, respectively. Fresh cut haylage samples were collected at the time of chopping to determined DM content and yield. In 1991, the MH plots were harvested

Table 3.2. Characterization of the grazing season, stocking rate and initial weights during the four year grazing study

Year	Grazing season			Stocking rate, steers/ha		Total number of steers	Steer initial weight, kg
	Start	End	Length, d	Low	High		
1989	May 19	Aug. 29	103	5.9 ¹	11.7	72	239
1990	May 14	Aug. 30	108	5.3	10.5	48	232
1991	May 13	Sept. 2	112	5.3	7.9	40	237
1992	May 13	Sept. 8	118	5.3	7.9	40	265

¹Stocking rates during the first 24 d were 7.9 and 15.8 steers/ha and then reduced for the remainder of the grazing season to 5.3 and 10.5 steers/ha for the low and high SR, respectively

as large round-bale hay. The first cutting was made on June 8 and the second in late July. Hay samples were not collected for DM analysis, therefore, an 85% DM content was used to calculate DM yield/ha. The MH plots were not harvested in 1992.

Feedlot management

Steers from each pasture plot were fed as a group in the same pen throughout the feedlot phase. Following the rumen equilibration period, steers were adjusted to a high concentrate diet. The diet consisted of 81% high moisture corn or dry corn, 14% corn silage and 5% protein-mineral supplement. The CP content of the diet was 10.5% (DM basis), and the energy density was 2.33 Mcal/kg NE_m and 1.54 Mcal/kg NE_g. Weights obtained after the rumen equilibration period were used as the initial weights for the feedlot phase with steers being weighed at 28 or 56 d intervals until slaughter. Dry matter intake was determined from orts collected during each weigh period. Steers were on feed for 222, 234, 194, and 194 d for 1989, 1990, 1991, and 1992, respectively. At the conclusion of the feedlot phase, the steers were weighed on two consecutive days and transported to the slaughter plant. Carcass weight, quality grade and yield grade were determined.

Data collection and analysis**Forage data collection and analyses**

Pasture samples were collected in 1989, 1990 and 1991 to determine pasture yield. Nutritive quality as measured by crude protein (CP, total N x 6.25), organic matter (OM), and in vitro organic matter digestibility (IVOMD) was determined on forage samples for 1989 and 1990. Prior to steer entry, paddock-forage samples were randomly collected from three (.5 x .5 m) quadrants in each paddock. In 1989 and 1990, extended canopy heights were also determined at four random sites within each paddock prior to steer entry.

Forage samples from the three quadrants were composited and split into two subsamples. Both subsamples were weighed. One subsample was frozen for wet analyzes, the other subsample dried at 55°C for 48 h (AOAC, 1984). The dried sample was ground through a 1 mm screen in a Wiley mill. In duplicate, 1 g of each ground sample was placed in a 500°C muffle furnace for 12 h to determine ash content and OM (100 - %Ash). A 1 g sample, in triplicate, was used to determine IVOMD using the Tilley and Terry (1963) procedure with urea (.5 g/L) added to 1 part strained ruminal fluid:1 part McDougall's Buffer (McDougall, 1948) and a 24-h acid-pepsin digestion phase (Mader and Horn (1986). Residual DM was collected in a Buchner funnel fitted with a pre-weighed, oven-dried Whatman No. 541 filter paper. The residual DM and filter paper were placed in a pre-weighed 50 ml beaker and dried 12 h in a 60°C oven. The beaker, containing the filter paper and residual DM, was weighed and then placed in a 500°C muffle furnace for 12 h to determine residual ash content.

The frozen sample was thawed, chopped with a Hobart chopper and assayed for total nitrogen by the Kjeldahl procedure using a Technicon auto-analyzer system (AOAC, 1984).

Esophageal extrusa collection and analysis

In 1989 and 1990, extrusa boluses were collected from esophageally fistulated steers fitted with esophageal cannulas (Precision Machine Co., Inc., Lincoln, NE) to determine the nutritive quality of forage consumed. Sampling coincided with the movement of the 4-paddock GM (12 d). This resulted in every fourth paddock sampled for the 13-paddock GM and every paddock for the 4-paddock GM. Esophageally

fistulated steers were removed from pasture for 2 h prior to sampling. Steers were fitted with collection bags (Cheyenne Awning Co., Cheyenne, WY) which covered the fistulae and collected the extrusa boluses. Cannulated steers were then placed in an ungrazed paddock for .5 h. Samples were removed from the collection bags and kept cool until all paddocks were collected and then frozen for later analysis. Bolus samples were freeze-dried and ground through a 2 mm screen in a Wiley mill. The dried samples were analyzed for DM, OM, CP, and IVOMD as described above.

In situ ruminal DM and CP degradation of the esophageal extrusa samples were determined by the methods described by Wilkerson, (1990) and Karges et al. (1992). A 5 g dried and ground sample of esophageally collected extrusa was placed in a labeled and weighed 10 x 20 cm dacron bag (Ankom, Fairport, NY). The bag was sealed with a #8 stopper and two #18 rubber bands. Four bags were prepared for each sample. Each replicate (one of the 4 bags) was placed in a larger mesh bag and soaked in warm (39°C) water for 20 min prior to rumen incubation. Two rumen fistulated steers were used for the analysis. The steers were fed a bromegrass diet. Two large mesh bags containing approximately 25 dacron bags were placed in the rumen of each steer just prior to feeding. After the 16 h of rumen incubation, the mesh bags were placed in warm water and rinsed until all particulate matter was gone, .5 to 1 h. Next, individual dacron bags were rinsed with warm water as the rubber bands and stopper were removed. The residue remaining was washed to the bottom of the bag and the bag was air dried. The air-dried bags containing residue were dried in a 65°C oven overnight. The oven-dried bags were allowed to equilibrate to room conditions for three hours then weighed. One gram of the residue was used to determine total nitrogen. From these

analyses, ruminal DM degradation and ruminal undegradable protein could be determined.

Pasture botanical composition

On April 23, 1989, prior to the initiation of grazing, alfalfa plant densities were determined. Plant counts were determined from 60 randomly placed quadrants (.5 x .5 m). Before grazing was initiated in years 3 and 4, three quadrants were collected from each plot. The samples were combined and separated into alfalfa and other plant material. The plant species subsamples were dried at 55° C for 48 h to estimate the percent alfalfa in the pastures.

Ingestive behavior observations

Visual observations of cattle behavior were recorded on June 20 and August 7, 1990. Observations began at 0600, with steers being observed every 15 min until 2145 and 2100 for June 20 and August 7, respectively. The difference was due to the decrease in daylight. Observers recorded whether steers were grazing, ruminating, drinking, consuming mineral, or idle. To determine time spent in each activity, steers were assumed to be engaged in an activity until the next observation was made.

Statistical analysis

For statistical analysis, the pasture plot was treated as the experimental unit in both the grazing and feedlot phases. Data were analyzed using the General Linear Model subroutine of SAS (1987). Grazing systems in year 1 (1989) and 2 (1990) were analyzed

individually, whereas animal performance data from year 3 (1991) and 4 (1992) were pooled. The model for year 1 and 2 included; block, GM, SR, and the interaction GM x SR. The probabilities for the main effects, GM and SR, and the interaction GM x SR were determined. If there was a significant GM x SR interaction ($P < .10$), the treatment means were separated using a Bonferroni t-test. Statistical differences were denoted by superscripts. This procedure was also used to analyze forage presentation in 1991, and pasture botanical composition collected in 1991 and 1992.

To analyze year 3 and 4, the 4 year average of animal performance on pasture, and the 3 year average of forage presentation, a model including; year, block, GM, SR, GM x SR, year x GM, year x SR, and year x GM x SR within the GLM procedure of SAS (1987) was utilized. If there was a significant GM x SR interaction ($P < .10$), the treatment means were separated using a Bonferroni t-test and denoted as discussed previously. Significant year interactions were determined and denoted by superscripts.

Comparisons of MH forage presentation and botanical composition with the grazing systems utilized a model which included treatment and block, in the GLM procedure of SAS (1987). A Dunnett's t-test (Gill, 1978a) was used to determine if the grazing systems were different from MH. Differences were denoted with superscripts.

Visual observations from year 2 were analyzed with a GLM including; block, GM, SR, observation date (OBS); and OBS x GM, OBS x SR, GM x SR, and OBS x GM x SR interactions. Although OBS was significant ($P < .10$) for each activity, interactions involving OBS were not and the interactions were dropped from the model. There were no significant ($P > .10$) GM x SR interactions.

RESULTS AND DISCUSSION

Year 1: 1989

In 1989, SR impacted animal and plant productivity to a greater extent than the grazing method (Table 3.3). As expected, when SR is increased, individual animal performance decreased (Joyce and Brunswick, 1977; Marsh and Brunswick, 1978). In this experiment, 4-H and 13-H steers had 14% lower ($P=.002$) live-weight at the end of the grazing season than 4-L and 13-L steers. The lower weight was a result of a 72% lower ($P=.002$) ADG than 4-L and 13-L. When determining the correct SR to use, individual animal performance must be weighed against production of the land area. The 4-H and 13-H plots were over-stocked initially and even after a 33% decrease in SR, were not able to produce the quantity of live-weight gain as compared to the 4-L and 13-L systems. Due to the over-stocking, steers consumed a greater proportion of the available forage and required more days on supplemental pasture. Steers on the 4-L plots remained on the assigned plots 26.5 days more ($P<.05$) than the 4-H steers with 13-L and 13-H steers intermediate. The 43% decrease in the number of days on pasture and lower ADG for 4-H steers resulted in a 51% decrease ($P=.07$) in live-weight gain per hectare. The decrease in animal performance due to increased SR, can in part be explained by the negative impact on forage presentation (Table 3.4). High SR tended to have 22% less ($P=.09$) forage presentation over the 103-d grazing season than low SR. Further evidence shows the tendency for high SR to have 19% lower ($P=.103$) canopy heights than low SR.

Although forage presentation was decreased in 4-H and 13-H plots, forage nutritive quality was increased, as measured by CP and IVOMD. Numerically, forage

Table 3.3. Effect of grazing method and stocking rate on animal productivity (1989)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Stocking rate, steers/ha							
d 0 to 25	7.89	15.79	7.89	15.79			
d 0 to 103	5.26	10.53	5.26	10.53			
Steer weight, kg							
d 0	238	239	238	239	2.0	.91	.68
d 25	254	244	256	244	3.2	.85	.05
d 103	295	260	308	259	4.0	.23	.001
Average daily gain, kg							
d 0 to 25	.65	.24	.73	.20	.11	.89	.03
d 26 to 103	.59	.19	.66	.14	.03	.84	.001
d 0 to 103	.60	.20	.69	.16	.04	.53	.002
Days on pasture, d							
d 0 to 25	24.5	24.5	24.5	24.5	0	0	0
d 26 to 103	71.0 ^a	44.5 ^b	63.0 ^{ab}	57.0 ^{ab}	2.8	.47	.01
d 0 to 103	95.5 ^a	69.0 ^b	87.5 ^{ab}	81.5 ^{ab}	2.8	.47	.01
Gain per hectare, kg							
d 0 to 25	124	95	141	77	41.6	.99	.34
d 26 to 103	222	85	217	88	25.6	.96	.01
d 0 to 103	346	180	358	165	66.3	.98	.07

^aSignificant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .05)

Table 3.4. Effect of grazing method and stocking rate on forage yield, canopy height and forage quality (1989)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Forage presentation, kg/ha	6195	4564	6670	5476	569	.31	.09
Canopy height, cm	43.69	34.26	41.65	35.05	3.45	.87	.10
Forage samples							
Crude protein, % ¹	16.75	20.57	17.50	19.65	.64	.40	.14
IVDMD, % ²	60.33 ^d	64.36 ^c	60.13 ^d	60.49 ^d	.48	.02	.02
Esophageal extrusa samples							
Crude protein, % ¹	20.01	21.42	23.00	23.41	2.02	.31	.68
IVOMD, % ²	75.59	72.15	71.73	70.49	2.66	.38	.44
Rumen DMD, % ^{2,3}	81.76	78.19	78.46	79.19	1.64	.53	.45
Rumen UDP, % ^{3,4}	13.51	18.28	15.67	16.09	1.87	1.00	.27
							.34

^{cd}Significant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .10)

¹OM basis

²DM basis

³Rumen dry matter degradation determined from a 16 h in situ incubation

⁴Rumen undegradable protein (% of CP) determined from a 16 h in situ incubation

from 4-H and 13-H pastures showed a trend ($P = .14$) of increased CP content of 20.57 and 19.65%, respectively, as compared to 16.75 and 17.50% for 4-L and 13-L pastures. Forage IVOMD was affected by GM and SR with forage from 4-H tending to have 7% more ($P < .10$) IVOMD than forage from 4-L, 13-L, or 13-H. These observations agree with Hintz and Albrecht (1991) who determined a negative relationship between stem height and CP content; and a positive correlation between height and NDF content. This may explain the inverse relationship observed in this study between CP and IVOMD content of the forages and the measured canopy height.

Esophageal extrusa samples were collected to determine the selectivity of cattle when first placed into the ungrazed paddocks. Clearly, the cattle used to collect the extrusa samples selected forage high in CP and IVOMD. There was a tendency for steers on the low SR to select forage higher in CP than the average CP content of clipped forage samples. Although, the CP content of esophageal and clipped forage was similar in the high SR. There were no differences in the quality of selected forages between the grazing systems. Extrusa samples were further evaluated to determine rumen dry matter degradation (DMD) and undegradable protein (UDP) content. Rumen DMD ranged from 78.19 to 81.76 % with no differences between grazing systems. Likewise, rumen UDP was similar for all grazing systems and ranged from 13.51 to 18.28%. Rumen UDP values were not adjusted for microbial attachment to the residue, and thus, values may be overestimated. According to Anderson et al. (1988), rumen UDP may be limiting in lush pastures and therefore needs to be supplemented. Anderson et al. (1988) demonstrated a linear increase in daily gain with the addition of .11 to .34 kg steer⁻¹ d⁻¹

of corn gluten and blood meal mixture to crossbred steers grazing smooth brome grass. Rumen UDP of the smooth brome grass ranged from 9.2 to 13.1% of the nitrogen.

Following the 103-d grazing season in 1989, the steers were placed into a feedlot for 222 d. Steers that entered the feedlot with the heaviest weights (4-L and 13-L), were heavier ($P=.001$) after 56 d (d 159) and there was a numerical advantage for low SR steers to have greater live-weights than high SR steers at the end of the 222 d (d 325, Table 3.5). Steers had similar ADG throughout the feedlot period, although there was a trend for 4-H and 13-H steers to have greater ADG than 4-L and 13-L steers. This trend may suggest these steers were exhibiting some compensatory gain. Dry matter intakes of 4-H and 13-H steers during the first 56 d were 14% lower ($P=.02$) than 4-L and 13-L steers resulting in a 22% increase in feed efficiency. Waggoner et al. (1988) demonstrated compensatory gain in steers placed in the feedlot following summer pasture. Daily gains were 100% greater during the first 28 d as compared with the second 28-d period. Waggoner et al. (1988) did not see a consistent difference in ADG of steers from continuous or rotationally-stocked pastures at moderate (.41 steer/ha) or high (.55 steers/ha) SR. When ADG was expressed over the entire 325-d study, 4-L and 13-L had 13% greater ($P=.04$) ADG than 4-H and 13-H steers. Most of the advantage was achieved during the pasture phase when ADG of 4-L and 13-L were 258% greater ($P=.002$) than 4-H and 13-H (Table 3.3).

Dry matter intake tended to be depressed 6% ($P=.09$) in 4-H and 13-H steers during the last 167 d of the feedlot phase and were 8% lower ($P=.005$) over the entire 222-d feeding period. Steers from the 4-paddock GM (4-L and 4-H) tended to have greater ($P=.08$) intakes during the last 167 d and over the entire 222 d ($P=.01$) than

Table 3.5. Effect of grazing method and stocking rate on subsequent gain, dry matter intake and feed efficiency in the feedlot (1989)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Steer weight, kg							
d 103 ¹	295	260	308	259	4.0	.23	.002
d 159	398	359	395	365	2.3	.75	.001
d 325	636	558	612	581	9.0	.98	.01
Average daily gain, kg							
d 103 to 159	1.84	1.78	1.55	1.93	.07	.39	.11
d 159 to 325	1.43	1.38	1.31	1.30	.06	.22	.65
d 103 to 325	1.54	1.48	1.37	1.46	.05	.14	.73
d 0 to 325	1.24	1.08	1.16	1.04	.04	.23	.04
Daily dry matter intake, kg							
d 103 to 159	10.76	9.57	10.65	8.94	.30	.30	.02
d 159 to 325	10.05	9.19	9.16	8.82	.19	.08	.09
d 103 to 325	10.22	9.29	9.54	8.85	.11	.01	.005
Feed efficiency, kg gain/ kg intake							
d 103 to 159	.1714	.1866	.1470	.2021	.0127	.75	.07
d 159 to 325	.1416	.1490	.1422	.1382	.0042	.31	.71
d 103 to 325	.1494	.1588	.1429	.1545	.0041	.28	.08

¹Days since the beginning of the grazing season

13-L and 13-H steers. The cause of the increased intake is unclear. Feed efficiency was similar for steers during the last 167 d of feeding, but over the entire 222 d, 4-H and 13-H steers tended to have 7% better ($P=.08$) feed efficiency than 4-L and 13-L steers.

At slaughter, 4-L and 13-L steers had heavier ($P=.002$) hot carcass weights but similar dressing percentages and yield grades as 4-H and 13-H steers (Table 3.6). The proportion of carcasses that graded choice for 13-H was 20% lower ($P<.05$) than 4-L, 4-H or 13-L carcasses. Although the difference cannot be explained, the 13-H steers had the lowest carcass weight, dressing percent and yield grade which would suggest lower carcass fat.

Year 2: 1990

In year 2, steers were placed on a standard alfalfa haylage diet before and after grazing alfalfa pasture to equalize gut fill and accurately report changes in steer weight. Therefore, steer weight and ADG were based on weights determined following a week on the standard haylage diet. As in year 1, SR had a strong influence on final steer weight and ADG. The 4-H and 13-H steers had 12% lower ($P=.003$) weight than 4-L and 13-L steers on d 115 (Table 3.7).

Steers had similar ADG during the first 25 d, but during d 26 to 115, 4-L and 13-L steers had greater ($P=.003$) ADG than 4-H and 13-H steers. In addition, 13-L and 13-H steers tended to have greater ($P=.07$) ADG than 4-L and 4-H steers during the same period. Over the entire 115-d period, 4-H and 13-H steers had 38% lower ($P=.002$) ADG than 4-L and 13-L steers.

Table 3.6. Effect of grazing method and stocking rate on subsequent carcass weight and quality following a feedlot phase (1989)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Hot carcass weight, kg							
	369	341	360	334	3.7	.08	.01
Dressing percent							
	58.03	63.90	58.32	57.93	7.72	.35	.37
Percent choice quality grade ¹							
	100 ^a	100 ^a	100 ^a	80.5 ^b	.3	.04	.04
Estimated yield grade							
	2.65	2.55	2.80	2.45	.13	.85	.17

^aSignificant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .05)

¹Choice quality grade or higher

Table 3.7. Effect of grazing method and stocking rate on animal productivity (1990)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Stocking rate, steers/ha							
d 0 to 108	5.26	10.53	5.26	10.53			
Steer weight, kg							
d 0	231	232	232	232	1.0	.69	.84
d 25	251	246	250	244	4.9	.74	.31
d 115	335	296	346	303	4.4	.14	.003
Average daily gain, kg							
d 0 to 25	.81	.54	.69	.47	.22	.71	.34
d 26 to 115	.93	.55	1.06	.66	.04	.07	.003
d 0 to 115	.91	.55	.98	.62	.03	.13	.002
Days on pasture, d							
d 0 to 108	106.5 ^a	86.3 ^b	108.0 ^a	100.8 ^a	1.4	.01	.002
Gain per hectare, kg							
d 0 to 108	508 ^{de}	496 ^c	557 ^{cd}	653 ^c	20.4	.01	.13
							.08

^{a,b}Significant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .05)

^{cd,e}Significant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .10)

Utilizing the reduced SR throughout year 2 reduced the over-stocking of the 4-H and 13-H plots and increased the number of days those steers remained on their assigned plots. Although weather conditions were more favorable in year 2, damage to pasture stands in the second block of plots still necessitated the need for supplemental pastures. The 4-H steers spent fewer ($P < .05$) days on pasture than the 4-L, 13-L and 13-H steers which were 86.3, 106.5, 108 and 100.8 d, respectively.

With the increased ADG and days on pasture as compared to year 1, live-weight gains per hectare were improved. The 13-H steers produced 653 kg/ha followed by 13-L, 4-L and 4-H with 557, 508 and 496 kg/ha, respectively. The 13-H steer live-weight gain tended to be greater ($P < .10$) than 4-L and 4-H steer live-weight gain. In addition, live-weight gain of 13-L steers tended to be greater ($P < .10$) than 4-H.

Forage presented (Table 3.8) increased in year 2 as compared numerically with year 1 and may have contributed to the increase in steer production. The 4-H and 13-H plots produced 21% less ($P = .04$) forage than 4-L and 13-L. There was also a trend toward decreased ($P = .14$) canopy heights of 4-H and 13-H plots as seen in year 1. As in year 1, there was a slight trend ($P = .21$) for 4-H and 13-H forage to have greater CP content than 4-L and 13-L pastures. In vitro organic matter digestibility followed a similar trend as observed with CP. Forage from 4-H and 13-H plots had 6% greater ($P = .02$) IVOMD than 4-L and 13-L forage samples.

Based on composition of esophageal extrusa and clipped forage samples, steers did not select forage of higher CP. This observation is not in agreement with year 1, although extrusa samples were numerically higher in IVOMD content than the clipped forage samples. As seen with clipped forage samples, extrusa samples from steers

Table 3.8. Effect of grazing method and stocking rate on forage yield, canopy height and forage quality (1990)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Forage presentation, kg/ha	8178	6458	8817	6952	166	.34	.04
Canopy height, cm	52.55	48.21	50.60	46.59	2.12	.46	.14
Forage samples							
Crude protein, % ¹	23.91	24.06	23.09	23.98	.33	.27	.21
IVOMD, % ²	62.20	66.07	60.27	64.18	.87	.12	.02
Esophageal extrusa samples							
Crude protein, % ¹	22.20	21.17	23.94	23.72	2.46	.45	.82
IVOMD, % ²	73.56	75.68	74.14	75.72	.50	.58	.03
Rumen DMD, % ^{2,3}	87.03	85.49	81.77	83.58	3.21	.35	.97
Rumen UDP, % ^{3,4}	11.94	10.64	12.12	12.43	1.11	.44	.68

¹OM basis²DM basis³Rumen dry matter degradation determined from a 16 h in situ incubation⁴Rumen undegradable protein (% of CP) determined from a 16 h in situ incubation

grazing 4-H and 13-H plots contained a higher proportion ($P=.03$) of IVOMD than samples from 4-L and 13-L plots. There were no differences in rumen DMD or UDP between the grazing systems. Rumen DMD was numerically greater in year 2 than year 1 and rumen UDP was less than year 1. Rumen UDP in year 2 was from 10.64 to 12.43% and was within the range of UDP which showed a benefit to escape protein supplementation (Anderson et al., 1988).

The heaviest steers entering the feedlot were also the heaviest at the end of the feedlot period (Table 3.9). In year 1 there was only a numerical difference in steer weight between SR at the end of the feedlot period, but in year 2, 4-L and 13-L steers were heavier ($P=.004$) at the end of the 227-d feedlot period than 4-H and 13-H steers. Although steer weight showed similar trends as in year 1, compensatory gain was not evident in year 2. All steers had similar ADG throughout the feeding period. The 4-L and 13-L steers had 18% greater ($P=.003$) ADG over the entire 342-d study than 4-H and 13-H steers. This observation is in agreement with the analysis reported in year 1. Again, the advantage in ADG was attained during the pasture phase when 4-L and 13-L steers had 62% greater ($P=.002$) ADG than 4-H and 13-H steers.

Dry matter intake was similar for all steers during the first 48 d (d 115 to 163) of the feeding program; but during the last 179 d, 4-H and 13-H had lower DMI than 4-L and 13-L steers. Over the entire 227-d feedlot period, steers from plots with low SR had greater DMI ($P=.005$) than high SR; and steers from 4-paddock GM consumed more than 13-paddock GM ($P=.01$). The difference in DMI is confounded with difference in BW. When expressed as a percent of BW, 4-L steers consumed 1.7% and the 13-H

Table 3.9. Effect of grazing method and stocking rate on subsequent gain, dry matter intake, and feed efficiency in the feedlot (1990)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Steer weight, kg							
d 115 ¹	335	296	346	304	4.4	.14	.003
d 163	389 ^a	355 ^b	398 ^a	346 ^b	2.6	.97	.0005
d 342	619	574	646	567	7.5	.28	.004
Average daily gain, kg							
d 115 to 163	1.23	1.26	1.11	.919	.04	.008	.11
d 164 to 342	1.28	1.23	1.39	1.23	.02	.06	.01
d 115 to 342	1.26	1.23	1.32	1.16	.02	1.00	.02
d 0 to 342	1.15	1.01	1.22	.99	.02	.26	.003
Daily dry matter intake, kg							
d 115 to 163	8.17	7.66	7.72	6.77	.48	.26	.22
d 164 to 342	11.27	9.44	9.86	8.91	.51	.15	.07
d 115 to 342	10.60	9.06	9.41	8.45	.38	.10	.05
Feed efficiency, kg gain/kg intake							
d 115 to 163	.1475	.1608	.1407	.1358	.0076	.13	.62
d 164 to 342	.1146	.1309	.1416	.1401	.0074	.10	.40
d 115 to 342	.1199	.1362	.1415	.1384	.0051	.10	.29

^{a,b}Significant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .05)

¹Days since the beginning of the grazing season

steers 1.5% of BW. Feed efficiencies over the 227 d tended to be greater ($P = .10$) for 13-paddock steers.

Steers from grazing systems in year 2 showed similar trends in carcass weight and quality as those from year 1 (Table 3.10). Carcasses from 4-L and 13-L systems were heavier ($P = .002$) and had higher ($P = .01$) yield grades than 4-H and 13-H steers. In year 1, dressing percentages were similar among grazing systems but in year 2, 4-L and 13-L steers had greater ($P = .03$) dressing percents than 4-H and 13-H steers. The 13-H steers had a lower percentage of choice carcasses than the three other grazing systems. Again, this may be due to the lower slaughter weights and decreased dressing percent and yield grade.

Year 3 and 4: 1991 and 1992

Years 3 and 4 are unique from the previous years because the high SR was reduced by 25%, from 10.5 to 7.9 steers/ha. The premise that individual animal performance decreases with increasing SR was discussed earlier, therefore, when SR was decreased, individual animal performance should improve. In fact, ADG was increased for the 7.9 steers/ha in years 3 and 4 compared with 10.5 steers/ha in year 2 by 35.6% (.80 versus .59 kg/d, Table 3.11). Whereas the high SR reduced the off-pasture weight by 14 and 12% in year 1 and 2, the reduction in steer weight was only 5% less in years 3 and 4.

Average daily gain was similar for all grazing systems during the first 26 d, but during the remainder of the grazing season, 4-H and 13-H steers tended to have 17% lower ($P = .09$) ADG than 4-L and 13-L steers. This was also the case when ADG was evaluated over the entire 122-d grazing season.

Table 3.10. Effect of grazing method and stocking rate on subsequent carcass weight and quality following the feedlot phase (1990)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	GM x SR
Hot carcass weight, kg							
362 ^{ab}		336 ^b	381 ^c	326 ^a	4.0	.25	.05
Dressing percent							
58.50		58.06	58.89	57.50	.22	.73	.12
Percent choice quality grade ¹							
100		100	100	94	.03	.39	.39
Estimated yield grade							
2.50		2.19	2.88	2.32	.08	.05	.22

^{ab}Significant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .05)

¹Choice quality grade or higher

Table 3.11. Effect of grazing method and stocking rate on animal and plant productivity (1991-1992)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	GM x SR
Stocking rate, steers/ha							
d 0 to 115	5.26	7.89	5.26	7.89			
Steer weight, kg							
d 0	250	252	252	251	1.8	.65	.61
d 26	275	272	272	270	3.2	.46	.92
d 122 ¹	361	344	367	346	5.8	.51	.77
Average daily gain, kg							
d 0 to 26	.94	.77	.76	.72	.11	.34	.57
d 26 to 122	.93	.80	1.03	.82	.09	.51	.71
d 0 to 122 ¹	.94	.79	.97	.80	.05	.66	.84
Days on pasture, d							
d 0 to 115	115	115	115	115			
Gain per hectare, kg							
d 0 to 115	569	715	589	725	39	.71	.90
Forage presentation (1991), kg/ha							
d 0 to 112	11198	11383	11618	10881	226	.87	.13

¹Significant year x stocking rate interaction ($P < .10$)

Unlike the previous two years, cattle did not require supplemental pasture for part of the grazing season. The increase in days on pasture and the increase in ADG of the 4-H and 13-H steers increased the live-weight gain/ha. The live-weight gains/ha of the 4-H and 13-H plots were 24% greater ($P=.008$) than gains from 4-L and 13-L plots. It would appear, based on the improved live-weight gain/ha that the optimum SR is between 5.3 and 7.9 steers/ha. Forage presentation increased numerically in 1991 to 11270 kg/ha up from 5726 and 7601 kg in 1989 and 1990, respectively. This suggests that an alfalfa pasture stand increases yields through the third year of production. This was not the case in Northwest Saskatchewan where the productivity of smooth brome-grass-alfalfa and intermediate wheatgrass-alfalfa pastures declined with successive years (1955 to 1961, Cooke et al., 1965).

When the steers were placed in the feedlot, 4-L and 13-L steers had greater ($P=.06$) live-weights after 64 d than 4-H and 13-H steers. This trend in steer live-weight was observed in years 1 and 2 as well. By slaughter, all steers had similar BW (Table 3.12). Average daily gains were similar for the first 64 d, but steers from the 13-paddock GM tended to have greater ($P=.09$) gains during the last 123 d. Over the entire 187-d feedlot period, all steers had similar ADG. During the first 2 years, 4-L and 13-L steers had greater ADG over the entire study, whereas, all steers had similar ADG over the 309-d study in year 3 and 4. The primary reason was the reduction in high SR which decreased the difference in ADG between the low and high SR while on pasture.

Table 3.12. Effect of grazing method and stocking rate on subsequent gain, dry matter intake, and feed efficiency in the feedlot (1991-1992)

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	GM x SR
Steer weight, kg							
d 122 ^{1,2}	361	344	367	346	5.8	.51	.77
d 185 ²	457	448	460	439	6.9	.61	.38
d 309 ²	601	600	621	599	10.1	.40	.33
Average daily gain, kg							
d 123 to 184 ²	1.62	1.88	1.62	1.66	.12	.35	.36
d 186 to 309	1.17	1.20	1.41	1.30	.09	.09	.43
d 123 to 309	1.31	1.46	1.51	1.41	.09	.42	.20
d 0 to 309	1.14	1.13	1.19	1.12	.03	.42	.35
Daily dry matter intake, kg							
d 123 to 184	8.76	9.34	8.92	9.08	.32	.88	.54
d 186 to 309	8.43	9.04	8.79	9.41	.32	.29	1.00
d 123 to 309	8.53	9.14	8.83	9.31	.30	.45	.84
Feed efficiency, kg gain/kg intake							
d 123 to 184	.1869	.2045	.1832	.1791	.0117	.25	.38
d 186 to 309	.1388	.1329	.1318	.1387	.0097	.18	.40
d 123 to 309	.1538	.1606	.1724	.1513	.0103	.67	.21

¹Days since the beginning of the grazing season

²Significant year x stocking rate interaction ($P < .10$)

Dry matter intake over the first 64 d in the feedlot was similar for all steers but there was a tendency for 4-H and 13-H steers to have greater ($P = .10$) intake during the last 123 d and over the entire feeding period ($P = .11$) as compared to 4-L and 13-L steers. This was an opposite response to that observed in the first two years where intake was closely associated with body weight. Although DMI tended to be different between SR, feed efficiency was similar for all steers throughout the feeding period.

Hot carcass weight, dressing percentage and proportion of choice quality grade were similar for all steers (Table 3.13). The 13-H steers had lower quality grades than cattle from the other grazing systems over the four-year study. The reason for this is unclear as stated previously, but in previous years, may have been associated with decreased carcass weights, dressing percents and yield grades. In this case, 13-H steers did not have the lowest carcass weight or dressing percent but still graded below the other groups.

Mechanical Harvest

In 1989, forage presentation from 13-L was 132% greater ($P < .05$) than MH (Table 3.14). The other grazing systems had forage presentations which were numerically 53 to 116% greater than MH. The reason for the large difference in forage presentation may be due to the poor harvesting schedule and weather in 1989. The first cutting was made at the appropriate time, but the haylage remained in the field for nearly two weeks before removal. During this time, the cut alfalfa was rained on numerous times. Most harvesting schedules for alfalfa recommend 3 to 4 harvests per season (Sheaffer et al., 1988) as compared to the 2 harvest scheme used in this study.

Table 3.13. Effect of grazing method and stocking rate on subsequent carcass weight and quality grade following a feedlot phase (1991-1992)

Item	Grazing System					Probability	
	4-L	4-H	13-L	13-H	SEM	GM	SR
Hot carcass weight, kg ¹							
338		342	361	342	4.3	.03	.11
Dressing percent							
56.32		57.06	58.49	57.10	.77	.19	.68
Percent choice quality grade ²							
88		92	100	71	.97	.69	.23
							.13

¹Significant year x stocking rate interaction (P < .10)

²Choice quality grade or higher

Table 3.14. Comparison of forage presentation from grazed and harvested plots (1989-1991)

Item	Harvest System					SEM
	4-L	4-H	13-L	13-H	MH	
1989 Forage presentation, kg/ha						
	6195	4564	6670*	5476	2864 ¹	674
1990 Forage presentation, kg/ha						
	8178	6458	8817	6952	8289 ¹	443
1991 Forage presentation, kg/ha						
	11199**	11383**	11618**	10881**	6540 ²	324
3 year average, kg/ha ³						
	8524**	7468*	9035**	7770**	5898	312

*Differs from MH (P < .05)

**Differs from MH (P < .01)

¹Harvested as haylage

²Harvested as round bale hay

³Significant (P = .002) treatment x year interaction

Forage presentation in 1990 was similar among the grazing systems and MH plots. Favorable weather allowed the timely harvest of the MH plots preventing the loss of DM seen in the previous year from leaching.

One noticeable difference in 1991 is while the forage presentation of the grazing systems increased, the forage presentation of MH did not. In addition, forage presentation of the grazings systems were 66 to 78% greater ($P < .01$) than MH. This may be due to the way the MH plots were harvested. In 1991, the MH plots were harvested as round bale hay instead of haylage. Harvesting alfalfa at a lower moisture content increases the amount of field loss, primarily from leaf shatter (Baylor, 1991; Harrison and Fransen, 1991).

Over the three years in which forage presentation was determined, forage presentation of 4-L, 4-H, 13-L and 13-H was 27 to 53% greater ($P < .05$) than MH. Some caution must be used when interpreting these numbers because there was a significant year x treatment interaction, possibly as a result of the weather or harvesting method.

Botanical composition

Essentially, the botanical composition of the pastures when first grazed in 1989 were 80 to 90% alfalfa with plant densities at 97 ± 4.2 alfalfa plants per $.25 \text{ m}^2$. In the spring of 1991, alfalfa constituted 24 to 33% of the forage DM in each pasture (Table 3.15a). There were no differences in botanical composition between the grazing systems in 1991 or 1992. In 1992, the percentage of DM from alfalfa increased to 34

Table 3.15a. Effect of grazing method and stocking rate on pasture botanical composition

Item	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
1991							
Alfalfa, % ¹	32.9	29.2	24	30.8	6.5	.61	.82
Other, % ^{1,2}	67.1	70.8	76.0	69.2	6.5	.61	.82
1992							
Alfalfa, % ¹	41.2	36.6	34.3	38.9	6.5	.74	.99
Other, % ^{1,2}	58.8	63.4	65.7	61.1	6.5	.74	.99

¹Percent of dry matter

²Includes all plants other than alfalfa

to 41% of the pasture DM. The reason for the increase is unclear, unless, weather influenced the growth rate of the alfalfa or weeds differently in the respective years.

The grazing system plots had similar alfalfa composition as the MH plots in 1991 and 1992 (Table 3.15.b). The percentages of alfalfa DM in MH plots were numerically 50 and 21% greater than the grazing systems in 1991 and 1992, respectively. As seen in Table 3.14, the total forage presentation did not decrease with the loss of alfalfa, but was offset by the addition of grasses and weeds.

Ingestive behavior

Steers grazed an average of 9.8 h/d (Table 3.16). This is in agreement with studies by Forbes and Hodgson (1985) and Walker and Heitschmidt (1989) which observed grazing times for cows from 9.5 to 10.9 h. Lofgreen et al. (1957) observed steers grazing considerably less time ranging between 5.6 to 7.9 h. Steers from 13-L and 13-H systems grazed 14% longer ($P=.0009$) than 4-L and 4-H steers. This could explain, the numerical improvement in ADG and gain/ha seen in 13-L and 13-H as compared with 4-L and 4-H grazing systems. Steers from the 13-paddock GM ruminated 32% longer ($P=.012$), but spent 39% less ($P=.0006$) time inactive. Steers were observed to ruminate 1.5 to 2.2 h; this is lower than 4 to 7.8 h determined by Lofgreen et al. (1957) and Welch and Hooper (1988). Ruckebusch (1988) states that 2/3 of the rumination occurs at night. Since ingestive behavior was not measure at night, this may explain why the rumination times the author observed were lower.

Stocking rate affected time spent consuming water and mineral. The 4-H and 13-H steers drank and consumed mineral 75% longer ($P=.06$) than 4-L and 13-L steers. One

Table 3.15b. Effect of treatment on pasture botanical composition

Item	Treatment				
	4-L	4-H	13-L	13-H	MH
1991					
Alfalfa, % ¹	32.9	29.2	24.0	30.8	43.8
Other, % ^{1,2}	67.1	70.8	76.0	69.2	56.2
1992					
Alfalfa, % ¹	41.2	36.6	34.3	38.9	45.7
Other, % ^{1,2}	58.8	63.4	65.7	61.1	54.3

¹Percent of dry matter

²Includes all plants other than alfalfa

Table 3.16. Effect of grazing method and stocking rate on steer activity during daylight hours as assessed by visual observation (1990)

Activity	Grazing System				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Grazing time, h	9.34	9.02	10.24	10.79	.29	.001	.71
Rumination time, h	1.69	1.47	2.20	2.00	.17	.01	.25
Water and mineral consumption time, h	.44	.94	.44	.60	.16	.31	.06
Inactive time, h	4.16	4.20	2.76	2.38	.34	.001	.50
							.42

explanation for the phenomenon is that alfalfa is a natrophobic specie. Natrophobic **s**pecies preferentially accumulate sodium in the roots rather than in the leaves and stem (**D**ouglas, 1986). Therefore, alfalfa is unlikely to contain adequate sodium for livestock. **J**oyce and Brunswick (1975a,b) demonstrated that sodium supplementation of beef cattle **g**razing alfalfa increased live-weight and carcass weight 16 to 48% and 22 to 30% faster **t**han non-supplemented animals. Because 4-H and 13-H steers presumably had less **a**lfalfa intake, increased mineral intake would be required.

Four year summary

A four-year summary of the grazing study is presented in Table 3.17. Over the 4-**y**ear study, ADG on pasture of 4-L and 13-L steers were 49% greater ($P = .0001$) than **4-H** and 13-H. Increasing SR decreased ADG in a similar manner as demonstrated by **J**oyce and Brunswick (1977) and Marsh and Brunswick (1978, Table 2.2) in New **Z**ealand. Maximum production per hectare from rotationally stocked alfalfa was **a**chieved with 7.7 and 6.7 steers/ha by Joyce and Brunswick (1977) and Marsh and **B**runswick (1978), respectively. These SR would be in agreement with the findings of **t**he present study in which maximum gains per hectare were produced with SR of 5.3 to **7.9** steers/ha. The per hectare gains of the New Zealand studies were 923 and 886 kg. **T**he production from New Zealand is greater due to the longer grazing seasons used by **J**oyce and Brunswick (1977) and Marsh and Brunswick (1978), which were 130 and 179 **d**, respectively.

In 1989 and 1990, steers did not remain on the experimental plots during the entire **g**razing season. With improved weather and a decrease in the high SR in 1991 and

Table 3.17. Four year summary of animal performance and forage production

Item	Grazing Systems				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	GM x SR
Stocking rate, steers/ha							
1989	5.9	11.7	5.9	11.7			
1990	5.3	10.5	5.3	10.5			
1991 to 1992	5.3	7.9	5.3	7.9			
4 year average	5.5	9.5	5.5	9.5			
Average daily gain, kg							
1989	.60	.20	.69	.16			
1990	.91	.55	1.06	.66			
1991 to 1992	.94	.79	.97	.80			
4 year average ^{1,2}	.85	.58	.91	.60	.03	.26	.47
Days on pasture							
1989	95.5	69.0	87.5	81.5			
1990	106.5	86.3	108.0	100.8			
1991 to 1992	115.0	115.0	115.0	115.0			
4 year average ^{1,2,3}	108 ^a	96 ^c	106 ^a	103 ^b	.76	.004	.0001

Table 3.17. (Cont'd)

Item	Grazing systems				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Gain/ha, kg							
1989	346	180	358	165			
1990	508	496	557	653			
1991 to 1992	569	715	589	725			
4 year average ^{1,2}	499	527	524	568	27.6	.25	.21
Forage presentation, kg/ha							
1989	6195	4564	6670	5476			
1990	8178	6458	8817	6952			
1991	11199	11383	11618	10881			
3 year average	8524	7468	9034	7770	315	.22	.004
							.74

^{ab}Means with unlike superscripts differ (P < .01)

¹Significant grazing method x year (P < .10)

²Significant stocking rate x year interaction (P < .10)

³Significant grazing method x stocking rate x year interaction (P < .10)

1992, availability of forage permitted grazing on the experimental plots during the entire grazing season. The 4-L and 13-L steers spent 4% more ($P < .01$) days on pasture than 13-H and 11% ($P < .01$) more than 4-H; and 13-H spent 7% more ($P < .01$) days on pasture than 4-H.

The 13-H system was the most productive system, in terms of beef gain per hectare (averaging 568 kg/ha), three out of four years. Stocking rate nor GM influenced gain/ha when analyzing the 4-year average. Because SR varied over the 4 years, differences in the high SR masked the differences seen in individual years. With respect to GM, the 13-paddock GM had greater gain/ha, numerically, as compared to its 4-paddock GM counterpart in every year except in 1989 when 4-H was greater than 13-H. This may suggest that at high SR, there would be an advantage to the 13-paddock GM. At the low SR, the 13-paddock systems consistently had numerically greater ADG and live-weight gains/ha and forage presented.

Previous alfalfa grazing studies reported beef production/ha from 317 to 828 kg (Table 2.3) which is similar to the present study, but the 1120 to 2017 kg beef gain per hectare suggested by a Great Plains States extension bulletin (Corah and Bartley) would be difficult to achieve in Michigan with a 100 to 120 d grazing season.

As stated previously, forage presented increased with each year of the study. In 1989 and 1990, 4-L and 13-L had greater forage presentation than 4-H and 13-H, but forage presented was similar in 1991. The 3-year average demonstrated that SR did impact forage presentation by decreasing it 13% ($P = .004$) when comparing the high to the low SR.

A four year summary of the feedlot phase and carcass characteristics are present in Table 3.18. Grazing method did not impact final slaughter weight, ADG during the feedlot phase or over the entire study. In addition, DMI, feed efficiency, HCW, DP, and the number of carcasses grading choice were similar between the GM. As stated previously, caution must be used to interpret the results because SR change three times throughout the four-year study. Stocking rate did decrease ($P < .0001$) slaughter weight 5% but had no affect on ADG during the feedlot phase. Over the entire study steers for high SR plots had 8% lower ($P < .0001$) ADG than low SR steers. Dry matter intake and feed efficiency were similar for all systems. Hot carcass weight was 7% greater ($P < .05$) for 13-L than 4-L, 4-H, and 13-H, but DP were similar. Throughout all four year, 13-L had a greater ($P < .05$) number of steers achieving the choice quality grade than 13-H steers.

IMPLICATIONS

Increasing paddock number from 4 to 13 did not improve ADG or live-weight gain/ha; therefore the additional expense of 13 paddocks was not warranted. Optimal stocking rate for this alfalfa pasture was 5.3 to 7.9 steers/ha. Supplementation of a rumen undegradable protein may be necessary to increase gains due to the high rumen digestibility of protein in alfalfa.

Forage presentation of alfalfa pastures increased into the third year after establishment, although the low yields during the establishment year may suggest mechanical harvest for hay or silage is preferred. Although, over the 3 years which

Table 3.18. Four year summary of feedlot performance and carcass characteristics

Item	Grazing Systems				Probability		
	4-L	4-H	13-L	13-H	SEM	GM	SR
Slaughter weight, kg ¹	614	591	625	586	5.8	.60	.0001
Average daily gain, kg							
Feedlot phase ²	1.35	1.41	1.36	1.43	.04	.73	.88
Day 0 to slaughter, kg ¹	1.16	1.09	1.19	1.07	.02	.74	.0001
Dry matter intake, kg ¹	9.47	9.16	9.15	8.98	.21	.25	.25
Feed efficiency, kg gain/kg intake							
	.1442	.1537	.1569	.1480	.0002	.50	.95
Hot carcass weight, kg ^{1,3}	352 ^b	340 ^{bc}	365 ^a	336 ^c	2.8	.13	.0001
Dressing percent	57.3	57.5	58.5	57.4	1.3	.20	.27
Percent choice quality grade ^{2,4}							
	93.8 ^{ab}	95.8 ^{ab}	100 ^a	80.9 ^b	4.4	.34	.07

^{ab}Significant grazing method x stocking rate interaction, means with unlike superscripts differ (P < .05)

¹Significant stocking rate x year interaction (P < .10)

²Significant grazing method x stocking rate x year interaction (P < .10)

³Significant grazing method x year interaction (P < .10)

⁴ Choice quality grade or higher

forage presentation was determined, grazing systems had greater forage presentation than the mechanical harvest system.

Compensatory gain was not consistently observed in steers entering the feedlot off alfalfa pasture. If steer ADG on pasture was suppressed below .59 kg/d as a result of increasing the stocking rate, these steers would not reach comparable slaughter weights after 226 days on feed as steers gaining 1 kg/d on pasture.

CHAPTER 4: EVALUATION OF A SLOW-RELEASE CHROMIUM BOLUS, PREDICTION OF INTAKE OF HOLSTEIN STEERS GRAZING ALFALFA AND ESTIMATION OF THE ENERGY VALUE OF ALFALFA

SUMMARY

A study was conducted to determine the intake of Holstein steers grazing alfalfa pasture and estimate the net energy of the grazed alfalfa. Twelve steers (262 ± 5.9 kg) were randomly assigned to two grazing methods, 4 or 13 paddocks (6 steers/method), and one of three grazing times; 6, 10 or 24 h (2 steers/time period). Steers grazed an alfalfa pasture from May 20 till August 25. Occupation periods were 12 and 3 d for the 4 and 13 paddocks grazing methods, respectively, resulting in a 36-d rest period. Initial weights were measured as the average of two weights taken on consecutive days and intermediate weights determined every 12 d. Pasture DM, OM, CP, IVDMD, and IVOMD were determined from a composite of 3 quadrants (.5 x .5 m) collected each time steers moved to the next paddock. Fecal DM and OM output were determined by total collection and Cr-marker dilution over a 3 or 4 d-period. Intake (DM and OM) was determined from fecal output and forage digestibility. From ADG and intake estimates, a regression equation was developed. From the regression equations, alfalfa NE_m was predicted from intake when $ADG = 0$ kg/d and the estimated NE_m requirement (NRC, 1984) of the animal. Likewise, alfalfa NE_g was calculated from intake at various ADG

and the corresponding NE_g (NRC, 1984) required to attain that ADG. Fecal DM and OM output estimates by Cr-marker were 39 and 38% greater ($P < .001$), respectively, than total collection. Daily intakes were $3.84 \pm .40$ kg OM and $4.28 \pm .45$ kg DM. Based on regression equations, alfalfa NE_m ranged from 1.18 to 1.56 Mcal/kg and NE_g from .85 to 1.15 Mcal/kg. Based on this study, NRC (1984) underestimates the net energy value of grazed alfalfa.

INTRODUCTION

A major concern in grazing research and forage evaluation is the inability to measure intake of grazing animals. Prediction of intake is critical in determining SR and consequently, animal performance. Would cattle consume similar amounts of forage whether grazing or as soilage? Lofgreen et al. (1956) demonstrated that steers consuming alfalfa soilage had intakes which were 22 to 43% greater than steers grazing alfalfa pasture (5.9 versus 4.1 to 4.8 kg). Average daily gain (.74 kg), alfalfa digestibility (59%) and TDN (57%) were similar. Lofgreen et al. (1956) concluded that utilization of TDN was greater in grazing steers and suggested that the pasture had a higher net energy value than soilage. Presumably, the higher energy value of grazed forage resulted from selective grazing.

Lofgreen et al. (1956) used pre- and post-grazing clippings and total fecal collections with chromogen analysis to determine intake of grazing steers. The difference technique overestimates intake due to sampling error (Lofgreen et al., 1956), and chromogen was not quantitatively recovered (Cochran et al., 1987). Total fecal collections can be accomplished but may change grazing behavior (Le Du and Penning,

1982). Momont et al. (1990) found a good correlation between total fecal collection and fecal output predicted from a slow release Cr-bolus.

Recognizing the need to measure and predict forage intake, the objectives for this study were to evaluate the use of a slow release Cr-bolus, predict intake of steers grazing alfalfa and to calculate a net energy value for alfalfa pasture.

MATERIAL AND METHODS

Pasture and animal management

This experiment was conducted in conjunction with year 1 (1989) of the study to determine the effect of GM and SR on animal and plant productivity (Chapter 3). In addition, this study was completed under the approval of the Michigan State University All-University Committee on Animal Use and Care (AUF# 8/88-321-01). Twenty-four Holstein steers were received in April, weighed, ear tagged, dehorned, vaccinated against IBR, PI₃, and treated for parasites with ivermectin (MSDAGVET, Rahway, NJ). Steers were placed on a corn silage-hay diet upon arrival until May 11. On May 11, steers were offered an alfalfa haylage diet supplemented with a poloxalene-mineral mix (Table 3.1) till May 20. Initial weights (250 kg) were determined on May 17 and 19. On May 19, steers were implanted with estradiol 17- β (ELANCO, Indianapolis, IN), tagged with a fly repellant ear tag (Coopers Animal Health Inc. Kansas City, KS), and randomly assigned to two GM. On May 20, steers were fed alfalfa haylage and poloxalene-mineral mix in the morning and were transported .8 km to the pasture site at 1400. Each group of 12 steers were placed into a .76 ha plot divided into 4 (Plot 11, 4-H) or 13 (Plot 12,

13-H) paddocks (Figure 2.1, 2.2). Stocking rates were 15.8 steers/ha and corresponded to the high SR of the grazing system study.

The alfalfa (variety Big Ten) was seeded in 1987. The pastures were managed as described in Chapter 3. Occupation periods were 8 and 2 d for the first grazing cycle and 12 and 3 d for the second and third cycle for the 4 (4-H) and 13 (13-H) paddock GM, respectively.

As with the grazing system study, after 24 d of grazing, it was realized that the pastures were overstocked. Also, photosensitivity was observed during this period as was the case in the grazing system study. Therefore, 6 steers exhibiting photosensitivity and 2 additional steers were removed from pasture on June 16 (d 27), reducing the SR to 10.5 steers/ha. Steers in plot 11 (4-H) grazed from May 20 to June 25 (d 36) completing 1 grazing cycle. Plot 12 (13-H) steers grazed from May 20 to June 16. In both cases when steers were removed from their assigned experimental plots, the steers were placed on supplemental alfalfa pasture.

On June 26, the 16 remaining steers were given free access to alfalfa hay (2.3 kg DM/steer) and water until 1600. The next day, following a 16 h shrink, steers were weighed. To decrease possibility of bloat, steers were fed alfalfa hay (2.3 kg DM/steer) and placed into their assigned experimental plots. Two steers in each plot were replaced by animals with esophageal and duodenal cannulas. This was done because protein flow to the small intestine was to be measured. Due to complications with the duodenal cannulas, this could not be completed.

The six non-cannulated steers in each plot were randomly assigned to one of three grazing time allotments (2 steers/time). Grazing time allotments were varied to produce

differences in pasture intake and subsequent ADG. The grazing times were 6, 10 and 24 h. Steers grazing 10 h were placed on pasture at 0800 and the 6 h steers at 1200. Both the 6 and 10 h grazers were removed from pasture at 1800 and placed in a vegetation-free pen with ad libitum access to water and poloxalene-mineral mix. This regime continued for the remainder of the grazing season (Aug. 25, d 97). Steers were weighed every 12 d coinciding with the movement of the 4-paddock GM.

Forage sample collection and analysis

Forage samples from each paddock were randomly collected from three quadrants (.5 x .5 m) prior to steer entry. At the same time, extended canopy heights were determined from four random sites within the paddock. Forage samples from each quadrant were composited and split into two subsamples. Both subsamples were weighed. One subsample was frozen for CP analysis, the other dried at 55°C for 48 h (AOAC, 1984) to determine forage DM and pasture yield. The dried sample was ground through a 1 mm screen of a Wiley mill. In duplicate, 1 g of each ground sample was placed in a 500°C muffle furnace for 12 h to determine ash content and OM (100 - %Ash). In triplicate, 1 g of the ground sample, was used to determine IVDMD and IVOMD utilizing the Tilley and Terry (1963) procedure with urea (.5 g/L) added to 1 part strained ruminal fluid:1 part McDougall's Buffer (McDougall, 1948) and a 24-h acid-pepsin digestion phase (Mader and Horn (1986). Residual DM was collected in a Buchner funnel fitted with a pre-weighed, oven-dried Whatman No. 541 filter paper. The residual DM and filter paper were placed in a pre-weighed 50 ml beaker and dried 12 h in a 60°C oven. The beaker, containing the filter paper and residual DM, was

weighed and then placed in a 500°C muffle furnace for 12 h to determine residual ash content.

The frozen sample was thawed at 4°C overnight, chopped with a Hobart chopper and assayed for total nitrogen ($CP = N \times 6.25$) by the Kjeldahl procedure using a Technicon auto-analyzer system (AOAC, 1984).

Total fecal collection

A ruminal Cr_2O_3 bolus (Quad Five, Ryegate, MT) was given to each steer on July 22 (d 63, Figure 4.1). Chromium release was allowed to equilibrate for 7 d before total fecal collection began. The average Cr_2O_3 release rate was 1641 mg/d (1116 mg Cr/d) as determined by CSIRO Chiswick Research Station, Armidale, NSW, Australia. Fecal collection bags (Cheyenne Awning Co., Cheyenne, WY) were placed on 6 animals in each paddock on July 29 (d 70) at 0800. Accumulated feces were removed at 24 h intervals for 3 d (July 30 to August 1). The collected feces were weighed each day and a 500 g sample frozen. A second fecal collection period of 4 d was performed from August 7 (d 79) to August 11 (d 83). Each fecal collection was made within a separate 12-d weigh period.

Fecal output and intake prediction

Fecal samples were allowed to thaw overnight at 4°C. Samples were analyzed for total N by the Kjeldahl procedure using a Technicon auto-analyzer system (AOAC, 1984) and converted to CP values. Fecal DM content was determined by placing a 250 g sample in a weighed aluminum pan and dried at 55°C for 48 h (AOAC, 1984). Dried

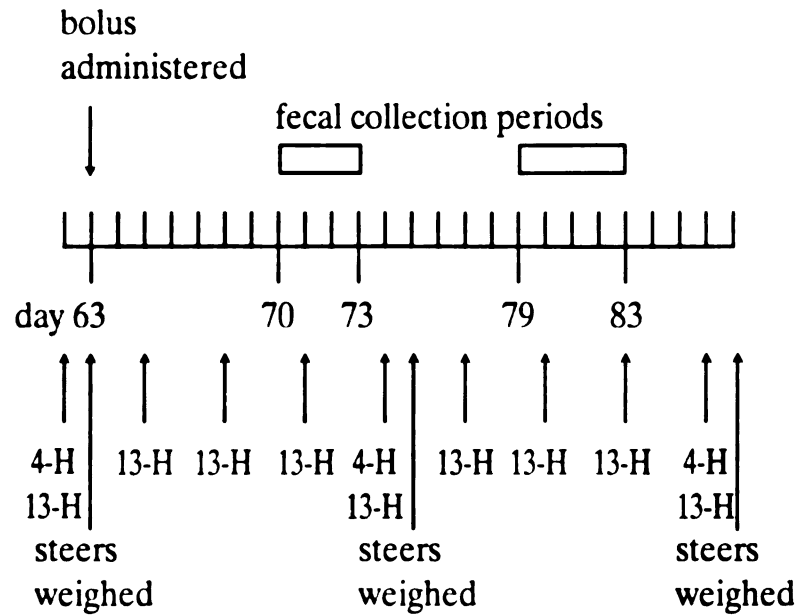


Figure 4.1. Total fecal collection schedule. Days of study are given below time line. Collection periods are represented as boxes above the time line. Rotation of paddocks is indicated by treatment abbreviation below the time line.

samples were ground through a 1 mm screen of a Wiley mill and analyzed for OM (AOAC, 1984). Chromium content was determined by wet-ash digestion of the sample (Analytical Methods Committee, 1960) and subsequent analysis by atomic emission spectrophotometry.

Fecal output was determined in two ways. First, total fecal collections were averaged within a period, then across periods to determine an average daily DM and OM fecal output for each animal. Second, the Cr content of the feces was used to estimate DM and OM fecal output utilizing the following equation (Le Du and Penning, 1982):

$$\text{Daily feces produced (g/d)} = \frac{\text{Weight of marker given (g/d)} \times \text{Marker recovery (\%)}}{\text{Mean concentration of the marker in feces (g/g)}}$$

The weight of the marker given (Cr-bolus release rate) was 1.116 g/d, as determined by the manufacturer. Marker recovery was assumed to be 100%, following the characteristics of an ideal marker (Le Du and Penning 1982).

Intake was determined from daily fecal output and forage digestibility with the following equation (Le Du and Penning, 1982):

$$\text{Intake (kg)} = \frac{\text{Fecal output (kg)}}{1 - \text{digestibility}}$$

Both IVDMD and IVOMD were used to estimate DM and OM intake, respectively. Digestibility of alfalfa taken during each fecal collection period was used to predict intake. Intake predicted from digestibility of esophageal extrusa samples gives a more accurate prediction than digestibility from clipped samples (Greenhalgh, 1982). Digestibility of DM and OM from the esophageal extrusa samples from the 4-H and 13-H systems in the grazing system study (Chapter 3) were 15% greater than clipped samples in that study (Table 3.4). Dry matter and OM intake were determined from the following four procedures: 1) total fecal collection and forage digestibility (TC-D); 2) total fecal collection and forage digestibility increased 15% to simulate esophageal extrusa samples (TC-15D); 3) Cr predicted fecal output and forage digestibility (CR-D); and 4) Cr predicted fecal output and forage digestibility increased 15% (CR-15D).

Development of regression equations and net energy values

Average daily gains, over the two 12-d weigh periods when fecal collections were made, were regressed and correlated to fecal CP and intake. The GM were pooled to

provide 12 observations for each analysis. The regression and correlation procedures of SAS (1987) were used. From the equations generated, the NE_m and NE_g of the alfalfa could be estimated.

To determine NE_m of alfalfa from the regression equations, the intake at y (ADG) = 0 was calculated. Steers averaged 262 ± 5.9 kg during the collection period would require 5.01 Mcal/d NE_m ($NE_m = .077BW^{.75}$; NRC, 1984). Net energy for maintenance (Mcal/kg) of alfalfa was then estimated by dividing NE_m required (5.01 Mcal/d) by intake (kg/d).

Intakes at ADG of .25, .50, .75, and 1.00 kg/d were determined from the regression equations. Net energy for gain of large-frame steer calves required to achieve the live-weight gains (LWG) selected were .70, 1.50, 2.34, and 3.21 Mcal/d ($NE_g = .0493BW^{.75}(LWG)^{1.097}$; NRC, 1984). Intake determined for maintenance was subtracted from the intake calculated for each rate of gain. The NE_g (Mcal/d) required for each rate of gain was divided by the remaining intake (kg/d) to estimate the NE_g (Mcal/kg) of alfalfa.

Statistical analysis

Steer ADG, fecal components (DM, OM, CP), fecal output and intake were analyzed as a 2 x 3 factorial experiment utilizing the General Linear Model of SAS (1987). The model consisted of GM (4 or 13 paddocks), grazing time allotments (6, 10, or 24 h) and the interaction. The animal was used as the experimental unit. Mean separation for grazing time utilized orthogonal polynomial contrasts to determine a linear or quadratic response (Gill, 1987a). Coefficients used in the contrast correspond to

unequally spaced levels of 0, 2, 9 (Gill, 1987b). If a significant ($P < .10$) time x GM interaction was present, means were separated using a Bonferroni t-test and significant differences were indicated with superscripts.

Differences between total fecal collections and predicted fecal output were analyzed using a pair-wise t-test of the Means procedure of SAS (1987). The average value over both collection periods was used in the analysis with the animal as the experimental unit.

RESULTS AND DISCUSSION

Forage production and nutritive quality

A summary of forage presentation, canopy height, and forage CP, IVDMD, and IVOMD is presented in Table 4.1. Forage presentation from the intake pastures (plots 11 and 12) had numerically greater production than the corresponding plots (4-H and 13-H) of the grazing system study (5041 and 5848 versus 4564 and 5476 kg/ha). This may be explained by the age of the stand as this was the second harvest year as compared to the first harvest year in the grazing systems study. Canopy heights were also greater for plots 11 and 12 as compared to 4-H and 13-H (41.2 and 46.3 versus 34.3 and 35.0 cm). Forage CP content and digestibility were similar between plots 11 and 12 and 4-H and 13-H of the companion grazing system study.

Steer performance and fecal output

Prior to steers being assigned to grazing time allotments (d 0 to 37), steers in the 13-H system had greater ($P = .002$) ADG than 4-H steers (Table 4.2). The reason for

Table 4.1. Forage production, canopy height, and nutritive quality of alfalfa pasture used to determine dry matter intake

Date	Forage presentation, kg		Canopy height, cm		Forage CP, % (OM basis)		Forage IVDMD, %	
	4-H	13-H	4-H	13-H	4-H	13-H	4-H	13-H
May 20	295 ¹	609 ²	32.25	45.88	28.00	29.53	67.15	63.87
May 28	656	787	56.25	59.31	21.95	23.93	66.88	61.29
June 5	664	691	55.50	64.50	20.13	19.88	60.18	57.00
June 13	538	174	----	----	----	----	----	----
June 25	314	475	48.75	45.00	21.88	22.33	72.81	65.90
July 9	255	474	39.25	49.81	20.76	20.22	59.78	63.92
July 21 ³	386	718	30.25	51.69	17.77	15.57	58.24	62.21
Aug 2 ⁴	354	309	38.50	26.38	17.08	18.93	59.68	57.19
Aug 14	369	208	29.00	27.44	23.08	23.50	69.43	66.30
Total	3831	4445	----	----	----	----	----	----
Per ha	5041	5848	----	----	----	----	----	----
Season average			41.22	46.25	21.33	21.74	64.27	62.21
							63.17	63.17

¹Forage presentation per paddock²Forage presentation of two to four paddocks coinciding with the occupation period of the 4-H system³Period in which first fecal collections occurred⁴Period in which second fecal collections occurred

Table 4.2. Effect of grazing method and grazing time on weight gain

Item	Grazing time, h			Probability		
	6	10	24	SEM	Time	GM
D 0 to 36 ADG, kg (prior to grazing time allotments)						
4-H	.44	-.04	.18	.14	.46	.002
13-H	.76	.96	.64			.12
D 37 to 97 ADG, kg (during grazing time allotments)						
4-H	.02	-.19	-.05	.14	.66	.17
13-H	-.20	-.25	-.40			.65
D 63 to 87 ADG, kg (fecal collection period)						
4-H	-.29	-.50	.01	.16	.20	.003
13-H	.26	.35	.45			.45

this difference is not apparent since there were no differences during this same period between the 4 and 13 paddock GM of the companion. The 13-H plot had accumulated approximately 300 kg more forage presentation at this point which could explain the discrepancy.

After grazing time allotments were initiated, steer ADG was similar among allotments and GM, but drastically lower than the previous period. An increase in ADG would be expected with increased grazing time. This was not observed, and the reverse was true for the 13-H plot. During the period (d 70 to 73 and 79 to 83) when fecal collections were made, there was a trend ($P=.20$) of increased ADG as grazing time increased.

All steers had similar fecal DM, OM and CP content (Table 4.3). Likewise, there were no differences in fecal output among steers when determined with total collection or predicted from Cr marker (Table 4.4). A trend ($P=.12$) for increased fecal DM and OM output with increased grazing time was observed with total collections but not with Cr-predicted fecal output.

Fecal output prediction procedures

Estimation of fecal output by Cr marker resulted in an increase ($P<.001$) of 39 and 38% for fecal DM and OM output, respectively, as compared to total fecal collection (Figure 4.2). The difference was due to an over-prediction of Cr release rate. The manufacturer's rumen release rate was 1.116 g/d whereas the average amount of Cr release determined from total collection and fecal Cr concentration was .85 g/d. Brandyberry et al. (1991) also demonstrated a lower release rate than that reported by

Table 4.3. Effect of grazing method and grazing time on fecal DM, OM, and CP content

Item	Grazing time, h				Probability		
	6	10	24	SEM	Time	GM	Time x GM
Fecal DM, %							
4-H	16.71	16.83	15.09	1.14	.42	.34	.38
13-H	16.61	13.88	15.27				
Fecal OM, %							
4-H	86.60	84.90	87.08	.48	.27	.29	.34
13-H	85.39	85.52	85.76				
Fecal CP, % (DM basis)							
4-H	13.96	13.20	13.93	.41	.13	.56	.42
13-H	13.56	13.47	14.68				
Fecal CP, % (OM basis)							
4-H	16.14	15.54	16.00	.51	.27	.42	.45
13-H	15.89	15.75	17.12				

Table 4.4. Effect of grazing method and grazing time on fecal output

Item	Grazing time, h			SEM	Probability		
	6	10	24		Time	GM	Time x GM
Total fecal DM output (TC-D), kg							
4-H	1.39	1.22	1.66	.18	.12	.29	.96
13-H	1.62	1.35	1.82				
Total fecal OM output (TC-15D), kg							
4-H	1.20	1.07	1.44	.15	.12	.36	.93
13-H	1.39	1.16	1.53				
Predicted fecal DM output (CR-D), kg							
4-H	3.22	2.71	3.28	.43	.29	.34	.65
13-H	3.14	3.12	4.03				
Predicted fecal OM output (CR-15D), kg							
4-H	2.79	2.31	2.87	.38	.28	.42	.68
13-H	2.68	2.67	3.43				

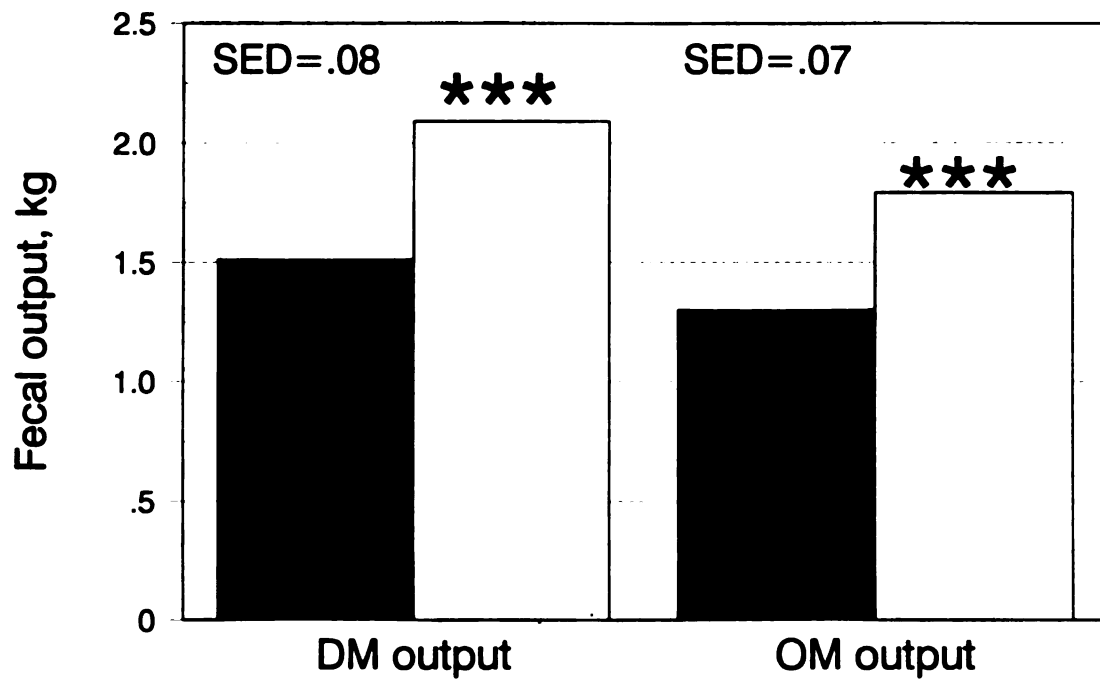


Figure 4.2. Effect of procedures for determining fecal output. Solid and open bars represent total fecal collection and Cr-predicted fecal output, respectively. *** $P < .001$

the manufacturer (.876 g versus 1.123 g). In addition, Brandyberry et al. (1991) and Buntinx et al. (1992) determined the use of Cr_2O_3 bolus over-estimated fecal output, although an earlier study by Momont et al. (1990) found a positive correlation between actual and predicted output.

Predicted DM intake

Predicted DMI ranged from 2.96 kg for TC-D (Table 4.5) to 7.13 kg calculated for the CR-15 procedure (Table 4.6). A similar range was observed for OMI. Grazing allotment time tended to affect ($P < .12$) intake as measured by total fecal collection (TC). The 24 h steers having the greatest intakes, 6 h intermediate and the 10 h steers the lowest level of intake. Steers allotted to 10 h should have been able to consume their daily energy and protein requirement. Visual observation from the system study (Table 3.16) suggest steers actively graze 9 to 11 hours each day. The 13-H steers had 28 and 39% greater ($P < .05$) OMI (TC-D and TC-15D) than 4-H steers but DMI was similar. This may be related to the greater forage presentation of the 13-H plots during the period of fecal collections. Organic matter intake also factors out possible differences in mineral consumption from the poloxalene-mineral mix.

There were significant time x GM interactions for each of the CR predicted intakes. Dry matter intake (CR-D) of 13-H steers at 6, 10, and 24 h was 13% greater ($P < .05$) than 4-H steers grazing 10 or 24 h. The 13-H steers had 27% greater ($P < .05$) OMI (CR-D) than 4-H steers. When intake was based on CR-15D, 13-H steers allowed to graze 24 h had 22% greater DMI than 4-H steers grazing 10 h. Organic matter intake

Table 4.5. Effect of grazing method and grazing time on predicted DMI and OMI from total fecal collections

Item	Grazing time, h				Probability		
	6	10	24	SEM	Time	GM	Time x GM
DMI (TC-D), kg/d							
4-H	3.39	2.96	4.04	.45	.12	.23	.97
13-H	4.01	3.35	4.51				
OMI (TC-D), kg/d¹							
4-H	2.85	2.44	3.42	.40	.10	.04	.96
13-H	3.77	3.14	4.26				
DMI (TC-15D), kg/d							
4-H	4.32	3.77	5.15	.57	.12	.20	.96
13-H	5.16	4.30	5.80				
OMI (TC-15D), kg/d¹							
4-H	3.58	3.07	4.30	.51	.09	.02	.94
13-H	5.10	4.25	5.75				

¹Intake increased linearly with increased grazing time ($P < .10$)

Table 4.6. Effect of grazing method and grazing time on predicted DMI and OMI from Cr-estimated fecal outputs

Item	Grazing time, h			SEM	Probability		
	6	10	24		Time	GM	Time x GM
DMI (CR-D), kg/d							
4-H	5.09 ^{ab}	4.58 ^b	4.98 ^b	.11	.08	.001	.10
13-H	5.31 ^a	5.37 ^a	5.54 ^a				
OMI (CR-D), kg/d							
4-H	4.20 ^b	3.79 ^b	4.16 ^b	.10	.12	.0001	.07
13-H	4.97 ^a	5.14 ^a	5.26 ^a				
DMI (CR-15D), kg/d							
4-H	6.48 ^{ab}	5.84 ^b	6.34 ^{ab}	.14	.08	.0006	.10
13-H	6.83 ^{ab}	6.90 ^{ab}	7.13 ^a				
OMI (CR-15D), kg/d							
4-H	5.28 ^b	4.77 ^b	5.23 ^b	.12	.11	.0001	.06
13-H	6.71 ^a	6.94 ^a	7.11 ^a				

^{ab}Means within the same intake prediction with different superscripts differ ($P < .05$).

for CR-15D followed similar trends as observed with CR-D predictions, the 13-H steers had 36% greater ($P < .05$) OMI than 4-H steers.

One may notice when digestibility was increased 15%, intake also increased. Common sense would suggest that if a forage is more digestible intake would be less. The reason for the discrepancy is that the equation to determine intake is based on the indigestibility of the forage. Therefore, as indigestibility decreases, intake will increase.

Regression equations

Fecal CP and DMI from the 12 steers were regressed against ADG over the 24-d collection period. A study by McCollum (1990) demonstrated a positive correlation between fecal N (OM basis) with N intake and ADG. Coefficients of determination (r^2) for McCollum's (1990) study were .74 and .78 for N intake and ADG, respectively. These values are considerably larger than the determined r^2 in this study ($r^2 = .21$, Table 4.7). In addition, the slope for the equation of fecal N versus ADG was greater in the McCollum study (1.23 versus .24). The greater slope demonstrates a stronger relationship of fecal N and ADG of steers grazing tallgrass prairie. This does not suggest that increased fecal N can increase ADG, but that greater N intake may increase fecal N. This may be explained by the differences in N content between the two types of forage. The CP content of tallgrass prairie ranged from 9 to 14% as compared 16 to 19% for alfalfa.

The r^2 for ADG regressed against intake ranged from .34 to .74. A smaller percentage of the variation in ADG could be accounted for by DMI and OMI with the total collection than CR-prediction methods. In all cases, DMI had lower r^2 values than

Table 4.7. Regression and correlation coefficients of fecal N and intake versus ADG

Item	Y-intercept	SE	Probability	Slope	SE	Probability	r ²	Correlation coefficient, r	Probability
Fecal N									
DM basis	-4.11	2.30	.10	.31	.17	.10	.25	.50	.10
OM basis	-3.86	2.38	.14	.24	.15	.13	.21	.46	.13
Intake based on TC-D									
DMI	-1.14	.54	.06	.32	.14	.05	.34	.58	.05
OMI	-1.22	.40	.01	.38	.12	.01	.52	.72	.01
Intake based on TC-15D									
DMI	-1.16	.52	.05	.25	.11	.04	.35	.59	.04
OMI	-1.19	.33	.01	.28	.07	.003	.59	.76	.003
Intake based on CR-D									
DMI	-4.67	1.12	.002	.92	.22	.002	.64	.80	.002
OMI	-2.59	.50	.004	.58	.11	.0003	.74	.85	.0003
Intake based on CR-15D									
DMI	-4.49	1.04	.002	.69	.16	.001	.66	.81	.001
OMI	-2.02	.40	.001	.34	.07	.0004	.73	.86	.0004

OMI intake. As stated previously, this may be a result of removing the variation of mineral intake. Increasing forage digestibility by 15% to simulate esophageal extrusa digestibility increased the r^2 for intakes based on TC but not for CR-methods. Equations with r^2 greater than .5 are presented graphically in Figures 4.3 to 4.5.

Intakes predicted from regressions with r^2 greater than .5 (OMI, TC-D; OMI, TC-15D; DMI, CR-D; OMI, CR-D; DMI, CR-15D; and OMI, CR-15D), are presented in Table 4.8. For steers weighing 262 kg and gaining between .25 to 1.0 kg/d, NRC (1984) would predict DMI between 6.21 to 7.07 kg/d and OMI (based on 90% OM) from 5.59 to 6.36 kg/d. Dry matter intake based on CR-D are below estimated intakes (NRC, 1984), but intakes determined from CR-15D is within the range. Organic matter intakes determined in this study from TC-D, TC-15D and CR-D are within this range, but OMI determined from CR-15D is considerably greater.

Net energy of alfalfa

Estimated NE_m for alfalfa ranged from .84 to 1.56 Mcal/kg OM and .77 to .99 Mcal/kg DM depending on intake prediction procedure (Table 4.9). Values for NE_m from NRC (1984) for midbloom alfalfa are 1.24 (DM basis) and 1.36 (OM basis) Mcal/kg. The NRC values are considerably higher than those estimated from this study. Miller et al. (1991) demonstrated a decrease of NE_m with increasing maturity (1.48 to 1.33 Mcal/kg for early and late cut alfalfa, respectively). Net energy for maintenance predicted from OMI(TC-D) and OMI(TC-15D) provided the best fit to NRC (1984) values (1.56 and 1.18 versus 1.36 Mcal/kg OM).

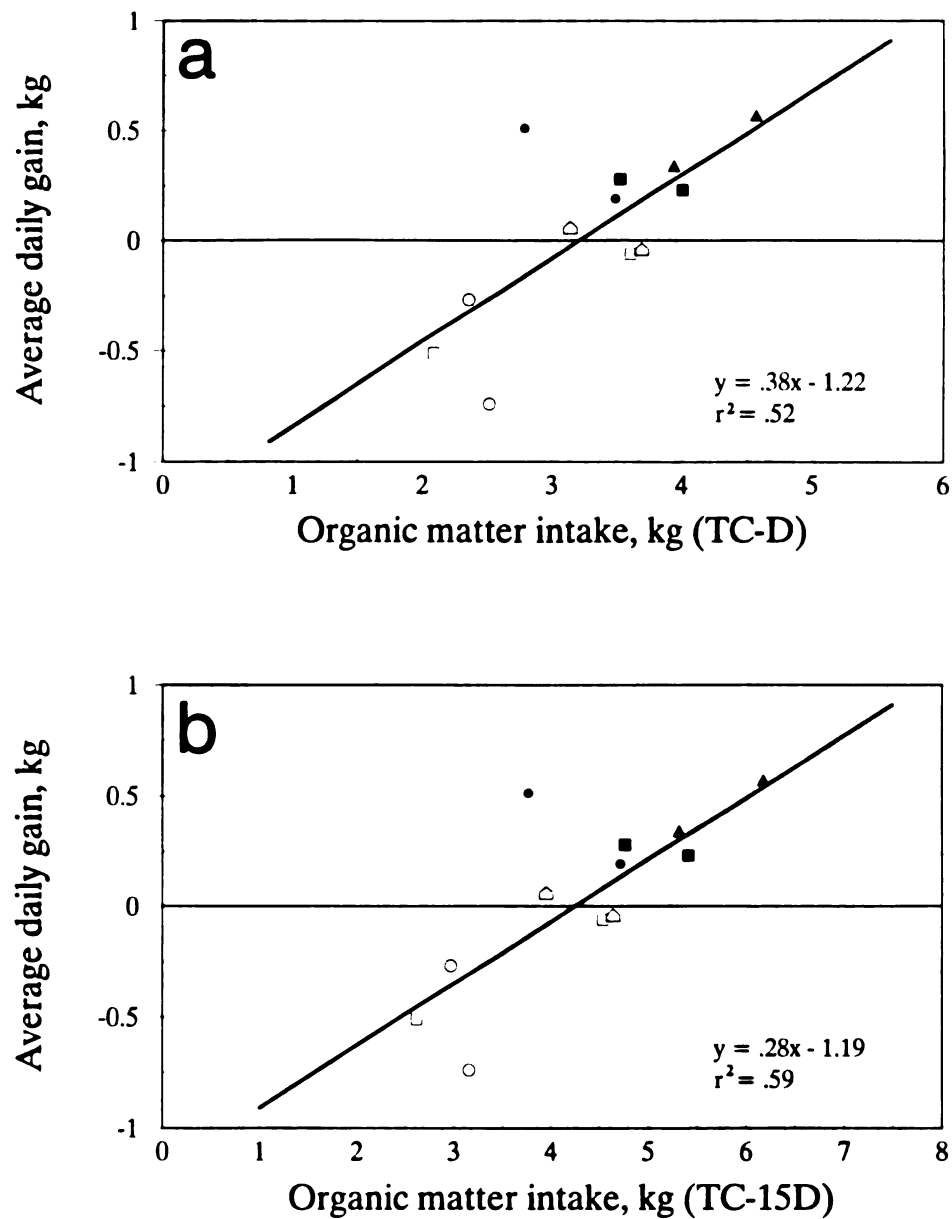


Figure 4.3. Relationship between average daily gain and organic matter intake as determined by total fecal collection and two OM digestibilities a) IVOMD, b) IVOMD increased 15%. Solid line is the regression equation based on 12 steers from two grazing methods (4-H, open points and 13-H closed points) and three grazing time allotments (6 h, $\square$ ■; 10 h $\circ$ ●; and 24 h, $\triangle$ ▲).

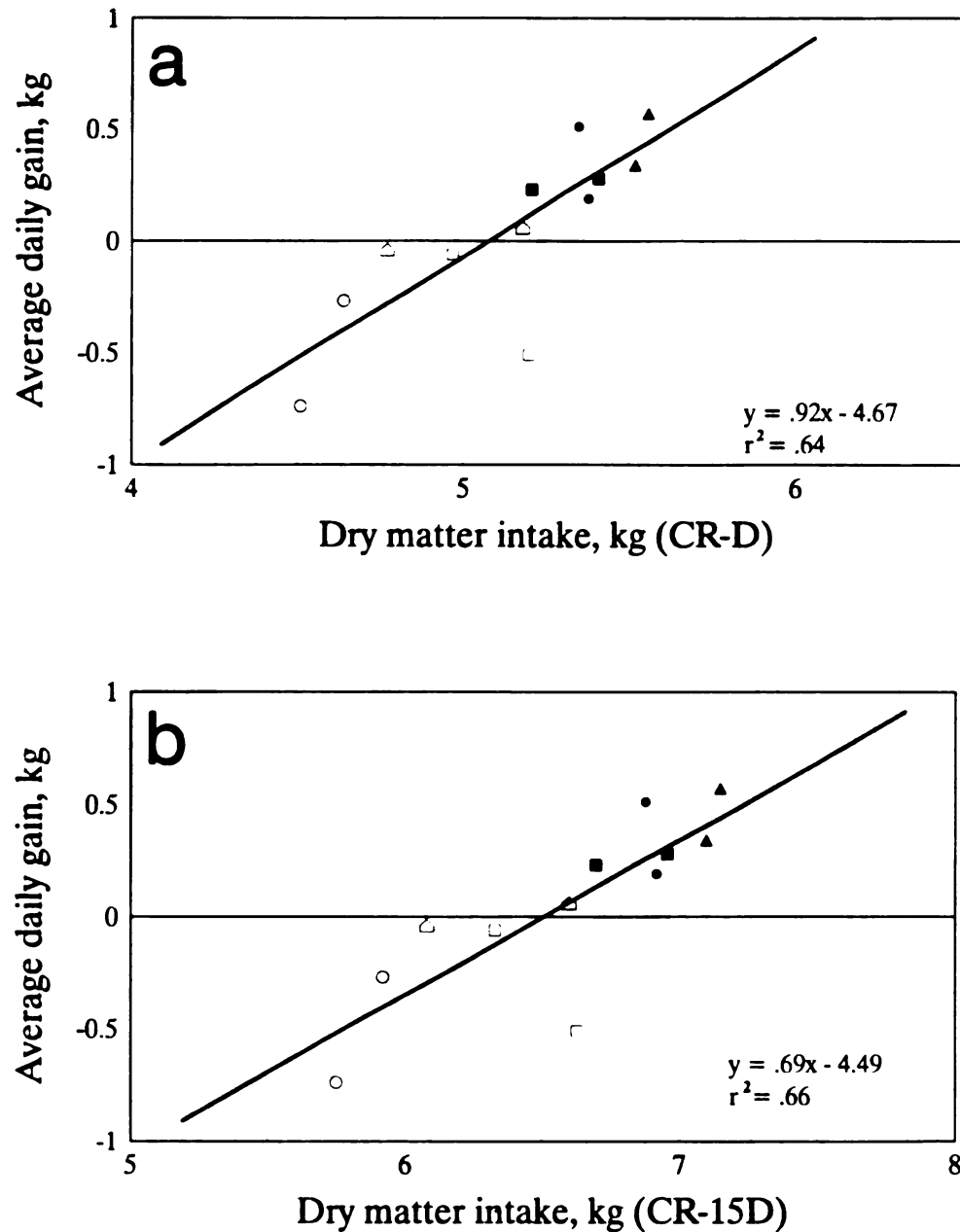


Figure 4.4. Relationship between average daily gain and dry matter intake as determined by CR-predicted fecal output and two DM digestibilities a) IVDMD, b) IVDMD increased 15%. Solid line is the regression equation based on 12 steers from two grazing methods (4-H, open points and 13-H closed points) and three grazing time allotments (6 h, $\square$ $\blacksquare$; 10 h $\circ$ $\bullet$; and 24 h, $\triangle$ $\blacktriangle$).

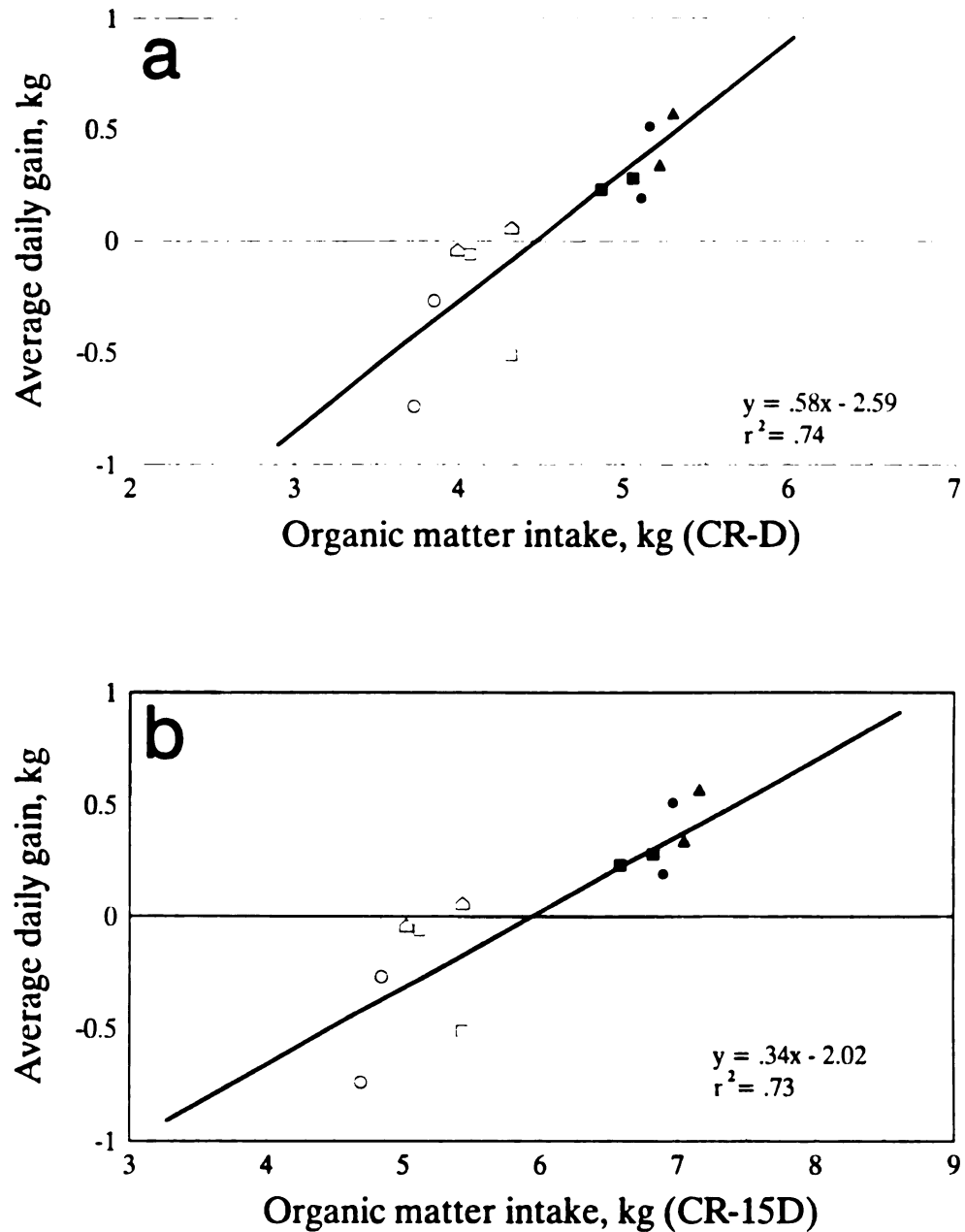


Figure 4.5. Relationship between average daily gain and organic matter intake as determined by Cr-predicted fecal output and two OM digestibilities a) IVOMD, b) IVOMD increased 15%. Solid line is the regression equation based on 12 steers from two grazing methods (4-H, open points and 13-H closed points) and three grazing time allotments (6 h, $\square$ $\blacksquare$; 10 h $\circ$ $\bullet$; and 24 h, $\triangle$ $\blacktriangle$).

Table 4.8. Predicted intakes derived from regression equations developed from six intake prediction procedures

ADG, kg	Intake prediction procedures					
	OMI (TC-D)	DMI (CR-D)	OMI (CR-D)	OMI (TC-15D)	DMI (CR-15D)	OMI (CR-15D)
	Predicted intake, kg					
0	3.21 (1.23) ¹	5.07 (1.94)	4.47 (1.71)	4.25 (1.62)	6.51 (2.48)	5.94 (2.27)
.25	3.87 (1.48)	5.35 (2.04)	4.90 (1.87)	5.14 (1.96)	6.87 (2.62)	6.68 (2.55)
.50	4.53 (1.73)	5.62 (2.15)	5.33 (2.03)	6.04 (2.31)	7.23 (2.76)	7.41 (2.83)
.75	5.18 (1.98)	5.89 (2.25)	5.76 (2.20)	6.93 (2.65)	7.59 (2.90)	8.15 (3.11)
1.00	5.84 (2.23)	6.16 (2.35)	6.19 (2.96)	7.82 (2.98)	7.96 (3.03)	8.88 (3.39)

¹Values in parentheses represent intakes expressed as a percent of BW (262 kg).

Table 4.9. Predicted net energy values of alfalfa derived from regression equations developed from six intake prediction procedures

Intake prediction procedures						
ADG, kg	OMI (TC-D)	DMI (CR-D)	OMI (CR-D)	OMI (TC-15D)	DMI (CR-15D)	OMI (CR-15D)
Estimated net energy for maintenance (NE _m) from regression equations, Mcal/kg						
0	1.56	.99	1.12	1.18	.77	.84
Estimated net energy for gain (NEg) from regression equations, Mcal/kg						
.25	1.06	2.59	1.63	.79	1.94	.95
.50	1.14	2.78	1.74	.84	2.08	1.02
.75	1.19	2.89	1.81	.87	2.17	1.05
1.00	1.22	2.97	1.87	.90	2.21	1.09
Average	1.15	2.81	1.76	.85	2.10	1.03

Average steer wt = 262 kg

NE_m required = 5.01 Mcal/d (NRC, 1984)

NE_g required = .70, 1.50, 2.34, and 3.21 Mcal/d for .25, .50, .75, and 1.00 kg LWG, respectively (NRC, 1984)

Greater variability was seen in the prediction of NE_g . National Research Council (1984) lists NE_g for midbloom alfalfa as .68 and .74 Mcal/kg for DM and OM, respectively. All values of NE_g determined in this study are considerably greater than the NRC values and those determined by Welch et al. (1969) for alfalfa hay and Miller et al. (1991) for alfalfa cubes. Net energy for gain greater than 1.75 Mcal/kg would appear unrealistic because these values would be greater than the NE_g for corn (NRC, 1984). Welch et al. (1969) determined the NE_g of alfalfa with 20% CP to be .88 Mcal/kg whereas Miller et al. (1991) reported values of .55 to .68 Mcal/kg. The differences between Welch et al. (1969) and Miller et al. (1991) and the present study are that the energy values calculated would suggest the energy value of pasture is greater than harvested forage. This observation would agree with those of Lofgreen et al. (1956) who saw similar gains in steers grazing alfalfa pasture or consuming silage but the grazing steers had 22 to 43% lower intakes. This, therefore led Lofgreen et al. (1956) to conclude that the alfalfa pasture had a greater NE value than did the silage.

Grass in early vegetative stage have greater NE_m and NE_g values than midbloom alfalfa (Table 4.10). As grass infiltrates the alfalfa pasture, the net energy value of the pasture could increase if the pasture is grazed when the grasses are at the early vegetative stage. If grasses are grazed at the midbloom to mature stage, the average of the pasture will be lower than a monoculture alfalfa pasture.

Table 4.10. Net energy values for common grasses and alfalfa (NRC, 1984)

Species and maturity	NE_m (Mcal/kg)¹	NE_g(Mcal/kg)
Bluegrass, kentucky		
fresh, early vegetative	1.70	1.08
fresh, mature	1.18	.61
Brome, smooth		
fresh, early vegetative	1.73	1.11
fresh, mature	1.07	.52
Orchardgrass		
fresh, early vegetative	1.70	1.08
fresh, midbloom	1.21	.64
Alfalfa		
fresh, late vegetative	1.41	.83
fresh, early bloom	1.31	.74
fresh, midbloom	1.24	.68
fresh, full bloom	1.14	.58

¹DM basis

IMPLICATIONS

The use of a slow-release Cr bolus must be used with caution because marker recovery was below 100% and Cr-release rates were below that reported by the manufacturer which resulted in increased fecal output estimates. Allotting animals to restricted grazing times did alter intakes and daily gains. Intakes of alfalfa pasture averaged 3.84 kg OM and 4.28 kg DM based on total fecal collections. Net energy for maintenance of alfalfa was estimated to be 1.18 to 1.56 Mcal/kg OM and NE_g at .85 to 1.15 Mcal/ kg OM. Therefore, NRC (1984) underestimates the net energy value of grazed alfalfa.

CHAPTER 5: CHARACTERIZATION OF PHOTSENSITIVITY OF CATTLE GRAZING ALFALFA PASTURES

SUMMARY

A study was conducted to characterize photosensitivity in cattle grazing a predominantly alfalfa pasture. Ninety-six Holstein steers (242 kg) were placed on an alfalfa pasture on May 20, 1989. Seventeen days after the initiation of the study, the first steer showed signs of hair loss and skin lesions. Twenty-one steers experiencing photosensitivity plus 11 non-affected steers were removed from the alfalfa pasture (d 24). The steers were placed in a feedlot with partially covered pens, and fed a corn silage-high moisture corn diet. A numerical scale was devised to separate steers into 4 groups based on severity of hair loss and lesion formation. Two blood samples were drawn from each steer 32 and 75 d following the beginning of the grazing study. The blood was used to determine the extent of liver damage by evaluating the concentration of two liver enzymes, aspartate transaminase (AST) and sorbitol dehydrogenase (SDH). Steers were weighed at the initiation of the grazing study and on d 24, 32, and 75. In 1990, a microbial assay was used to determine the potential of primary photosensitivity of the pasture. Fresh alfalfa samples, frozen alfalfa samples from 1989, grasses, and weeds found in the pasture were evaluated. All steers had similar weights over the period of the study. Serum AST values were within normal levels during the photosensitive (d 0

to 32) and recovery (d 33 to 75) periods. All steers had SDH levels 3.7 times greater than normal during the photosensitive period (68.75 IU/L) and 2.7 times greater during the recovery period (51.05 IU/L). No plants were found to have the potential to produce primary photosensitivity with the microbial assay used. Elevated SDH levels, an indication of liver damage, and the lack of a primary photosensitizer, may indicate hepatogenous photosensitivity had occurred.

INTRODUCTION

Photosensitivity is the sensitization of the superficial layers of lightly pigmented skin to sunlight. Photosensitivity is categorized into four groups; primary, hepatogenous, aberrant pigment metabolism and photosensitization of unknown origin (Clare, 1955; Johnson, 1986; Scott, 1988). Primary photosensitization is due to the ingestion of a photodynamic compound that enters the blood unchanged and causes a reaction in the skin. Buckwheat (*Polygonum fagopyrum*) and St. John's wort (*Hypericum perforatum*) are plants that cause primary photosensitivity in livestock (Evans, 1987).

Hepatogenous photosensitivity is a secondary condition caused by liver damage from an ingested hepatotoxin (Cornelius et al., 1965) or a genetic defect that occurs in sheep (Hancock, 1950). The liver damage or genetic defect decreases the ability of the liver to excrete phylloerythrin, which is the endproduct of the anaerobic breakdown of chlorophyll by microorganisms in the rumen and lower gastrointestinal (Clare, 1955; Scott, 1988). The accumulated phylloerythrin spills over into the serum and produces photosensitivity in peripheral tissues. Hepatogenous photosensitivity can be caused by plants, mycotoxins, infections, neoplasia, or chemicals (Scott, 1988).

Aberrant pigment metabolism results in photosensitization due to accumulation of porphyrins in the blood and body tissues due to aberrant porphyrin synthesis (Scott, 1988). Bovine congenital protoporphyria and bovine erythropoietic porphyria are examples of aberrant pigment metabolism due to autosomal recessive traits (Ruth et al., 1977).

Reports of photosensitivity often occur when common plants are grazed. These include alfalfa (*Medicago sativa*), clovers (*Trifolium spp.*), vetches (*Vicia spp.*) and oats (*Avena sativa*; Clare, 1955; Johnson, 1986; Scott, 1988), but the origin of the phototoxin is unknown.

The objective of this study was to characterize the photosensitive condition that developed unexpectedly in Holstein steers grazing alfalfa pastures, and characterize the origin of the photodynamic agent.

MATERIALS AND METHODS

Background

In 1989, 72 (239 kg) steers were randomly allocated to eight alfalfa (variety WL225) pasture plots (.76 ha) and four grazing systems. The systems consisted of a 4-paddock or a 13-paddock rotational grazing methods with SR of 7.9 and 15.8 steers/ha (Chapter 3). Twenty-four additional steers (250 kg) were on an alfalfa intake study grazing an adjacent pasture seeded to alfalfa (variety Big Ten) in 1987 (Chapter 4).

The first steer showed signs of erythema, hair loss, and necrosis of the lightly pigmented skin within 17 d (June 5) from the onset of grazing alfalfa (Figure 5.1). By d 24 (June 12), 21 steers showed varying degrees of hair loss. Hair loss ranged from



Figure 5.1. Steer exhibiting erythema, hair loss and skin necrosis following removal from an alfalfa pasture.

loss on the top line of the animal to extensive losses over the shoulder. Twenty-one steers (14 from the grazing system study, 7 from the intake study) with signs of sensitivity and 11 additional steers (10 from the grazing system study, 1 from the intake study) with normal appearance of the hair and skin were removed from the pasture study to allow the animals to recuperate.

Photosensitivity characterization

This study was conducted under approval from the Michigan State University All-University Committee on Animal Use and Care (AUF# 8/88-321-01). A system based on visual observation was devised to classify the severity of hair loss and skin damage in the 32 steers removed from pasture. The four point scoring system ranged from 0 to 3 with a score of 0 representing no hair loss; 1) hair loss only on the top line; 2) hair loss on top line and top of shoulder; and 3) considerable hair loss on top line and over the shoulders.

Cattle were grouped and housed according to hair loss score in five pens with concrete floors and partial cover (6.4 to 10.2 m²/steer). There were two pens of steers with a hair loss score of 0 and one pen for each of the other hair loss groups. Steers had ad libitum access to feed and water. The diet consisted of 64% corn silage, 30% high moisture corn, and 6% protein-mineral supplement (DM basis). Steers were weighed at the initiation of the grazing experiment (d 0) and 24 d later when steers were removed from the pasture. Eight days (d 32) and 51 d (d 75) after removal from pasture, steers were weighed and blood samples collected by jugular venipuncture. Serum samples were analyzed to determine extent of liver damage by evaluation of serum aspartate

transaminase (AST) and sorbitol dehydrogenase (SDH) concentrations. Aspartate transaminase and SDH are liver enzymes that become concentrated in the blood due to liver damage. The serum was analyzed by Veterinary Clinical Pathology Laboratory at Michigan State University which utilized enzyme kits to quantify serum AST (Electro-nucleonics, Fairfield, NJ) and SDH (Sigma Chemical Co., St. Louis, MO).

Variations in response between steers with different hair loss scores were determined with the General Linear Model subroutine of SAS (1987). Least square means were calculated and a Dunnett's test was used to compare cattle with hair loss scores 0 to 3 (Gill, 1978a).

Microbial assay

During the summer of 1990, pasture and weed specimens (Table 5.1) were collected to determine the potential for primary photosensitivity of the pasture. In addition, the photosensitivity potential of two alfalfa samples from the period when photosensitivity occurred in 1989 were analyzed. A microbial assay developed by Daniels (1965) as modified by Rowe et al. (1987) was used. The method developed by Daniels (1965) was used for the identification of plants or plant materials with photosensitizing properties of the psoralen type. Rowe et al. (1987) used the procedure by Daniels (1965) to identify *Cooperia pedunculata* as the photosensitizing agent of cattle in southwest Texas.

Fresh and frozen plant samples were placed on Sabouraud dextrose agar inoculated with a *Candida albicans* culture. The *C. albicans* culture was grown for 48 h in

Table 5.1. Plant specimens used to determine primary phototoxic potential of alfalfa pasture

Plant name	Plant part	Zone of Inhibition
Parsley (<i>Petroselinum crispum</i>)	stem	positive
	leaf	positive
Alfalfa (<i>Medicago sativa</i>)	stem	negative
	leaf	negative
1989 Alfalfa sample # 1	leaf	negative
1989 Alfalfa sample #2	leaf	negative
Wild carrot (<i>Daucus carota</i>)	leaf	negative
Alsike clover (<i>Trifolium hybridum</i>)	leaf	negative
Red clover (<i>Trifolium pratense</i>)	leaf	negative
White clover (<i>Trifolium repens</i>)	leaf	negative
White cockle (<i>Lychnis alba</i> Mill)	leaf	negative
Curly dock (<i>Rumex crispus</i>)	flower	negative
	leaf	negative
Dandelion (<i>Taraxacum officinale</i> Weber)	leaf	negative
Lambsquarter (<i>Chenopodium album</i> L.)	leaf	negative
Orchardgrass (<i>Dactylis glomerata</i>)	leaf	negative
Pennsylvania smartweed (<i>Polygonum pensylvanicum</i> L.)	flower	negative
	leaf	negative
Quackgrass (<i>Agropyron repens</i> L. Beauv)	leaf	negative

Sabouraud broth before the assay began. Penicillin and streptomycin were added to the agar (100 mg/L) to inhibit bacterial growth.

Eight plant particles per specie; leaves, stems or flowers, were placed on duplicate plates inoculated with the culture (4 particles/plate). One plate was placed under an 8 watt-longwave UV light (Fisher Scientific, Pittsburgh, PA) and the second plate was non-irradiated and placed in a dark box. The UV light was placed 22 cm above the plates. Parsley (*Petroselinum crispum*), a known primary photosensitizer (Daniels, 1965) was used as a positive control.

Forty-eight hours after initial UV irradiation, plates were observed for zones of inhibition around the plant particles. Irradiated plant particles exhibiting a zone of inhibition greater than the non-irradiated particles were considered to contain a primary phototoxin.

RESULTS AND DISCUSSION

Hair loss score groups 1,2, and 3 had similar ($P > .05$) weights on d 24, 32, and 75 as the control group (Table 5.2). Average daily gains were not different from d 0 to 32, but groups 1 and 2 had lower ($P < .05$) ADG during the recovery period than group 0. The normal range for AST and SDH is 45.3 to 110.2 and 6.1 to 18.4 IU/L (Fraser, 1986), respectively. Serum AST levels were within the normal range during the photosensitive (d 0 to 32) and recovery (d 33 to 75) periods (Table 5.3), and all steers had similar AST levels. Steers had SDH levels approximately 3.7 times greater than normal values during the photosensitive period and 2.7 times greater during the recovery period. Serum SDH levels were similar for each hair loss group during the

Table 5.2. Effects of photosensitization on live-weight gains

Item	Hair Loss Score							
	0	SE	1	SE	2	SE	3	SE
Number of steers	11		6		7		8	
Steer weight, kg								
Initial, d 0	236	8.3	237	11.2	244	10.4	243	9.7
Pasture removal, d 24	244	8.7	245	11.8	252	10.9	250	10.2
1st blood collection, d 32	243	8.0	248	10.8	254	10.0	247	9.4
2nd blood collection, d 75	302	9.7	283	13.1	292	12.1	302	11.3
Average daily gain, kg								
day 0 to 24	.36	.13	.47	.17	.34	.16	.28	.15
photosensitivity period ¹	.23	.10	.45	.14	.29	.13	.10	.12
recovery period ²	1.35	.10	.81*	.14	.89*	.13	1.30	.12

¹Photosensitivity period: d 0 to d 32

²Recovery period: d 32 to d 75

*Different than hair loss score 0 (P < .05)

photosensitive period and AST levels were similar during the photosensitive, but group 2 had higher ($P < .01$) SDH levels than control (0 hair loss score group) during the recovery period. Why this difference existed is not apparent.

All pasture plant specimens were negative, exhibiting no zone of inhibition. Parsley, a positive control, did show a zone of inhibition around the plant particles when irradiated with UV light. It is possible that plants present in 1989 were not present in 1990 or environmental conditions that caused the malady were different.

Development of similar symptoms has been reported from Oklahoma (Glenn et al., 1964; Putnam et al., 1986) in cattle fed water-damaged alfalfa hay. Clinical signs described were very similar to those observed in this study. Environmental similarities prior to the onset of the photosensitization were observed. In early June, 1989 East Lansing, MI experienced 8 cm of rain over a 3 d period which may have influenced the alfalfa plant in a similar fashion as in the Oklahoma study. Through histological liver studies, Glenn et al. (1964) determined liver dysfunction had occurred but the causative agent was not identified.

In the report by Putnam et al. (1986), two cows were fed the water-damaged alfalfa hay to determine the effects on liver function and hepatic enzyme activities. After feeding alfalfa, there was a rapid increase in AST (456%) and SDH (3500%) levels, peaking 8 to 11 d after alfalfa consumption. Following the initial peak, enzyme levels decreased but did not return to normal levels until the diet was changed. Cholestasis and bile duct necrosis were indicated as serum γ -glutamyl transferase was increased. Putnam et al. (1986) believed the photosensitivity resembled facial eczema caused by the

hepatotoxin sporidesmin. Sporidesmin is produced by the fungus *Pithomyces chartarum*. Attempts were made to detect molds, but none could be found.

In another report, cattle experienced photosensitivity grazing cicer milkvetch (*Astragalus cicer*) pastures (Marten et al., 1987). In that study, hair loss and sloughing of skin occurred only on white pigmented areas and a genetic predisposition to develop the malady was observed. Results from this study would support the previous premise of a genetic predisposition, in that not all the cattle developed hair loss even though enzyme levels were elevated and only white pigmented areas were affected. Marten et al. (1990) also observed photosensitivity in Hampshire sheep grazing alsike clover (*Trifolium hybridum*).

The actual cause of the photosensitivity observed has not been determined. Elevated SDH levels, an indication of liver damage, and the lack of a primary photosensitizer, may indicate hepatogenous photosensitivity had occurred. Steers developed photosensitivity grazing alfalfa pastures seeded in different years with different varieties. One field was infested with weeds whereas the other was not, which further suggest that the alfalfa was the source of the photosensitivity. Further studies need to be completed to determine whether the causative agent was plant, fungal or environmental and to define the relationship between these conditions and the development of the phenomenon. Although, this would be difficult to accomplish until a suitable model is developed.

IMPLICATIONS

This study cannot conclusively determine that the origin of the photosensitivity, but the elevated liver enzyme concentrations and absence of a primary photosensitizer suggests that hepatogenous photosensitivity was observed. In addition, the results from this study would suggest that all steers do not react to a photodynamic agent in a similar fashion as is evident by the increased SDH levels by steers in all hair loss score groups. Through the understanding of how environmental factors interact, photosensitivity may be prevented.

CHAPTER 6: CONCLUSIONS

The four year study described in this thesis determined that increasing paddock number from 4 to 13, did not increase beef produced per hectare or forage presented. Stocking rate impacted the grazing system to a far greater extent than did paddock number. The optimum stocking rate was 5.3 to 7.9 steers/ha (1289 to 1922 kg/ha). To further elucidate the stocking rate at which optimum per animal and per hectare gains are achieved further studies utilizing stocking rates between 5.3 to 7.9 steers/ha should be used.

As stated in the introduction of this thesis, a drawback to grazing experiments is the uncontrollable environment. In the first year, excessive rain in May and June resulted in trampling of the alfalfa and reduction of the stand. To alleviate this problem, a grass pasture available to place cattle in to prevent this trampling would be beneficial. Unfortunately, this strategy requires the removal and reintroduction of an alfalfa diet increasing the risk of bloat.

In addition to trampling problems, alfalfa weevils and alfalfa leaf hopper infested the pastures. Neither did extensive damage to the pasture, but the harvested plots turned yellow from the leaf hopper. This may also explain the poor yields from the harvested plots in year 1. Also in year 1, photosensitivity was observed. Before this condition was observed the author knew very little about the malady, and by the time the subject

was understood, the condition disappeared and did not surface again, preventing a complete analysis.

The importance of the electric fence cannot be overlooked, because without it, this study would be difficult and very expensive to conduct. In future studies, adapting steers to an electric fence prior to placement on pasture would be beneficial. This study did not train steers and the co-mingling of animal groups occurred in the first two weeks. In addition, paddocks to be grazed later in the grazing cycle were grazed before the scheduled time. The fence charger should be fully charging the fence before animals are placed on pasture.

As the study progressed, encroachment of grasses and weeds into the alfalfa pasture occurred. Animal and plant productivity increased annually over the four year study. This is likely the result of better environmental conditions and improved management skills by the author and the guidance committee. Alfalfa-grass pastures have been shown to produced more beef per hectare than grasses alone (Van Keuren and Heinemann, 1958; Van Keuren and Matches, 1988), but this author could not find research which compared an alfalfa-grass pasture to a pure stand of alfalfa. The author believes this would be a logical step in continuing research in the use of alfalfa for pasture.

The use of esophageally cannulated animals is effective in determining what the cattle consume. The animals require a great deal of post-operative care and the chance of the esophageal fistula closing is always a concern. More animals than needed should be fistulated to insure enough animals will be available for sample collection. Steers should be trained to a halter to allow easy collection of samples. The author would not

suggest the collection of esophageal extrusa unless a well defined objective for these samples is determined because the time required to collect such samples is great.

Answering objective two, comparing the forage productivity of a pasture system to a mechanically harvested system, was not accomplished as well as the other objectives. The main problem was the communication between the group conducting the research and those in charge of cutting and harvesting the alfalfa. The fields did not get cut when needed and the forage was not harvested in a timely fashion allowing increased field losses. The easiest way to alleviate this problem would be to have equipment available when needed. This is not always practical or possible. The other option is to use smaller areas and use plot harvesters or hand clipped areas to simulate mechanical harvest.

The feedlot phase (objective three) of the study did not demonstrate compensatory gain following a summer grazing program. During the first two years, steers entering the feedlot heavier were also slaughtered at heavier weights and tended to have greater estimated yield grades. Further studies should slaughter steers at an equal weight end point to determine if differences in carcass fat exist or if this observation was related to steer weight. A common end weight would also allow analysis of the number of days spent in the feedlot and the additional cost of light-weight steers entering the feedlot.

This thesis as well as other studies evaluated the use of a slow-release Cr bolus and determined it was not effective for determination of fecal output. Total fecal collection is time consuming and the animals should be trained to wear the harness and bag prior to collection, but it is the most accurate method to determine fecal output. Animals were not trained in this study and the animals were annoyed by the bags the first few hours.

The use of time allotments to alter intakes and ADG was effective (objective four). During the period of fecal collection, steers from the intake study had similar ADG as those steers used in evaluating grazing systems. Again, I stress the need for animals which are halter trained to allow the removal of animals from pasture.

It is difficult to know how accurately intakes were estimated. Based on NRC (1984), steers weighing 262 kg and gaining up to .45 kg/d should have a DMI at 2.4% of BW as compared to 1.6% of BW observed in this study. This would explain the increase in calculated net energy values (objective five). Estimation of intakes should be determined over an entire grazing season not just at one time point. In addition, digestible energy intake could be determined from gross energy values from forage samples, collected feces, and if possible esophageal extrusa samples. The estimated digestible energy intake could be used to check the accuracy of the calculated net energy values.

This author as well as the members of the guidance committee learned a great deal about conducting grazing experiments. Grazing experiments are expensive to initiate and very time consuming. This project expanded the knowledge base on alfalfa grazing systems in North America, and demonstrated the productive potential of such a system. Further research needs to explore the differences between pure alfalfa and alfalfa-grass pastures; the effect of grazing or mechanically harvesting alfalfa the summer following a late summer seeding; and the interaction of stocking rate on steer production.

APPENDICES

APPENDIX A: TERMINOLOGY OF GRAZING LANDS AND GRAZING ANIMALS

Defined by the Forage and Grazing Terminology Committee, 1991

Aftermath: Forage grown following a harvest.

Animal unit: One mature non-lactating bovine weighing 500 kg and fed at maintenance level, or the equivalent, expressed as (weight)⁷⁵, in other kinds of classes of animals (Table A.1).

Animal unit day: The amount of dry forage consumed by one animal unit per 24-hour period.

Browse: Leaf and twig growth of shrubs, woody vines, trees, cacti, and other non-herbaceous vegetation available for animal consumption. To browse. The consumption of browse by animals.

Carrying capacity: The maximum stocking rate that will achieve a target level of animal performance in a specified grazing method, that can be applied over a defined time period without deterioration of the ecosystem.

Continuous stocking: A method of grazing livestock on a specific unit of land where animals have unrestricted and uninterrupted access throughout the time period when grazing is allowed.

Creep grazing: The practice of allowing juvenile animals to graze areas that their dams cannot access at the same time.

Extensive grazing management: Grazing management that utilizes relatively large land areas per animal and a relatively low level of labor, resources or capital.

First-last grazing: A method of utilizing two or more groups of animals, usually with different nutritional requirements, to graze sequentially on the same land area.

Forage: Edible parts of plants, other than separated grain that can provide feed for grazing animals, or that can be harvested for feeding. To search for, or to consume forage.

Forb: Any herbaceous broadleaf plant that is not a grass and is not grass-like.

Forward creep: (see First-last grazing)

Graze: The consumption of forage by animals.

Grazing cycle: The time elapsed between the beginning of one grazing period and the beginning of the next grazing period in the same paddock where the forage is regularly grazed and rested.

Grazing event: The length of time that an animal grazes without stopping.

Grazing land management: The manipulation of the soil-plant-animal complex of the grazing land in pursuit of a desired result.

Grazing management: The manipulation of animal grazing in pursuit of a defined objective.

Grazing management unit: The grazing land area used to support a group of grazing animals for a grazing season. It may be a single area or it may have a number of subdivisions.

Grazing method: A defined procedure or technique of grazing management designed to achieve a specific objective(s).

Grazing period: The length of time that grazing livestock or wildlife occupy a specific land area.

Grazing pressure: The relationship between the number of animal units and the weight of forage dry matter per unit area at any one point in time; an animal-to-forage relationship.

Grazing season: The time period during which grazing can normally be practiced each year or portion of each year.

Grazing system: A defined, integrated combination of animal, plant, soil, and other environmental components and the grazing method by which the system is managed to achieve specific results or goals.

Herbaceous: Non-woody.

Intensive grazing management: Grazing management that attempts to increase production or utilization per unit area or production per animal through a relative increase in stocking rates, forage utilization, labor, resources, or capital.

Herbage: The biomass of herbaceous plants, other than separated grain, generally above ground but including edible roots and tubers.

Intermittent grazing: A method that imposes grazing for indefinite periods at irregular intervals.

Mixed grazing: Grazing by two or more species of grazing animals on the same land unit, not necessarily at the same time but within the same grazing season.

Mob grazing: In the management of a grazing unit, grazing by a relatively large number of animals at a high stocking density for a short time period.

Paddock: A grazing area that is a subdivision of a grazing management unit, and is enclosed and separated from other areas by a fence or barrier.

Pasture: A type of grazing management unit enclosed and separated from other areas by fencing or other barriers and devoted to the production of forage for harvest primarily by grazing.

Period of occupation: The length of time that a specific land area is occupied whether by one animal group, or by two or more animal groups in succession.

Period of stay: The length of time that a particular animal group occupies a specific land area.

Put-and-take stocking: The use of variable animal numbers during a grazing period or grazing season, with a periodic adjustment in animal numbers in an attempt to maintain desired sward management criteria, i.e., a desired quantity of forage, degree of defoliation or grazing pressure.

Residue: Forage remaining on the land as a consequence of harvest.

Ration grazing: Confining animals to an area of grazing land to provide the daily allowance of forage per animal.

Rest: To leave an area of grazing land ungrazed or unharvested for a specific time, such as a year, a growing season, or a specified period required within a particular management practice.

Rotational stocking: A grazing method that utilizes recurring periods of grazing and rest among two or more paddocks in a grazing management unit throughout the period when grazing is allowed.

Sequence grazing: The grazing of two or more land units in succession that differ in forage species composition.

Seasonal grazing: Grazing restricted to one or more specific seasons of the year.

Stocking density: The relationship between the number of animals and the specific unit of land being grazed at any one point in time.

Stocking rate: The relationship between the number of animals and the grazing management unit utilized over a specified time period.

Strip grazing: Confining animals to an area of grazing land to be grazed in a relatively short period of time, where the paddock size is varied to allow access to a specific land area.

Set Stocking: The practice of allowing a fixed number of animals on a fixed area of land during the time when grazing is allowed.

Stockpiling forage: To allow forage to accumulate for grazing at a later period.

Sward: A population of herbaceous plants, characterized by a relatively short habit of growth and relatively continuous ground cover, including both above and below-ground parts.

Table A.1. Factors for converting the number of grazing animals of different species and weight into standard livestock units (500 kg non-lactating bovine)

Sheep		Cattle	
Live weight, kg	Livestock units	Live weight, kg	Livestock units
10	.038	100	.30
20	.063	200	.50
30	.086	300	.68
40	.106	400	.84
50	.126	500	1.00
60	.145	600	1.15
70	.163	700	1.29

**APPENDIX B: COMMON AND SCIENTIFIC NAMES OF GRASSES AND
LEGUMES (Heath et al., 1985)**

Alfalfa	<i>Medicago sativa</i> L.
Bahiagrass	<i>Paspalum notatum</i> Flugge
Bermudagrass	<i>Cynodon dactylon</i> (L.) Pers.
Bluegrass, kentucky	<i>Poa pratensis</i> (L.)
Bromegrass, smooth	<i>Bromus inermis</i> Leyss.
Clover, alsike	<i>Trifolium hybridum</i> L.
Clover, red	<i>Trifolium pratense</i> L.
Clover, subterranean	<i>Trifolium subterraneum</i> L.
Clover, white	<i>Trifolium repens</i> L.
Corn	<i>Zea mays</i> L.
Crownvetch	<i>Coronilla varia</i> L.
Fescue, red	<i>Festuca rubra</i> L.
Fescue, tall	<i>Festuca arundinacea</i> Schreb.
Limpograss	<i>Hemarthria altissima</i> (Poir.) Stapf and Hubbard
Lupines	<i>Lupinus</i> spp. L.
Milkvetch, cicer	<i>Astragalus cicer</i> L.
Oats	<i>Avena sativa</i> L.
Orchardgrass	<i>Dactylis glomerata</i> L.
Quackgrass	<i>Agropyron repens</i> (L.) Beauv.
Rye	<i>Secale cereale</i> L.
Ryegrass, perennial	<i>Lolium perenne</i> L.
Sainfoin	<i>Onobrychis viciifolia</i> Scop.
Sweetclover, yellow	<i>Melilotus officinalis</i> Lam.
Trefoil, birdsfoot	<i>Lotus corniculatus</i> L.
Wheatgrass, intermediate	<i>Elytrigia intermedia</i> (Host) Nevski

APPENDIX C: TEMPERATURE AND RAINFALL DATA FOR 1989 THROUGH 1992

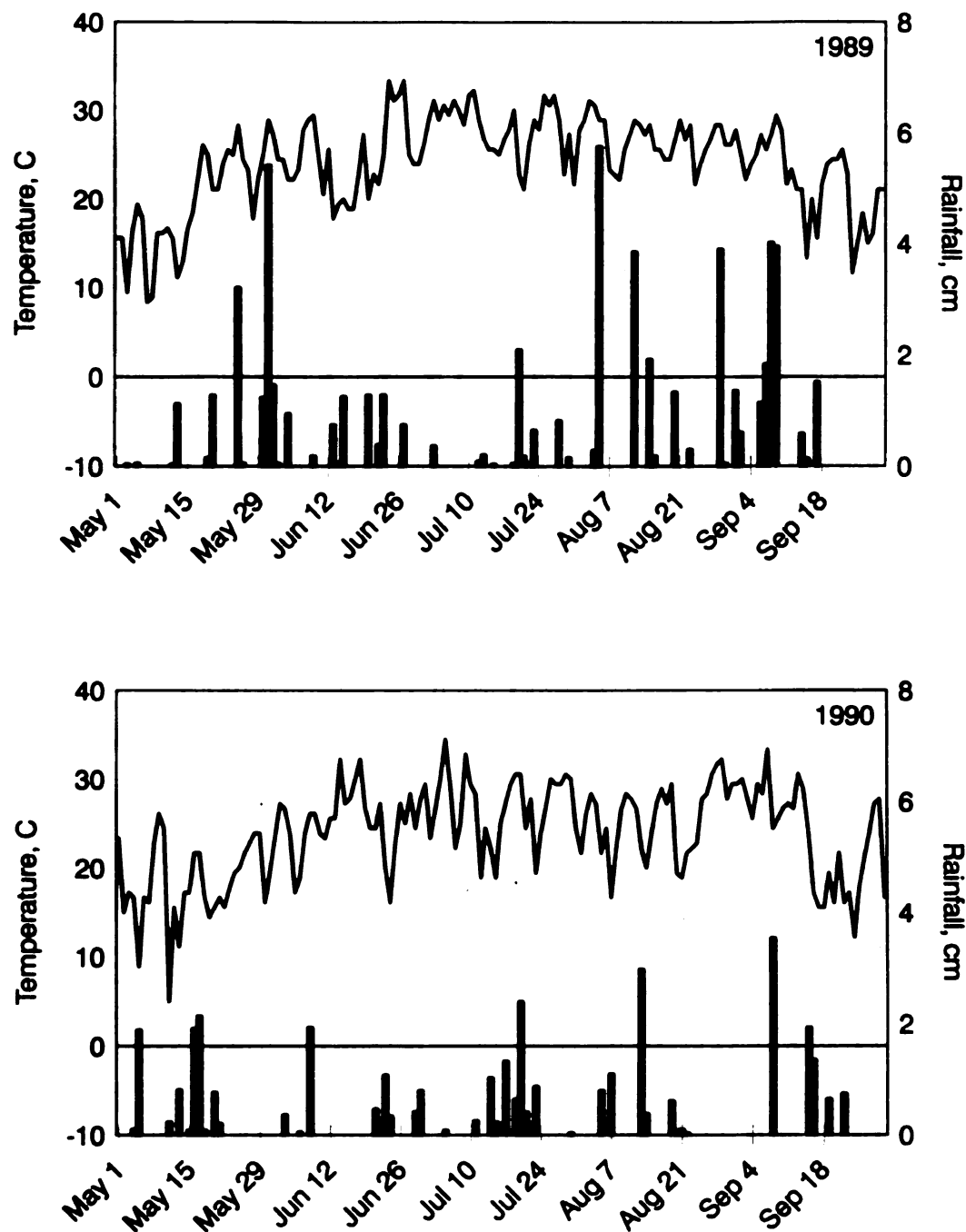


Figure C.1. Daily high (solid line) and low (dashed line) temperatures and daily rainfall (solid bars) from May to September 1989 and 1990.

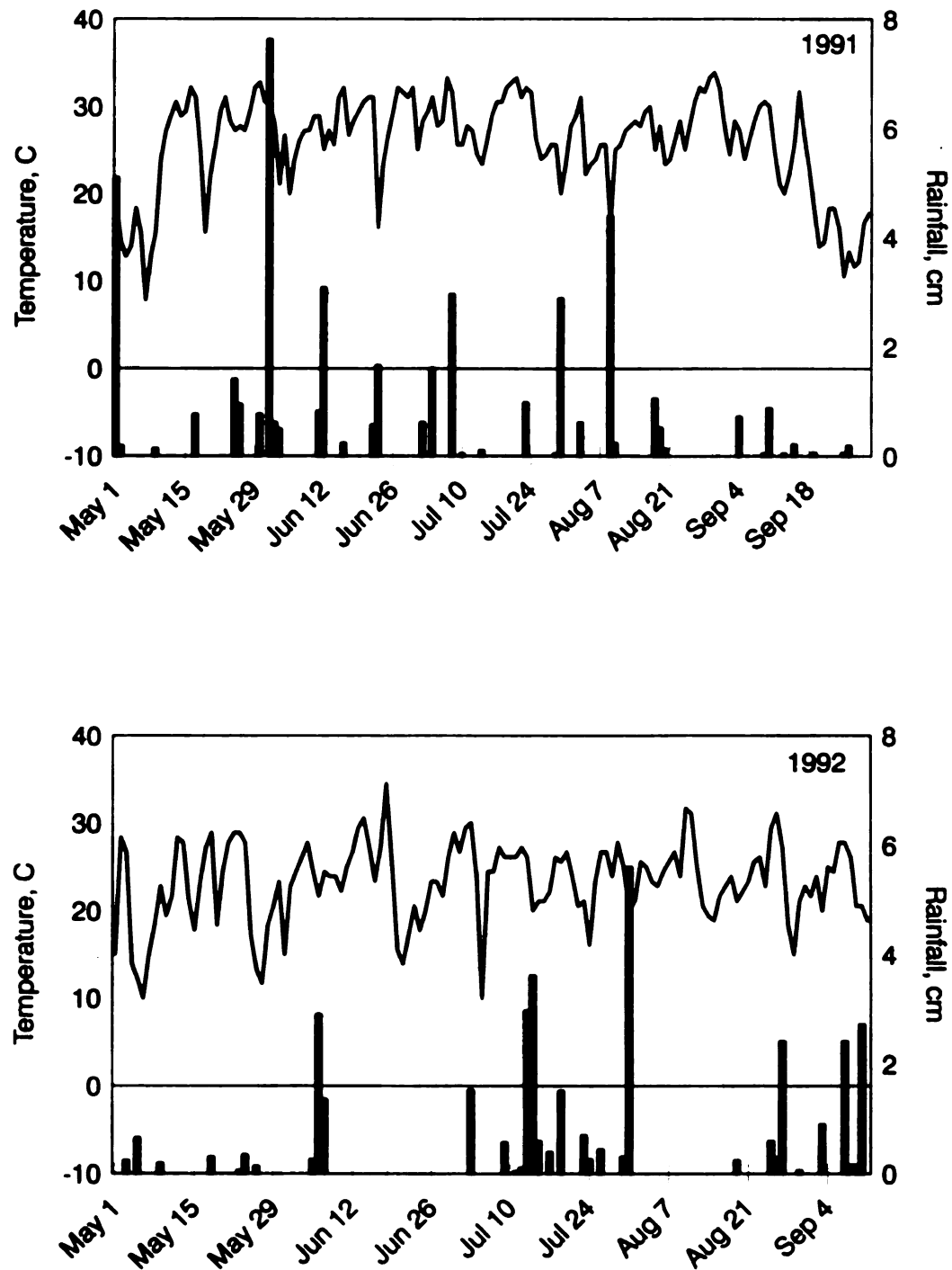


Figure C.2. Daily high (solid line) and low (dashed line) temperatures and daily rainfall (solid bars) from May to September 1991 and 1992.

**APPENDIX D: RAW DATA FROM THE GRAZING SYSTEM
STUDY, INTAKE STUDY AND CHARACTERIZATION OF
PHOTOSENSITIVITY**

Table D.1. Individual performance and carcass characteristics (1989)

Plot	GM	SR	Anim No.	1989				Pasture phase				Feedlot phase									
				Day 0				Avg.													
				05/17	05/19	06/13	06/25	38	38	06/27	07/22	08/15	08/30	08/30	09/26	10/25	11/22	12/20			
				full	full	full	full	wt.,lb	wt.,lb	shrunken	wt.,lb	wt.,lb	shrunken	wt.,lb	full	full	full	full	wt.,lb	wt.,lb	wt.,lb
1	4	L	6	465	425	445	510	533	555	585	621	621	585.0	609	795	930	1065	215			
1	4	L	12	510	495	503	515	500	521	611	651	651	615.0	641	780	890	995	1080			
1	4	L	15	530	505	518	530	Photosensitive (Group 1)													
1	4	L	26	485	465	475	505	500	521	588	608	608	560.0	583	675	760	855	945			
1	4	L	33	440	430	435	480	Reduced stocking rate (Group 0)													
1	4	L	103	465	470	468	500	500	521	600	648	648	615.0	641	760	845	945	1045			
2	13	L	22	525	505	515	550	572	596	673	703	703	690.0	719	850	950	1050	1085			
2	13	L	42	450	425	438	485	495	516	570	585	585	560.0	583	685	785	880	940			
2	13	L	50	495	485	490	556	576	600	649	665	665	640.0	667	775	875	920	1005			
2	13	L	74	490	485	488	505	Photosensitive (Group 3)													
2	13	L	92	460	460	460	510	547	570	611	630	630	595.0	620	765	815	895	960			
2	13	L	120	495	475	485	525	Photosensitive (Group 3)													
3	13	H	1	525	500	513	520	Reduced stocking rate (Group 0)													
3	13	H	5	435	420	428	445	Reduced stocking rate (Group 0)													
3	13	H	24	520	500	510	515	552	575	555	551	551	505.0	526	600	780	865	970			
3	13	H	25	520	485	503	530	577	601	575	626	626	550.0	573	665	800	875	925			
3	13	H	36	495	470	483	505	Photosensitive (Group 1)													
3	13	H	59	480	450	465	486	Reduced stocking rate (Group 0)													
3	13	H	64	480	455	468	495	535	557	550	564	564	525.0	547	610	735	830	925			
3	13	H	73	495	465	480	525	563	586	575	638	638	585.0	609	Removed from trial						
3	13	H	86	525	520	523	565	547	570	585	621	621	585.0	609	685	835	915	960			
3	13	H	97	500	465	483	500	542	565	572	575	575	540.0	563	655	815	895	955			
3	13	H	99	470	450	460	468	507	528	500	523	523	485.0	505	575	720	785	820			
3	13	H	115	480	445	463	470	503	524	505	509	509	470.0	490	610	780	830	900			
4	4	H	10	505	520	513	505	527	549	565	560	560	540.0	563	645	745	860	945			

Table D.1. (Cont'd.)

Plot	GM	SR	Anim No.	1989			Pasture phase			Feedlot phase									
				05/17	05/19	Day 0	24/25	38	38	63	87	103	103	08/30	08/30	09/26	10/25	11/22	12/20
				full	full	full	full	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	shrunken	shrunken	wt.,lb	wt.,lb	wt.,lb	wt.,lb
4	4	H	43	450	440	445	470	500	521	510	522	470.0	490	490	640	750	130	159	215
4	4	H	46	465	440	453	470	534	556	590	612	Died from bloat 8/25/89	500	500	630	755	875	945	945
4	4	H	63	495	480	488	500	504	525	570	600	480.0	500	500	665	785	850	905	945
4	4	H	68	525	495	510	520	505	526	560	598	545.0	568	568	710	810	910	990	990
4	4	H	69	525	490	508	500	554	577	600	610	570.0	594	594	710	810	895	920	920
4	4	H	80	490	465	478	500	549	572	620	632	600.0	625	625	710	810	860	940	940
4	4	H	94	500	490	495	520	Photosensitive (Group 3)	548	571	575	553	530.0	552	690	785	860	940	940
4	4	H	95	525	480	503	515	Photosensitive (Group 3)	680	708	650	618	590.0	615	740	840	955	1035	1035
4	4	H	113	465	435	450	455	Reduced stocking rate (Group 0)	652	679	655	625	585.0	609	675	780	865	920	920
4	4	H	119	535	495	515	530	Reduced stocking rate (Group 0)	604	629	600	566	535.0	557	625	740	835	870	870
4	4	H	122	490	440	465	480	Photosensitive (Group 2)	564	588	565	541	505.0	526	680	825	900	1020	1020
6	13	H	11	645	620	633	660	Photosensitive (Group 2)	603	628	613	640	560.0	583	700	840	920	1000	1000
6	13	H	13	595	580	588	600	Reduced stocking rate (Group 0)	611	636	640	654	605.0	630	795	915	990	1100	1100
6	13	H	16	640	630	635	655	Reduced stocking rate (Group 0)	658	685	650	665	605.0	630	670	775	830	885	885
6	13	H	34	595	575	585	575	Reduced stocking rate (Group 0)	610	635	598	564	540.0	563	760	920	1030	1135	1135
6	13	H	47	550	535	543	530	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
6	13	H	51	560	535	548	555	Reduced stocking rate (Group 0)	574	598	681	700	650.0	677	785	920	1055	1140	1140
6	13	H	52	545	520	533	520	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
6	13	H	65	580	540	560	530	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
6	13	H	87	580	560	570	600	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
6	13	H	106	550	550	550	590	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
6	13	H	116	590	575	583	520	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
6	13	H	123	580	560	570	555	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
7	4	L	4	640	630	635	700	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140
7	4	L	41	580	555	568	595	Photosensitive (Group 2)	574	598	681	700	650.0	677	785	920	1055	1140	1140

Table D.1. (Cont'd.)

1989				Pasture phase				Feedlot phase													
Plot	GM	SR	Anim No.	05/17	05/19	Day 0	24/25	38	38	63	87	103	103	Feedlot phase							
				full	full	full	full	shrunken	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb		
7	4	L	78	570	560	565	580	556	579	660	693	635.0	661	755	890	985	1080				
7	4	L	93	535	545	540	580	566	590	660	698	650.0	677	760	880	970	1060				
7	4	L	110	565	550	558	605	596	621	710	734	690.0	719	780	910	895	1070				
7	4	L	121	600	590	595	620	Reduced stocking rate (Group 0)													
8	4	H	2	620	590	605	630	593	618	672	680	Died from bloat 8/25/89				845	1025				
8	4	H	19	550	550	550	580	569	593	625	645	600.0	625	705	845	930					
8	4	H	29	575	585	580	610	615	641	657	665	Died from bloat 8/25/89									
8	4	H	30	570	545	558	545	Photosensitive (Group 2)													
8	4	H	40	560	560	560	610	Photosensitive (Group 1)													
8	4	H	53	590	575	583	600	Photosensitive (Group 3)													
8	4	H	55	600	570	585	585	583	607	615	610	560.0	583	665	810	925	1030				
8	4	H	56	560	545	553	545	565	589	620	630	560.0	583	660	835	940	990				
8	4	H	58	610	575	593	585	585	609	604	617	Died from bloat 8/25/89									
8	4	H	77	535	540	538	570	565	589	615	635	580.0	604	640	800	865	945				
8	4	H	79	545	545	545	570	552	575	572	593	530.0	552	605	755	850	960				
8	4	H	88	565	545	555	545	Photosensitive (Group 3)													
9	13	L	9	585	570	578	620	Reduced stocking rate (Group 0)													
9	13	L	17	580	565	573	580	Reduced stocking rate (Group 0)													
9	13	L	21	595	580	588	615	612	638	681	708	675.0	703	775	850	945	1020				
9	13	L	57	545	540	543	590	616	642	645	645	615.0	641	735	870	995	1090				
9	13	L	101	580	550	565	600	601	626	700	712	685.0	714	800	900	1000	1070				
9	13	L	112	580	565	573	630	662	690	736	782	760.0	792	830	920	970	1045				

Table D.1. (Cont'd.)

Anim No.	Carcass Data									
	243 01/17 full wt.,lb	271 02/14 full wt.,lb	299 03/14 full wt.,lb	324 04/08 full wt.,lb	325 04/09 full wt.,lb	Avg. End wt.,lb	Hot carcass wt.,lb	Dressing percent, %	Choice Quality Grade	Yield Grade
6	1280	1375	1440	1600	1590	1595	932	58.43	1	4
12	1175	1230	1280	1380	1370	1375	804	58.47	1	2
15										
26	1035	1100	1140	1205	1210	1208	685	56.73	1	2
33										
103	1110	1210	1260	1390	1375	1383	784	56.71	1	2
22	1220	1320	1395	1465	1460	1463	830	56.75	1	3
42	1045	1110	1200	1255	1245	1250	766	61.28	1	3
50	1145	1230	1290	1350	1320	1335	767	57.45	1	2
74										
92	1055	1120	1190	1260	1235	1248	692	55.47	1	3
120										
1										
5										
24	1070	1185	1260	1365	1360	1363	750	55.05	1	2
25	1030	1135	1225	1290	1300	1295	727	56.14	1	2
36										
59										
64	1040	1145	1200	1235	1265	1250	747	59.76	1	2
73										
86	1060	1130	1210	1290	1290	1290				
97	1060	1155	1235	1335	1300	1318	759	57.61	1	3
99	945	1050	1110	1205	1195	1200	669	55.75	1	3
115	1010	1110	1190	1230	1240	1235	692	56.03	1	2
10	1060	1140	1230	1245	1270	1258	754	59.96	1	2

Table D.1. (Cont'd.)

Anim No.	Carcass Data									
	243 01/17 full wt.,lb	271 02/14 full wt.,lb	299 03/14 full wt.,lb	324 04/08 full wt.,lb	325 04/09 full wt.,lb	Avg. End wt.,lb	Hot carcass wt.,lb	Dressing percent, %	Choice Quality Grade	Yield Grade
43										
46										
63	1065	1150	1220	1265	1290	1278	756	59.18	1	3
68										
69	1045	1160	1225	1340	1330	1335	766	57.38	1	3
80	1000	1060	1100	1185	1205	1195	698	58.41	1	3
94	1090	1155	1230	1300	1300	1300	769	59.15	1	3
95	1020	1110	1160	1205	1220	1213	716	59.05	1	3
113										
119	1020	1040	1105	1190	1185	1188	642	54.06	1	2
122										
11	1140	1205	1275	1325	1320	1323	859	64.95	1	3
13										
16	1005	1085	1125	1150	1140	1145	769	67.16	1	2
34	995	1040	1135	1165	1170	1168	688	58.93	1	3
47										
51										
52	1125	1250	1270	1365	1350	1358	660	48.62	1	2
65										
87	1095	1220	1240	1290	1280	1285	810	63.04	1	2
106	1175	1260	1340	1415	1425	1420	763	53.73	1	3
116	945	1000	1025	1080	1090	1085	812	74.84	0	3
123	1240	1355	1400	1475	1485	1480	582	39.32	0	2
4										
41	1245	1360	1410	1480	1490	1485	872	58.72	1	3

Table D.1. (Cont'd.)

Anim No.	Carcass Data									
	243 01/17 full wt.,lb	271 02/14 full wt.,lb	299 03/14 full wt.,lb	324 04/08 full wt.,lb	325 04/09 full wt.,lb	Avg. End wt.,lb	Hot carcass wt.,lb	Dressing percent, %	Choice Quality Grade	Yield Grade
78	1160	1235	1310	1370	1385	1378	817	59.31	1	3
93	1145	1225	1320	1405	1405	1405	813	57.86	1	2
110	1165	1235	1305	1380	1390	1385	803	57.98	1	3
121										
2										
19	1140	1240	1300	1415	1375	1395	810	58.06	1	2
29										
30										
40										
53										
55	1130	1210	1280	1345	1355	1350	811	60.07	1	3
56	1110	1165	1285	1335	1375	1355	763	56.31	1	2
58										
77	1050	1115	1215	1310	1310	1310	771	58.85	1	3
79	935	1055	1190	1330	1285	1308	726	55.53	1	2
88										
9										
17										
21	1115	1190	1220	1300	1325	1313	784	59.73	1	3
57	1200	1295	1380	1465	1475	1470	852	57.96	1	3
101	1135	1175	1295	1385	1380	1383	794	57.43	1	2
112	1135	1195	1275	1345	1330	1338	809	60.49	1	3

Table D.2. Individual performance and carcass characteristics (1990)

1990			Pasture phase										Average			Rumen adapt.			period
			DAY 0		25		49		73		97		108		109		115	116	Adapt.
			Anim.	05/13	05/14	Average	wt.,lb	06/08	wt.,lb	07/02	wt.,lb	07/26	wt.,lb	08/19	wt.,lb	08/30			
Plot	GM	SR	No.	wt.,lb	480	485	545	597	653	700	695	675	685	745	755	750			
1	4	L	43	490	480	485	545	597	653	700	695	675	685	745	755	750			
1	4	L	45	475	465	470	510	548	595	620	620	625	623	655	675	665			
1	4	L	74	510	510	510	545	602	640	675	665	675	670	730	735	733			
1	4	L	100	495	495	495	530	587	634	667	650	640	645	680	690	685			
2	13	L	52	510	505	508	565	606	670	709	690	715	703	715	740	728			
2	13	L	66	500	500	500	540	600	631	695	695	720	708	730	745	738			
2	13	L	84	495	485	490	555	610	686	735	730	710	720	785	770	778			
2	13	L	95	485	485	485	540	607	675	715	715	745	730	785	760	773			
3	13	H	10	500	490	495	535	567	586	605	640	605	623	660	660	660			
3	13	H	21	475	475	475	515	560	581	616	630	620	625	695	680	688			
3	13	H	40	505	530	518	525	564	555	572	595	570	583	615	630	623			
3	13	H	49	490	490	490	505	535	547	570	585	575	580	645	640	643			
3	13	H	55	505	510	508	520	596	581	607	620	595	608	650	660	655			
3	13	H	63	485	480	483	515	542	562	571	590	560	575	600	610	605			
3	13	H	76	505	510	508	545	583	585	600	645	610	628	665	675	670			
3	13	H	92	485	475	480	525	563	566	600	635	595	615	670	655	663			
4	4	H	6	505	490	498	520	565	579	630	640	595	618	660	620	640			
4	4	H	23	485	490	488	500	555	534	593	605	560	583	620	540	580			
4	4	H	26	475	475	475	475	500	490	542	560	535	548	590	555	573			
4	4	H	28	510	510	510	535	585	600	635	680	655	668	700	665	683			
4	4	H	29	500	500	500	520	566	583	632	620	600	610	660	650	655			
4	4	H	50	500	495	498	505	535	543	579	565	550	558	595	605	600			
4	4	H	71	505	510	508	500	530	541	582	575	565	570	615	615	615			
4	4	H	82	510	525	518	570	620	625	659	680	660	670	715	740	728			
6	13	H	7	535	530	533	535	550	569	574	600	580	590	620	640	630			
6	13	H	15	515	535	525	555	590	600	610	655	640	648	685	685	685			
6	13	H	20	520	520	520	565	620	609	644	650	615	633	720	725	723			

Table D.2. (Cont'd.)

Anim. No.	Feedlot phase				Carcass Data										Yield Grade
	140	163	190	219	247	274	303	338	341	342	Avg. End	Hot carcass wt., lb	Dressing percent, %	Choice Quality Grade	
No.	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb			
43	810	895	980	1055	1140	1240	1315		1410	1405	1408	821	58.33	1	2
45	700	780	885	975	1050	1135	1205		1285	1285	1285	741	57.67	1	2
74	765	840	960	1050	1135	1220	1305		1345	1360	1353	813	60.11	1	3
100	730	835	940	1005	1085	1170	1245		1305	1305	1305	768	58.85	1	3
52	815	875	1005	1070	1120	1185	1280	1335	1360	1360	1360	789	58.01	1	2
66	805	865	1000	1100	1170	1255	1360	1445	1460	1460	1460	859	58.84	1	3
84	840	845	1035	1120	1195	1285	1380	1490	1470	1460	1465	880	60.07	1	3
95	825	880	1010	1215	1175	1260	1380	1465	1460	1450	1455	857	58.90	1	4
10	700	745	845	935	995	1085	1155	1190	1180	1190	1185	684	57.72	1	2
21	705	780	895	955	1055	1150	1260	1345	1340	1340	1340	792	59.10	1	2
40	640	685	770	830	920	995	1095	1145	1145	1155	1150	650	56.52	0	3
49	680	770	875	940	975	1065	1185	1210	1215	1225	1220	715	58.61	1	3
55	680	735	835	920	1015	1100	1170	1245	1240	1240	1240	707	57.02	1	2
63	610	660	780	870	965	1040	1120	1210	1190	1200	1195	669	55.98	1	2
76	740	805	930	1010	1090	1190	1290	1390	1345	1375	1360	799	58.75	1	2
92	685	745	830	870	935	1025	1115	1150	1145	1155	1150	680	59.13	1	2
6	755	825	965	1040	1105	1210	1270	1330	1340	1340	1340	810	60.45	1	3
23	690	750	870	955	965	1055	1135	1230	1240	1250	1245	724	58.15	1	2
26	655	720	825	920	1000	1070	1170	1265	1250	1260	1255	693	55.22	1	2
28	655	750	830	935	1010	1100	1235	1310	1310	1310	1310	760	58.02	1	2
29	710	780	880	915	995	1095	1180	1245	1235	1240	1238	728	58.83	1	2
50	655	705	805	875	915	1000	1085	1100	1080	1090	1085	628	57.88	1	3
71	690	740	855	925	970	1065	1165	1240	1250	1240	1245	723	58.07	1	2
82	740	795	900	960	1030	1095	1200	1245	1260	1265	1263	714	56.55	1	2
7	715	770	875	960	1045	1100	1180	1240	1260	1275	1268	727	57.36	1	2
15	720	695	785	885	920	980	1055	1140	1150	1140	1145	643	56.16	1	2
20	770	760	820	915	955	995	1015	1055	1050	1040	1045	611	58.47	1	2

Table D.2. (Cont'd.)

Anim. No.	Feedlot phase										Carcass Data				Yield Grade
	140	163	190	219	247	274	303	338	341	342	Avg.	Hot carcass wt., lb	Dressing percent, %	Choice Quality Grade	
No.	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb			
58	775	840	930	1020	1095	1185	1255	1295	1310	1320	1315	729	55.44	1	2
73	865	895	1030	1100	1220	1305	1385	1480	1505	1510	1508	876	58.11	1	3
78	655	725	800	870	930	1000	1105	1190	1205	1195	1200	675	56.25	1	2
98	780	830	930	1030	1125	1210	1300	1410	1430	1420	1425	835	58.60	1	3
101	720	770	860	945	995	1085	1110	1245	1250	1255	1253	711	56.77	1	3
11	775	865	960	1040	1105	1190	1235	1240	1270	1260	1265	747	59.05	1	3
17	885	940	1050	1145	1190	1270	1310	1425	1460	1450	1455	840	57.73	1	3
48	810	925	1025	1170	1215	1305	1390	1480	1505	1505	1505	862	57.28	1	2
64	795	855	965	1040	1120	1195	1275	1310	1350	1335	1343	792	58.99	1	2
3	760	825	940	1065	1125	1205	1260	1330	1330	1315	1323	774	58.53	1	3
4	770	825	920	1005	1065	1145	1230	1300	1305	1305	1305	719	55.10	1	2
8	735	800	905	1025	1075	1200	1235	1295	1295	1295	1295	775	59.85	1	2
38	745	785	910	985	1045	1135	1200	1295	1290	1285	1288	758	58.87	1	2
54	785	865	985	1090	1170	1265	1320	1370	1380	1375	1378	788	57.21	1	2
57	725	800	905	1030	1090	1185	1245	1300	1300	1290	1295	757	58.46	1	2
59	765	820	920	970	1045	1110	1185	1225	1215	1215	1215	711	58.52	1	2
75	665	725	825	895	965	1055	1110	1195	1190	1180	1185	701	59.16	1	2
5	865	905	1010	1105	1180	1225	1335	1445	1445	1440	1443	848	58.79	1	3
41	805	885	1000	1105	1155	1230	1325	1400	1400	1395	1398	842	60.25	1	2
42	760	815	930	1010	1105	1200	1270	1340	1320	1315	1318	764	57.99	1	3
77	860	945	1050	1165	1215	1315	1400	1515	1490	1515	1503	876	58.30	1	3

Table D.3. Individual performance and carcass characteristics (1991)

1991			Pasture phase				Rumen adapt. period				Feedlot phase																		
Plot	GS	SR	Anim No.	05/11		05/13		Day 0		24		81		112		119		120		Adapt. period		136		137		Avg. init		192	
				wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb
1	4	2	279	500	490	495	580	690	750	805	810	808	805	830	818	1015													
1	4	2	280	480	475	478	569	675	630	625	628	628	600	Removed from trial										805					
1	4	2	309	430	435	433	435	540	585	605	610	608	605	605	603	805													
1	4	2	310	510	510	510	534	625	670	705	710	708	725	710	718	925													
2	13	2	258	470	470	470	484	585	635	680	675	678	705	700	703	940													
2	13	2	276	515	510	513	522	610	665	705	710	708	700	700	700	860													
2	13	2	289	455	445	450	500	575	620	670	665	668	660	680	670	815													
2	13	2	296	485	480	483	525	635	680	710	710	710	730	740	735	970													
3	13	3	257	500	500	500	529	680	780	810	790	800	795	800	798	1070													
3	13	3	263	480	480	480	529	600	650	700	700	700	720	730	725	970													
3	13	3	273	460	465	463	501	590	725	750	765	758	775	775	775	985													
3	13	3	283	460	440	450	451	530	655	700	695	698	690	695	693	885													
3	13	3	291	460	450	455	498	590	585	660	645	653	640	640	640	880													
3	13	3	299	500	485	493	510	580	600	665	660	663	610	610	610	840													
4	4	3	252	475	460	468	469	540	565	605	590	598	550	560	555	835													
4	4	3	265	510	505	508	567	690	745	775	765	770	745	740	743	960													
4	4	3	281	490	490	490	542	665	710	725	725	725	705	725	715	955													
4	4	3	284	490	470	480	515	675	740	775	765	770	750	750	750	970													
4	4	3	312	470	475	473	467	540	565	600	590	595	585	585	585	885													
4	4	3	315	460	445	453	476	585	650	680	665	673	645	650	648	935													
6	13	3	251	565	570	568	617	690	710	780	770	775	795	800	798	1070													
6	13	3	255	550	535	543	611	670	680	755	745	750	750	765	758	985													
6	13	3	256	540	530	535	607	650	675	770	755	763	760	780	770	995													
6	13	3	259	670	670	670	729	790	810	905	900	903	900	925	913	1185													
6	13	3	277	580	590	585	655	675	680	760	745	753	750	760	755	1000													

Table D.3. (Cont'd.)

Plot	GS	SR	Anim No.	1991		Pasture phase		Rumen adapt. period		Feedlot phase		Avg. init feedlot wt.,lb	192 wt.,lb
				05/11 wt.,lb	05/13 wt.,lb	Day 0 Avg. wt.,lb	06/06 wt.,lb	08/02 wt.,lb	09/02 wt.,lb	09/09 wt.,lb	09/10 wt.,lb	09/26 wt.,lb	11/21 wt.,lb
6	13	3	287	530	530	530	527	545	535	640	620	635	920
7	4	2	267	610	605	608	610	735	785	880	865	905	1110
7	4	2	269	565	575	570	638	780	840	875	835	870	1095
7	4	2	271	535	520	528	512	615	665	715	675	720	930
7	4	2	275	545	540	543	580	710	760	805	765	805	950
8	4	3	253	620	625	623	669	790	730	835	790	850	1130
8	4	3	254	540	540	540	591	680	715	825	800	825	1035
8	4	3	260	610	595	603	619	665	675	795	770	805	1035
8	4	3	262	560	555	558	557	680	735	780	750	790	1000
8	4	3	264	555	565	560	570	645	685	735	715	730	995
8	4	3	282	515	525	520	591	665	690	760	750	800	995
9	13	2	266	625	620	623	666	770	805	910	875	930	1160
9	13	2	268	600	600	600	626	760	765	865	840	860	1075
9	13	2	274	555	555	555	572	675	715	825	780	830	990
9	13	2	297	525	520	523	532	620	660	750	705	725	940

Table D.3. (Cont'd.)

Anim No.	252 01/20 wt.,lb	312 03/20 wt.,lb	313 03/21 wt.,lb	Avg. End wt.,lb	Carcass Data			Choice Quality Grade	Yield Grade
					Hot carcass wt.,lb	Dressing percent, %	Hot carcass wt.,lb		
279	1090	1240	1225	1233	703	57.04	1	1	3
280									
309	1005	1165	1155	1160	644	55.52	1	1	3
310	1085	1290	1285	1288	710	55.15	1	1	2
258	1160	1380	1375	1378	700	50.82	1	1	3
276	1040	1265	1260	1263	687	54.42	1	1	3
289	960	1145	1130	1138	932	81.93	1	1	2
296	1110	1310	1300	1305	728	55.79	1	1	3
257	1200	1400	1400	1400	794	56.71	1	1	2
263	1125	1320	1315	1318	766	58.14	1	1	3
273	1130	1310	1305	1308	728	55.68	1	1	3
283	990	1145	1140	1143	712	62.32	1	1	2
291	1020	1265	1270	1268	635	50.10	1	1	2
299	1055	1245	1230	1238	681	55.03	1	1	2
252	1035	1215	1205	1210	657	54.30	1	1	2
265	1115	1305	1295	1300	731	56.23	1	1	2
281	1085	1280	1265	1273	717	56.35	1	1	2
284	1075	1280	1270	1275	717	56.24	0	0	
312	1110	1320	1305	1313	726	55.31	1	1	3
315	1110	1335	1335	1335	749	56.10	1	1	2
251	1255	1445	1435	1440	846	58.75	0	0	
255	1115	1340	1340	1340	747	55.75	1	1	3
256	1165	1370	1375	1373	780	56.83	1	1	3
259	1395	1585	1570	1578	912	57.81	1	1	3
277	1135	1290	1290	1290	708	54.88	1	1	2

Table D.3. (Cont'd.)

Anim No.	252 01/20 wt.,lb	312 03/20 wt.,lb	313 03/21 wt.,lb	Avg. End wt.,lb	Carcass Data			Yield Grade
					Hot carcass wt.,lb	Dressing percent, %	Choice Quality Grade	
279	1090	1240	1225	1233	703	57.04	1	3
267	1295	1470	1475	1473	726	49.30	1	3
269	1270	1470	1460	1465	859	58.63	1	4
271	1120	1290	1275	1283	690	53.80	1	2
275	1100	1270	1270	1270	716	56.38	1	2
253	1305	1530	1525	1528	848	55.52	1	2
254	1145	1305	1315	1310	746	56.95	1	3
260	1230	1320	1320	1320	753	57.05	1	
262	1120	1300	1295	1298	840	64.74	1	3
264	1140	1360	1340	1350	767	56.81	0	1
282	1150	1260	1275	1268	720	56.80	1	3
266	1295	1500	1475	1488	830	55.80	1	3
268	1240	1395	1390	1393	796	57.16	1	3
274	1090	1265	1255	1260	717	56.90	1	3
297	1060	1250	1245	1248	706	56.59	1	3

Table D.4. Individual performance and carcass characteristics (1992)

1992				Pasture phase				Avg. off pasture				Rumen adapt. period			
Plot	GS	SR	Anim No.	05/11	05/13	Day 0	28	56	118	119	Avg. off pasture	125	126	Adapt. period	
				wt.,lb	wt.,lb	Avg. wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb
1	4	2	715	515	520	518	590	668	780	790	785	820	835	828	
1	4	2	732	545	535	540	612	670	750	760	755	775	785	780	
1	4	2	752	570	570	570	632	710	790	805	798	780	815	798	
1	4	2	754	550	525	538	587	693	790	805	798	830	850	840	
2	13	2	712	545	545	545	580	687	800	810	805	820	850	835	
2	13	2	739	520	510	515	605	697	770	785	778	790	820	805	
2	13	2	743	570	575	573	637	729	855	870	863	880	915	898	
2	13	2	755	555	565	560	587	650	785	795	790	835	880	858	
3	13	3	714	510	510	510	552	630	665	675	670	720	710	715	
3	13	3	726	570	575	573	608	700	765	770	768	820	805	813	
3	13	3	727	535	535	535	562	650	700	700	700	755	750	753	
3	13	3	738	580	575	578	611	710	755	755	755	810	790	800	
3	13	3	759	555	560	558	565	688	785	785	785	820	805	813	
3	13	3	760	540	545	543	589	680	710	735	723	760	755	758	
4	4	3	724	560	575	568	654	695	730	715	723	760	740	750	
4	4	3	736	530	510	520	582	625	705	700	703	760	730	745	
4	4	3	745	565	570	568	627	670	735	740	738	765	745	755	
4	4	3	751	530	535	533	590	630	710	700	705	730	700	715	
4	4	3	753	535	560	548	632	670	725	715	720	740	710	725	
4	4	3	757	580	590	585	596	670	715	700	708	720	685	703	
6	13	3	710	640	635	638	686	735	740	755	748	795	785	790	
6	13	3	713	600	600	600	620	670	665	695	680	740	720	730	
6	13	3	716	595	605	600	649	705	710	740	725	780	780	780	
6	13	3	717	645	650	648	724	820	840	865	853	900	900	900	

Table D.4. (Cont'd.)

Plot	GS	SR	Anim No.	1992		Pasture phase			Avg. off pasture		Rumen adapt. period	
				05/11	05/13	Day 0	28	56	118	119	125	126
				wt.,lb	wt.,lb	Avg. wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	wt.,lb	Avg. wt
6	13	3	720	655	680	668	727	760	775	800	855	850
6	13	3	756	585	585	585	632	690	700	735	775	770
7	4	2	708	620	615	618	720	800	870	890	945	915
7	4	2	718	650	665	658	723	755	830	835	865	850
7	4	2	721	620	625	623	725	815	880	880	940	915
7	4	2	740	580	590	585	642	725	790	785	830	800
8	4	3	706	600	605	603	638	700	770	765	820	810
8	4	3	731	660	670	665	765	825	Died of bloat (7/20/92)			815
8	4	3	737	585	575	580	656	705	815	815	865	850
8	4	3	741	600	600	600	663	710	820	810	860	860
8	4	3	746	645	635	640	688	750	800	770	805	820
8	4	3	748	635	630	633	670	725	805	800	845	840
9	13	4	722	585	590	588	663	730	810	835	860	865
9	13	4	742	610	610	610	667	725	785	780	815	835
9	13	4	749	630	620	625	696	765	860	880	905	925
9	13	4	758	645	645	645	728	725	865	895	895	905

Table D.4. (Cont'd.)

Anim No.	Feedlot phase				Carcass Data						Yield Grade
	153 10/13 wt.,lb	181 11/10 wt.,lb	209 12/08 wt.,lb	265 02/02 wt.,lb	307 03/16 wt.,lb	308 03/17 wt.,lb	Avg. End wt.,lb	Hot carcass wt.,lb	Dressing Percent, %	Choice Quality Grade	
715	915	1030	1095	1210	1340	1335	1338	709	53.01	1	3
732	885	995	1060	1150	1295	1305	1300	747	57.46	0	2
752	875	1005	1070	1190	1350	1375	1363	772	56.66	0	2
754	930	1065	1140	1310	1470	1470	1470	837	56.94	1	3
712	935	1025	1115	1260	1360	1380	1370	819	59.78	1	2
739	890	990	1090	1230	1345	1350	1348	792	58.78	1	3
743	1010	1125	1230	1380	1495	1515	1505	857	56.94	1	2
755	955	1065	1160	1300	1445	1450	1448	823	56.86	1	2
714	775	850	935	1045	1165	1165	1165	669	57.42	0	2
726	875	960	1040	1165	1250	1250	1250	741	59.28	1	2
727	795	860	930	1020	1140	1135	1138	654	57.49	0	2
738	870	935	1050	1185	1285	1300	1293	742	57.41	1	2
759	890	980	1090	1200	1340	1335	1338	781	58.39	1	3
760	830	835	960	1100	1245	1240	1243	720	57.95	0	2
724	900	1030	1085	1180	1310	1310	1310	731	55.80	1	2
736	875	1000	1060	1150	1270	1285	1278	741	58.00	1	2
745	885	965	1035	1140	1270	1270	1270	740	58.27	1	3
751	850	945	1015	1110	1265	1260	1263	711	56.32	1	2
753	870	980	1075	1240	1360	1360	1360	806	59.26	1	3
757	840	980	1040	1170	1300	1305	1303	737	56.58	1	2
710	880	980	1060	1180	1280	1295	1288	733	56.93	1	2
713	840	970	1050	1215	1320	1315	1318	764	57.99	1	2
716	925	1030	1090	1245	1400	1410	1405	785	55.87	0	2
717	945	1075	1180	1315	1485	1500	1493	857	57.42	1	2

Table D.4. (Cont'd.)

Anim No.	Feedlot phase				Carcass Data				Choice Quality Grade	Yield Grade	
	153 10/13 wt.,lb	181 11/10 wt.,lb	209 12/08 wt.,lb	265 02/02 wt.,lb	307 03/16 wt.,lb	308 03/17 wt.,lb	Avg. End wt.,lb	Hot carcass wt.,lb			Dressing Percent, %
720	945	1065	1130	1290	1430	1450	1440	832	57.78	1	3
756	780	895	975	1170	1275	1295	1285	735	57.20	0	2
708	1005	1115	1175	1280	1410	1395	1403	827	58.97	1	2
718	940	1040	1090	1170	1295	1300	1298	751	57.88	1	3
721	1005	1135	1165	1275	1375	1375	1375	803	58.40	1	2
740	900	1005	1045	1170	1255	1260	1258	755	60.04	1	2
706	900	1030	1060	1190	1315	1310	1313	774	58.97	1	2
731											
737	920	1020	1070	1175	1325	1315	1320	743	56.29	1	2
741	945	1005	1090	1230	1410	1405	1408	789	56.06	1	2
746	910	1040	1085	1230	1450	1450	1450	835	57.59	1	2
748	935	1010	1025	1160	1330	1345	1338	758	56.67	1	2
722	930	1035	1130	1240	1385	1385	1385	827	59.71	1	2
742	940	1030	1155	1295	1455	1465	1460	864	59.18	1	3
749	940	1045	1140	1245	1370	1375	1373	792	57.70	1	2
758	1005	1170	1245	1395	1520	1530	1525	877	57.51	1	3

Table D.5. Forage presentation per rotation and over the entire grazing season (1989 to 1991)

Plot	Year	GS	SR	Summer	Rotation 2	Rotation 3	Overall	Fall
				Rotation 1				Rotation 4
				kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
1	1989	4	L	3706	2631	572	6909	1491
2	1989	13	L	3340	3218	1395	7953	1650
3	1989	13	H	3403	2291	950	6643	1618
4	1989	4	H	2675	1493	424	4592	1618
5	1989	Haylage		1948	685	--	2633	1015
6	1989	13	H	2411	1159	740	4309	1389
7	1989	4	L	2177	2689	614	5480	1357
8	1989	4	H	2570	1658	308	4536	1055
9	1989	13	L	2084	2121	1182	5387	1300
10	1989	Haylage		1964	1131	--	3095	1638
1	1990	4	L	2988	3482	1707	8177	--
2	1990	13	L	2830	3639	2920	9389	--
3	1990	13	H	2201	2583	2426	7210	--
4	1990	4	H	2201	2426	1213	5840	--
5	1990	Haylage		4762	3751	--	8513	--
6	1990	13	H	2269	2493	1932	6694	--
7	1990	4	L	2449	4246	1483	8178	--
8	1990	4	H	2112	3459	1505	7076	--
9	1990	13	L	2224	3482	2538	8244	--
10	1990	Haylage		3414	4650	--	8064	--
1	1991	4	L	4972	3596	2573	11140	--
2	1991	13	L	4608	3876	3050	11533	--
3	1991	13	H	4191	3808	3031	11029	--
4	1991	4	H	4416	4824	2545	11784	--
5	1991	Hay		4093	1970	--	6063	--
6	1991	13	H	4135	3666	2931	10733	--
7	1991	4	L	4724	3812	2720	11257	--
8	1991	4	H	4083	4454	2444	10981	--
9	1991	13	L	4073	3869	3761	11703	--
10	1991	Hay		4733	2285	--	7018	--

Table D.6. Nutrient composition of forage samples (1989)

Plot	Period	DM, %	Ash, %	OM, %	CP, (% DM)	CP, (% OM)	IVDMD, %	IVOMD, %
1	A	16.76	9.33	90.67	17.99	19.84	74.37	74.79
1	B	16.85	11.21	88.79	19.54	22.01	61.94	62.38
1	C	No sample						
1	D	18.68	4.98	95.02	15.67	16.49	53.62	51.17
1	E	17.52	10.09	89.91	19.46	21.64	55.93	50.75
1	F	19.78	10.13	89.87	17.39	19.35	54.07	52.14
1	G	22.98	10.47	89.53	17.51	19.56	63.62	62.66
1	H	26.92	7.55	92.45	15.87	17.16	60.73	58.06
1	I	15.75	11.53	88.47	23.00	25.99	64.71	63.32
2	A	15.23	10.10	89.90	24.15	26.86	68.60	68.38
2	B	15.30	10.04	89.96	21.06	23.41	56.86	54.56
2	C	19.06	9.12	90.88	17.56	19.32	61.93	62.31
2	D	18.16	8.68	91.32	19.54	21.40	57.70	54.09
2	E	16.59	10.14	89.86	18.27	20.33	59.73	59.20
2	F	27.47	8.66	91.34	16.79	18.38	61.76	59.27
2	G	25.03	8.21	91.79	17.28	18.83	62.14	60.22
2	H	22.80	8.85	91.15	19.05	20.90	62.50	59.31
2	I	16.16	11.01	88.99	22.78	25.60	64.96	62.84
3	A	14.57	10.39	89.61	23.71	26.46	67.46	66.75
3	B	16.46	10.06	89.94	18.10	20.13	55.07	53.94
3	C	19.86	8.97	91.03	18.23	20.03	55.50	56.01
3	D	20.08	8.83	91.17	17.92	19.65	57.39	54.94
3	E	17.47	10.71	89.29	19.39	21.71	64.46	60.52
3	F	20.40	8.72	91.28	19.84	21.74	60.90	60.09
3	G	34.58	6.94	93.06	14.21	15.27	64.11	63.73
3	H	21.14	10.21	89.79	20.21	22.51	63.49	61.79
3	I	14.80	12.63	87.37	26.47	30.30	68.05	68.61
4	A	17.39	9.46	90.54	19.77	21.83	71.63	74.84
4	B	18.67	8.95	91.05	19.92	21.88	55.59	55.19
4	C	No sample						
4	D	20.94	11.27	88.73	16.06	18.10	59.79	60.19
4	E	17.43	10.42	89.58	19.49	21.75	66.15	63.45
4	F	24.52	8.69	91.31	16.09	17.62	57.90	56.47
4	G	24.29	17.45	82.55	16.68	20.21	59.42	66.04
4	H	25.00	8.64	91.36	19.06	20.87	66.69	67.58
4	I	17.36	11.98	88.02	21.78	24.75	69.30	69.59
6	A	15.70	10.21	89.79	24.00	26.73	66.62	67.17
6	B	9.42	11.22	88.78	24.40	27.49	58.73	54.71
6	C	15.51	9.92	90.08	16.51	18.33	59.46	59.50
6	D	25.22	8.98	91.02	11.58	12.72	54.86	54.11
6	E	18.05	10.92	89.08	21.66	24.31	63.55	60.88
6	F	24.14	11.59	88.41	18.57	21.00	57.35	58.09
6	G	28.36	16.01	83.99	18.28	21.77	55.44	61.95
6	H	20.91	13.76	86.24	19.57	22.69	60.19	61.09
6	I	15.10	14.47	85.53	23.04	25.38	65.15	64.80
7	A	14.98	9.23	90.77	21.37	23.75	64.87	64.48
7	B	17.49	10.04	89.96	15.45	17.00	66.38	66.08

Plot	Period	DM, %	Ash, %	OM, %	CP, (% DM)	CP, (% OM)	IVDMD, %	IVOMD, %
7	C	No sample						
7	D	20.52	9.14	90.86	27.98	30.86	59.22	55.86
7	E	18.50	9.36	90.64	17.23	18.98	64.59	60.57
7	F	22.33	9.21	90.79	15.24	16.42	55.34	53.54
7	G	29.54	7.16	92.84	17.27	18.56	66.33	66.12
7	H	28.99	6.97	93.03	22.88	25.27	64.52	63.12
7	I	19.27	9.48	90.52	26.09	30.51	62.76	60.27
8	A	14.81	10.12	89.88	25.52	28.39	70.42	70.70
8	B	16.33	10.66	89.34	21.33	23.88	65.61	65.17
8	C	No sample						
8	D	18.45	8.33	91.67	21.11	23.03	58.26	58.88
8	E	14.65	12.18	87.82	27.66	31.50	67.04	63.94
8	F	18.92	8.93	91.07	16.81	18.46	56.66	56.85
8	G	30.48	6.65	93.35	16.88	18.09	72.00	72.27
8	H	28.09	7.57	92.43	17.50	18.94	63.67	62.17
8	I	20.68	10.84	89.16	22.07	24.75	68.17	66.40
9	A	16.22	11.32	88.68	23.04	25.99	71.04	70.85
9	B	15.50	11.86	88.14	22.78	25.85	59.63	57.72
9	C	21.96	12.91	87.09	16.47	18.92	57.74	58.96
9	D	22.26	8.63	91.37	12.43	13.60	53.12	53.50
9	E	16.54	9.49	90.51	23.90	26.41	66.27	63.21
9	F	21.92	8.58	91.42	19.59	21.43	61.22	59.48
9	G	28.99	10.71	89.29	14.80	16.58	61.54	63.76
9	H	24.17	10.27	89.73	16.92	18.86	57.13	55.57
9	I	13.59	10.14	89.86	21.61	24.05	60.62	58.97

Period	Date
A	19-May
B	27-May
C	01-Jun
D	09-Jun
E	25-Jun
F	09-Jul
G	21-Jul
H	02-Aug
I	14-Aug

Table D.7. Canopy heights (1989)

Date	Plot Day	1	2	3	4	6	7	8	9
height, cm									
05/19/89	0	37.75	38.50	35.25	31.50	32.00	37.50	27.75	28.50
05/21/89	2		37.00	38.25		39.00			31.75
05/23/89	4		45.50	45.50		42.00			22.50
05/25/89	6		45.75	48.50		38.25			42.25
05/27/89	8	53.00	53.25	49.00	49.00	52.75	46.75	44.00	43.00
05/29/89	10		49.25	50.25		51.00			44.75
05/31/89	12		49.50	45.00					49.75
06/01/89	13								
06/03/89	15		55.75	51.00		45.50			37.00
06/04/89	16								
06/05/89	17		50.25	54.50		40.33			45.25
06/07/89	19		53.25	56.75					
06/09/89	21	62.25	59.25	58.25			48.00	58.50	40.00
06/11/89	23		52.00	67.25					
06/25/89	37	43.00	41.25	29.50	46.50	38.75	48.25	39.00	43.75
06/30/89	42		40.75	39.00		38.75			39.25
07/03/89	45		45.25	44.50		30.25			39.00
07/06/89	48		52.75	43.75		28.50			55.25
07/09/89	51	52.75	53.75	46.50	38.25	31.50	54.25	50.25	58.50
07/12/89	54		53.25	48.00		25.75			52.00
07/15/89	57		47.25	25.00		25.00			50.50
07/18/89	60		55.50	38.50		28.00			52.50
07/21/89	63	38.75	42.00	20.00	15.25	28.25	39.25	27.50	36.75
07/24/89	66		55.00	31.00		13.75			27.50
07/27/89	69		51.75	47.00		11.50			48.75
07/30/89	72		54.25	48.25		20.00			28.00
08/02/89	75	52.00	54.00	42.75	22.25	14.50	32.25	23.50	17.00
08/05/89	78		25.50	15.75		17.50			26.75
08/08/89	81		27.25	26.25		21.00			27.00
08/11/89	84		31.00	23.25		19.25			23.50
08/14/89	87	28.50	23.00	25.00	19.25	20.75	24.75	24.00	25.50
08/17/89	90		32.25	31.50		23.75			30.50
08/20/89	93		40.75	34.00		21.00			28.50
08/23/89	96		41.50	35.00		32.00			37.25

Table D.8. Esophageal extrusa nutrient composition (1989)

Plot	1989 Period	OM, %	CP, (% of OM)	IVOMD, (% of DM)	Rumen DMD, %	Rumen UDP (% of CP)
1	E	90.36	25.83	69.23	76.95	16.53
1	F	93.08	23.93	93.00	87.13	11.54
1	G	93.51	20.58	77.24	78.67	14.61
1	H	91.09	14.73	76.99	81.69	14.07
1	I	89.18	23.25	66.20	82.73	12.50
2	E	90.09	26.63	62.54	77.75	19.67
2	F	91.53	27.04	71.19	82.39	10.37
2	G	93.45	20.41	75.63	77.97	15.47
2	H	92.85	15.22	74.42	79.37	16.14
2	I	91.58	27.76	75.95	81.00	11.29
3	E	91.46	26.88	75.22	79.62	14.88
3	F	89.59	26.06		83.58	11.85
3	G	92.82	18.89	73.98	73.94	20.95
3	H	92.87	13.83	73.80	78.03	19.89
3	I	91.08	27.34	73.81	78.28	16.75
4	E	90.64	27.25	64.98	73.18	18.99
4	F	No sample				
4	G	91.34	19.46	73.21	78.28	19.25
4	H	90.82	18.18	67.31	75.56	20.23
4	I	89.45	26.78	72.04	70.67	28.53
6	E	89.14	26.40	60.01	84.88	11.11
6	F	93.35	27.71	59.41	79.65	14.48
6	G	90.71	17.53	75.37	76.87	19.28
6	H	86.12	22.46	64.91	80.52	13.83
6	I	84.18	27.01	74.14	76.52	17.90
7	E	90.70	31.19	69.10	78.89	14.81
7	F	90.70	26.00	68.72	86.03	10.48
7	G	88.06	18.81	83.34	84.44	11.22
7	H	88.06	15.74	80.31	79.94	16.17
7	I	92.53		73.17	81.16	
8	E	90.62	31.93	69.56	80.70	11.52
8	F	91.02	27.03	79.30	80.63	16.46
8	G	93.40	18.48	78.26	80.04	17.62
8	H	92.81	16.57	71.92	79.66	15.83
8	I	91.66	28.58	75.53	83.62	12.60
9	E	91.19	25.94	75.87	86.40	10.45
9	F	91.67	26.30	74.34	80.56	12.75
9	G	93.56	18.32	75.84	76.58	16.45
9	H	92.45	17.17	65.65	68.79	24.13
9	I	87.78	25.18	65.83	73.74	20.20

Period	Date
E	06/25/89
F	07/09/89
G	07/21/89
H	08/02/89
I	08/14/89

Table D.9. Nutrient composition of forage samples (1990)

Plot	1990 Period	DM, %	Ash, %	OM, %	CP	CP	IVDMD, %	IVOMD, %
					(% DM)	(% OM)		
1	A	13.76	10.59	89.41	21.46	24.00	77.46	75.69
1	B	11.17	11.78	88.22	28.13	31.88	71.13	69.49
1	C	13.41	8.53	91.47	23.22	25.38	69.62	69.15
1	D	19.65	8.61	91.39	21.97	24.04	69.86	67.93
1	E	21.70	7.21	92.79	20.64	22.24	49.74	47.36
1	F	22.38	8.00	92.00	17.15	18.64	48.65	45.52
1	G	22.17	7.88	92.12	18.04	19.59	63.77	62.58
1	H	19.81	8.08	91.92	19.62	21.34	56.43	53.92
1	I	20.88	9.54	90.46	18.47	20.42	59.75	60.00
1	J	20.81	9.04	90.96	22.27	24.48	65.34	63.23
2	A	12.07	9.98	90.02	27.32	30.35	77.71	76.13
2	B	12.49	9.77	90.23	24.37	27.01	71.77	69.78
2	C	15.41	9.18	90.82	21.72	23.92	66.10	63.62
2	D	18.57	9.27	90.73	20.99	23.14	64.75	62.11
2	E	16.21	8.96	91.04	20.83	22.88	58.51	57.05
2	F	19.91	7.85	92.15	18.60	20.18	52.89	49.46
2	G	21.25	7.96	92.04	17.01	18.48	56.08	53.65
2	H	21.36	8.76	91.24	18.23	19.98	56.11	51.69
2	I	23.52	8.37	91.63	17.79	19.41	55.79	55.82
2	J	18.35	8.67	91.33	21.97	24.05	59.41	56.32
3	A	13.41	10.20	89.80	25.85	28.79	77.28	76.06
3	B	12.24	10.07	89.93	24.88	27.67	71.71	70.14
3	C	16.78	10.44	89.56	21.93	24.49	69.77	66.38
3	D	17.73	9.52	90.48	21.29	23.53	67.61	65.70
3	E	15.75	9.22	90.78	22.92	25.24	66.38	64.41
3	F	19.34	8.93	91.07	20.27	22.26	65.79	62.95
3	G	21.17	8.05	91.95	18.81	20.45	60.74	58.38
3	H	23.03	9.55	90.45	18.22	20.14	65.96	63.26
3	I	18.40	9.13	90.87	21.09	23.21	63.32	61.23
3	J	16.63	9.73	90.27	22.41	24.82	63.79	62.42
4	A	13.9	9.56	90.44	23.12	25.56	77.68	77.14
4	B	13.03	9.80	90.20	24.16	26.79	74.65	72.85
4	C	13.49	11.31	88.69	20.08	22.64	67.55	65.95
4	D	19.53	9.60	90.40	22.18	24.54	67.00	64.46
4	E	19.91	9.66	90.34	20.49	22.68	69.95	68.44
4	F	18.24	9.90	90.10	23.25	25.80	65.61	63.51
4	G	21.70	9.34	90.66	17.89	19.73	63.88	62.28
4	H	18.67	8.71	91.29	22.23	24.36	64.88	64.01
4	I	18.61	9.32	90.68	22.11	24.39	68.69	66.94
4	J	20.22	9.98	90.02	19.71	21.90	64.47	61.80
6	A	13.27	10.12	89.88	23.51	26.16	76.84	75.89
6	B	12.45	10.04	89.96	22.54	25.06	70.77	68.73
6	C	17.70	9.67	90.33	19.71	21.82	66.89	64.55
6	D	18.75	8.88	91.12	21.34	23.42	65.56	63.00
6	E	14.49	9.53	90.47	25.97	28.70	63.16	60.15
6	F	23.54	8.17	91.83	17.27	18.81	62.60	59.58
6	G	20.51	8.22	91.78	21.01	22.89	63.25	61.06

Table D.9. (Cont'd.)

Plot	1990		Ash, %	OM, %	CP		IVDMD, %	IVOMD, %
	Period	DM, %			(% DM)	(% OM)		
6	H	18.28	9.47	90.53	22.12	24.44	61.26	57.42
6	I	18.70	9.08	90.92	21.16	23.27	63.27	61.47
6	J	17.40	10.01	89.99	21.99	24.43	63.46	60.83
7	A	16.96	9.76	90.24	25.35	28.10	80.84	81.43
7	B	11.58	10.51	89.49	26.28	29.37	74.60	72.87
7	C	11.24	10.83	89.17	29.32	32.88	71.39	68.84
7	D	17.72	8.90	91.10	23.13	25.38	70.73	68.40
7	E	19.46	8.61	91.39	22.21	24.30	58.67	55.67
7	F	20.76	7.99	92.01	18.59	20.21	54.70	51.00
7	G	26.52	6.96	93.04	16.60	17.84	55.54	54.46
7	H	26.34	7.04	92.96	17.83	19.18	54.39	51.91
7	I	18.34	8.77	91.23	22.77	24.96	65.75	63.57
7	J	20.42	7.05	92.95	22.23	23.92	62.75	60.94
8	A	16.67	9.40	90.60	23.97	26.46	79.19	79.40
8	B	11.6	10.14	89.86	25.37	28.24	73.02	71.30
8	C	17.65	9.44	90.56	20.14	22.24	70.62	69.03
8	D	17.49	9.52	90.48	25.33	27.99	71.72	69.22
8	E	18.12	9.60	90.40	22.86	25.29	67.44	64.86
8	F	21.36	7.42	92.58	18.25	19.72	51.30	48.37
8	G	22.07	8.21	91.79	19.50	21.24	64.41	61.68
8	H	20.73	8.41	91.59	21.78	23.78	59.85	61.75
8	I	17.97	8.74	91.26	23.34	25.58	68.07	66.19
8	J	19.74	11.31	88.69	19.79	22.31	64.73	62.09
9	A	13.96	11.81	88.19	24.48	27.75	77.10	78.21
9	B	12.51	10.08	89.92	26.84	29.85	73.84	72.38
9	C	17.70	9.26	90.74	20.81	22.93	68.07	65.98
9	D	19.24	8.85	91.15	21.30	23.36	65.17	64.33
9	E	16.80	8.18	91.82	21.23	23.12	57.26	54.61
9	F	22.24	7.83	92.17	18.10	19.64	57.72	52.82
9	G	22.03	7.29	92.71	17.98	19.39	57.47	54.63
9	H	22.88	8.24	91.76	18.43	20.09	58.24	56.21
9	I	20.90	8.29	91.71	20.19	22.01	56.07	53.00
9	J	18.87	9.22	90.78	21.91	24.13	58.97	57.56

Period	Date
A	05/14/90
B	05/18/90
C	05/26/90
D	06/07/90
E	06/19/90
F	07/01/90
G	07/13/90
H	07/25/90
I	08/06/90
J	08/18/90

Table D.10. Canopy heights (1990)

Date	Plot Day	1	2	3	4	6	7	8	9
height, cm									
05/14/90	0	42.50	39.25	38.75	38.75	40.25	41.50	40.00	38.75
05/16/90	2		44.25	46.25		46.75			31.50
05/18/90	4	42.25	45.25	44.25	40.75	42.75	43.75	44.75	38.75
05/20/90	6		45.50	44.75		50.00			43.75
05/22/90	8								
05/24/90	10		52.75	46.00		46.00			47.75
05/26/90	12	53.50	53.25	34.75	33.75	41.50	48.00	52.00	54.75
05/29/90	15		56.75	41.25		42.50			56.50
06/01/90	18		72.50	54.00		49.25			52.25
06/04/90	21		68.25	65.25		53.00			59.00
06/07/90	24	71.00	77.00	45.25	41.50	45.50	55.00	49.75	56.00
06/10/90	27		54.75	47.25		43.25			51.00
06/13/90	30		54.25	49.25		50.25			48.25
06/16/90	33		54.25	49.25		46.50			49.50
06/19/90	36	51.00	54.00	51.25	52.75	50.00	53.50	52.25	52.75
06/22/90	39		56.75	47.50		47.25			46.50
06/25/90	42		48.50	44.25		48.50			61.25
06/28/90	45		66.50	60.50		69.75			74.25
07/01/90	48	65.00	74.75	65.00	47.75	59.00	57.75	49.00	64.00
07/04/90	51		60.25	53.25		44.50			60.75
07/07/90	54		62.50	56.25		69.75			74.25
07/10/90	57		59.25	59.25		49.75			56.00
07/13/90	60	64.75	64.75	59.50	60.25	55.25	65.25	63.25	51.50
07/16/90	63		66.00	60.00		49.75			64.25
07/19/90	66		73.50	53.25		35.50			48.50
07/22/90	69		57.25	50.75		52.50			60.00
07/25/90	72	62.75	37.00	31.00	42.50	38.50	52.25	58.00	39.00
07/28/90	75		46.75	44.25		40.75			42.50
07/31/90	78		48.00	53.50		56.25			45.00
08/03/90	81		47.75	53.00		49.75			53.75
08/06/90	84	60.75	51.00	64.75	62.25	51.50	51.00	53.50	55.75
08/09/90	87		54.50	60.00		41.25			54.00
08/12/90	90								0.00
08/15/90	93		48.25	54.00		49.75			51.75
08/18/90	96	54.25	54.75	52.25	34.00	34.25	45.50	47.25	43.25
08/21/90	99		56.00	50.50		46.50			43.50
08/24/90	102		53.75	45.00		40.50			53.25
08/27/90	105		55.75	50.00		51.25			54.50

Table D. 11. Esophageal extrusa nutrient composition (1990)

Plot	1990 Period	OM, %	CP (% of OM)	IVOMD (% of OM)	Rumen DMD, %	Rumen UDP (% of CP)
1	D	89.86	25.91	74.18	78.99	13.99
1	E	90.34	25.27	68.44	87.45	15.88
1	F	92.01	25.97	69.72	77.50	12.70
1	G	No sample				
1	H	91.82	23.73	77.84	83.13	9.60
1	I	91.69	23.19	75.19	84.64	10.40
1	J	90.49	25.05	76.37	81.11	15.55
2	D	88.40	28.26	72.86	80.56	18.00
2	E	90.17	29.03	71.86	81.63	12.85
2	F	91.70	24.23	65.45	76.13	13.18
2	G	No sample				
2	H	92.33	20.69	81.72	84.37	11.03
2	I	91.59	24.31	76.02	84.61	9.83
2	J	90.92	26.00	75.86	78.64	17.28
3	D	89.91	26.54	72.80	78.31	15.28
3	E	90.10	33.96	74.14		
3	F	90.24	30.08	73.89	85.28	6.89
3	G	No sample				
3	H	91.96	23.43	78.54	79.96	16.11
3	I	84.83	27.95	78.39	84.25	8.32
3	J	91.62	25.42	82.06	85.19	10.75
4	D	No sample				
4	E	90.54	29.07	72.04	93.62	9.70
4	F	87.99	26.01	69.06	78.61	15.33
4	G	No sample				
4	H	92.15	24.90	79.48	87.51	6.30
4	I	90.72	27.54	79.51	87.74	7.51
4	J	92.01	23.09	77.95	79.45	15.86
6	D	91.46	20.43	73.49	68.27	23.23
6	E	90.27	29.95	76.43	86.49	9.12
6	F	90.43	28.12	73.33	82.70	9.41
6	G	No sample				
6	H	91.60	22.08	80.79	90.63	4.54
6	I	82.92	25.70	73.83	83.01	10.84
6	J	90.55	22.45	70.91	72.95	23.13
7	D	No sample				
7	E	89.23	29.94	70.24	83.65	11.53
7	F	91.47	29.08	74.70		
7	G	No sample				
7	H	91.60	22.27	75.14	87.51	6.76
7	I	90.76	17.97	76.53	86.22	14.28
7	J	91.20	26.67	70.88	99.24	
8	D	89.65	30.17	74.28	80.36	13.75
8	E	90.41	24.25	74.98	87.17	8.67
8	F	91.70	26.15	76.65	86.02	13.43
8	G	No sample				

Table D. 11. (Cont'd.)

Plot	1990 Period	OM, %	CP (% of OM)	IVOMD (% of OM)	Rumen DMD, %	Rumen UDP (% of CP)
8	H	92.09	24.72	75.70	87.67	5.97
8	I	91.68	26.24	79.75	89.79	5.29
8	J	90.37	25.17	73.14	82.47	14.93
9	D	91.39	25.41	76.92	81.45	9.47
9	E	90.94	28.89	73.82	82.82	11.47
9	F	91.09	22.01	64.50	74.42	15.43
9	G	No sample				
9	H	91.92	23.29	78.80	90.93	4.62
9	I	86.20	23.79	79.02	83.04	8.69
9	J	90.31	26.05	72.83	82.64	13.51
Period		Date				
D		06/07/90				
E		06/19/90				
F		07/01/90				
G		07/13/90				
H		07/25/90				
I		08/06/90				
J		08/18/90				

Table D.12. Forage sample fiber analysis (1989)

Plot	GM	SR	Date	NDF, %	ADF, %	Lignin, %
1	4	L	05/18/89	31.50	21.41	3.95
1	4	L	06/25/89	54.99	36.66	9.71
1	4	L	07/21/89	46.74	31.73	8.67
1	4	L	08/14/89	39.53	25.32	7.48
2	13	L	05/18/89	29.73	18.86	3.27
2	13	L	06/03/89	49.80	33.33	7.38
2	13	L	06/30/89	42.96	27.53	6.71
2	13	L	07/21/89	40.16	24.46	7.03
2	13	L	08/14/89	40.88	25.98	7.67
2	13	L	10/29/89	54.01	36.64	9.42
3	13	H	08/14/89	33.26	20.49	5.85
3	13	H	05/18/89	31.30	21.16	4.11
3	13	H	06/03/89	49.67	34.30	8.05
3	13	H	06/30/89	42.28	25.95	6.45
3	13	H	07/21/89	51.00	32.96	9.14
4	4	H	05/18/89	29.57	19.74	3.83
4	4	H	06/25/89	44.24	27.44	7.33
4	4	H	07/21/89	44.95	22.23	5.14
4	4	H	08/14/89	34.72	21.10	6.29
4	4	H	10/26/89	28.88	17.90	7.09
5	Haylage		06/20/89	64.37	46.31	11.64
5	Haylage		08/21/89	62.65	39.29	12.64
5	Haylage		10/26/89	47.67	30.79	22.55
6	13	H	05/18/89	41.83	25.79	5.57
6	13	H	06/04/89	46.08	32.43	7.07
6	13	H	06/30/89	49.73	31.33	8.33
6	13	H	07/21/89	41.73	23.92	7.00
6	13	H	08/14/89	33.29	20.24	6.05
6	13	H	10/27/89	31.26	18.83	5.15
7	4	L	05/18/89	39.56	26.20	6.06
7	4	L	06/25/89	47.20	31.36	8.01
7	4	L	07/21/89	38.77	24.59	6.44
7	4	L	08/14/89	43.55	26.57	8.44
7	4	L	10/29/89	44.57	29.01	8.16
8	4	H	05/18/89	34.89	21.17	4.40
8	4	H	06/25/89	44.90	29.36	7.39
8	4	H	07/21/89	38.93	21.78	6.18
8	4	H	08/14/89	35.04	20.24	5.57
8	4	H	10/26/89	28.59	16.29	5.05

Table D.12. (Cont'd.)

Plot	GM	SR	Date	NDF, %	ADF, %	Lignin, %
9	13	L	05/18/89	44.07	24.30	3.01
9	13	L	06/04/89	41.65	27.04	5.98
9	13	L	06/30/89	36.73	24.85	6.27
9	13	L	07/21/89	44.87	30.39	8.04
9	13	L	08/14/89	43.48	28.30	8.19
9	13	L	10/27/89	48.37	30.84	12.69
10	Haylage		06/20/89	60.54	41.19	9.27
10	Haylage		08/21/89	62.18	39.55	11.08
10	Haylage		10/26/89	47.76	28.66	7.33
11	4	H	06/25/89	43.21	29.53	6.77
12	13	H	06/25/89	45.39	28.76	6.75

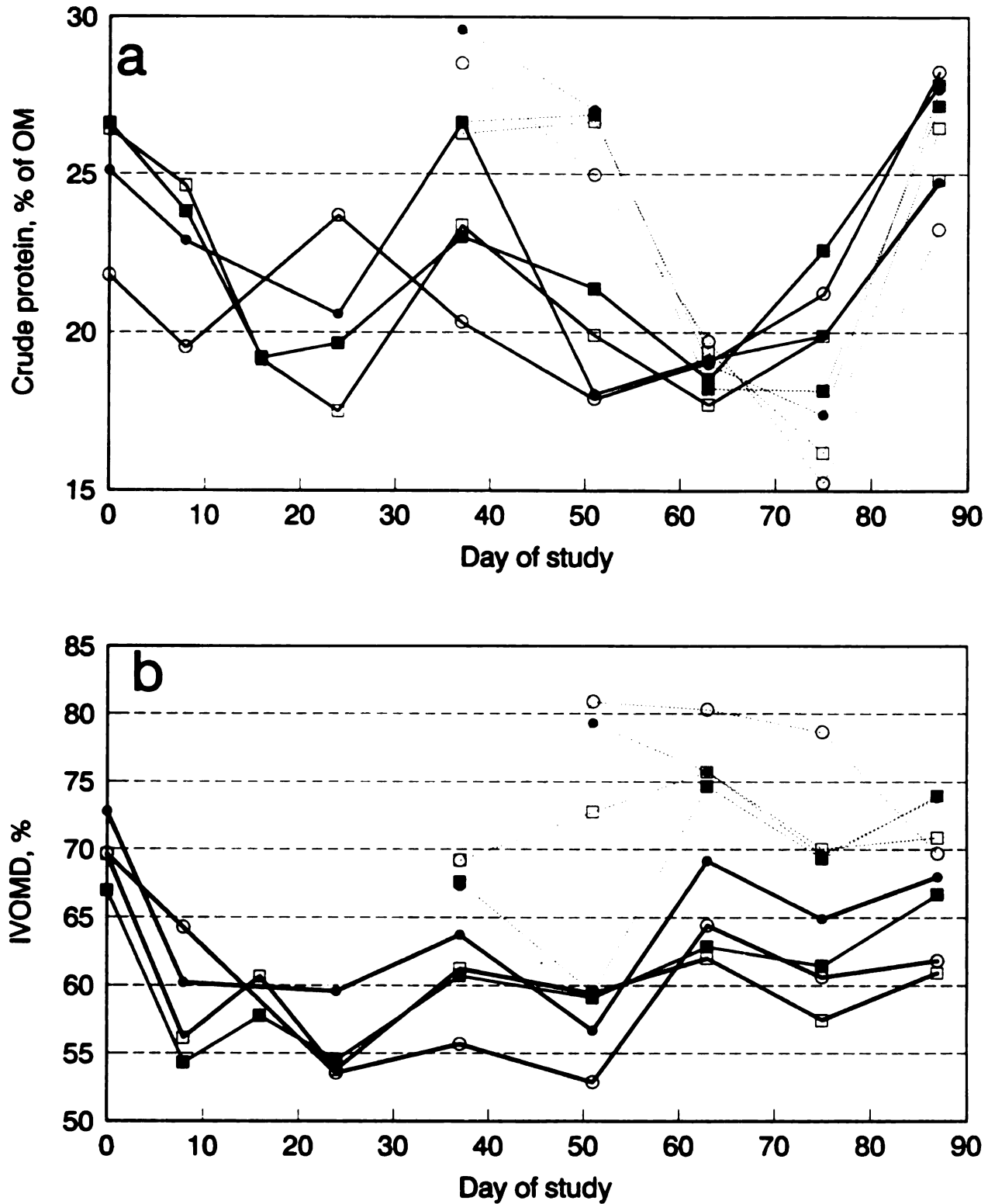


Figure D.1. Crude protein (a) and IVOMD (b) composition of forage (solid lines) and extrusa (dashed lines) over the 1989 grazing season collected from 4 paddock (circles) and 13 paddock (squares) systems at the low (open) and high (closed) stocking rates.

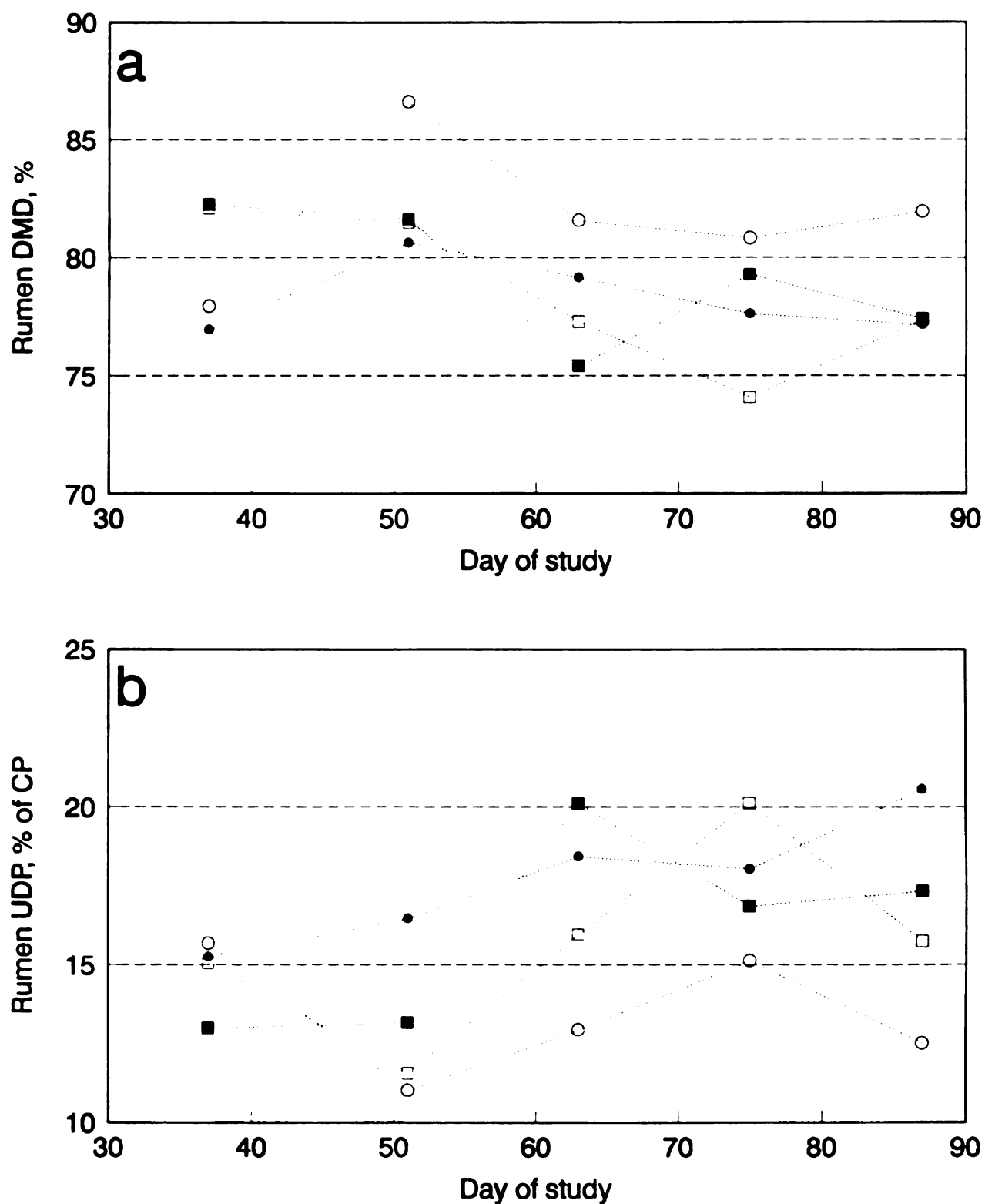


Figure D.2. Rumen DMD (a) and UDP (b) of extrusa samples over the 1989 grazing season collected from 4 paddock (circles) and 13 paddock (squares) systems at the low (open) and high (closed) stocking rates.

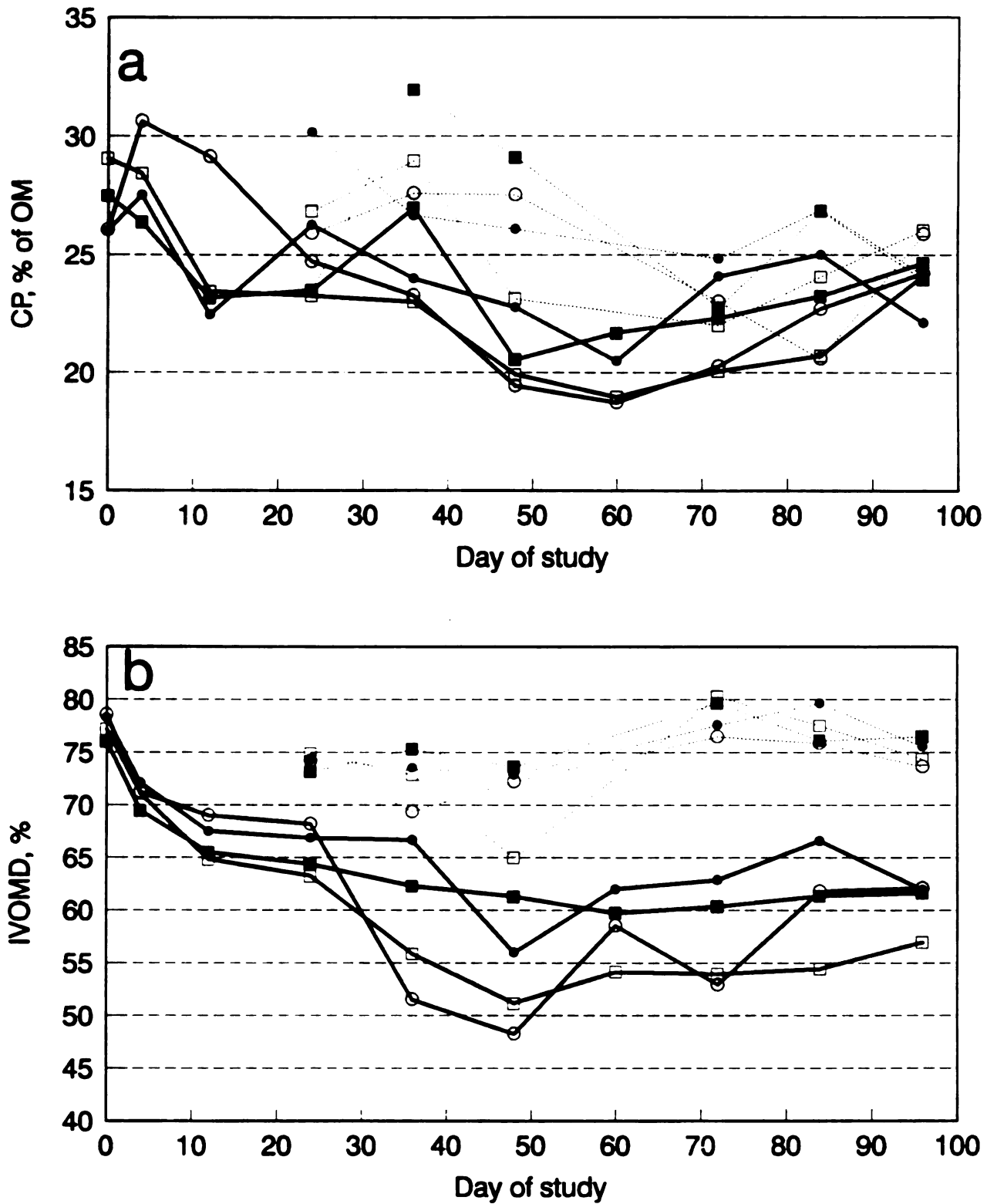


Figure D.3. Crude protein (a) and IVOMD (b) composition of forage (solid lines) and extrusa (dashed lines) over the 1990 grazing season collected from 4 paddock (circles) and 13 paddock (squares) systems at the low (open) and high (closed) stocking rates.

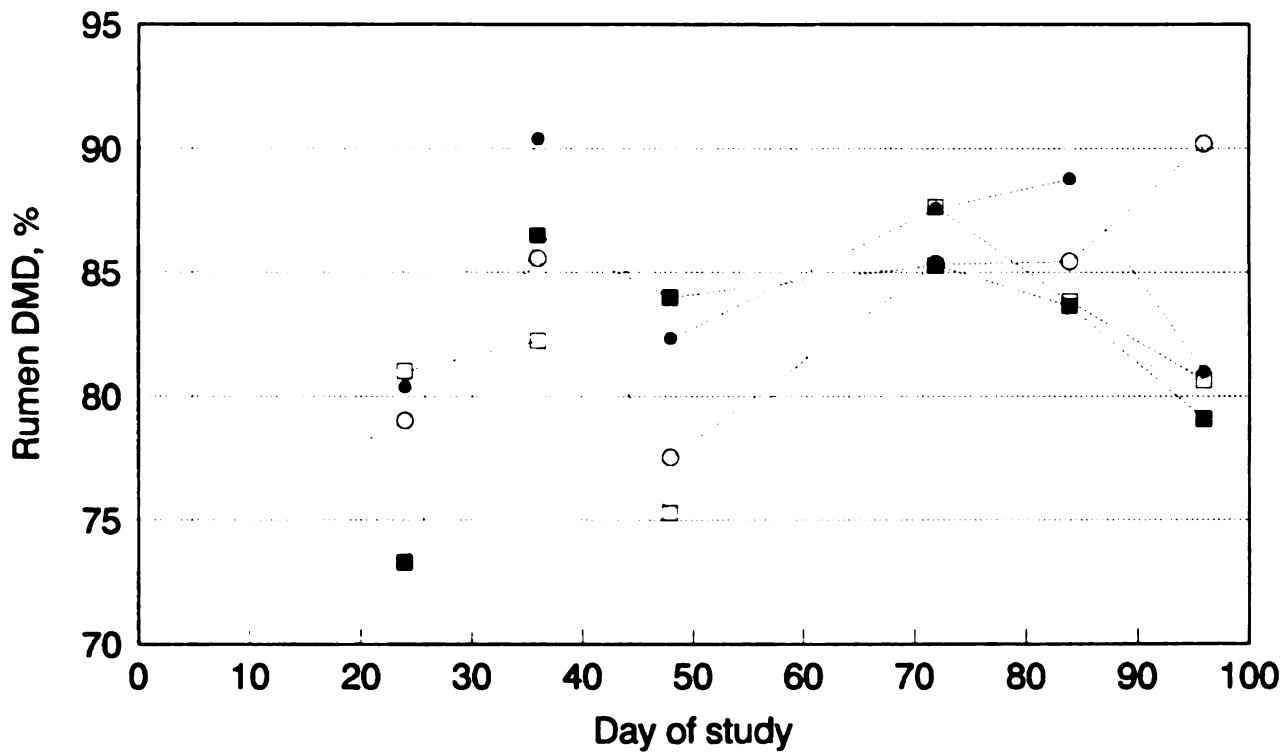
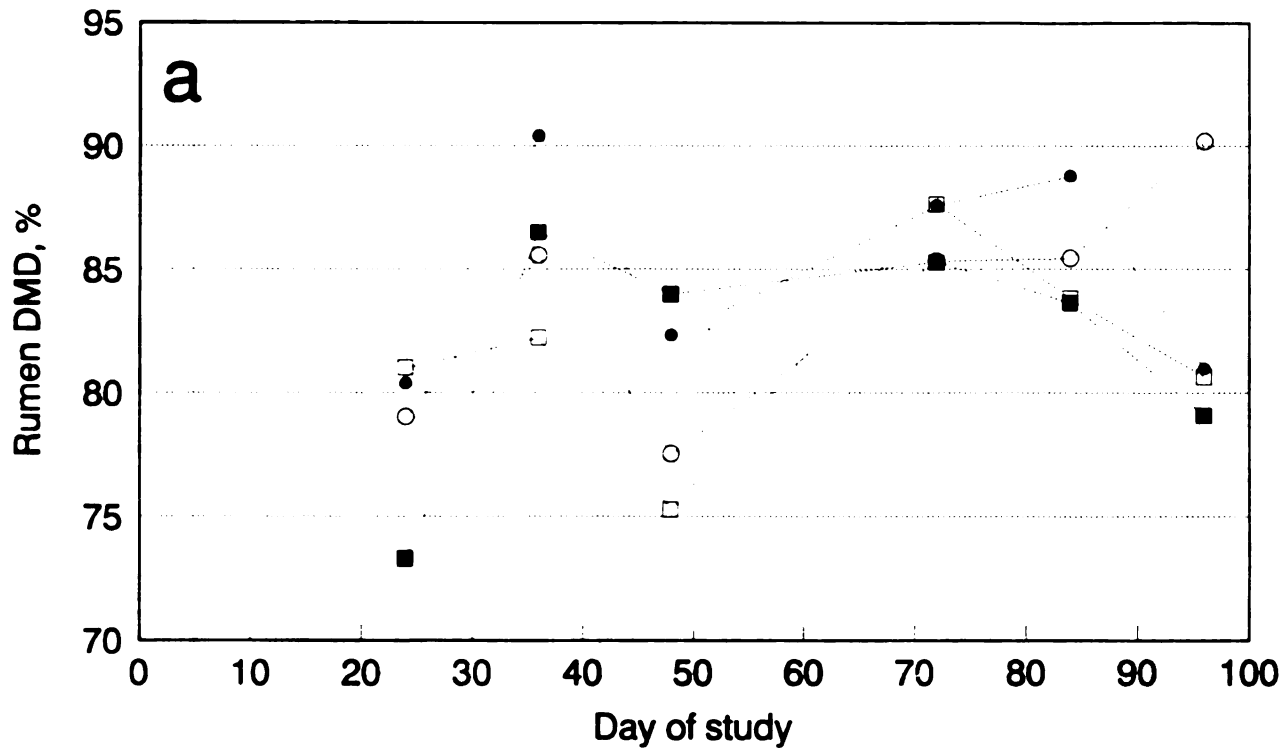


Figure D.4. Rumen DMD (a) and UDP (b) of extrusa samples over the 1990 grazing season collected from 4 paddock (circles) and 13 paddock (squares) systems at the low (open) and high (closed) stocking rates.

Table D.13. Individual animal performance and plot gains from fall grazing (1989)

Animal No. Tag	Tag 2	Plot	GM	SR	Day -2		Day -1 10/13/89	Final shrunk wt., lb	Date of final shrunk wt	Final full wt., lb	Date of final full wt.	Days on pasture
					10/07/89 full wt., lb	10/12/89 full wt., lb						
793	116	1	4	L	795	830	790	800	11/16/89	810	11/20/89	35
780	7728	1	4	L	795	810	780	815	11/16/89	820	11/20/89	35
981	8907	1	4	L	765	780	770	785	11/16/89	810	11/20/89	35
789	8996	1	4	L	770	665	650	805	11/16/89	820	11/20/89	35
994	8983	2	13	L	780	710	710	795	11/16/89	795	11/20/89	35
787	8986	2	13	L	800	840	805	805	11/16/89	810	11/20/89	35
977	8988	2	13	L	785	790	740	800	11/16/89	810	11/20/89	35
776	8993	2	13	L	740	770	715	780	11/16/89	775	11/20/89	35
983	3	3	13	H	825	830	820	N/A	10/31/89	N/A	11/03/89	18
998	8654	3	13	H	740	740	730	705	10/31/89	780	11/03/89	18
979	8870	3	13	H	785	790	785	755	10/31/89	820	11/03/89	18
781	8898	3	13	H	815	695	680	795	10/31/89	860	11/03/89	18
800	8984	3	13	H	755	770	755	725	10/31/89	790	11/03/89	18
999	8991	3	13	H	780	790	780	745	10/31/89	810	11/03/89	18
782	8997	3	13	H	790	830	800	735	10/31/89	815	11/03/89	18
990	8999	3	13	H	780	805	775	745	10/31/89	830	11/03/89	18
799	2	4	4	H	790	810	800	810	11/02/89	830	11/05/89	18
984	148	4	4	H	780	785	780	770	11/02/89	795	11/05/89	18
995	154	4	4	H	775	805	800	770	11/02/89	800	11/05/89	18
783	1619	4	4	H	785	820	790	760	11/02/89	790	11/05/89	18
989	8797	4	4	H	750	650	630	730	11/02/89	750	11/05/89	18
991	8813	4	4	H	790	800	800	765	11/02/89	805	11/05/89	18
792	8987	4	4	H	795	805	780	785	11/02/89	815	11/05/89	18
797	8989	4	4	H	765	775	735	735	11/02/89	760	11/05/89	18
1000	7	6	13	H	850	860	850	840	10/29/89	850	11/01/89	16
796	129	6	13	H	875	895	840	800	10/29/89	825	11/01/89	16
791	161	6	13	H	850	900	855	810	10/29/89	805	11/01/89	16

Table D.13. (Cont'd.)

Animal No. Tag	Plot	GM	SR	Day -2 10/07/89		Day -1 10/13/89		Final shrunk wt., lb	Date of final shrunk wt	Final full wt., lb	Date of final full wt.	Days on pasture
				full wt., lb	full wt., lb	full wt., lb	shrunk wt., lb					
790	8899	6	13	H	905	960	933	925	865	880	11/01/89	16
785	8947	6	13	H	830	845	838	835	795	795	11/01/89	16
777	8985	6	13	H	845	880	863	855	810	820	11/01/89	16
982	8995	6	13	H	870	910	890	865	825	830	11/01/89	16
992	8998	6	13	H	810	845	828	830	780	790	11/01/89	16
976	153	7	4	L	820	860	840	835	880	855	11/20/89	34
795	224	7	4	L	825	745	785	705	865	835	11/20/89	34
985	1819	7	4	L	865	870	868	845	915	870	11/20/89	34
968	8895	7	4	L	820	760	790	740	865	850	11/20/89	34
987	4	8	4	H	880	895	888	860	N/A	N/A	11/03/89	18
798	130	8	4	H	820	860	840	815	810	885	11/03/89	18
778	8794	8	4	H	865	910	888	860	835	905	11/03/89	18
788	8807	8	4	H	840	865	853	850	825	910	11/03/89	18
978	8857	8	4	H	825	845	835	825	795	865	11/03/89	18
794	8896	8	4	H	870	880	875	850	850	920	11/03/89	18
980	8992	8	4	H	900	925	913	890	890	945	11/03/89	18
986	8994	8	4	H	820	750	785	720	790	850	11/03/89	18
993	5	9	13	L	780	820	800	775	820	830	11/20/89	35
786	112	9	13	L	900	945	923	900	900	900	11/20/89	35
784	8897	9	13	L	820	865	843	840	860	875	11/20/89	35
997	8900	9	13	L	845	740	793	725	845	870	11/20/89	35

Table D.13. (Cont'd.)

Animal No. Tag	Plot	Full wt. ADG lb/d	Shrunk wt ADG lb/d	Full Gain/ac, lb	Shrunk Gain/ac, lb
793 116	1	-0.06	0.29	73.99	117.73
780 7728	1	0.45	1.03		
981 8907	1	0.96	0.44		
789 8996	1	2.63	4.56		
994 8983	2	1.28	2.50	39.38	114.99
787 8986	2	-0.26	0.00		
977 8988	2	0.58	1.76		
776 8993	2	0.51	1.91		
983 3	3			135.53	-32.18
998 8654	3	1.82	-0.74		
979 8870	3	1.48	-0.88		
781 8898	3	4.77	3.38		
800 8984	3	1.25	-0.88		
999 8991	3	1.14	-1.03		
782 8997	3	0.23	-1.91		
990 8999	3	1.70	-0.88		
799 2	4	1.25	0.50	41.89	4.79
984 148	4	0.52	-0.50		
995 154	4	0.42	-1.50		
783 1619	4	-0.52	-1.50		
989 8797	4	2.08	5.00		
991 8813	4	0.42	-1.75		
792 8987	4	0.63	0.25		
797 8989	4	-0.42	0.00		
1000 7	6	-0.25	-0.63	-157.45	-175.53
796 129	6	-3.00	-2.50		
791 161	6	-3.50	-2.81		

Table D.13. (Cont'd.)

Animal No. Tag	Plot Tag 2	Full wt. ADG lb/d	Shrunk wt ADG lb/d	Full Gain/ac, lb	Shrunk Gain/ac, lb
790 8899	6	-2.63	-3.75		
785 8947	6	-2.13	-2.50		
777 8985	6	-2.13	-2.81		
982 8995	6	-3.00	-2.50		
992 8998	6	-1.88	-3.13		
976 153	7	0.38	1.32	59.12	212.77
795 224	7	1.28	4.71		
985 1819	7	0.06	2.06		
968 8895	7	1.54	3.68	145.48	-9.12
987 4	8				
798 130	8	2.05	-0.28		
778 8794	8	0.80	-1.39		
788 8807	8	2.61	-1.39		
978 8857	8	1.36	-1.67		
794 8896	8	2.05	0.00		
980 8992	8	1.48	0.00		
986 8994	8	2.95	3.89		
993 5	9	0.77	1.32	56.09	101.30
786 112	9	-0.58	0.00		
784 8897	9	0.83	0.59		
997 8900	9	1.99	3.53		

Table D.14. Individual animal performance of steers used for intake study

1989			Day 0	25	37	37	49	61	73	85	96
Anim. No.	Plot	Grazing Time, h	05/20	06/15	06/27	06/27	07/09	07/21	08/02	08/14	08/25
			Avg.	full	shrunk	adjust.	full	full	full	full	full
			wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb	wt., lb
35	11	6	550	525	538	565	547	570	577	550	542
114	11	6	560	530	545	595	563	586	596	593	620
102	11	10	540	525	533	530	485	505	541	502	488
105	11	10	500	510	505	550	505	526	549	535	495
89	11	24	565	550	558	575	536	558	572	575	573
91	11	24	525	520	523	560	530	552	575	573	526
39	12	6	580	545	563	595	595	620	603	615	578
45	12	6	510	530	520	570	566	590	589	604	578
81	12	10	525	495	510	545	565	589	568	578	557
117	12	10	545	520	533	580	590	615	598	625	581
75	12	24	520	515	518	540	554	577	588	606	Died of bloat
109	12	24	535	525	530	570	555	578	579	609	526

Table D.15. Daily fecal output and fecal DM, OM, CP and Cr concentrations

Sample No.	Collection Date	Anim. No.	Total Feces wt., lb	Fecal DM, %	Fecal OM, % of DM	Fecal CP, % of DM	Fecal Cr, ug/g DM
2000	7-30-89	35	10.9	17.23	83.62	13.30	907.97
2001	7-30-89	89	31.2	11.20	81.68	16.47	731.25
2002	7-30-89	91	25.9	28.18	85.26	8.85	694.08
2003	7-30-89	102	4.3	19.30	82.88	10.49	974.38
2004	7-30-89	105	27.0	16.75	83.78	13.20	1046.81
2005	7-30-89	114	23.2	16.43	81.84	13.59	831.52
2008	7-30-89	39	15.4	17.08	86.45	11.73	645.12
2009	7-30-89	45	14.7	16.11	82.39	11.88	580.01
2010	7-30-89	75	31.3	14.80	86.86	11.45	484.45
2011	7-30-89	81	24.7	14.48	86.08	11.08	672.55
2012	7-30-89	109	33.4	14.16	86.24	10.45	651.52
2013	7-30-89	117	24.7	12.17	87.05	11.49	569.85
2016	7-31-89	35	16.8	15.95	86.10	15.62	N/A
2017	7-31-89	89	30.6	13.08	85.46	18.36	988.80
2018	7-31-89	91	29.7	14.36	84.75	16.64	705.37
2019	7-31-89	102	23.1	17.06	84.26	15.70	874.22
2020	7-31-89	105	14.8	15.74	85.95	17.82	1085.12
2021	7-31-89	114	26.6	15.21	85.35	16.15	820.58
2024	7-31-89	39	24.3	16.39	85.42	11.71	657.04
2025	7-31-89	45	29.9	16.41	85.67	13.56	640.72
2026	7-31-89	75	16.2	14.45	87.67	13.47	571.86
2027	7-31-89	81	21.7	15.59	83.36	13.78	606.08
2028	7-31-89	109	37.2	15.57	86.47	12.92	625.61
2029	7-31-89	117	13.1	13.24	86.75	12.83	388.37
2032	8-1-89	35	4.6	19.88	83.26	14.58	784.68
2033	8-1-89	89	19.8	13.27	84.48	13.04	703.44
2034	8-1-89	91	9.1	16.11	79.49	13.17	701.87
2035	8-1-89	102	12.4	19.03	74.36	13.65	682.10
2036	8-1-89	105	9.7	18.36	78.75	15.26	767.52
2037	8-1-89	114	15.6	16.59	83.27	13.91	507.67
2040	8-1-89	39	22.1	15.50	85.16	12.83	444.89
2041	8-1-89	45	24.7	14.60	85.99	15.58	479.42
2042	8-1-89	75	31.5	11.69	86.73	16.82	437.83
2043	8-1-89	81	No sample				
2044	8-1-89	109	26.6	13.36	87.72	16.26	430.46
2045	8-1-89	117	13.5	11.13	87.19	13.24	535.30
2048	8-8-89	35	13.7	17.48	81.79	13.54	467.37
2049	8-8-89	89	41.9	13.61	83.21	13.05	296.48
2050	8-8-89	91	37.4	12.67	85.52	14.58	419.66
2051	8-8-89	102	22.7	17.07	80.99	14.61	454.92
2052	8-8-89	105	20.9	14.79	85.46	15.14	461.02
2053	8-8-89	114	31.3	15.38	82.72	13.79	366.08
2054	8-8-89	39	28.6	17.40	81.06	12.36	521.07
2055	8-8-89	45	23.0	17.28	78.33	13.84	528.57
2056	8-8-89	75	22.6	17.76	79.02	14.09	475.24
2057	8-8-89	81	29.8	14.35	82.26	15.15	494.05

Table D.15. (Cont'd)

Sample No.	Collection Date	Anim. No.	Total Feces wt., lb	Fecal DM, %	Fecal OM, % of DM	Fecal CP, % of DM	Fecal Cr, ug/g DM
2058	8-8-89	109	21.3	16.40	81.76	15.01	387.33
2059	8-8-89	117	19.2	12.91	82.93	15.08	405.72
2060	8-9-89	35	9.2	17.50	83.34	13.23	475.91
2061	8-9-89	89	16.1	13.17	84.42	13.34	427.95
2062	8-9-89	91	12.1	14.06	89.27	15.78	330.10
2063	8-9-89	102	18.3	17.78	83.59	12.27	421.19
2064	8-9-89	105	19.1	14.59	80.62	13.45	475.31
2065	8-9-89	114	32.0	15.58	86.98	13.27	301.98
2066	8-9-89	39	23.6	16.34	83.08	13.45	479.08
2067	8-9-89	45	20.0	15.99	81.54	16.20	552.08
2068	8-9-89	75	28.6	15.32	81.24	15.81	529.01
2069	8-9-89	81	21.6	13.89	77.91	14.98	470.63
2070	8-9-89	109	33.4	15.20	82.26	16.32	344.13
2071	8-9-89	117	24.2	11.46	80.18	15.15	404.22
2072	8-10-89	35	19.3	18.56	83.64	11.26	500.02
2073	8-10-89	89	22.2	14.13	85.69	11.27	431.56
2074	8-10-89	91	20.8	14.88	89.53	13.51	333.85
2075	8-10-89	102	13.6	19.16	82.95	11.13	362.12
2076	8-10-89	105	9.8	12.12	85.54	9.64	552.40
2077	8-10-89	114	25.4	14.94	87.15	11.86	315.93
2078	8-10-89	39	22.0	16.16	85.00	14.40	388.55
2079	8-10-89	45	11.1	18.16	81.47	13.44	511.26
2080	8-10-89	75	20.2	16.50	78.28	15.79	508.53
2081	8-10-89	81	13.2	14.08	80.64	13.91	472.35
2082	8-10-89	109	13.4	14.90	81.65	13.97	207.14
2083	8-10-89	117	17.1	14.12	82.22	12.36	495.44
2084	8-11-89	35	16.8	17.01	85.40	12.15	518.92
2085	8-11-89	89	14.5	15.27	86.43	11.75	483.87
2086	8-11-89	91	28.7	15.42	89.81	14.18	375.64
2087	8-11-89	102	14.0	18.29	84.71	11.12	423.54
2088	8-11-89	105	15.1	13.71	82.39	8.97	631.67
2089	8-11-89	114	20.0	15.89	88.10	18.05	298.64
2090	8-11-89	39	23.4	18.18	80.57	13.90	480.46
2091	8-11-89	45	16.2	18.07	78.55	16.28	484.63
2092	8-11-89	75	20.5	17.38	78.89	14.40	576.54
2093	8-11-89	81	18.7	18.36	78.99	14.50	759.43
2094	8-11-89	109	23.4	18.06	80.77	17.79	171.25
2095	8-11-89	117	35.7	14.02	81.63	14.27	769.08

Table D.16 Individual live-weight and enzyme levels of photosensitive steers

Anim. No.	Hair Loss Score	1989							
		Initial wt., lb 05/20	Day 24 wt., lb 06/14	Day 32 wt., lb 06/22	Day 75 wt., lb 08/04	AST IU/L 06/22	AST IU/L 08/04	SDH IU/L 06/22	SDH IU/L 08/04
1	0	513	520	545	725	66	59	70	30
5	0	428	445	475	640	69	25	84	62
9	0	578	620	615	725	71	59	55	34
13	0	588	600	620	710	119	59	178	58
17	0	573	580	565	680	57	59	36	26
33	0	435	480	500	655	61	65	59	40
46	0	453	470	430	505	1340	43	37	62
51	0	548	555	530	685	61	52	50	43
59	0	465	480	470	590	63	34	48	67
84	0	537	550	550	650	50	53	23	37
121	0	595	620	605	750	68	75	50	42
15	1	518	530	555	625	58	58	60	54
31	1	530	560	530	620	49	52	47	40
36	1	483	505	520	590	89	59	154	41
40	1	560	610	610	695	57	34	35	51
43	1	445	470	495	560	68	67	24	61
107	1	555	565	575	655	71	64	96	28
4	2	635	700	690	810	88	78	43	63
30	2	558	545	560	675	71	72	60	51
47	2	543	530	540	660	61	84	52	114
62	2	525	560	530	615	68	59	224	43
65	2	560	530	565	615	57	51	33	86
76	2	493	550	550	590	56	66	50	114
122	2	456	480	485	545	56	61	45	65
3	3	670	685	645	820	67	86	31	53
7	3	528	570	555	720	68	72	34	26
53	3	583	600	600	640	65	59	103	29
60	3	533	525	550	645	59	58	180	33
74	3	488	505	490	610	72	24	82	59
88	3	555	545	520	640	47	48	51	30
113	3	450	455	470	600	54	55	53	27
120	3	485	525	520	660	48	48	30	33

AST: Aspartate transaminase
SDH: Sorbitol dehydrogenase

APPENDIX E: EFFECT OF GRAZING METHOD AND STOCKING METHOD ON HEIFERS GRAZING STOCK-PILED ALFALFA PASTURES IN THE FALL

Forty-eight cross-bred heifers (371 kg) were utilized to study the effects of grazing method, 4 or 13 paddocks, and stocking rate, 5.3 and 10.5 heifers/ha, on ADG and gain per hectare stock-piled alfalfa forage. Alfalfa was stock-piled from September 1, 1989 until October, 12, 1989. On October 7, 1989, heifers were weighed and allowed ad libitum access to alfalfa haylage and water for the next week prior to initiation of the study. The heifers were divided into 2 weight blocks (354 kg, 388 kg) and randomly assigned to 1 of 4 grazing treatment combinations. On October 12, 1989 heifers were weighed full, and following 16 h without feed and water, a shrunk weight was determined. On October 14, heifers were fed alfalfa haylage and transported .8 km to the alfalfa pasture. On pasture, heifers had ad libitum access to water and a poloxalene block. Heifers were rotated through 1 grazing cycle and were moved to the next paddock based on forage availability. Forage samples were collected from each paddock prior to heifer entry from 3 randomly placed quadrants (.5 x .5 m), and analyzed for DM to determine forage presentation. When all paddocks had been grazed, heifers were returned to the MSU Beef Cattle Research Center and withheld from feed and water for 16 h to determine a shrunk weight. Three days later, a full weight was determined. Average daily gain was determined from the difference between the 2 full or shrunk weights. Gain per hectare was calculated by multiplying ADG x SR x Days on pasture. Forage presentation is presented in Table D.5 and animal performance and plot gains is presented in Table D.13.

Stocking rate nor GM influenced ADG primarily due to the large variation in animal response. Unlike the grazing study over the summer, there was no clear relationship among SR and ADG. Heifers from high SR plots spent 50% less ($P < .05$) days on pasture than the low SR plots. This response would be expected with a fix amount of forage but twice the number of animals. Live-weight gain per hectare and forage present were similar for all plots. There was no clear trends in gains with the amount of forage present. This would suggest that difference in forage quality may have been produces the varied outcome. Although production from stock-piled alfalfa was variable, the use of fall pasture can increase the amount of beef produced per hectare in a given year.

Table E.1. Effect of grazing method and stocking rate on live-weight gains and forage presentation

Item	4-L	4-H	13-L	13-H	SEM	Effects ¹
Average daily gain, kg	.41	.56	.29	-.12	.54	- -
Days on pasture	34.5	18.0	35.0	17.0	.48	SR
Gain per hectare, kg	74.6	105.0	53.5	-12.3	96.3	- -
Forage presentation, kg/ha	1424	1337	1475	1504	93	- -

¹Main effect statistical significance, ($P < .05$)

APPENDIX F: PROBLEMS ENCOUNTERED THROUGHOUT THE 4 YEAR GRAZING STUDY

YEAR 1: 1989

5-19-89 Steers in plots 1-4 were placed on pasture.

5-20-89 Steers in plots 6-9 were placed on pasture.

The staggered start was done to save time but caused more work because instead of sampling paddocks every 3 days, samples needed to be collected 2 out of every 3 days.

5-30-89 5.4 cm of rain

6-1-89 1100 Steers in plot 3 and 6 were moved to the alleys to prevent trampling of paddocks. (1.4 cm of rain)

Afternoon Steers were moved to drier paddocks.

Plots 1-4, next paddock

Plots 6-9, last paddock, because central paddocks were low lying

6-4-89 Moved cattle in plots 6 and 9 due to wet paddocks. (.9 cm rain)

6-5-89 Steer #113 was noticed with sunburn (photosensitivity).

6-6-89 Steer #3 (plot 11) observed with photosensitivity.

Noticed 4-H plots low in forage (1st indication that the paddocks were overstocked).

6-7-89 Additional steers became photosensitive.

Hay field cut, but center part of plot 5 and west side of plot 10 were not due to wet ground.

6-9-89 All paddocks previously grazed were sprayed with Sevin [Carbaryl (1-naphthyl N-methyl carbamate)] to control alfalfa weevils.

Year 1 (Cont'd.)

- 6-13-89 One-third of the cattle were removed from the study to reduce the stocking rate.
- 9 steers: not photosensitive
 - 21 steers: showing photosensitivity
 - 1 steer: with one testicle
 - 1 steer: with an infected ear implant
- Cattle from plots 2,3,6, and 9 were placed on supplemental pasture.
- 6-15-89 Duodenal cannulas came out of the duodenally fistulated steers, and re-inserted. (cannulas were made of silastic tubing)
- Steers in plots 4 and 12 were placed on supplemental pasture.
- 6-21-89 Steers in plots 1,7, and 8 were moved to supplemental pasture.
- 6-25-89 Steers in plot 11 were moved to supplemental pasture.
- 6-26-89 Steers were fed alfalfa hay (2.3 kg DM/steer) and allowed access to water and poloxalene-mineral mix. At 1600 fed, water and poloxalene-mineral mix were removed for a 16 h shrink.
- 6-27-89 A shrunk weight was determined on all steers, fed alfalfa hay as the day before and placed back on assigned plots
- 7-9-89 Steer #91 looked bloated, administered a mixture of poloxalene-mineral mix and water, and .9 L of mineral oil
- 7-11-89 Steer #2981 (esophageally fistulated) collapsed, because its esophageal cannula fell out. Other steers which lost their cannulas had the fistulae grow shut, but in the case of #2981, the fistulae did not close and the steer die of dehydration.
- 7-26-89 Pump engine on mobile water tank broke, and cattle had to be water by gravity (repaired next day).
- 8-2-89 Potato leaf hopper infested the alfalfa field. The hay fields were affected to a greater extent than the pastures.
- 8-18-89 Steer #75 found dead of bloat (steer jumped fence and grazed lush alfalfa).
- 8-20-89 Esophageal steers #9 and #95 were bloated from jumping a fence into lush pasture. Steers were given .5 to 1 L of mineral oil by stomach tube.

Year 1 (Cont'd.)

- 8-21-89 Plot 8 was out of forage, so steers received 4.5 kg alfalfa hay per steer to maintain similar rate of growth.
- Seven steers from plot 12 were bloated. Steers were given .5 to 1 L of mineral oil.
- 8-22-89 Steers in plot 8 were given 4.5 kg alfalfa hay per steer.
- 8-23-89 Steers in plot 4 and 8 were moved to lush supplemental pasture and given 2.3 kg alfalfa hay per steer to try to reduce incidence of bloat.
- 8-24-90 Steers on supplemental pasture were moved to the next paddock.
- 8-25-89 0800 Steer #58 and #29 were found dead of bloat, but the remaining steers were fine.
- 1500 Steer #68 was found dead, and #2 was severely bloated. After attempts were made to relieve the bloat, steer #2 died. Seven additional steers were bloated and were stomach tube to relieve the bloat.
- 8-29-89 All steers removed from pasture.
- 10-12-89 Cross-bred heifers used for fall grazing study and not tame and will not stay in their assigned paddocks. Also the fence charger is weak and not charging the fence to its maximum potential
- 11-15-89 A few inches of snow fell prompting removing the heifers from pasture.

YEAR 2: 1990

- 5-14-90 Steers moved to pasture.
- 5-15-90 Steers did more walking around the paddocks as if they did not know what to eat.
- 5-29-90 Low stocked plots infested with curly dock.
- 6-6-90 Canadian thistle started to infest pastures.
- 6-21-90 Five steers were treated for pink eye. Steer #42 was blind in one eye from pink eye

Year 2 (Cont'd.)

- 6-29-90 Four steers treated for pink eye.
- 7-4-90 Two steers were treated for pink eye.
- 7-18-90 Three steers were treated for pink eye.
- 7-29-90 Two steers were treated for pink eye.
- 8-1-90 Two esophageally fistulated steers lost cannulas, although, the cannulas were replaced.
- 8-3-90 Steer #42 contracted pink eye in the second eye and become totally blind, but eating and doing well.
- 8-30-90 Steers removed from pasture.

YEAR 3: 1991

- 5-13-91 Steers placed on pasture.
- 6-5-91 Alley-ways were bush-hogged to increase fence voltage.
- 6-6-91 Four steers treated for pink eye.
- 7-15-91 One steer treated for pink eye.
- 9-2-91 Steers removed from pasture.

YEAR 4: 1992

- 5-13-92 Steers placed on pasture.
- 7-20-92 Steer #731 died of bloat.
- 8-9-92 Steer found with lacerated leg.
- 9-8-92 Steers removed from pasture.

MICHIGAN STATE UNIVERSITY

ALL UNIVERSITY COMMITTEE ON ANIMAL USE AND CARE
 C BUILDING • CLINICAL CENTER
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MEMORANDUM

TO: Benson, Margaret E.
 Animal Science
 105D Anthony

FROM: Richard Malshaw, Chairperson
 All-University Committee on Animal Use and Care

DATE: August 30, 1988

SUBJECT: APPROVAL of Application to Use Vertebrate Animals in Research

This is to notify you that your recent application to use vertebrate animals in research or teaching has been approved by the All University Committee on Animal Use and Care. This approval is for a one-year period, beginning on the date of approval by the committee. Should your work extend beyond the end of that year, you must resubmit your request to the committee. For your convenience, the new Animal Use Form is designed so that resubmissions may be accomplished by merely identifying the earlier proposal and indicating that the proposal is being resubmitted without revisions.

The title of your approved proposal, the date of approval, and the tracking numbers assigned (both OFD and AUF numbers) are given below. You should retain this information for future use. Please note that, according to University policy, no significant changes may be made to your animal-use plan without prior approval from the AUCAUC. Requests for review of proposed revisions may be made by submitting a new Animal Use Form or by sending a letter to the AUCAUC.

Title of Proposal: Energy Efficient Harvest Methods for Michigan Pasture Lands

Date of approval: 8/26/88

OFD Number: n/a

AUF Number: 8/88-321-01

Funded by: Department

CSPW/cjf

CC: Maynard Hogberg, Chairperson
 Animal Science
 102 Anthony

LIST OF REFERENCES

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