MANAGEMENT OF SUMMER GRAZED ALFALFA

by

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DEDICATION

To Mom and Dad

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Cool, moist conditions are optimum for cool season grasses and legumes. In general, the productivity of cool season species declines during hot, dry summer months with plants becoming semidormant. However, alfalfa, (<u>Medicago sativa</u> L.) can tolerant hot, dry conditions. The productivity of alfalfa does not drop as drastically as other cool season species during the summer due to the deep taproot. Therefore, in summer, grazing alfalfa could supplement cool season pastures if yield and stand longevity were not depressed.

In Virginia, alfalfa management recommendations include rotationally grazing for a short duration at the 1/10 bloom stage leaving a low stubble. Close and/or frequent grazing has been thought to cause reduced yields and stand longevity. In order to produce high alfalfa yields, a high potassium (K) fertility level should be maintained. Potash fertilizer may increase shoot number, yield, and winter survival.

Recent research at Virginia Tech has indicated alfalfa may be tolerant of grazing during early spring. Grazing that begaun in April and continued for 25 days resulted in little or no damage to the stand or decrease in total seasonal production.

The objective of this research was to investigate the effect of grazing on alfalfa yield, regrowth, quality, and stand longevity during the summer. An additional objective included comparing high K fertility (560 kg k/ha above recommended rates) with recommended rates.

LITERATURE REVIEW

CUTTING AND GRAZING MANAGEMENT

In Virginia, alfalfa grazing management recommendations are to graze rotationally when plants reach the 1/10 bloom stage, and to graze for a short duration and to leave a low stubble (White, 1980). However, recent research at Virginia Tech indicated that grazing early spring growth continuously for a 25-day period did not decrease subsequent hay yields (Cardina, 1979). Other studies have shown that alfalfa stands deteriorated quickly under continuous grazing, while rotational grazing resulted in higher yields, better winter survival and stand persistency (Nielson et al., 1954; Hart, 1981). Several authors reported that increasing the number of harvests decreased yield and stand longevity (Nelson, 1925; Reynolds, 1971). Frequent cutting of alfalfa in premature stages depleted the root total nonstructural carbohydrates (TNC). This resulted in slow recovery and growth rate, low yields, and weed infestation. An increase in the number of crown buds, shoots and main stems occurred as an immediate effect of frequent and early cutting. Average height and total yield of topgrowth were much less than that of infrequent cuttings at a mature stage, (Nelson, 1925). Smith and Silva (1969) concluded that tolerance to frequent cutting depended on the residual leaves and root TNC level. Frequent cutting or grazing has been possible at tall stubble heights since residual leaves contributed to the plant's regrowth (Hodgkinson et al., 1972).

Grazing for a short duration to a low stubble followed by a long recovery period has increased yield and stand longevity (Smith, 1972). However, O'Connor (1970) found no difference in yields from grazing durations of 3 to 8 days. Wilman (1977) claimed the recovery time necessary for high TNC accumulation was more important than the grazing duration on influencing yield and stand longevity. Frequent defoliation of alfalfa decreased root TNC (Cooper and Watson, 1968) and low carbohydrates were associated with reduced yields and stand losses (Bryant and Blaser, 1964).

Wolf et al. (1962) reported highest yields were obtained with infrequent harvests at low stubble heights. Fuess and Tesar (1968) showed that infrequent cutting allowed the leaf area to increase after each harvest and a high leaf area index (LAI) at cutting resulted in high yields. In relation to LAI, Robison and Massengale (1968) found no significant difference in forage yields for plants cut at different stubble heights if harvested at the 25% bloom stage or

50% bud stage. Leach (1970) cut plants at 2, 5, or 10 cm above the crown, and found that cutting at high levels increased shoot number only slightly and produced little effect on yield. Nearly all shoots arose from the crown itself or within the first 2 cm above it. Shoots arising from the crown resumed extensive growth earlier and, therefore, grew larger since shoot growth rate was independent of cutting treatment. Hodgkinson (1973) reported cutting at high levels (15 cm) only increased yield if plants were cut frequently. Similar results were found by Hildebrand and Harrison (1939) where a 15 cm stubble height produced the most recovery topgrowth when harvested weekly or biweekly and a 3 cm stubble height produced the most when cut monthly.

TOTAL NONSTRUCTURAL CARBOHYDRATES

Total nonstructural carbohydrates in alfalfa taproots have been shown to consist largely of starch (Jung and Smith, 1961). Smith et al. (1964) reported most photosynthate was translocated to other plant parts to be used for respiratory substrate, metabolized into cell constituents, or accumulated in storage sites.

Root TNC levels have been associated with the stage of maturity (Brown et al., 1972). Hodgkinson (1969) concluded that in early spring, new growth was initiated and developed at the expense of organic reserves in the taproot. Carbohydrates continued to decrease for 20 to 30 days following growth initiation or until the bidirectional movement of carbohydrates within the regrowing stem equaled the growth requirements. May (1960) found root respiration to continue following defoliation. Therefore, the total decline in carbohydrates in the taproot may not be entirely attributed to the initiation and growth of new shoots. During the bud and flowering stages, carbohydrates rapidly accumulated in the roots. By the seed development stage carbohydrate percentage reached an ultimate high and remained constant until harvest (Cooper and Watson, 1968).

In relation to the stage of maturity, the time and frequency of harvests have been associated with root carbohydrate fluctuations (Bryant and Blaser, 1964; Cooper and Watson, 1968; Gayland and Massengale, 1968). Cutting at a vegetative stage has been shown to decrease the vigor and yield of alfalfa, since root TNC declines for 2 to 3 weeks after harvest (Gayland and Massengale, 1968).

Cooper and Watson (1968) found that frequent defoliation of alfalfa decreased root TNC. In addition, low carbohydrates were associated with reduced yields and stand losses (Bryant and Blaser, 1968). In contrast, Reynolds (1971) reported that a treatment of 8 harvests per year had higher root TNC than treatments of 2, 3, 4, 5, and 6 cuts per year.

Additional studies demonstrated that root TNC is influenced by the stubble height remaining after harvest (Robison and Massengale, 1968; Leach, 1970). Tall stubble had higher root TNC percentage than short stubble since residual leaves contributed energy for regrowth (Leach, 1970). The effect of stubble height decreased with subsequent harvests and successive weeks following a harvest (Robison and Massengale, 1968).

Environmental conditions have also been associated with fluctuations in root TNC (Bryant and Blaser, 1963; Robison and Massengale, 1968; Smith, 1969). Both Bryant and Blaser (1963) and Robinson and Massengale (1968) found increases in TNC under cool, dry conditions. Their data indicated a possible negative relationship between high night temperatures and alfalfa growth. Root TNC composition was also altered by temperature. Smith (1969) reported reducing sugars, starch, and TNC percentage were highest in roots under cool conditions, but total sugar percentage was highest under warm conditions.

A minimal level of carbohydrates has been shown to be necessary for winter survival and regrowth in spring (Hodgkinson, 1969). Barnes et al. (1979) predicted winter injury by correlating winter injury to height of fall growth. In October each plant was scored for plant height on a 1-9 scale; 1 = >40 cm, 2 = 35-40 cm, ••• 9 = 0-5 cm. The higher the fall growth score the more dormant a plant was found to be and less winter injury occurred.

FORAGE QUALITY

Forage quality has been characterized by digestibility, nature of the digested products, and chemical composition. Several factors including plant part, growth stage, climate, and soil conditions were found to influence alfalfa quality (Barnes and Gordon, 1972). Forage constituents can be divided into two classes; cellular contents and plant cell wall. Leaves were shown to be composed mainly of cellular contents, which were highly digestible and included proteins, sugars, starch, and organic acids. Stems contained mostly cell walls, which were the structural parts of the plant and represented the fibrous, less digestible fraction. The cell wall consisted of cellulose, hemicellulose, lignin, and tannins (Van Soest, 1973; Loper, 1980).

Chemical composition was found to differ by plant part. Smith (1970) concluded the highest concentration of constituents important in animal nutrition occurred in the leaves. Leaf tissue was higher than stem tissue in concentrations of protein, phosphorus (P), calcium (Ca), and magnesium (Mg). Stems were highest only in reducing and total sugars, fiber, and K.

Barnes and Gordon (1972) found that the stage of growth at the time of harvest was the most important factor influencing forage quality. As alfalfa matured, the leaf: stem ratio changed with an increase in the amount of stems (Luckett and Klopfenstein, 1970). Therefore, Loper (1980) concluded the cell wall content formed a higher proportion of the dry matter of the plant as the plant matured and resulted in forage of low digestibility. In addition, as the stage of growth increased, mineral and protein concentration decreased (Luckett and Klopfenstein, 1970; Rammah and Hamza, 1981). However, Barnes and Gordon (1972) reported Ca, Mg, and P had no systematic trends or declined only slightly with increased plant maturity.

Several authors have shown that climate, temperature, moisture, and light, influenced forage quality (Ludlow, 1976; Smith, 1970; Vough and Marten, 1971). Under high temperatures alfalfa was found to have low digestibility and high acid detergent fiber (ADF) percentage even though leaf and crude protein (CP) percentage increased (Vough and Marten, 1971). Smith (1970) reported herbage mineral constituents including P, K, Ca, and Mg increased with increasing temperatures.

In an experiment conducted by Vough and Marten (1971), alfalfa grown under drought stress had higher leaf percentage, mineral concentration, and in vitro dry matter digestability (IVDMD) but lower ADF and lignin percentage. The increase in leaf percentage at high moisture stress was associated with short plants having short internodes and small stem diameters. Increase in herbage digestibility with increasing moisture stress was due primarily to the increased digestibility of stems rather than leaves. Low ADF concentrations under high moisture stress was dependent of the greater leaf percentage.

Ludlow (1976) demonstrated shading altered plant development and dry matter distribution and, therefore, influenced plant quality. Shading reduced leaf initiation and tillering but increased plant height. Low radiation could be associated with tall plants having long internodes and low leaf percentage. These factors contributed to a low quality forage.

Soil conditions have been shown to influence forage quality by affecting the available minerals in the soil solution which are required for plant growth (Barnes and Gordon, 1972). Liebig (1940) stated that plant growth was retarded by the essential element in least relative amount. An excessive use of a single fertilizer element or unbalanced fertilization, could result in higher yields but low biological value (Barnes and Gordon, 1972).

POTASSIUM FERTILIZATION

Soil type, available nutrients, and climate have been shown to influence the recommended rate of applied K for alfalfa (Rhykerd and Overdahl, 1972). In general, to maintain a vigorous, high-yielding (13450 kg/ha) alfalfa stand on a productive soil, 290 kg of K/ha should be applied each year (Schaller, 1978; Tesar, 1981). Potassium fertilizer should be applied during fall, the dormant season, or after the first or second cutting (White, 1980). Tesar (1981) found when high levels of K fertilizer were used, a split application in the fall, spring, and after each cut increased yields more than if one application was practiced. Rhykerd and Overdahl (1972) stated that frequent broadcast applications are necessary after establishment since alfalfa is a perennial crop and seeded in a solid stand. In addition, Peterson et al. (1983) found highest K recovery occurred if K was located on or near the soil surface.

In the soil, K can be fixed in an expanding type clay, on an exchange site of a soil colloid, or in the soil solution. If a soil colloid is saturated with K, the addition of Ca from lime can result in a release of K since colloids attract Ca ions more strongly than K ions. Increase in temperature has been shown to increase the level of exchangeable K. However, studies were not conclusive (Tisdale and Nelson, 1975).

Plant absorption can occur if K is in the soil solution. Chapman and Pratt (1961) reported that, during absorption, the plant root exchanged a cation such as H^+ for K^+ or absorbed an anion such NO_3^- or $H_2PO_4^-$ along with the K^+. The uptake of K by plants was normally in proportion to the amount of available K in the soil (Wilkinson, 1973).

The K concentration in a plant has been shown to depend on temperature (Smith, 1969), plant part (Jung and Smith, 1961), and stage of maturity (Rhykerd and Overdahl, 1972). Jung and Smith (1961) found that during fall the K concentration increased in alfalfa crowns and decreased in the roots. In late September, alfalfa crowns reached a maximum K percentage and a minimum K percentage occurred in late November in the roots. The K concentration of all tissues remained constant during winter until early April. After April all tissues increased in K. Following this increase the crowns decreased in K. In general, Smith (1969) reported herbage from a warm regime (32 C) contained a higher K concentration than herbage from a cool regime (18 C).

Pearce et al. (1968) concluded that stage of maturity had a very pronounced effect on K concentration in alfalfa. Young vegetative plants tended to be high in K and as the plant matured the percentage K decreased. Loss of K with age was associated with a decrease in photosynthesis.

Rhykerd and Overdahl (1972) found K to be essential in many plant physiological processess. Potassium inhanced nitrogen (N) metabolism and the synthesis of protein thereby reducing the level of nonprotein nitrogen (NPN). If K was deficient, N accumulated in plants as soluble NPN and the resulting amino acids were not readily assimilated into protein. As K increased, nitrate concentrations decreased in plant tissue.

Smith (1981) reported that within a plant K interacts with many other mineral nutrients. While K concentrations of a plant increased as K topdressing rate increased, Mg, P, and Ca decreased. These elements were similar chemically to K and many plant functions were nonspecific so subsitution of various elements with K could have occurred (Thompson and Troeh, 1978).

Several studies showed increasing the K concentration in plants increased the synthesis and degradation of carbohydrates and translocation of starch. These processes resulted in high leaf area and delay of leaf senescence (Cooper et al., 1967; Haeder et al., 1973).

Many factors have been associated with increased yields from K fertilization. These included an increase in chlorophyll content (Collins and Duke, 1981), carbon exchange rate (CER) (Wolf et al., 1976), and nodule and shoot number (Collins and Duke, 1981). The increase in CER was closely paralleled to the increase in chlorophyll concentrations. Both CER and chlorophyll content increased linearly in response to K. Potassium fertilization stimulated N_2 fixation and nodulation by increasing the translocation of photosynthates to roots and nodules (Duke et al., 1980). Shoot number increased in response to K and has been suggested to be related to the increase in nodule number (Collins and Duke, 1981).

Smith (1981) found stand percentage and winter survival improved with K fertilization. Stand percentage increased steadily up to 450 or 670 kg/ha rate of K, with little difference at higher K rates. During winter, alfalfa stands with no K fertilization were killed. However, residual yields and stands increased with each increase in K applied. In contrast, Romero et al., (1981) reported there was no relationship between winter hardiness and response to K fertility.

Potassium fertilization has been shown to improve many plant physiological processes and characteristics, however, overall alfalfa quality was not improved. Klebasadel and Brinsmade (1966) found the percent CP in alfalfa was unaffected but total CP production increased with increasing rates of K fertilization. An experiment conducted by Smith (1981) showed no effect on in vitro digestible dry matter with high K levels.

MATERIALS AND METHODS

TREATMENT MANAGEMENT

A randomized complete block design with four replications was used to investigate the influence of summer grazing by sheep on alfalfa, regrowth, quality, and stand durability. In addition, a split plot arrangement of treatments was used to compare high K fertility to recommended rates. Each main plot was 4 x 8 meters.

A two year-old stand of Arc alfalfa was located on Landisburg and Greendale silt loams with a slope of 2-7 percent. Greendale soil series is average for alfalfa productivity and classified as a Typic Hapludult. Landisburg differs from Greendale principally in having a fragipan in the subsoil. Fertilizer was applied according to soil test recommendations of the Virginia Polytechnic Institute and State University Extension Soil Testing Laboratory (Donohue and Gettier, 1979). Methoxychlor[1] and Dylox[2] insecticides were applied in July to control leafhopper. Hay was cut and

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[1] Marlate; E. I. dePont de Nemours and Co. Wilmington, Delaware.

[2] Trichlorfon; Mobay Chem. Corp. Ag. Chem. Div. Kansas City, MO.

removed from the entire area on 17 May and 2 July. Following the July cutting, the K treatment was broadcast at a rate of 560 kg K/ha.

After 2 July the alfalfa regrew until there was approximately 450 kg/ha of dry matter available, at which time grazing treatments began. Treatments included grazing for 2-, 4-, or 6-weeks (begun when regrowth accumulation was approximately 450 kg/ha), grazing for a short duration beginning at early bud (delayed grazing), grazing for a short duration beginning at early bloom (conventional grazing), and non-grazed where forage was removed as hay that was cut at 1/10 bloom stage (non-grazed). Grazing treatment initiation and termination dates are given in Table 1.

Grazing pressure was high on delayed and conventional treatments to obtain a low stubble within a 7 to 10 day period. An attempt was made on 2-, 4-, and 6-week grazing treatments to maintain a constant leaf area index (LAI) of about 0.25. Numbers of sheep per unit area were varied throughout the trial to meet these two objectives. During grazing periods sheep were fenced out of areas not being grazed but had access to all grazed areas as treatments were opened or excluded. Following grazing, the alfalfa was allowed to regrow to the 1/10 bloom stage or until damaged by frost. Depending on the grazing duration, one or two hay

Table 1. Dates of the beginning and end of grazing and of post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing dates		Harvest dates	
	Begin	End	Summer	Fall
2 week	14 July	28 July	26 Aug.	14 Oct.
4 week	14 July	11 Aug.	---	1 Oct.
6 week	14 July	25 Aug.	---	14 Oct.
Delayed	26 July	5 Aug.	14 Sept.	14 Oct.
Conventional	5 Aug.	12 Aug.	---	1 Oct.
Non-grazed	---	---	10 Aug.	1 Oct.

cuts were taken in the season after grazing, with variable regrowth periods (Table 1).

PARAMETERS MEASURED

Yield, leaf area, leaf percentage, tiller number, plant height, root total nonstructural carbohydrates (TNC), and various indications of herbage quality were measured before and after grazing. In addition, all measurements plus percent weeds were made on regrowth at the 1/10 bloom stage or on herbage after the first killing frost in the fall. Growth stage, regrowth time, rainfall, temperature, and day length influenced measurements at fall harvest. Since these factors had compounding effects, only hay harvests from 4-week grazing, conventional grazing, and non-grazed treatments were comparable for plant productivity and quality measurements at this harvest. On 23 May 1983, residual effects on yield, tiller number, and percent weed were determined on the spring growth at the late bud stage.

A subsample of the herbage was separated into leaf and stem fractions to determine LAI and percent leaves. Taproots were obtained from five plants within each plot, for determination of TNC. Tillers were counted within a randomly placed 930 square centimeter area. Plant height was measured on 10 random plants in each plot. The 1/10 bloom stage for hay harvests was determined from 100 randomly chosen stems in which 10 buds showed color. All plant material for chemical analyses was dried at 70 C for 24 hours and ground to pass through a 40 mesh screen.

LABORATORY ANALYSES

Root TNC was measured by a semi-automated method and reported as equivalent glucose percentage (Smith, 1969). In vitro dry matter digestibility (IVDMD) was determined by the method of Tilley and Terry (1963) modified by Barnes (1969). Crude protein (CP) concentration was determined by the Kjeldahl procedure and was calculated as N x 6.25 (A. O. A. C., 1975). Forage was analyzed for acid detergent fiber (ADF) and neutral detergent fiber (NDF) concentrations by the method of Goering and VanSoest (1970). Hemicellulose was calculated as the difference between NDF and ADF. Lignin and cellulose were determined as a continuation of the ADF procedure using the permanganate method of VanSoest and Wine (1968). All mineral concentrations were determined from a subsample digested by nitric-perchloric acid. After digestion K, Ca, and Mg were determined by atomic absorption spectroscopy and P by a colorimetric technique (Fiske and Subbarow, 1925). Data on available dry matter, leaf percentage, crude protein, acid and neutral detergent fiber, lignin, cellulose, hemicellulose, and IVDMD were presented on a dry matter basis.

STATISTICAL ANALYSIS

All data were subjected to analysis of variance. Since interactions did not occur between grazing treatments and fertilizer rates, the K rates were averaged for each grazing treatment. Significant differences at the 0.05 level of probability among grazing treatment means were determined by the Duncan's Multiple Range Test. Since there was a significant time x treatment interaction the data were further analyzed using a t-test for difference between beginning and end of grazing for the 2-week, delayed, and conventional grazing treatments. Means for 4- and 6-week grazing treatments were not tested for differences since a single data set was collected over the entire 2-, 4- and 6-week treatment area at the beginning of grazing on these systems. These systems were initiated simultaneously with no prior treatment influence.

RESULTS AND DISCUSSION

FORAGE PRODUCTIVITY

Available Dry Matter

Initial available dry matter generally increased as the growth stage increased (Table 2). Although differences were not significant between conventional and non-grazed treatments, the increasing trend was continued. The 2-, 4-, and 6-week grazing treatments, at an early vegetative stage, had the lowest available forage while the non-grazed treatment, at the 1/10 bloom stage, had the highest available forage. Grazing for 2 weeks did not significantly reduce forage availablility but 4- and 6-week grazing treatments reduced available dry matter. Delayed and conventional treatments decreased in available forage through grazing. When grazing terminated, these treatments had more available forage than the 4- or 6-week grazing treatments, however, the forage was a stemmy residue indicating sheep grazed selectively and consumed more of the young, leafy tissue.

Summer hay yields were lowest following 2-week grazing. Although 2-week, delayed, and non-grazed systems were all harvested at the 1/10 bloom stage, the total regrowth time

Table 2. Available dry matter at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest		
	Begin	End	Summer	Fall	Total
	----------------		kg/ha	------------------	
2 week	480a†	370a	1340a	620a	1960
4 week	480a	160b	---	580a	580
6 week	480a	130b	---	310b	310
Delayed	1560b	410a***	2400b	640a	3040
Conventional	2190c	920c***	---	1420c	1420
Non-grazed	2570c	----	2570b	1680d	4250

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, Differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

in the 2-week system was approximately 10 days shorter than the other two systems (Table 3). This shorter time period would account for much of the difference in dry matter accumulation although rainfall and available moisture were also lower prior to this treatment's harvest (Fig. 1).

At fall harvest the 4-week, conventional and non-grazed systems had very comparable regrowth conditions. They occurred simultaneously with only 3 days total difference in length of time (Table 3). Lowest hay yields occurred from 4-week grazing (Table 2). The total accumulation of dry matter on this system was too low to be harvested for hay under pratical conditions. Conventional grazing also resulted in lower hay yields than the non-grazed control. These results indicate that grazing by either system reduced the regrowth of the alfalfa. Grazing for 4 weeks was more detrimental to regrowth than the conventional system, however, and resulted in a 65% reduction in yield at this harvest.

Only the conventional grazing system and the non-grazed control had sufficient regrowth to make hay harvesting practical at the fall harvest date. However, the 2-week and delayed systems had been harvested in late August and mid-September, respectively. Regrowth following grazing by the 4- and 6-week systems was too low for any hay harvest to be

Table 3. Regrowth duration for hay harvests following grazing.

Grazing treatment	Post-grazing harvest Summer	Fall
	-------- days	---------
2 week	28	48
4 week	--	50
6 week	--	49
Delayed	39	29
Conventional	--	49
Non-grazed	38	51

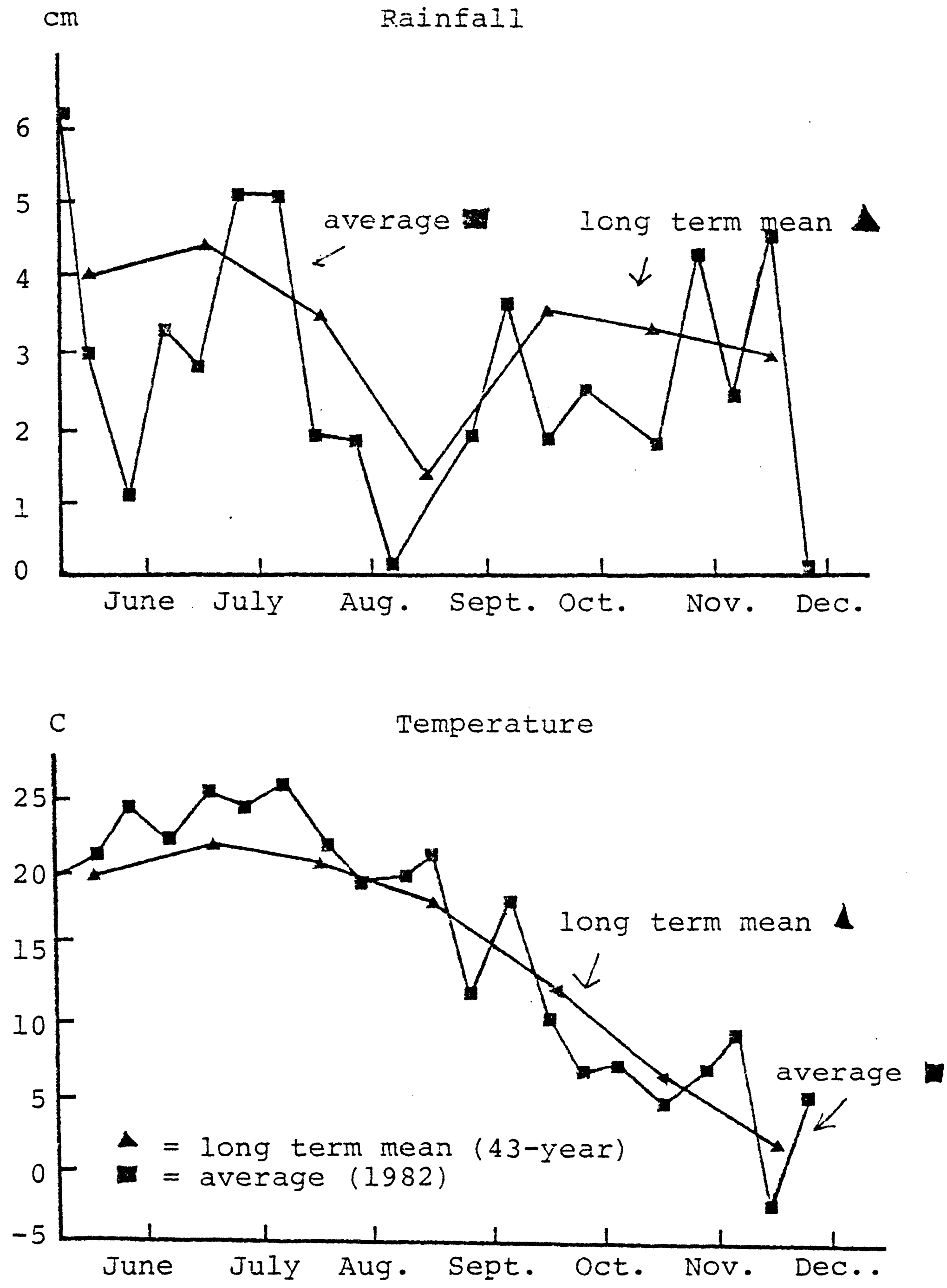

Figure 1. Rainfall and temperature averaged over 10 day intervals and long term means at Blacksburg, Virginia during the summer and fall of 1982.

feasible following grazing. On a practical basis the timing of the subsequent hay harvest could be altered by the system of grazing or it could be completely negated. Grazing by any system resulted in the sacrifice of some hay yield not only through forage consumed by grazing but by reduction of yield in the subsequent hay harvest.

Leaf Area Index

Initial leaf area index increased as the stage of growth increased (Table 4). Delayed and conventional grazing treatments decreased in LAI during grazing indicating selective grazing of the leaves by sheep. Leaf area index was not significantly altered by two-week grazing and a higher LAI was maintained than for the 4- or 6-week systems, reflecting the higher available dry matter. Fuess and Tesar (1968) have shown that for each LAI unit increase an estimated 460 kg/ha of dry matter was produced.

At summer harvest, 2-week grazing resulted a lower LAI in forage harvested as hay than did delayed grazing or non-grazed treatments. Leaf area index differed among 4-week grazing, conventional grazing, and non-grazed treatments at fall hay harvest, again paralleling dry matter accumulation.

Table 4. Leaf area index (LAI) of six alfalfa grazing treatments at the beginning and end of grazing and at post-grazing hay harvests.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	---------------- LAI	---------------------		
2 week	0.66a†	0.51a	1.61a	0.69a
4 week	0.66a	0.22b	--	0.64a
6 week	0.66a	0.25b	--	0.36a
Delayed	1.69b	0.28b***	3.05b	1.02b
Conventional	2.75c	0.32b***	--	1.36c
Non-grazed	3.39d	---	3.39b	1.84d

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*,**, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

Leaf Percentage

All treatments were similar in leaf percentage at grazing initiation (Table 5). Studies have shown the percentage of leaf tissue declines with maturity (Troelsen and Campbell, 1969; Luckett and Klapfenstein, 1970). However, Kiesselbach and Anderson (1926) found that the largest decrease in leafiness occurred between full bloom and seed stages.

Leaf percentage decreased through selective grazing in delayed and conventional grazing treatments. Grazing in the 2-weeks did not significantly reduce leaf percent. The high leaf percentage of herbage from 6-week grazing system may have been influenced by environmental conditions. Average temperatures were above normal during the beginning of August (Fig. 1). Marten (1970) has shown alfalfa harvested under a warm regime had a high leaf percentage.

Hay cut from delayed and 2-week grazing had higher leaf percentage than non-grazed at summer harvest. The suggestion of environmental influences on precent leaf is strengthened by the pattern observed in summer hay harvest. Summer hay on the 2-week system and the end of grazing on the 6-week system occurred on 26 and 25 August, respectively. Summer hay on the non-grazed system and end of grazing on the 4-week system was harvested on 10 and 11 August, respectively. Both the late August forages were higher in

Table 5. Alfalfa leaf percentage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------------	%	---------------------	
2 week	45.4†	39.9a	50.8a	51.7ab
4 week	45.4	36.7a	--	49.5abc
6 week	45.4	63.0b	--	53.1a
Delayed	43.9	16.4c***	48.7a	50.3ab
Conventional	44.7	10.9c***	--	44.1c
Non-grazed	41.0	--	41.0b	45.8bc

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

percent leaf than the forages in early August. In fall 4-week grazing, conventional grazing, and non-grazed systems had similar leaf percentages. Days until harvest, stage of maturity, and environmental conditions during growth were similar for these treatments.

Plant Height

Plant height generally increased as the growth stage increased as shown by treatments at the beginning of grazing (Table 6) but did not increase further between the conventional and non-grazed systems. Plant height increased during 2-week grazing treatment but was similar for the 2-, 4-, and 6-week systems. On the basis of plant height, a relatively constant grazing pressure was maintained for the 2-, 4- and 6-week systems. Delayed and conventional grazing resulted in a tall stubble due to selective grazing.

Two-week continuous grazing was lower in plant height than the non-grazed treatment at summer harvest. Both 4-week and conventional grazing had shorter plants than the non-grazed treatment in fall. Low plant height may be due to low root TNC (Leach, 1970). If plant height in fall was an indicator of susceptibility to winter injury, 2-, 4-, and 6-week grazing and delayed grazing systems would be more subject to winter injury than the non-grazed system (Barnes et al., 1979).

Table 6. Plant height at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	cm			
2 week	7.0a†	8.7ab***	35.9a	19.2a
4 week	7.0a	7.6b	--	29.0b
6 week	7.0a	8.2ab	--	17.0ac
Delayed	23.9b	11.4a***	39.7ab	13.9c
Conventional	44.8c	24.4c***	--	39.8d
Non-grazed	41.2c	--	41.2b	44.2e

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, *** differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

Tiller Number

Tiller number generally decreased with plant maturity as reflected by treatments at grazing initiation (Table 7). Bula and Massengale (1972) found that shading reduced tiller numbers. Shading of lower plant parts increases as the canopy developes. Decreases in tillers/m^2 occurred during grazing for most treatments, indicating selective grazing for young, leafy tillers. Tiller number did not decline during the first two weeks of grazing perhaps due to an initially low stocking rate or a change in grazing behavior as the sheep adjusted to the forage.

At summer harvest, delayed grazing treatments had higher tillers/m^2 than 2-week grazing or non-grazed treatments. Of these treatments, delayed grazing had the highest plant height at the end of the grazing period. Leach (1970) reported the height of cutting or grazing had a direct effect on the number of stems subsequently developed by the plant, because almost all stem development of plants having a stubble was from axillary buds. If no stubble remained, stem development was from crown buds resulting in fewer stems and delayed regrowth. Therefore, a higher tiller number from the delayed grazing treatment may have been due to the high stubble following grazing.

Table 7. Tiller count at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------------	m^2	-------------------	
2 week	880a†	840a	370a	321a
4 week	880a	654b	--	210b
6 week	880a	433c	--	153b
Delayed	698b	413c***	501b	452c
Conventional	496c	350c***	--	359ad
Non-grazed	388c	--	388a	423cd

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, *** differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

The four-week grazing system had lower tillers/m^2 than conventional grazing or non-grazed treatments at fall harvest. This may also be related to low plant height at the end of grazing (Leach, 1970; Hodgkinson, 1969). According to Bula and Massengale (1972) the productivity of an alfalfa stand is related to the number of stems per unit area. Following this thought, 2-, 4-, and 6-week grazing of alfalfa was damaging the productivity of the stand as indicated by fall harvest data.

Root Total Nonstructural Carbohydrates

Root TNC had declined when delayed grazing was initiated, but increased at the bloom stage (Table 8). These findings agree with the work of Hodgkinson (1969) and Cooper and Watson (1968).

Root TNC decreased during the 2-, 4- and 6-week grazing treatments indicating the young vegetative tillers utilized carbohydrates for growth faster than they were restored through photosynthesis. Delayed and conventional grazing treatments did not change in root TNC during the grazing period.

Root TNC differed among treatments at summer harvest. High root TNC from 2-week and delayed grazing may be due to a higher stubble height at the end of grazing as compared to

Table 8. Total nonstructural carbohydrates (TNC) in alfalfa roots at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------	---------- %	----------	----------
2 week	13.4ab†	9.5a ***	21.0a	32.5a
4 week	13.4ab	5.8b	--	25.7b
6 week	13.4ab	8.1ab	--	29.0c
Delayed	11.0b	11.1a	26.0b	27.8bc
Conventional	16.7a	15.0c	--	26.9bc
Non-grazed	15.9ab	--	15.9c	29.3c

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

the subble left by mowing. Leach (1970) suggested a relationship between height and root TNC accumulation. This result reflects treatment damage which is also indicated by yields. Four-week continuous grazing was lower in root TNC than the non-grazed treatment in fall. Conventional grazing also tended to be lower in TNC. This reduced TNC may well be related to the lower plant heights observed for these treatments at the fall harvest.

FORAGE QUALITY

Crude Protein

Crude protein of alfalfa herbage generally decreased as plant maturity increased at grazing initiation (Table 9). Forage from 2-, 4-, and 6-week systems contained higher CP levels than delayed, conventional, or non-grazed hay but all were above ruminant animal requirements for growth or production. At the end of grazing, CP decreased for all compared grazing treatments. The largest decrease in percent CP occurred in conventional grazing treatment. This treatment also had the greatest decline in percent leaf (Table 5). These results are in agreement with Chrisman and Kohler (1968) who found that alfalfa leaves contain much higher levels of CP than stems. Since a high leaf percentage was maintained by the 2-, 4- and 6-week systems, these treat-

Table 9. Percent crude protein (CP) of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------	---------- %	----------	----------
2 week	29.0a†	25.0a***	22.3a	23.8a
4 week	29.0a	24.7a	--	21.8bc
6 week	29.0a	27.6b	--	23.5ab
Delayed	22.2b	18.1c***	21.5a	29.2d
Conventional	22.1b	14.1d***	--	21.7c
Non-grazed	20.4c	--	20.4a	21.4c

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.

*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

ments retained a higher CP content than delayed or conventional treatments.

At post-grazing summer harvest, 2-week, delayed, and non-grazed treatments were not different in CP although they tended to again follow percent leaf. The 4-week, conventional, and non-grazed systems were also similar in CP at fall harvest. Matsushima (1972) stated the variability of CP depends largely on the stage of maturity. In this experiment, the compared treatments were at similar growth stage with a total regrowth period that varied by only 3 days. The 2- and 6-week grazing and delayed systems were harvested at a more immature and leafy growth stage (Table 5) which is reflected by higher CP content.

Neutral Detergent Fiber

Alfalfa at an early vegetative stage was lower in NDF than that at early bud or bloom stage (Table 10). An increase in NDF was measured with each measured increase in plant age. Loper (1980) concluded the cell wall formed a higher proportion of the dry matter as the plant matured and resulted in forage of low digestibility. Luckett and Kloptenstein (1970) found that as alfalfa matured the leaf:stem ratio changed with an increase in the amount of stems. However, in this experiment there was not a significant de-

Table 10. Cell wall content indicated by percent neutral detergent fiber (NDF) of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------------	%	--------------------	
2 week	33.9a†	39.7a**	37.4a	32.4a
4 week	33.9a	39.7a	--	36.9abc
6 week	33.9a	34.9a	--	33.7bc
Delayed	35.8b	52.3b***	38.3a	33.1c
Conventional	40.2c	57.1b***	--	37.7ab
Non-grazed	42.4d	--	42.4b	40.0a

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

crease in percent leaf to explain the increase in NDF. Following the grazing period, all compared treatments increased in NDF concentrations. Delayed and conventional systems had significantly higher values than 2-, 4-, and 6-week systems. Delayed and conventional grazing treatments reflected the preferential selecting of leaves, which contain a higher percent cell solubles and are of high quality.

Summer hay yields following 2-week and delayed grazing had lower NDF percentages than the non-grazed treatment. These results were again associated with leaf percentage (Table 5) indicating the primary importance of the leaf:stem ratio in determining forage quality (Barnes and Gordon, 1972; Luckett and Klopfenstein, 1970). At fall hay harvest 4-week grazing, conventional grazing, and non-grazed treatments were similar in both NDF and leaf percentages.

Lignin

Before grazing, lignin tended to increase slightly with increasing plant maturity (Table 11) but a significant increase occurred only in the non-grazed control. Bickoff et al. (1972) found the variability in the relative amounts of the various constituents of the plant material arose mostly from differences in stage of maturity. In addition, Barnes and Gordon (1972) reported an increase in lignin with advancing maturity.

Table 11. Lignin concentration of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------------	-------- % --------	----------------	
2 week	8.0a†	9.2a*	8.4ab	7.0a
4 week	8.0a	8.8a	--	8.2ab
6 week	8.0a	8.1a	--	7.4a
Delayed	8.3a	12.3b***	8.2b	5.2c
Conventional	8.8a	11.4b	--	9.4d
Non-grazed	10.3b	--	10.3a	9.3ad

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

Lignin in post-grazing forage on the conventional grazing system appeared to increase but differences were not significant. Post grazing residue of 2-week and delayed systems was higher in lignin than forage at the beginning of grazing for these treatments. The delayed and conventional grazing treatments also had large decreases in leaf percentage due to selective grazing. Marten (1970) found the lignin percentage of stems to be more than three times that of leaves. Lignin increased in alfalfa during the 5-day interval between initiation of the conventional grazing system and harvest of non-grazed hay. Post-grazing residues of delayed and conventional treatments were sampled 5 days prior to and 2 days after the non-grazed hay cut, respectively. Both residues contained more lignin (2.0 and 1.1 percent, respectively) than did the hay. The increase in lignin percentage at the end of grazing in delayed and conventional treatments can be attributed to both the stage of growth and decrease in leaf:stem ratio.

At summer hay harvest treatments ranged from 8.2 to 10.3 percent lignin. These values tended to be higher than percentages from hay taken in fall. This trend could be due in part to warm temperatures producing higher lignin percentages in summer. Vough and Marten (1971) found that alfalfa harvested at specific growth stages under warm vs. cool temperature regimes was higher in acid detergent lignin. Differences among treatments at summer hay harvest also follow temperature trends (Fig. 1). Hay harvested from the non-grazed system on 10 August contained the highest lignin level (Table 11). Temperatures had generally declined by 14 September when the delayed treatment was harvested at a similar growth stage and plants were lower in lignin concentrations at this date. This treatment was also higher in leaf:stem ratio.

At fall hay harvest 4-week and conventional grazing systems produced forage similar in lignin concentration to the non-grazed treatment. The low lignin concentration in the delayed treatment is probably due to a more immature growth stage since this treatment had the shortest regrowth period (Table 3). In this experiment the effects of both temperature and growth stage on lignin accumulation could be observed.

Cellulose

Initial cellulose content tended to increase with increased plant maturity (Table 12). According to Bickoff et al. (1972), concentrations of cellulose in alfalfa herbage depend primarily on the stage of maturity. Baumgardt and Smith (1962) sampled alfalfa herbage at a vegetative, pre-

Table 12. Cellulose concentration of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	------------------ % ------------------			
2 week	15.9a†	19.7a**	20.4a	16.5a
4 week	15.9a	19.0a	--	20.1b
6 week	15.9a	16.2a	--	16.4a
Delayed	19.2b	27.8b***	21.6ab	15.1a
Conventional	22.5c	32.8c***	--	20.3b
Non-grazed	23.5c	--	23.5b	20.9b

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

bud, midbud, 10% bloom, and full bloom stage and found cellulose increased with plant maturity. Results obtained in this experiment agree with their results.

Alfalfa herbage was higher in cellulose at the end than at the beginning of grazing for 2-week, delayed, and conventional treatments. The 2-, 4- and 6-week grazing systems remained relatively lower in cellulose during grazing then the other treatments since the growth stage did not vary greatly. Delayed and conventional grazing had the largest increase in cellulose content during grazing. These treatments contained a much higher percentage of stems. Bailey et al. (1970) found leaves contained about 10 percent cellulose while stem-cellulose was 27 percent during various growth stages. Since grazing and a more mature growth stage when grazing was intiated resulted in high stem percentage, cellulose values would be expected to be higher for delayed and conventional grazing treatments.

Cellulose concentrations of alfalfa herbage were similar for delayed grazing and non-grazed treatments at summer harvest. Two-week grazing had a lower cellulose percentage than the non-grazed treatment. Stage of maturity as indicated by percent bloom was similar for 2-week grazing and non-grazed treatments, but the 2-week treatment had a 10-day shorter accumulation time (Table 1). The low cellulose concentration from herbage of 2-week continuous grazing may be due to physiologically younger plant material as well as higher leaf percentage (Table 5). Conventional, 4-week, and non-grazed systems contained similar cellulose concentrations at fall harvest since environmental conditions, leaf percentage, and stage of maturity, and total regrowth time were similar among these treatments. Forages harvested from the other treatments in the fall were lower in cellulose, which was probably attributable to their more immature growth stage and generally higher percent leaf.

<u>Hemicellulose</u>

At initiating, alfalfa herbage was not significantly different in hemicellulose concentrations for each system, although there was a trend for hemicellulose to increase with advance in maturity (Table 13). Results were in agreement with Graber et al. (1927), in which the percentage of hemicellulose in herbage changed very little from early vegetative to mature seed stage of growth.

Hemicellulose concentrations tended to increase among treatments at the end of grazing although differences were only significant in the delayed system. Delayed and conventional grazing treatments tended to be higher than 2-, 4-, or 6-week systems. These treatments also had higher stem

Table 13. Hemicellulose concentration of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------------	%	----------------	
2 week	7.4†	9.6	9.8	8.9ab
4 week	7.4	10.0	--	9.1ab
6 week	7.4	10.1	--	9.6a
Delayed	8.0	13.5*	9.2	6.7b
Conventional	8.8	11.3	--	9.1ab
Non-grazed	8.9	--	8.9	9.8a

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, *** differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

percentages. Bailey et al. (1970) found slightly higher hemicellulose percentages in stems than leaves.

Hemicellulose concentrations in hay from summer harvest of 2-week grazing, delayed grazing, and non-grazed treatments were also similar. At fall hay havests, 4-week grazing, conventional grazing, and nongrazed treatments again contained similar hemicellulose percentages.

In Vitro Dry Matter Digestibility

The IVDMD of alfalfa generally decreased with plant maturity at the beginning of grazing (Table 14). Results agreed with Calder and MacLeod (1968) who found that IVDMD decreased as growth stage increased. Compared treatments also decreased in digestibility by the end of the grazing period. Digestibility decreased principally through selective grazing of highly digestible plant parts. Sheep tended to consume the leafy, top portion of the plant which has been found to be more digestible, using an in vitro system (O'Donovan et al., 1966). Delayed and conventional treatments decreased in leaf percentage through grazing. No significant difference in percent leaf was found due to the 2-week grazing system although there was a significant decline in IVDMD. However, since lignin and cellulose increased and CP decreased the difference in digestibility is

Table 14. In vitro dry matter digestibility (IVDMD) of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------------	%	----------------	
2 week	82.2a†	68.4a***	67.3	73.0ab
4 week	82.2a	66.7a	--	70.0bcd
6 week	82.2a	70.7a	--	71.5abc
Delayed	74.3b	57.5b***	67.9	74.3a
Conventional	69.3c	54.4b***	--	68.6cd
Non-grazed	67.0c	--	67.0	67.0d

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

not surprising. Delayed and conventional grazing systems resulted in the lowest IVDMD, due undoubtedly to the fact that the alfalfa was a stemmy residue at the end of grazing. The IVDMD of alfalfa stems has been found to decrease steadily during maturation, while the digestibility of leaves changed only slightly (Luckett and Klopfenstein, 1970).

At summer harvest 2-week continuous grazing, delayed grazing, and non-grazed treatments were similar in digestibility. Since forage from the non-grazed system was generally lower in percent leaf and higher in NDF, cellulose, and lignin the lack of difference in digestibility is hard to explain. Environmental influences on digestibility are usually also reflected in these individual constituents. Conventional grazing, 4-week, and non-grazed systems were similar in IVDMD at fall harvest. These treatments also were similar in growth stage, were grown under similar environmental conditions, and contained similar fiber and CP content.

MINERALS

Potassium

Forages for systems were similar in K concentrations at grazing initiation (Table 15). By the time the non-grazed system was harvested the K content had declined, reflecting

Table 15. Potassium concentration of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------------	---------------- %	----------------	----------------
2 week	3.3a†	3.1a	2.6ab	2.3abc
4 week	3.3a	3.0a	--	2.2bc
6 week	3.3a	3.0a	--	2.0c
Delayed	3.0ab	2.7a*	2.4b	2.9d
Conventional	3.1ab	2.7a*	--	2.5ab
Non-grazed	2.8b	--	2.8a	2.6ad

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.05, 0.01 and 0.001 level of probability.

a trend of K content to decrease as plant maturity increased. Van Riper and Smith (1959) found that K concentration declined from the vegetative to full-bloom stage. Potassium was also lower in residues on delayed and conventional systems.

Hay cut in summer and fall tended to contain lower K than herbage during the grazing period perhaps due to cooler temperatures. Smith (1969) found that the K concentration in alfalfa under a cool temperature regime (18 C/10 C) was 1.34% compared to 2.35% under warm temperatures (32 C/24 C).

Magnesium

The 2-, 4-, and 6-week grazing systems contained higher Mg levels than delayed, conventional, and non-grazed systems (Table 16) at each system initiation. In previous studies of the Mg concentration of alfalfa, a very slight decrease with stage of growth or advance in season has been observed (Davies et al., 1968).

Herbage generally decreased in Mg by the end of grazing. The stemmy residues of delayed and conventional systems had the lowest Mg concentration and followed the same trend as Ca. According to Luckett and Klopfenstein (1970), alfalfa leaves contain more nutrients than stems. Smith (1970) concluded leaf tissue was higher than stem tissue in Mg concentrations.

Table 16. Magnesium concentration of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	----------	---------- %	----------	----------
2 week	0.37a†	0.30a***	0.27a	0.29a
4 week	0.37a	0.30a	--	0.29a
6 week	0.37a	0.36b	--	0.29a
Delayed	0.25b	0.22c*	0.25a	0.30a
Conventional	0.25b	0.16d**	--	0.26ab
Non-grazed	0.23b	--	0.23a	0.23b

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.
*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.04, 0.01 and 0.001 level of probability.

Magnesium content of hay harvested in summer was similar among treatments. Hay from the non-grazed treatment contained lower Mg concentration than hay from the 4-week grazing treatment at fall harvest. This may be due to the slightly higher leaf percentage in herbage from 4-week grazing.

Phosphorus

The 2-, 4-, and 6-week grazing systems contained higher P concentrations than delayed grazing, conventional grazing, and non-grazed systems at grazing initiation (Table 17). In addition there was a trend of decreasing P with increasing plant maturity. The herbage from 2-, 4-, and 6-week grazing systems also had higher P concentrations than delayed or conventional grazing systems at the end of grazing. The lower P content in herbage from conventional grazing at the end of the grazing period may be due to the low leaf percentage. Smith (1970) found leaf tissue to contain more P than stems.

At summer harvest P concentration did not follow percent leaf trends. Forage on the delayed system contained lower P concentration than the other two systems. This forage was higher in percent leaf, however, than was the non-grazed forages. Conventional grazing, 4-week grazing, and

Table 17. Phosphorus concentration of alfalfa herbage at the beginning and end of grazing and at post-grazing hay harvests for six alfalfa grazing treatments.

Grazing treatment	Grazing period		Post-grazing harvest	
	Begin	End	Summer	Fall
	---------------	------- %	-------	---------------
2 week	0.36a†	0.38a	0.27a	0.28a
4 week	0.36a	0.38a	--	0.23b
6 week	0.36a	0.38a	--	0.27ac
Delayed	0.30b	0.28b	0.24b	0.39d
Conventional	0.29b	0.25b*	--	0.25bc
Non-grazed	0.28b	--	0.28a	0.24b

†Means within a column followed by the same letter do not differ significantly at the 0.05 level of probability.

*, **, ***, differences between means in columns one and two of the grazing period are significant at the 0.04, 0.01 and 0.001 level of probability.

non-grazed systems had similar P concentrations at fall harvest. Barnes and Gordon (1972) found no systematic trends of P through the growing season and none were apparent in this study.

Residual Effects

In fall, percent weeds was higher for the 2-, 4-, and 6-week systems (Fig. 2) than for the other systems. Weeds increased from 33% in 2-week to 65% in 6-week grazing systems. Delayed grazing, conventional grazing, and non-grazed treatments were similar in percent weeds in the fall. The 4-week grazing system resulted in the highest weed yield in kg/ha at the fall harvest (Table 18). On a kg/ha basis delayed grazing resulted in very low weed yield. However, due to the low yield of alfalfa at the fall harvest the percent weed content was similar to conventional and control treatments.

At spring hay harvests, all grazing treatments were similar in percent weeds (Fig. 2). Weeds were less in spring than fall in 2-, 4-, 6-week grazing treatments. The 4- and 6-week grazing systems had a 38 and 26 percent decline in weeds, respectively. Delayed, conventional, and non-grazed systems had higher percent weeds in spring than fall.

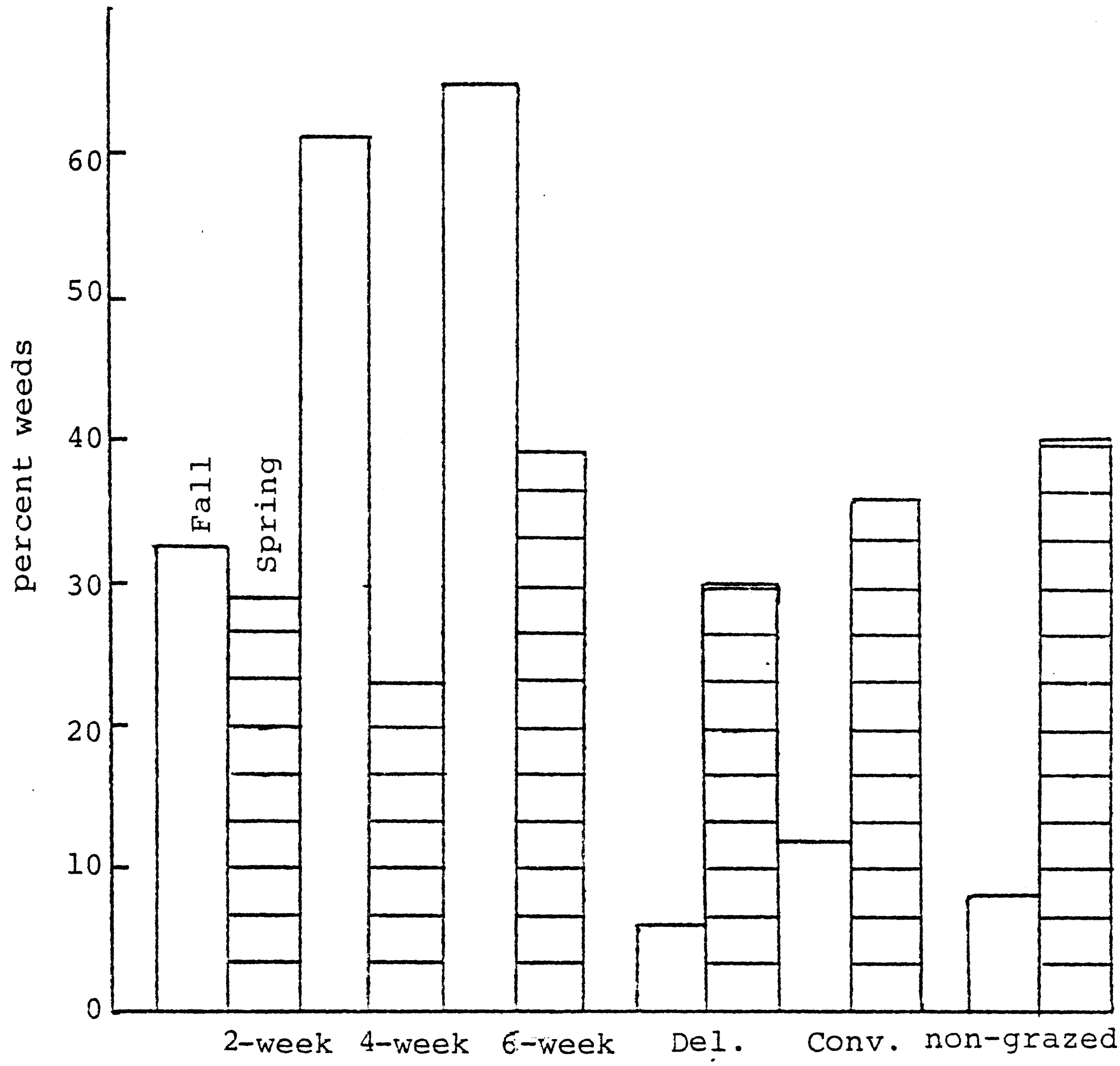

Figure 2. Percentage weeds at fall and spring harvest for 2-, 4-, and 6-week grazing, delayed (Del.) and conventional (Conv.) grazing, and non-grazed hay harvest.

Table 18. Weed growth at fall and spring harvest for six alfalfa grazing treatments.

Grazing treatment	Harvest	
	Fall	Spring
	----- kg/ha ----	
2 week	296	595
4 week	892	487
6 week	581	769
Delayed	35	593
Conventional	223	715
Non-grazed	148	783

Yields and tiller numbers were similar among treatments at spring harvest (Table 19) although yields on all systems were lower than would normally be expected for a spring harvest. Weather conditions during the spring growth period were abnormally cold and would have influenced yields.

Results of the spring harvest indicate grazing by these systems did not affect stand yield, tiller numbers, or percent weeds in spring regrowth. However, the abnormal spring growing conditions and low yields may have masked treatment effects at this stage. Differences in effect of treatments were apparent at the fall harvest with yield, LAI, plant height, tiller numbers, and root TNC. Further studies are needed to determine the influence of these grazing treatments on seasonal regrowth, weed encroachment, and stand longevity during subsequent growing seasons.

Table 19. Yield and tiller number at spring harvest for six alfalfa summer grazing managements with sheep.

Grazing treatment	Yield†	Tiller number†
	kg/ha	m^2
2 week	2050	359
4 week	2120	376
6 week	1970	362
Delayed	1980	354
Conventional	1990	294
Non-grazed	1960	320

†Means did not differ significantly at the 0.05 level of probability.

SUMMARY AND CONCLUSIONS

Productivity of cool season forage species declines during hot, dry summer months with plants becoming semidormant. Alfalfa is more tolerant than many species of hot, dry conditions due to a deep taproot system that can utilize subsurface moisture. Grazing of alfalfa could supplement cool season pastures if yield and stand longevity were not depressed. Alfalfa productivity, quality, and stand longevity were measured during six summer grazing managements with sheep. In addition the effect of high K fertility (560 kg K/ha above recommended rates) on yield, regrowth, and forage quality, was compared to recommended rates. The six grazing treatments were 2-, 4-, and 6-week grazing (begun when regrowth, following a July hay cut, was approximately 450 kg/ha); grazing for a short duration at the early bud (delayed); grazing for a short duration at early bloom (conventional); and non-grazed harvested as hay at 1/10 bloom.

Forage productivity as indicated by yield, LAI, and tiller number generally decreased during grazing on all treatments. Forage quality, as indicated by CP, NDF, lignin, cellulose and IVDMD, had generally declined in herbage by the end of the grazing period although the 2-, 4-, and 6-week systems maintained plants with a percent leaf similar to that of plants when grazing was initiated.

Grazing alfalfa by the 2-, 4-, or 6-week systems resulted in maintaining a higher quality forage in the pasture. When grazing was terminated, forage in these systems was higher in percent leaf, CP and IVDMD and was lower in cellulose, lignin and NDF than forage remaining in the other grazing systems at the end of their respective grazing periods. Grazing by the 2-, 4-, 6-week systems generally resulted in lower available pasture than the other systems but much of the forage remaining following delayed or conventional systems was a stemmy residue. When grazing was terminated root reserves of TNC were lower in the 2-, 4-, and 6-week systems indicating the possibility of detrimental effects of these systems on plant recovery.

The summer harvest from the 2-week, delayed, and non-grazed systems generally indicated that grazing decreased yield, LAI, and plant height but root TNC remained higher than in the non-grazed system. However, percent leaf, NDF, lignin, and cellulose was higher than in the hay from the non-grazed system. Crude protein tended to be higher in the grazed systems. These differences occurred even though all three hays were cut at the 1/10 bloom stage. Environment undoubtly influenced these results since harvest dates occurred at different times. It is interesting to note that even though several measures of forage quality increased in the grazed systems, the IVDMD did not differ significantly among these systems.

At fall hay harvest on 1 October, the 4-week, conventional, and non-grazed systems were compared. These systems were nearly identical in regrowth period (50, 49 and 51 days, respectively) and occurred simultaneously under the same environmental conditions. The 4-week and conventional grazing systems generally reduced forage productivity as indicated by yield, LAI, plant height, tiller number, and root TNC when compared to the non-grazed system. Measurements of forage quality indicated little variation among these treatments, however.

At the fall harvest the 2-, 4-, and 6-week grazing systems contained a higher percent of total dry matter as weeds than did the other three systems. No differences in either weeds or yield were detected in the spring hay cut in the following year. The unusually low yield of this harvest may have affected these results, however.

Based on one year's data it appears that grazing alfalfa during the summer results in some degree of yield reduction in the following hay cuts of that year as well as removal of plant tissue as grazed material. Conventional grazing resulted in the least relative reduction in yield. The other grazing systems resulted in too low a regrowth at frost for mechanical harvesting to be feasible although the 2-week and delayed systems resulted in hay harvests in late summer. No regrowth harvestable as hay followed the 4- and 6-week grazing systems. Although no differences in yield or percentage weed were obtained in stands the following spring at the 1/10 bloom stage, unusual weather conditions may have contributed to this lack of effect and more information is needed to determine effects of grazing on stand longevity in subsequent years.

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MANAGEMENT OF SUMMER GRAZED ALFALFA

by

Laurie Ann Hamilton

(ABSTRACT)

Alfalfa (Medicago sativa, L. cv. Arc) productivity, regrowth, and quality as affected by summer grazing management and K fertilization (560 kg K/ha) was investigated with sheep. Sheep grazed alfalfa for 2-, 4-, or 6-weeks following a 2 July hay cut when regrowth was 450 kg/ha dry matter; beginning in early bud for 10 days (delayed); at early bloom for 7 days (conventional); and non-grazed (hay removed at 1/10 bloom).

Forage yields, leaf area index (LAI), tiller numbers, crude protein (CP), and in vitro dry matter digestibility (IVDMD) generally declined during grazing. Neutral detergent fiber (NDF), lignin, and cellulose content generally increased on all grazing systems. Forage at the end of grazing was higher in percent leaf, CP, Mg, P, K and IVDMD and lower in cellulose, lignin and NDF on 2-, 4-, and 6-week systems than forage remaining on the other systems.

A late summer hay cut at 1/10 bloom was made on 2-week, delayed and non-grazed systems. Grazing by the 2-week system decreased yield, LAI, and plant height but forage quality as measured by percent leaf, NDF, lignin, and cellulose

was increased, compared to the non-grazed system. Grazing by the delayed system resultedin similar results as the 2-week system but differences were not as great. There were no differences in IVDMD.

On 1 Oct., 4-week and conventional grazing systems had reduced yields, plant height, tiller number, and root total nonstructural, but had no significant effect on forage quality. Conventional grazing resulted in the least damage to yield and productivity measurements. Percent weed increased in 2-, 4-, and 6-week systems in fall but no differences were measured in percent weed, yield, or tiller number in regrowth the following spring.