Short duration grazing on alfalfa
by Rodolfo Abel Agustinho

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Agronomy
Montana State University

Abstract:
Livestock grazing alfalfa (Medicago sativa L.) usually have higher average daily gains and higher total gains per hectare than livestock grazing pure grass pastures. Problems of stand maintenance and weed encroachment occur if grazing management is not adequate. A grazing method that maintains alfalfa stands and prevents weed encroachment is needed.

This study was conducted to determine the effect of ten Short Duration Grazing (SDG) treatments by comparison of these treatments with traditional grazing and haying treatments. Field studies were conducted at two locations, and greenhouse studies were performed with two alfalfa cultivars in 1987. Information on forage production, plant morphology and accumulation of root reserves was obtained. The best forage production was obtained under hay and traditional grazing treatments. Forage production decreased with increased clipping stress. Leaf area decreased in all the SDG treatments with successive harvests. Leaf area variability increased with high clipping stressed. The ratio of axial bud:crown bud did not produce a defined response. Root reserve accumulation was similar at greenhouse and field studies. Total nonstructural carbohydrates were lower with the high stress treatments and higher with the traditional grazing and hay treatments. Forage quality increased with clipping stress but was high under all treatments.

Forage quality and distribution throughout the season were also considered in the evaluation of the grazing systems.

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APPROVAL

of a thesis submitted by

Rodolfo Abel Augustinho

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

March 10, 1988 — Raymond L. [signature]
Date — Chairperson, Graduate Committee

Approved for the Major Department

March 11, 1988 — James W. Bauder
Date — Head, Major Department

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ABSTRACT

Livestock grazing alfalfa (Medicago sativa L.) usually have higher average daily gains and higher total gains per hectare than livestock grazing pure grass pastures. Problems of stand maintenance and weed encroachment occur if grazing management is not adequate. A grazing method that maintains alfalfa stands and prevents weed encroachment is needed.

This study was conducted to determine the effect of ten Short Duration Grazing (SDG) treatments by comparison of these treatments with traditional grazing and haying treatments. Field studies were conducted at two locations, and greenhouse studies were performed with two alfalfa cultivars in 1987. Information on forage production, plant morphology and accumulation of root reserves was obtained. The best forage production was obtained under hay and traditional grazing treatments. Forage production decreased with increased clipping stress. Leaf area decreased in all the SDG treatments with successive harvests. Leaf area variability increased with high clipping stressed. The ratio of axial bud:crown bud did not produce a defined response. Root reserve accumulation was similar at greenhouse and field studies. Total nonstructural carbohydrates were lower with the high stress treatments and higher with the traditional grazing and hay treatments. Forage quality increased with clipping stress but was high under all treatments. Forage quality and distribution throughout the season were also considered in the evaluation of the grazing systems.

CHAPTER 1

INTRODUCTION

Alfalfa (Medicago sativa L.) is the most important forage crop in the world. It is very high yielding, has excellent nutritional quality and is very widely adapted.

Most research has been conducted on how to improve alfalfa's hay production, and only limited research has been conducted on how to best manage alfalfa as a pasture crop. Grazing decreases alfalfa stand life and allows for rapid weed encroachment. A better grazing management system for alfalfa is needed.

Short Duration Grazing (SDG) has been used effectively on other forage species but has not been evaluated for use on alfalfa. The objective of this study was to evaluate the effect of various SDG treatments on alfalfa's yield, morphological characteristics, root reserves, and nutritional value.

CHAPTER 2

LITERATURE REVIEW

History

Alfalfa is the most important forage crop in the world and is grown on more than 33 million hectares (ha) worldwide (5). Alfalfa has a long history as a forage crop. Ancient civilizations (Persians, Medes, Romans) utilized alfalfa to feed domestic animals. Alfalfa was used in Turkey more than 3000 years ago. This geographic area appears to be the main distribution point of alfalfa during its early dissemination (5).

Alfalfa was introduced to the new world by Spanish conquerors shortly after the discovery of America. Initial use was only in South America (81).

In 1851 seed from Chile was planted in California. From this time, an impressive invasion occurred in two periods. For the first 50 years, alfalfa spread primarily throughout the western States. Since the turn of the century, expansion has been primarily in the central and the eastern United States (31). Currently, more than 50% of the alfalfa hectareage is in the midwestern and eastern United States (36,44).

Severe droughts occurred between 1934 and 1936, and alfalfa during this time yielded much better than the common forage crops

(Timothy--Phleum pratense L. and clovers--Trifolium spp.). This greatly improved alfalfa's popularity and resulted in an explosive expansion of the crop in the eastern States (82).

Other factors important to this expansion include: genetic improvement (decreased winter kill and improved pest resistance); adjusting the soil environment (liming and fertilization); improved seed bed preparation and seeding techniques; discovering the physiological principles for crop management (hay and pasture); improved nitrogen fixation (better rhizobia); and new knowledge about pesticides (19).

Cutting Frequency

Many agronomic studies have been conducted on alfalfa. They can generally be divided into hay production and grazing utilization.

Most research has been done on hay production and has generally concentrated on maximizing yield and stand life (especially as affected by winterkill). Research conducted early in this century is considered to include some classic studies.

In 1916, McKee (52) stated that very little work had been done to determine the effect of clipping on subsequent yields of alfalfa. Some state Agricultural Experiment Stations were advising against clipping, while others claimed better weed control, invigorated growth, and greater root development from clipping.

In 1924, Graber (29) stated that alfalfa's response to various cutting treatments was pronounced. Forage yield, stand longevity, plant vigor, and winter hardiness were greatly affected by cutting frequency at various growth periods. Plants were cut three, four, five, and six times per year. He concluded that

> ...the lessened vigor, diminution of stands, and consequent lower yields from early and frequent cutting of alfalfa was in part due to: 1) lack of sufficient root reserves for normal growth or an exhaustion of the reserves sufficient to cause actual death; 2) lessened absorptive capacity of plant roots for nutrients; 3) competition from encroaching weeds and grass due to less vigorous plants and thinning stands; and 4) greater susceptibility to winter-killing of plants with low food storage.[1]

Graber (29) stated

> A better understanding of the chemical and biological nature of root reserves, their utilization and disposition may well prove significant in the improvement of some of our field practices, such as the proper maintenance of our hay crops, pastures and lawns, the eradication of certain weeds, and the solution of many of our winter-killing difficulties.[2]

This basic knowledge persisted for several years and was used as a basis for many studies by other researchers (1,30,32,39,56,90,95) who generally confirmed his findings about alfalfa growth behavior.

In 1930, Willard (95) found that extensive reductions of alfalfa root reserves, as measured by total root weight per hectare, consistently resulted in reduced yield and vigor. He did not mention the kind of root reserves.

Cooper and Watson (16) reported on the Total Available Carbohydrates (TAC) in roots of sainfoin (Onobrychis viciifolia

[1]Graber, L. F. 1924. Hay crops: the growth of alfalfa with various cutting treatments. J. Am. Soc. Agron. 16. Page 172.
[2]Ibid.

Scop.) and alfalfa under several management regimes. They concluded that cutting treatments had little effect on the final TAC level in roots of either species at the end of the growing season.

Reynolds (65) compared nonstructural carbohydrates trends in alfalfa roots with six harvest frequencies (eight, six, five, four, three, and two cuts per year). He obtained the lowest forage yield and the lowest carbohydrate levels with the eight-cut treatment. Many other researchers (4,21,22,23,25,27,55,62,66,72) obtained similar results.

Fall Management

In 1937, Silkett, Megee and Rather (73) analyzed the effect of late summer and early fall cutting on alfalfa winter hardiness in Michigan. They found that total season hay yield from alfalfa cut on critical September dates was significantly less than that of plants which were not cut on these dates. Alfalfa plants cut in September were more susceptible to winter injury.

Rather and Dorrance (64) used sheep to graze the plots during the fall and arrived at similar results. Many researchers (22,33,39,45,51,71,75) have corroborated their findings.

A recent study by Tesar and Yager in 1985 (89) contradicts previous ideas concerning fall management. They state that the third cutting may be made in September or early October in southern Michigan without decreasing subsequent yield or stand persistence. Perhaps the cultivars they were testing had better winterhardiness than cultivars previously studied. Their findings are not in agreement with a recent Montana study (Welty and Ditterline, unpublished data) who found that cutting alfalfa 15-30 days prior to a killing frost severely reduced stand life and yield.

Many researchers attempted to obtain higher production through an increased number of cuttings per year (1,9,20,21,39,41,42,43,46, 47,54,58,59,65,77,78,85,86,88,92,96,97). All studies analyzed alfalfa production under hay management and found decreased yield with increased cutting frequency.

Grazing Alfalfa

There are a limited number of studies related to alfalfa under grazing, and most studies were conducted with alfalfa in mixtures with grasses (1,7,11,12,13,15,23,24,82,85,92,94,97).

In 1924, Cox (19) stated that the alfalfa's value as a pasture crop was becoming better understood but that little research has been done to compare alfalfa with other legumes and with pasture grasses.

Some of the research that followed was done under range conditions (7,11,12,15), and most studies were conducted using simulated grazing. Simulated grazing studies have received criticism, and there is still no agreement on the reliability of these studies (2,7,13,18,49,50,63,91). The main objection is that different results in forage production are obtained under simulated grazing than with grazing animals.

In 1984, Counce, Bouton, and Brown (17) studied alfalfa persistence under mowing and continuous grazing. They reported that the prospects for selecting alfalfa for persistence under grazing was promising, but that such selection could lead to less productive alfalfa cultivars unless care is taken to insure productivity as well as persistence.

In 1939, Hildebrand and Harrison (39) analyzed alfalfa production under a wide combination of frequencies and clipping intensities. They cut alfalfa every 7, 14, and 30 days to heights of 2.5, 7.5, 15, 22.5, and 30 cm. They concluded that: 1) cutting alfalfa frequently and close to the crown resulted in depleted food reserves in the roots and markedly decreased hay yield and plant vigor; 2) alfalfa cut frequently at 30 cm resulted in decreased yield due to leaf loss from mature stems and a lack of vegetative growth; 3) alfalfa remained vigorous when cut back to a 15 cm height either biweekly or monthly. One-week intervals between cuttings failed to allow sufficient stored food to maintain the plant under unfavorable periods of growth; 4) cutting back to the 22.5 cm level resulted in good yields of top growth and roots when cut at weekly or biweekly intervals, whereas the monthly interval of cutting allowed the plants to mature and retarded vegetative growth; and 5) although cutting at 30 cm resulted in an abundance of food storage, the top growth yield above the cutting level was relatively low due to the maturing of the tops below the cutting level.

In 1958, Gross et al. (34) conducted a simulated grazing experiment. They harvested several alfalfa cultivars whenever plant height reached 20 cm. They obtained five and six harvests per year, but dry matter production was lower compared with traditional hay management. They concluded that frequent cutting depressed the yields of all cultivars.

Dennis et al. (21) conducted a three-year study with different clipping frequencies. They began harvesting each season when the alfalfa was 20 cm tall and harvested every one, two, three, four, and six weeks. Alfalfa yield was associated with cutting interval. The more often alfalfa was cut, the less productive it became. Weed invasion increased, and root production and winter survival of alfalfa decreased in all plots cut frequently. Regrowth was stimulated by frequent cutting for a short period, after which new growth was curtailed.

Most recently, Veronesi et al. (93) conducted a study looking for tolerance to frequent cutting regimes. They performed two cycles of phenotypic recurrent selection on alfalfa for its ability to withstand frequent harvesting and evaluated the selected material by harvesting when the plants' height reached 0.30 m, 0.45 m, and 1/10 bloom. The selected alfalfa yielded more than the control for all treatments. The highest yield was obtained with the 0.30 m cutting level. They concluded that the selected alfalfa had increased persistence, dry matter, and crude protein yield within each harvest treatment, but the selection did not eliminate the differences among harvest treatments. They felt the common farming technique of cutting alfalfa at 1/10 bloom was best for exploiting alfalfa's potential, even with materials selected for tolerance to frequent cutting regimes.

A relatively new grazing system called Short Duration Grazing (SDG) has been successfully used on range and pasturelands (grasses) in southern Africa and the United States (28,38,40,61,87). This system involves subdividing existing range or pasture units into several paddocks (37,67) and grazing each paddock at a high stocking densities for a short time period so that all plants are uniformly grazed (69). All SDG studies have been conducted in areas with different climatic conditions than Montana's and with different types of vegetation (mainly grasses).

In 1980, Savory and Parson (68) described some of the main points of the grazing system. They state that it is not possible to work under rigid preconceptions. The stock (cattle, sheep or goats) are concentrated into substantial herds wherever possible for the desired herd effect of trampling, dunging, and urinating as they move around the paddock. The concentrated stock are held in each paddock for a very short time through the vegetation's growing months. These short periods are ideally anything from one day to about five days. The short grazing periods are interspersed with short rest periods ranging from 30 to 60 days. On planted pastures and with rhizomatous grasses, these rests are further reduced but not, as a general rule, on native range. Stocking rates are generally increased as soon as it is considered safe. The method is generally, but not always, applied through the use of a grazing cell layout of fencing. These areas, or cells, are developed with very simple, inexpensive fencing from a central point called a cell center. The cell center generally contains water and whatever handling facilities are desired. There are several variations of this theme depending upon topography, herd structures, and fixed features of the ranch.

Alfalfa has not been evaluated using this grazing management system.

CHAPTER 3

MATERIALS AND METHODS

Yield studies were established in the spring of 1986 at the Arthur H. Post Field Research Laboratory near Bozeman, Montana, and at the Northwestern Agricultural Research Center near Kalispell, Montana, to evaluate the effect of different harvest regimes on alfalfa. Two cultivars (Spredor II and Maxim) were seeded in a randomized complete block design with 13 harvest treatments per cultivar, and four replications (Tables 1, 2, and 3). Treatments one to nine were a 3 x 3 factorial of cutting frequency and cutting intensity. Cutting frequencies were 8, 16 and 32 days and cutting intensities were 67, 50 and 33 percent topgrowth removal (Table 1). Treatment 10 was a graduated Short Duration Grazing (SDG) treatment with variable harvesting frequencies and intensities. Plots were cut frequently, but at low intensities early in the grazing season and were cut less frequently but with greater intensity later in the season (Table 2). Treatments 11-13 were controls in which the alfalfa was harvested using traditional grazing and hay (Table 3).

Table 1. Factorial arrangement of clipping frequencies and intensities used to evaluate alfalfa's response to simulated Short Duration Grazing at Bozeman and Kalispell, MT, 1987.

TREATMENT IDENTIFICATION (#)	(ident.)	DAYS BETWEEN HARVEST (days)	TOPGROWTH REMOVED (%)	TOTAL HARVESTS PER TREATMENT (#)
I	8/67	8	67	14
II	8/50	8	50	14
III	8/33	8	33	14
IV	16/67	16	67	7
V	16/50	16	50	7
VI	16/33	16	33	7
VII	32/67	32	67	4
VIII	32/50	32	50	4
IX	32/33	32	33	4

Table 2. Clipping frequencies and intensities of Graduated Short Duration Grazing (SDG) (Treatment 10) applied on alfalfa at Bozeman and Kalispell, MT, and in the greenhouse, 1987.

HARVEST (#)	TOPGROWTH REMOVED (%)	HARVEST FREQUENCY (days)
1	33	8
2	33	8
3	33	16
4	50	16
5	50	32
6	67	Fall Management

Table 3. Traditional grazing and hay treatments (controls) applied on alfalfa at Bozeman and Kalispell, MT, and the greenhouse, 1987.

TREATMENT (#)	IDENTIFICATION (ident.)	TREATMENT DESCRIPTION
11	Prebud	After initial harvest (same date as the other treatments), it was cut at prebud stage to a height of 10 cm until August 14 (three cuts), then deferred until October 16 (Fall Management harvest)
12	Prebloom	Same as prebud, except at prebloom stage (two seasonal and fall harvest)
13	Hay	Harvested twice at ten percent bloom to a height of 10 cm and Fall Management harvest

Bozeman

1986

The experiment was seeded on May 16, 1986, in a Bozeman silt loam (Argic, Udic, Cryoboroll) soil that had previously been fertilized with 100 Kg/Ha of phosphorus. The fertilizer was incorporated and the seed bed firmly packed. Seeding rate was 11.2 Kg/Ha pure live seed (PLS) and the inoculated seed was planted approximately one cm deep. Plots were 1.5 m wide (five rows 30 cm apart) and 6 m long. A single row of orchardgrass (*Dactylis glomerata* L.) was established between each plot. The experiment was irrigated as needed to avoid moisture stress.

Management treatments were not imposed the establishment year. Only two hay harvests were made (August 4 and November 21). The plants were cut to a 10 cm height at each harvest. Total Dry Matter production was 3,704 and 3,396 Kg/Ha dry forage at each harvest, respectively.

Weeds were controlled by hand weeding in the establishment and 1.12 Kg/Ha AI Metribuzin [4-amino-6-(1,1-dimethoethil)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one][3] was applied in November 1986.

1987

Replication one was severely infested with Canada thistle (*Cirsium arvense* (L.) Scop.) and was eliminated from the study. The other three replications were relatively weed free.

All plots (except the traditional hay treatment) were harvested to the appropriate height when the alfalfa was 40 cm tall (May 23), and the harvest management treatments (Tables 1, 2, and 3) were then imposed (Table 4). Only one cultivar (Maxim) was used because weather precluded starting the management treatments on Spredor II at the correct time. The first harvest on the graduated short duration grazing treatment (SDG) was harvested one week earlier (May 15) than the other treatments because it rained immediately after these plots were harvested (Appendix A).

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[3]Mention of a trademark, proprietary, product, or vendor is included for the benefit of the reader and does not imply endorsement by Montana State University to the exclusion of other suitable products.

Table 4. Harvest dates at Bozeman and Kalispell, MT, and the greenhouse in 1987.

HARVEST (#)	BOZEMAN (date)	KALISPELL (date)	GREENHOUSE (date)
1	15/15	5/4	4/27
2	5/23	5/12	5/5-7
3	5/31	5/20	5/13
4	6/8	5/29	5/21
5	6/16	6/5	5/29
6	6/24	6/12	6/6-10
7	7/5	6/22	6/14
8	7/13-14	6/29	6/22
9	7/21	7/7	6/30
10	7/29	7/15	7/8-11
11	8/6	7/23	7/16-19
12	8/14	7/31	7/24
13	10/16 (a)	8/7	8/1
14	—	8/14-18	8/9
15	—	9/25 (a)	8/17
16	—	—	8/25 (b)

(a) Fall Management Harvest
(b) Harvest at ground level

Immediately before harvest, plant height (cm) was determined (average of five measurements per plot) in order to calculate the appropriate cutting height for each treatment.

The plots were trimmed to a length of approximately five meters before each harvest. Forage yield was determined by cutting the center two rows of each plot to the appropriate height with a flail harvester (Rem Manufacturing Inc., Swift Current, Saskatchewan, Canada) that had been modified to allow cutting at any height to 60 cm. Wet forage weight from each plot was recorded and a small sample (500 grams) was saved for moisture determinations. These samples (one for each plot/harvest) were weighed, dried at approximately 60^{o}C for four days and reweighed. Moisture percentages were used to calculate dry matter yield (Kg/Ha). The dried samples were saved for nutritional analyses.

Seven stems from the border rows of each plot were hand harvested at the same height as the harvested rows, carefully placed in paper bags and maintained in a chest filled with ice until they could be processed for further analysis. The border rows were then cut at the same height as the harvested rows.

The stems were placed in the cool room (2-3^{o}C) of the greenhouse immediately after leaving the field. Average time elapsed from cutting stems in the field to beginning leaf and stem measurements was 24 hours. Wet weight of stems with leaves was obtained. Leaflets from each stem were cut at the base of each pedicel and the total number of leaflets per plant and per stem were recorded. Leaflets from each plant were laid flat between two transparent sheets (10 x 28 cm) and placed on the belt of the leaf area meter (Hayashi Denko Co., AAM-5/7 model). Three measurements per sample were averaged to determine leaf area. A similar technique was used to measure stem area.

The materials were then dried for four days in a draft oven at 26°C and dry matter weights obtained. Leaflet area, stem area, stem area:leaflet area ratio, and dry matter were calculated.

On July 13, it was noted that the leaf area below the harvested cutting height was smaller than above the cutting height. Seven samples were then removed at each harvest, from the crown to the cutting height. They were handled as previously described.

Seven days after each harvest, a random 30 cm of row was measured to determine the number of axial and crown buds. Every visible crown bud was counted. Axial buds were counted when its regrowth level was higher than the previous harvest level. The axial bud:crown bud ratio was calculated for each plot after each harvest. A cumulative ratio was obtained for all buds throughout the growing season and was analyzed with MSUSTAT Program (Newman-Keuls test)(48).

The last forage harvest during the growing season was on August 14 to keep from confounding harvest regimes with fall management. The plots were harvested again on October 16, following a killing frost, at 10 cm height.

Five roots (approximately 30 cm long) per plant were obtained on August 14 and October 16 from the border rows. The roots were immediately hand cleaned, carefully stored in plastic bags and maintained in a chest filled with ice for approximately one hour, then stored in a freezer at -18°C. When the roots were completely frozen, they were cleaned with cold water. Roots were cut at the crown, 5 cm, and 20 cm below the crown, and root diameter (mm) was measured at each location. Roots (crown level to 20 cm below the crown) from each plot were weighed, placed into a sandwich bag and then into a temperature resistant (autoclave) bag and boiled for 30 minutes to stop the enzymatic activity (53) related with the stored root carbohydrates. The roots were then transferred to a perforated paper envelopes and heat dried on forced draft oven for one hour at 100°C and 24 hours at 70°C (until constant weight). Root weight was obtained. The roots were ground with a Cyclone Sample Mill (UD Corporation, Boulder, CO) and the ground material was stored in carefully sealed glass bottles to avoid moisture absorption (80). Ground root material was analyzed with the procedure described by Smith (83). The material was carefully handled in accordance with suggestions of various researchers (drying methods--60; extraction and analysis methods--33,35,70,76,84).

Forage samples used to determine moisture percentage at each harvest were finely ground with a Laboratory Mill Model 4 (Arthur Thomas Company, Philadelphia, PA), reground with a Cyclone Sample Mill (UD Corporation, Boulder, CO) and sent to Dr. Nick Hill, University of Georgia, Athens, Georgia, for nutritional quality analysis. The analysis was conducted on a Near Infrared Spectrophotometry previously calibrated over the range of each analysis. Analyses included: crude protein, in vitro digestibility (IVDMD), neutral detergent fiber (NDF), and acid detergent fiber (ADF).

Kalispell

1986

The experiment was seeded in May 1986 in a Creston silt loam, coarse-silty, mixed family classified as Udic Haploboroll soil with a pH of 7.8, with Spredor II alfalfa at 11.2 kilograms PLS per hectare. Plots were 2.4 m wide (eight rows, 30 cm apart) and 6 m long. Two hay harvests were made on July 28 and October 6. The plots were cut to 10 cm height. Total dry matter production was 5,425 and 2,959 Kg/Ha of forage at each harvest. All other procedures were the same as Bozeman.

1987

Forage yield, axial and crown bud, plant height, and forage quality measurements were obtained the same as Bozeman. The harvest management treatments (Tables 1, 2, and 3) were initiated on May 5.

Greenhouse

Three hundred and ninety-six Conetainers (Ray Leach Inc., Canby, OR) with 300 cubic centimeters capacity were filled with commercially available Sunshine Mix # 1 (Fisons Western Co., Canada). Spredor II (two seeds/conetainer) was planted on January 29, 1987, in the Plant Growth Center at Bozeman, Montana. The plants were grown with 16 hours day and 8 hours night photoperiod. Temperature was 26.4^{o}C during the day and 18^{o}C at night. Plants were irrigated daily throughout the trial.

After emergence, seedlings were thinned to one plant per container. The previously describe harvest treatments (Tables 1, 2, and 3) were arranged in a randomized complete block design with four replications. Each plot consisted of seven plants.

Granular fertilizer (100 Kg/Ha N,P,K) was applied on April 15. The plants were then allowed to grow until flowering (March 12) when they were cut back to 10 cm. Harvest management treatments (Tables 1, 2, and 3) were started on April 27, 1987, when the alfalfa was cut to the appropriate height with scissors. The procedures used were the same as for the Bozeman Field study with the exception of leaf area determinations. The forage obtained at each harvest was separated in two groups: the main stem and the remaining material. After weighing the two groups (and calculating the total forage per plot), the main stem was utilized to obtain information on leaf area as described in the Bozeman study.

One week after the last cutting date, all plants were harvested at soil level and total forage was determined.

A record was kept on the number of live plants/plot, live shoot:dead shoot ratio of each plant, and visual observations on morphological changes during the trial.

Roots of each plant were frozen immediately after the last cut and processed in the same manner described for the Bozeman study.

CHAPTER 4

RESULTS AND DISCUSSION

Forage Production

Forage Quantity

Bozeman--Total Annual Forage Yields (May-October). Significant differences were obtained among the 13 treatments for total forage production of Maxim alfalfa (Table 5).

Hay, Prebud and Prebloom treatments produced the highest yields. Although there were no significant differences among these treatments ($p = 0.09$), there was a tendency for increasing yield with fewer harvests.

The eight-day clipping frequency treatments produced the least amount of forage, particularly at the high intensities (50 and 67%). The graduated SDG, 32/50, 16/33, 32/33 and 16/50 treatments had similar yields.

Total forage yields increased almost linearly when the rest period was increased for treatments where 50 and 67% of the topgrowth was removed (Figure 1). Total forage yields for the less stressful treatments (33% topgrowth removal) increased as the rest period was increased from 8 to 16 days but decreased as the rest period was increased from 16 to 32 days.

Table 5. Dry matter forage production of Maxim alfalfa at Bozeman in 1987 as affected by hay and simulated grazing treatments.

TREATMENT	YIELD		
	SEASONAL (May-Aug.)	FALL (10/16)	TOTAL
	----------kilograms hectare^{-1}----------		
8/67	6,352	497	6,849
8/50	5,834	847	6,681
8/33	6,934	1,314	8,248
16/67	7,871	723	8,594
16/50	8,550	1,643	10,193
16/33	7,032	3,671	10,703
32/67	7,989	2,728	10,717
32/50	7,775	4,032	11,807
32/33	5,154	5,051	10,205
Graduated SDG	88,272	3,019	11,291
Prebud	11,260	1,656	12,916
Prebloom	9,905	3,513	13,418
Hay	11,520	2,509	14,029
LSD (0.05)	1,136	361.7	1,402

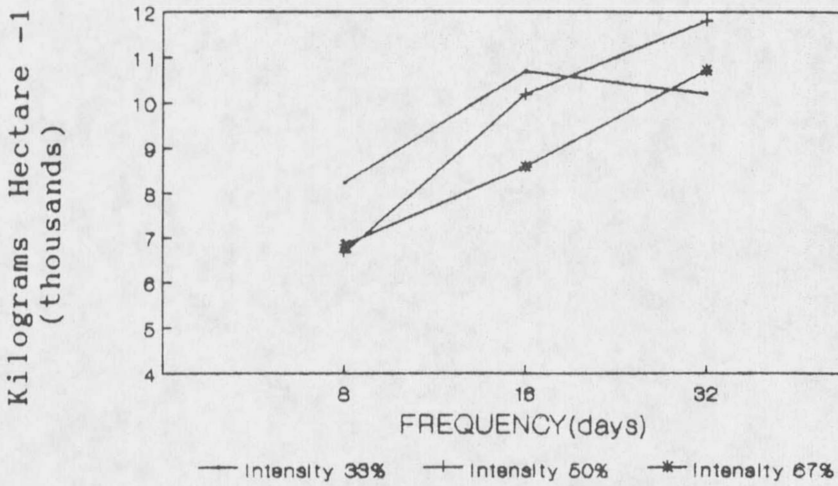

Figure 1. Total Dry Matter forage production of Maxim alfalfa as affected by clipping frequency and clipping intensity at Bozeman in 1987 (LSD at 0.05 = 791.9).

Bozeman-Seasonal Forage Yields (May-August). Hay and traditional grazing treatments (Prebud and Prebloom) produced more forage from May through August than the other grazing treatments (Table 5). Treatments Graduated SDG and 16/50 produced the most forage of the SDG treatments during the grazing season. Treatment 32/33 produced almost 50% of the total annual yield in October. Treatments that have a high percentage of the total forage produced in October would not be desirable because less forage would be available for grazing.

Seasonal yield of the 33% intensity remained relatively constant as clipping frequency decreased from 8 to 16 days and decreased when clipping frequency was decreased to 32 days (Figure 2).

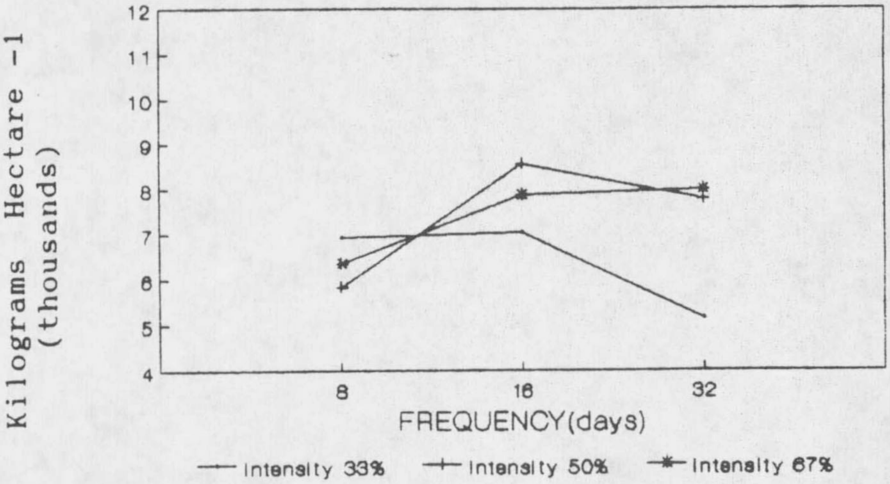

Figure 2. Seasonal Dry Matter forage production of Maxim alfalfa as affected by clipping frequency and clipping intensity at Bozeman in 1987 (LSD at 0.05 = 772.6).

Seasonal yield of the 67% intensity increased as clipping frequency decreased. Seasonal yield of the 50% intensity increased dramatically as clipping frequency decreased from 8 to 16 days, then decreased when clipping frequency was further decreased to 32 days. It appears that not enough topgrowth was removed on treatment 32/33 to allow adequate forage production from May through August. The lower yields of the 32/33 treatment may have been due to excessive leaf loss from shading.

Kalispell--Total Annual Forage Yields (May-October). Total annual forage production trends at Kalispell (Table 6) were similar to these at Bozeman (Table 5). Traditional treatments (Hay and Prebloom) produced the highest yields (Table 6). Hay produced 12 and 50% more forage than Prebloom and Prebud treatments, respectively. Four SDG grazing treatments (16/33, 32/67, 32/33 and Graduated) produced similar forage as the Prebud treatment. The interaction between frequency and intensity was non significant at Kalispell. Total forage yields increased almost linearly as days among harvests increased (Table 7). The shorter rest periods increased stress and reduced yields as compared to the longer rest periods. No differences were obtained between the 67 and 50% intensity treatment. Yields were significantly higher for the 33% treatment as compared to the 67 and 50% treatments (Table 8).

Kalispell--Seasonal Forage Yields (May-August). Low clipping intensity treatments (33 and 50%) had the lowest yields, regardless of clipping frequency (Table 6). Hay, Prebud and Prebloom treatments produced twice as much seasonal forage as most of the SDG treatments. The 32/67 treatment, which is similar to the Prebud treatment, produce more forage than any SDG treatment.

Seasonal production of the 67% intensity treatments was not affected by harvest interval (Figure 3). Forage yields for 50%

Table 6. Dry Matter Forage production of Spredor II alfalfa at Kalispell in 1987 as affected by haying and simulated grazing treatments.

	YIELD		
TREATMENT	SEASONAL (May-Aug.)	FALL (9/25)	TOTAL
	-----------kilograms hectare^{-1}---------------		
8/67	6,662	1,408	8,070
8/50	5,750	2,477	8,227
8/33	6,377	3,374	9,751
16/67	6,815	1,412	8,227
16/50	6,041	2,881	8,922
16/33	5,066	5,313	10,379
32/67	7,247	3,042	10,289
32/50	5,357	4,036	9,393
32/33	5,050	6,350	11,400
Graduated SDG	10,244	1,099	11,343
Prebud	10,278	594	10,872
Prebloom	9,668	4,812	14,480
Hay	11,029	5,245	16,274
LSD (0.05)	603.9	492.7	897.9

Table 7. Total forage production of 8, 16 and 32 day clipping frequency treatments at Kalispell in 1987 (averaged across intensity treatments).

REST PERIOD (days)	TOTAL DRY MATTER FORAGE (kilograms hectare^{-1})
8	8,683
16	9,170
32	10,360
LSD (0.05)	550.6

Table 8. Total forage production of 33, 50 and 67% intensity treatments at Kalispell in 1987 (averaged across clipping frequency treatments).

INTENSITY (% topgrowth removed)	TOTAL DRY MATTER FORAGE (kilograms hectare^{-1})
67	8,860
50	8,845
33	10,510
LSD (0.05)	550.6

treatments were reduced when the cutting interval was increased from 16 to 32 days and yields for the 33% treatments were reduced as the interval was increased from 8 to 16 days.

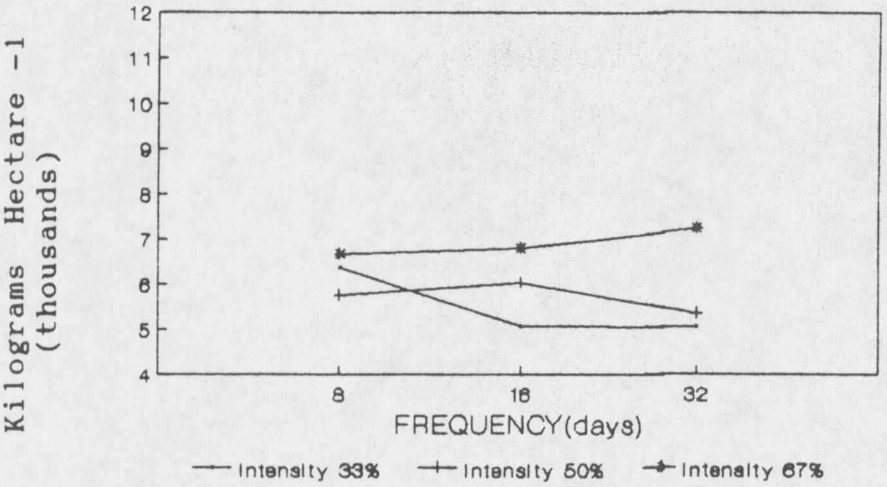

Figure 3. Seasonal Dry Matter production of Spredor II alfalfa as affected by clipping frequency and clipping intensity at Kalispell in 1987 (LSD at 0.05 = 374.6).

Greenhouse--Total Annual Forage Yields (May-August). As in the field studies, traditional management treatments (Hay, Prebud and Prebloom) produced the highest forage yields, and the treatments with higher stress (8/67 and 8/50) produced the lowest yields (Table 9).

The pattern for the significant frequency x intensity interaction, when total forage production was considered (Figure 4) was similar to Bozeman (Figure 1). Total forage yield responses for the 50 and 67% frequency intervals were almost linear, whereas a rest increase from 16 to 32 days decreased the yield of the 8-day treatment.

Table 9. Dry Matter Forage production of Spredor II alfalfa at the greenhouse in 1987 as affected by hay and simulated grazing treatments.

TREATMENT	YIELD		
	SEASONAL (May-Aug.)	LAST CUT (8/25)	TOTAL
	---grams plant^{-1}---		
8/67	1.803	0.422	2.225
8/50	1.890	0.510	2.400
8/33	1.830	0.948	2.778
16/67	2.205	0.660	2.865
16/50	1.963	1.134	3.097
16/33	1.680	1.475	3.155
32/67	2.102	1.243	3.345
32/50	1.670	1.615	3.285
32/33	1.030	1.843	2.873
Graduated SDG	2.223	0.957	3.180
Prebud	2.392	1.593	3.985
Prebloom	2.110	1.583	3.693
Hay	2.440	1.450	3.890
LSD(0.05)	0.336	0.181	0.399

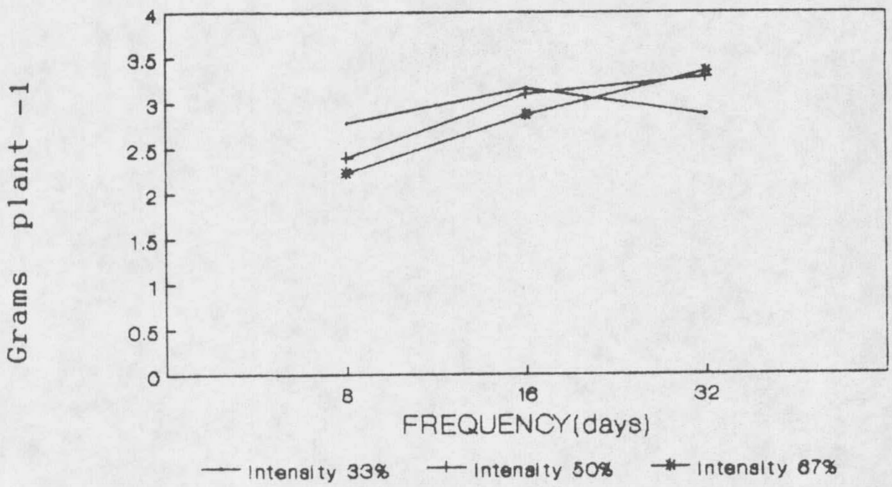

Figure 4. Total Dry Matter forage production of Spredor II alfalfa as affected by clipping frequency and clipping intensity at the greenhouse in 1987 (LSD at 0.05 = 0.226).

Greenhouse Seasonal Forage Yields (May-August). It is not possible to compare last harvest yields from the greenhouse study with the field studies, because different methodologies were used. Alfalfa at Bozeman and Kalispell were allowed a regrowth period after the last seasonal harvest of at least 45 days (until the first killing frost) and then were cut at 10 cm height. Alfalfa in the greenhouse study regrew only one week after the last seasonal harvest and were cut at ground level so that total dry matter production for the experiment could be determined.

Traditional management treatments produced the highest seasonal yields (Table 9). Graduated SDG, 32/67 and 16/67 had forage yields similar to the traditional treatments (Appendix B).

There was an interaction between frequency and intensity of clipping for seasonal forage production (Figure 5). It was similar to the interactions at at Bozeman and Kalispell, with only minor differences in the slope of the curves. As the number of days between harvest increased from 16 to 32 days, yields were decreased for all clipping intensities.

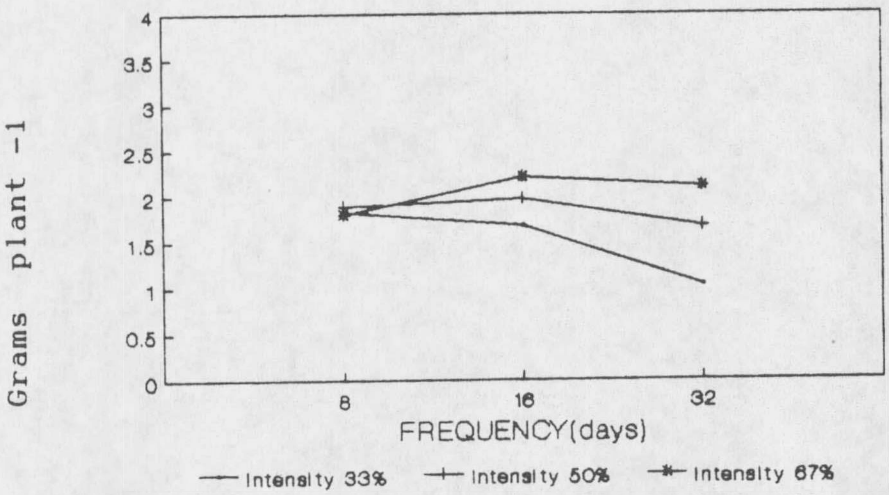

Figure 5. Seasonal Dry Matter forage production of Spredor II alfalfa as affected by clipping frequency and clipping intensity at the greenhouse in 1987 (LSD at 0.05 = 0.168).

Forage Quality

Crude Protein--Bozeman. Total crude protein production followed the same pattern as dry matter production at Bozeman (Figure 6). Prebud, Prebloom and Hay treatments produced more crude protein than many of the SDG treatments (8/67, 8/50, 8/33, 16/67, and 32/33).

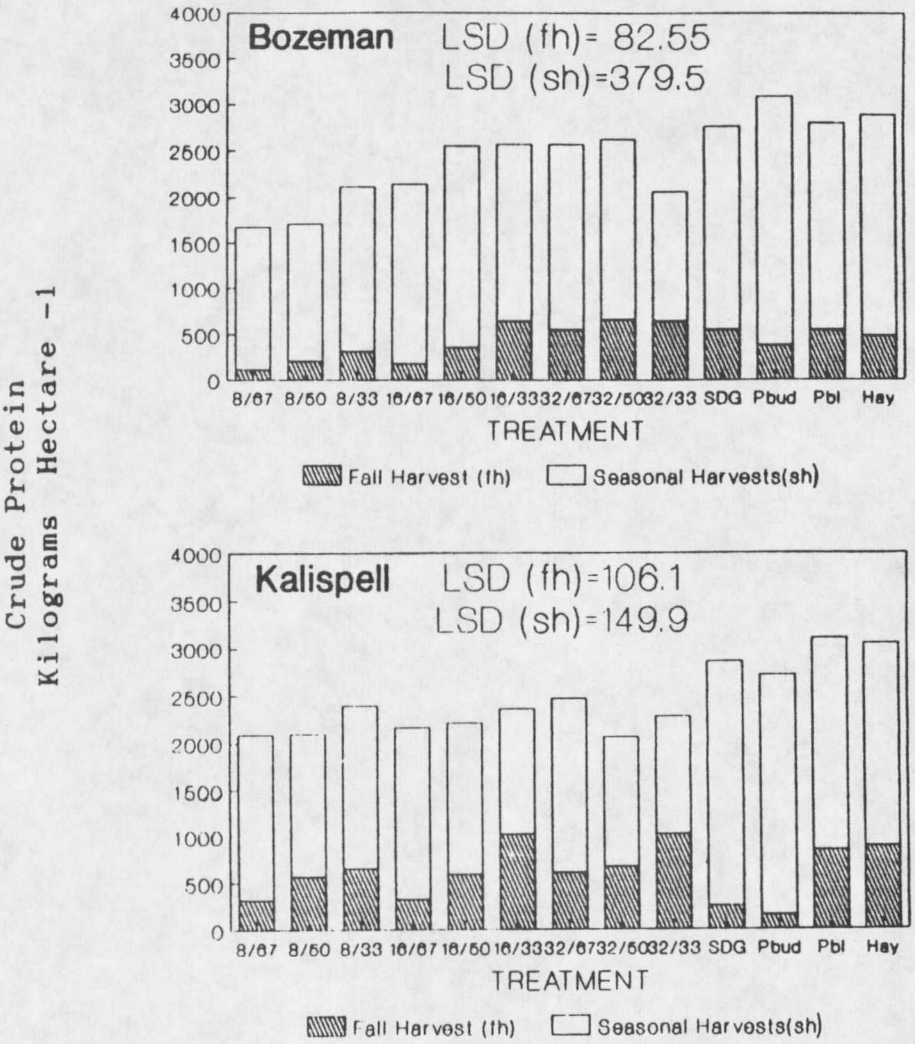

Figure 6. Total crude protein production of alfalfa grazing and hay treatments at Bozeman and Kalispell, MT, in 1987 (LSD at 0.05).

Eight-day treatments were low in total crude protein because of their low dry matter production. Total crude protein of treatment 32/33 was low because half of the forage was harvested in October (after killing frost) when protein percentages were low (10-14%).

Protein at the different harvests varied from 10 to 34%. Most of the protein values for the 8- and 16-day clipping frequencies were approximately 30% (Appendix C).

Crude protein levels of 30% are not necessary for adequate animal performance. Large frame bull calves and 300 pound yearling steers with expected average daily gains of 4 pounds require 24.7% crude protein in their diet (57). Crude protein requirements of most animals are below 20%.

Using forage with high crude protein can result in a waste of nutritional quality that will be used by the animal for less efficient processes (i.e., energy production). An excess of natural crude protein concentration in the forage will not have negative effects on animal production and will increase efficiency of feed use slightly (57).

Crude Protein--Kalispell. Total crude protein at Kalispell followed the same pattern as Bozeman (Figure 6). The traditional treatments (Hay, Prebud and Prebloom) and graduated SDG produced the most protein per hectare. The remaining nine treatments (factorial) did not have large variations in total protein production.

Total protein in the fall harvest at Kalispell comprised a large percentage of the total protein produced per hectare. Fall protein per hectare decreased as clipping intensity increased for each clipping frequency (8, 16, and 32 days). This is a direct reflection of dry matter production (Table 6). Actual protein percentage was higher for the more intensively clipped treatments, but protein per hectare was determined more from dry matter production (Appendix D).

At fall harvest, the crude protein concentrations in the forage were the lowest of any time in the year. Crude protein of the seasonal harvested forage were 20 to 30% with some harvests above 30%. Most of the protein determinations in the fall were below or around 20% (14).

In Vitro Dry Matter Digestibility (IVDMD)--Bozeman. The IVDMD values for the initial harvest of the 8-day treatments were approximately 70% and then decreased for the next two harvests, because each consecutive harvest collected forage from lower in the canopy (older and less digestible material) (Figure 7). By the fourth harvest, IVDMD values for all the 8-day clipping treatments had recovered. This pattern was repeated during the season. The fall harvest (after killing frost) produced IVDMD equal to the first harvest.

The 16-day clipping treatments had an IVDMD pattern similar to the 8-day treatments, but with smaller variations among harvests (Figure 7). Treatments 16/67 and 16/50 had a marked drop in IVDMD in the second harvest, but by the third harvest IVDMD increased and

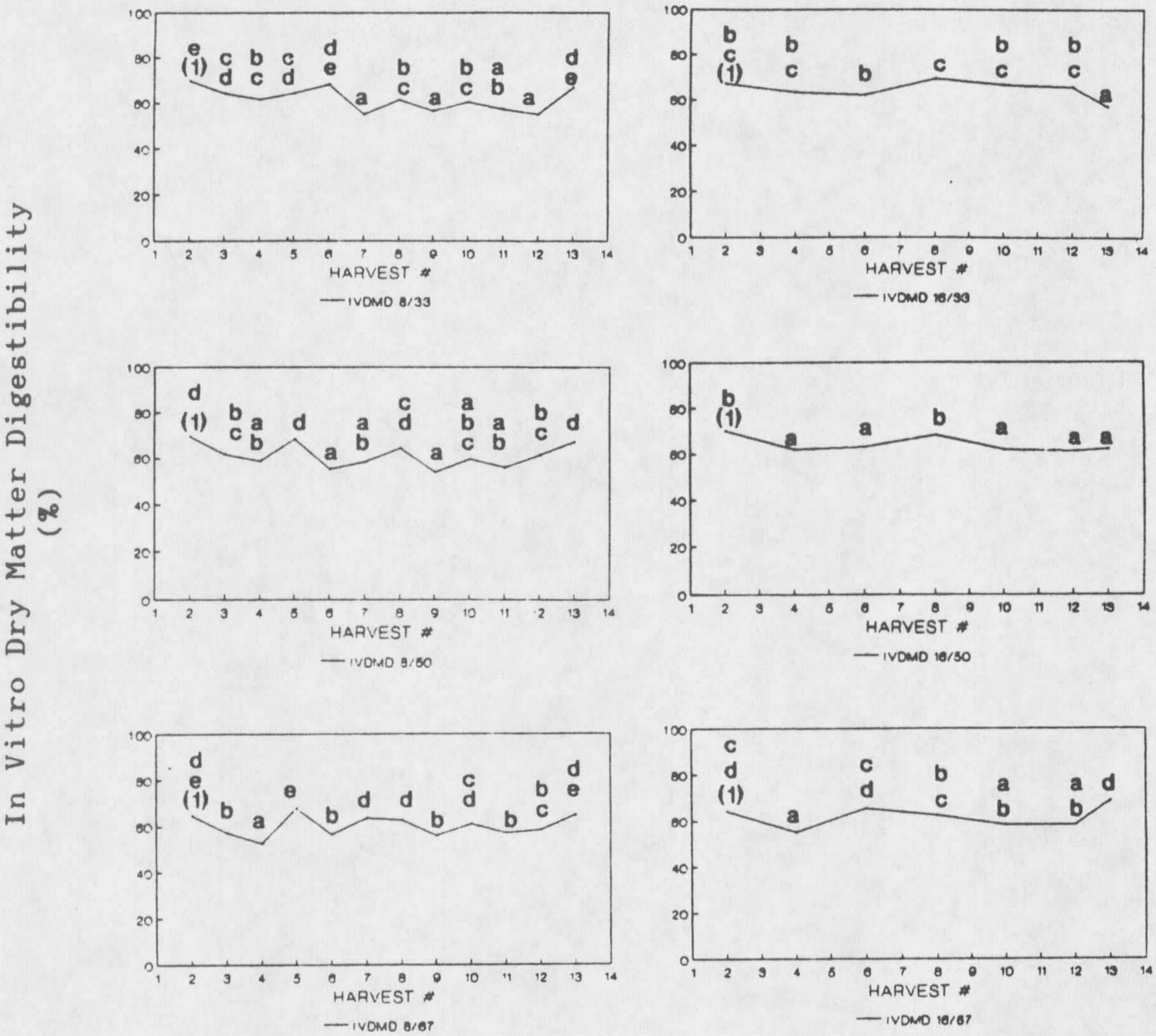

Figure 7. <u>In vitro</u> Dry Matter Digestibility (IVDMD) (treatments 8/33, 8/50, 8/67, 16/33, 16/50, and 16/67) at Bozeman, MT, in 1987. Fall management harvest identified as #13. (1) Harvests not identified by the same letter differ at the 0.05 probability level by Newman-Keuls test.

remained high thereafter. Treatments 16/50 and 16/33 never dropped below 60% IVDMD throughout the season. Only treatment 16/33 had a low IVDMD value in the fall, due to the accumulation of deferred forage. Graduated SDG treatment followed the same pattern as treatment 16/50.

The 32-day clipping treatments had a declining IVDMD pattern throughout the season (Figure 8). The decline was greater for 33% than for the 50 and 67% intensity treatments for fall harvest.

The IVDMD was significantly reduced from first to second harvest for the Prebloom treatment (Figure 8). The most stable treatment (fewer fluctuations for IVDMD) occurred for Prebud.

Generally, all treatments produced IVDMD levels above 60%. Some harvests for the 8-day clipping treatments had values of 70% which can be detrimental for animal production. IVDMD values above 68% can reduce animal intake (3).

Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF)--Bozeman. Neutral Detergent Fiber measures cell wall constituents including cellulose, hemicellulose, lignin, nitrogen and minerals, and is an indicator of animal intake while ADF is a measurement of cellulose, lignin and mineral residues (indigestible fraction) (26) and is related to digestibility. The lower the ADF value, the greater the digestibility.

Generally, NDF and ADF had similar response patterns for each treatment (Figures 9-12). Many treatments had increased NDF and ADF

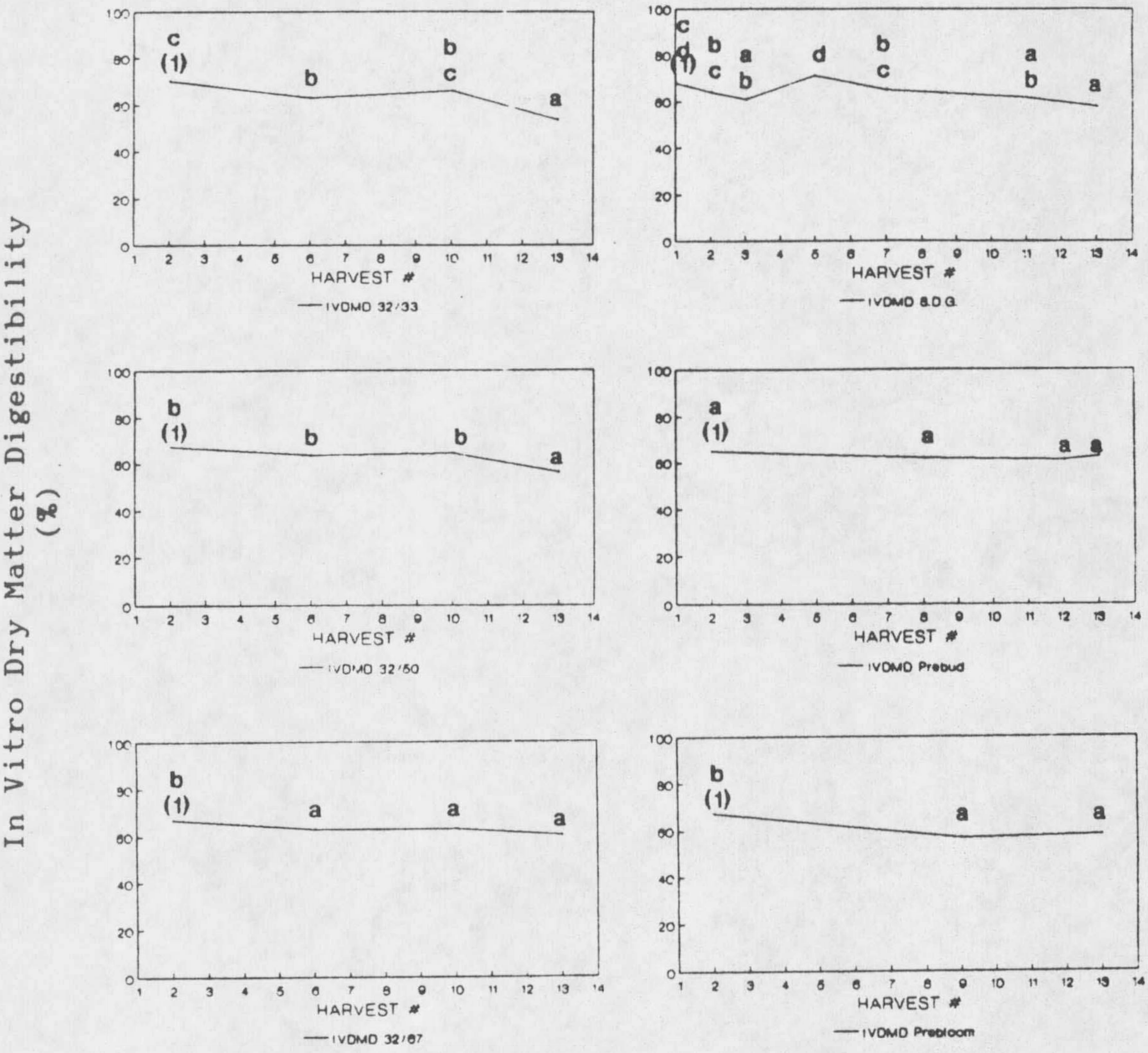

Figure 8. In vitro Dry Matter Digestibility (IVDMD) (treatments 32/33, 32/50, 32/67, Graduated SDG, Prebud and Prebloom) at Bozeman, MT, in 1987. Fall management harvest identified as #13. (1) Harvests not identified by the same letter differ at the 0.05 probability level by Newman-Keuls test.

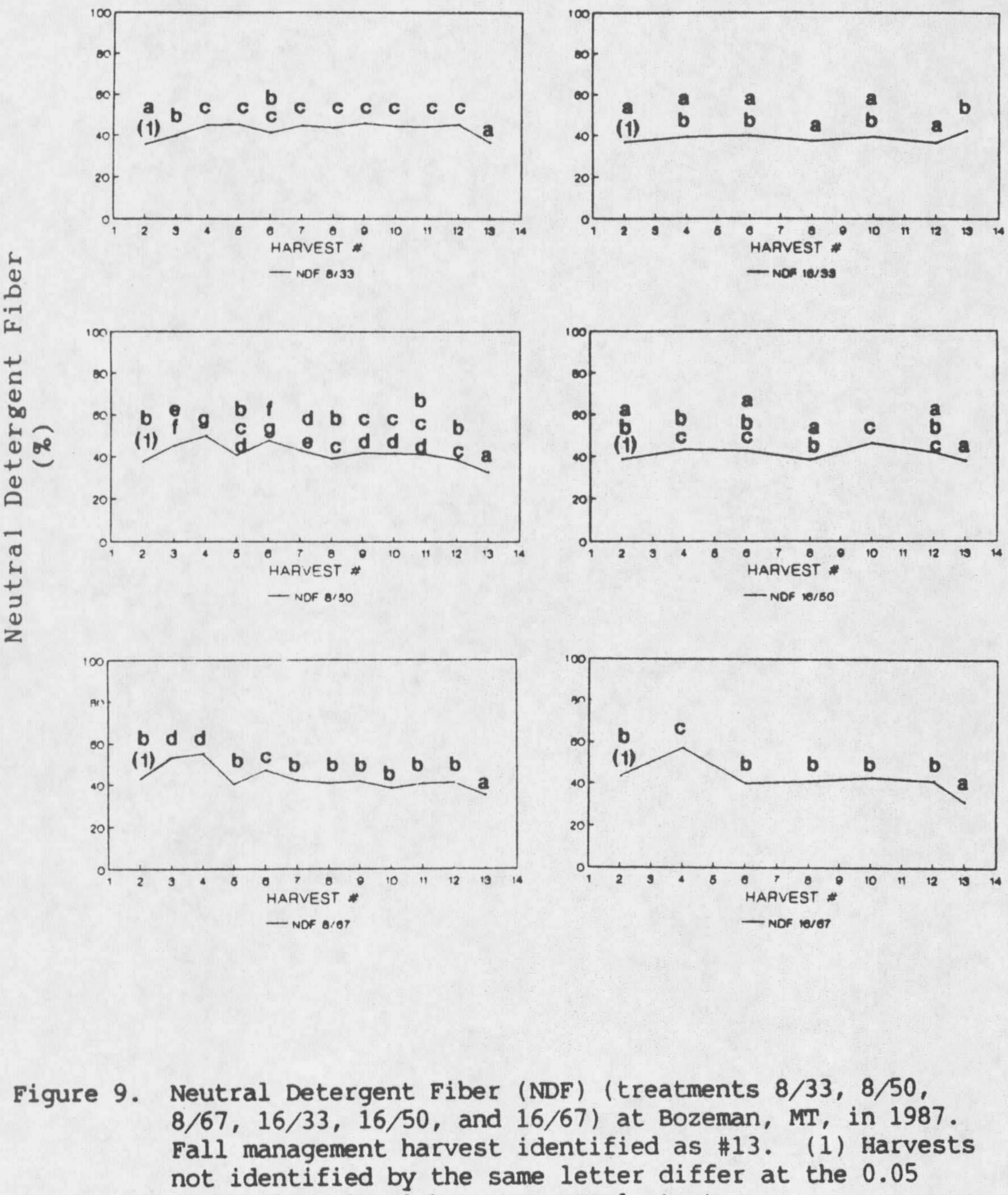

Figure 9. Neutral Detergent Fiber (NDF) (treatments 8/33, 8/50, 8/67, 16/33, 16/50, and 16/67) at Bozeman, MT, in 1987. Fall management harvest identified as #13. (1) Harvests not identified by the same letter differ at the 0.05 probability level by Newman-Keuls test.