

AN ABSTRACT OF THE THESIS OF

Iraj Motazedian for the degree of Doctor of Philosophy

in Rangeland Resources presented on July 20, 1983.

Title: Effect of Defoliation Treatments on Forage Quality, Quantity,
and Species Composition of a Lolium perenne (L.)-Trifolium
subterraneum (L.) Pasture.

Abstract approved:

Redacted for privacy

Steven H. Sharrow

As part of investigations to adapt a suitable grazing system in western Oregon, this research was designed to monitor the effects of defoliation treatments on dry matter production, forage quality, regrowth after defoliation, and species composition of a Lolium perenne - Trifolium subterraneum pasture for three consecutive growing seasons from 1980 to 1982. Defoliation treatments were three replications of all possible combinations of four defoliation intervals (clipped every 7, 21, 35 or 49 days) and three stubble heights (70, 55 or 40 mm of stubble remaining). A rear bagging rotary mower was used to defoliate the plots and to collect the phytomass at the assigned dates and heights. Grab samples of the forage produced from different treatments were analyzed to determine their digestibility and crude protein content. Leaf Area Index of the herbage

produced and the chlorophyll content of the remaining stubble after defoliation were measured in the first seven weeks of 1981 and 1982 growing seasons. Species composition and canopy cover were estimated prior to defoliation treatments each year. Plant density, basal area and root phytomass of perennial ryegrass plants were determined at the completion of the experiment. Collected data were analyzed as a split plot in time. Data within each year were a factorial arrangement of treatments in a randomized complete block design.

Defoliation treatments affected dry matter production and the rate of regrowth after defoliation. Total dry matter production in all three years increased as defoliation interval increased from one to seven weeks. Effects of stubble height on dry matter production were probably dictated by forage plant type and pasture species composition. Erect growing ryegrass, which was the major pasture species in 1980, produced more dry matter with lax defoliation; while the more prostrate subclover, which dominated the pasture in 1982, yielded more with close defoliation. Greater daily forage production per unit of land (herbage accumulation rate) on less frequently defoliated plots was associated with increases in leaf area index with time since defoliation. The stubble quality, as evaluated by its chlorophyll content and leaf area index, was lower in plots defoliated less frequently. However, lower initial photosynthetic capacity of the stubble on such plots was less important in determining total forage production than was the higher leaf area accumulated on plots which were defoliated less frequently.

Defoliation treatments were also effective in changing forage quality. In vitro digestibility and crude protein content of the forage decreased as the period and intensity of defoliation increased. Forage quality, however, was generally adequate on all treatments to meet the needs of most classes of livestock.

Finally, defoliation treatments had some effects on pasture species composition and perennial ryegrass persistence. Perennial ryegrass was replaced by subclover in all of the defoliated plots with time over the trial. Both of these plants, however, disappeared and were replaced by annual grasses in nondefoliated control plots. Plots defoliated every one or seven weeks, as compared to three or five weeks, had fewer ryegrass plants at the end of the experiment. Root phytomass of perennial ryegrass also decreased as defoliation frequency increased. The basal area of this plant, however, was similar for all defoliation treatments.

EFFECT OF DEFOLIATION TREATMENTS ON FORAGE QUALITY,
QUANTITY, AND SPECIES COMPOSITION OF A LOLIUM PERENNE

(L). - TRIFOLIUM SUBTERRANEUM (L.) PASTURE

by

Iraj Motazedian

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of
Doctor of Philosophy

Completed July 20, 1983

Commencement June 1984

APPROVED

Redacted for privacy

Associate Professor of Rangeland Resources in charge of major

Redacted for privacy

Associate Professor of Animal Science in charge of minor

Redacted for privacy

Head, Department of Rangeland Resources

Redacted for privacy

Dean of Graduate School

Date thesis is presented July 20, 1983

Typed by Sharon V. Bruno for Iraj Motazedian

DEDICATIONS

I would like to dedicate this work to my dear parents, Mr. Amir-Hossein and Mrs. Soodabeh Motazedian.

I would very much like to give them my best regards for a lifetime of support and encouragement, in person and at their presence. Due to the ever increasing agitation of the events in the human society, however, I am not able to do so. I would like them to know that I put all my effort to serve humanity as I would love to serve my parents.

ACKNOWLEDGEMENT

I would like to thank all of my friends and instructors who have made my education fruitful at Oregon State University, especially at the Department of Rangeland Resources. I would also like to thank the Computer Center of the University for providing a generous fund for the computer work of this research.

My great appreciations go to the members of my committee: Dr. Allen F. Agnew, my Graduate School representative; Dr. William C. Krueger, Head, Department of Rangeland Resources; Dr. Richard F. Miller, Eastern Oregon Agricultural Research Center; and Dr. Dale W. Weber, my Minor Professor, Department of Animal Science. It has been my great pleasure to know these people and to work with them.

I cannot word my great feelings toward my Major Professor, Dr. Steven H. Sharrow. All I can say is that I know him as a wise brother and a helpful friend. Without him this work could not be accomplished.

Finally, I have reserved my deepest love for my dear wife Nourieh and my lovely children Vahid and Tahirih. They all had a great understanding and were cooperative with me to fulfill my education. With great dedications and hard work to support the family, Nourieh has certainly a great share in this work.

TABLE OF CONTENTS

	<u>Page</u>
CHAPTER 1 - EFFECT OF DEFOLIATION TREATMENTS ON FORAGE QUALITY, QUANTITY, AND SPECIES COMPOSITION OF A <u>LOLIUM PERENNE</u> (L.) - <u>TRIFOLIUM SUBTERRANEUM</u> (L.) PASTURE.	
Introduction	1
Literature Review	3
A - Plant description	3
a) Perennial ryegrass (<u>Lolium perenne</u> L.)	3
b) Subterranean clover	5
B - Effect of defoliation on pasture dry matter production	7
C - Regrowth after defoliation	9
D - Forage quality	13
E - Plant persistence, pasture species composition and root growth	16
CHAPTER 2 - EFFECT OF FREQUENCY AND INTENSITY OF DEFOLIATION ON FORAGE DRY MATTER PRODUCTION OF A <u>LOLIUM PERENNE</u> (L.) - <u>TRIFOLIUM SUBTERRANEUM</u> (L.) PASTURE	20
Abstract	22
Introduction	23
Materials and Methods	24
Results and Discussion	26
Conclusions	40
Literature Cited	41
CHAPTER 3 - EFFECT OF FREQUENCY AND INTENSITY OF DEFOLIATION ON FORAGE QUALITY OF A <u>LOLIUM PERENNE</u> (L.) - <u>TRIFOLIUM SUBTERRANEUM</u> (L.) PASTURE	43
Abstract	45
Introduction	47
Materials and Methods	48
Results and Discussion	50
Management Implications	60
Literature Cited	71

	<u>Page</u>
CHAPTER 4 - EFFECT OF DEFOLIATION TREATMENTS ON PASTURE REGROWTH AS RELATED TO LAI AND THE REMAINING STUBBLE	74
Abstract	76
Introduction	78
Materials and Methods	79
Results and Discussion	82
Management Implications	102
Literature Cited	105
CHAPTER 5 - SPECIES COMPOSITION OF A <u>LOLIUM PERENNE</u> (L.) - TRIFOLIUM SUBTERRANEUM (L.) PASTURE UNDER DIFFERING DEFOLIATION TREATMENTS	108
Abstract	110
Introduction	112
Materials and Methods	113
Results and Discussion	116
Management Implications	126
Literature Cited	132
LITERATURE CITED	135
APPENDICES	146
A.	147
B.	148
C.	149
D.	150
E.	151
F.	152

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
CHAPTER 2		
2-1	Relationship ($r^2 = 0.88$) of total pasture dry matter (DM) yield with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble heights (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1980. Dry matter yield = $18139.70 - 102.21 (DI) - 447.05 (SH) + 2.57 (DI)^2 + 4.49 (SH)^2 + 1.22 (DI \times SH)$.	33
2-2	Relationship ($r^2 = 0.91$) of total pasture dry matter (DM) yield with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes in 1981. Dry matter yield = $2820.04 + 444.94 (DI) + 18.17 (DI)^2 + .25 (DI)^3$.	35
2-3	Relationship ($r^2 = 0.88$) of total pasture dry matter (DM) yield with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1982. Dry matter yield = $6894.41 - 20.99 (SH) + (DI)^2$.	37

- 3-1 Relationship ($r^2 = 0.91$) between digestible dry matter yield, defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble heights (SH; 70, 55 or 50 mm stubble remaining after defoliation) regimes in 1980. Digestible dry matter = $7674.51 - 194.692 (SH) + 2.078 (SH)^2 + .016 (DI)^3 + 0.449 (DI \times SH)$. 58
- 3-2 Relationship between digestible dry matter yield and defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes in 1981 ($r^2 = 0.88$) and 1982 ($r^2 = 0.69$). Digestible dry matter (1981) = $969.050 + 267.957 (DI) - 9.634 (DI)^2 + 0.134 (DI)^3$. Digestible dry matter (1982) = $4039.530 + 0.820 (DI)^2$. 61
- 3-3 Relationship ($r^2 = 0.67$) between crude protein yield (CPY), defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1980. Crude protein yield = $1508.040 + 0.002 (DI)^3 + 0.316 (SH)^2 - 0.099 (DI \times SH)$. 63

Figure

Page

- 3-4 Relationship ($r^2 = 0.95$) between crude protein yield (CPY), defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1981. Crude protein yield = $19.459 - 0.110 (DI) + 0.071 (SH)$. 65
- 3-5 Relationship ($r^2 = 0.40$) between crude protein yield (CPY), defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1982. Crude protein yield = $616.136 + 106.318 (DI) - 4.050 (SH)^2 + 0.049 (DI)^3 + 0.079 (SH)^2 + 0.312 (DI \times SH)$. 67

CHAPTER 4

- 4-1 Averaged terminal Leaf Area Index (LAI) measured on plots under different defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH; High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation) regimes during first seven weeks of the 1981 and 1982 growing seasons. 83

Figure

Page

- 4-2 Relationships between LAI, Herbage Accumulation Rate (HAR), and the efficiency of pasture dry matter production (E) in the first seven weeks of 1981 growing season. $HAR(r^2 = 0.99) = -1.99 + 0.08(LAI)$. 86
- 4-3 Relationships between LAI, Herbage Accumulation Rate (HAR), and the efficiency of pasture dry matter production (E) in the first seven weeks of 1982 growing season. $HAR(r^2 = 0.91) = 65.03 - 21.10(LAI) + 5.77(LAI)^2$. 88
- 4-4 Relationship ($r^2 = 0.93$) of Herbage Accumulation Rate (HAR) with defoliation interval (DF = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH; High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation) regimes during first seven weeks of the 1981 growing season. $HAR = -28.445 + 0.041 (DI)^2 + 0.036(SH)^2$. 94

FigurePage

- 4-5 Relationship ($r^2 = 0.89$) of Herbage Accumulation Rate (HAR) with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH; High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation) regimes during first seven weeks of the 1982 growing season.
$$\text{HAR} = 64.430 + 0.071 (\text{DI})^2 - 0.027 (\text{DI} \times \text{SH}).$$
 96

CHAPTER 5

- 5-1 Relationship ($r^2 = 0.65$) between density of perennial ryegrass plants and defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes at the end of experiment in 1982. $\text{Density} = 19.23 + 1.72 (\text{DI}) - 0.03 (\text{DI})^2.$ 123
- 5-2 Relationship ($r^2 = 0.84$) between mean root weight at the end of experiment in 1982 of perennial ryegrass plants and defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes. $\text{Mean root weight} = 1.85 + 0.11 (\text{DI}).$ 127

LIST OF TABLES

<u>Table</u>		<u>Page</u>
CHAPTER 2		
2-1	Species composition (SC) and canopy cover (CC) of the study area estimated at the initiation of defoliation treatments in March 1980, 1981, and 1982.	28
2-2	Total annual dry matter yield (kg/ha) of pasture under four different defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) in 1980, 1981 and 1982.	29
2-3	Total annual dry matter yield (kg/ha) of pasture under three stubble height treatments (SH = 70, 55 or 40 mm stubble remained after defoliation) in 1980, 1981 and 1982.	31
CHAPTER 3		
3-1	Yearly mean in vitro dry matter digestibility (IVDMD), crude protein content (CPC), digestible dry matter yield (DDM) and crude protein yield (CPY) of the forage produced averaged overall treatments in 1980, 1981 and 1982.	51

TablePage

3-2	Mean forage digestibility, digestible dry matter, crude protein content, and crude protein yield of pasture under four different defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) in 1980, 1981 and 1982.	53
3-3	Mean forage digestibility, digestible dry matter crude protein content and crude protein yield of pasture under three different stubble heights (SH; High = 70 mm, Medium = 55 mm, and Low = 40 mm stubble remaining after defoliation) in 1980, 1981 and 1982.	56
CHAPTER 4		
4-1	Leaf area/Dry matter weight (cm ² /g) for plots under different defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) treatments measured in first seven weeks of growing season, 1981 and 1982.	91

- 4-2 Mean Herbage Accumulation Rate (HAR) for the first and second seven week periods of the 1981 and 1982 growing seasons for plots under four defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and three stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes. 92
- 4-3 Dry matter (g/m^2) and leaf area index (LAI) of the stubble remaining after defoliation of plots under defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in the first 7 weeks of growing seasons, 1981. 100
- 4-4 Percent light absorbency of wavelengths 663 and 645 nm as a measurement of chlorophyll A and B respectively for the stubble materials of plots defoliated at different defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble heights (SH; 70, 55, or 40 mm stubble remaining after defoliation) during the first 7 weeks of the 1981 and 1982 growing seasons. 101

CHAPTER 5

- 5-1 Mean canopy cover (%) of perennial ryegrass (LOPE), tall fescue (FEAR), subclover (TRSU), and other plants under defoliation interval (DI = 7, 21, 35 or 49 days between two consecutive defoliations), stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes and nondefoliated and control plots in 1981 and 1982. 117
- 5-2 Mean species composition (%) of perennial ryegrass (LOPE), Tall fescue (FEAR), subclover (TRSU), and other plants under defoliation interval (DI = 7, 21, 35 or 49 days between two consecutive defoliations), stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes and nondefoliated and control plots in 1981 and 1982. 119
- 5-3 Mean density, basal area, plant, basal area/m², and root weight, plant in plots under defoliation interval (DI = 7, 21, 35 or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining) treatments and in control plots measured at end of experiment in 1982. 121

APPENDICES

<u>Table</u>	<u>Page</u>	
A	Mean dry matter (Kg/ha) harvested at the assigned dates of from plots under 7, 21, 35, or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.	147
B	Mean dry matter (Kg/ha) harvested at the assigned dates of the 1981 growing season from plots under 7, 21, 35, or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.	148
C	Mean dry matter (Kg/ha) harvested at the assigned dates of the 1982 growing season from plots under 7, 21, 35, or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.	149
D	Mean percent dry matter in vitro digestibility of herbage harvested at different dates of 1980, 1981, and 1982 growing seasons from plots under 7, 21, 35 or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.	150
E	Mean percent crude protein of forage harvested at different dates of the 1980, 1981, and 1982 growing seasons from plots under 7, 21, 35 or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.	151
F	The Combined analysis of variance table consists of dry matter (DM), in vitro dry matter digestibility (IVDMD), digestible dry matter yield (DDM), percent crude protein (PCP), and crude protein yield (CPY) of forage produced under defoliation interval (DI) and stubble height (SH) regimes in 1980, 1981 and 1982.	152

CHAPTER 1

EFFECT OF DEFOLIATION TREATMENTS ON FORAGE QUALITY, QUANTITY, AND SPECIES COMPOSITION OF A LOLIUM PERENNE (L.) - TRIFOLIUM SUBTERRANEUM (L.) PASTURE

Introduction

The successful establishment and maintenance of a pasture requires a sound knowledge of pasture plants and their relationships with herbivores and the environment. The most desirable forage species, in a pasture, should be provided the opportunity for maintaining and increasing their abundance when environmental conditions are favorable. Probably the most effective way to enhance or to discourage the perpetuation of such plants would be through defoliation or grazing regimes. Because of economic as well as biological considerations, grazing systems are often designed to maximize sustained production of forage and to provide a high level of animal performance. This would assure a reliable income for the costly investments of pasture establishment and maintenance. The high capital expenditures in fences, fertilizers, seed, and other inputs frequently does not leave room for mistakes especially those which affect production over a considerable period. Therefore, good plans of forage allocation and livestock performance are not achievable unless sufficient experimentation in this area is done and a sound knowledge of the subject is accumulated.

There has been intensive work done on grazing systems, pasture management, livestock and forage production, pasture species

composition, etc. in different parts of the world. The results of such research, naturally, consist of general agreements, controversies, as well as some unanswered questions. This necessitates a systematic investigation into the existing literature together with some new trials before proposition of workable pasture management plans for livestock grazing. From the voluminous literature available, some general information about the particular pasture plants used in this trial, along with the effect of defoliation regimes on forage production, forage quality, pasture regrowth, and species composition have been extracted in this report.

Literature Review

A. Plant description

a) Perennial ryegrass (Lolium perenne L.)

Perennial ryegrass is a cool season perennial bunch-grass which is capable of producing many tillers and high quality forage. It is used for grazing or hay production in pastures of Great Britain, New Zealand, Australia, and the United States. In the United States, it is most widely grown west of the Sierra Nevada mountains and the Cascade Ranges, and in the southern humid areas (Heath et al. 1973).

The annual cycle of forage production of perennial ryegrass is largely influenced by seasonal weather patterns and by transition from vegetative to reproductive phases of growth (Sheehy et al. 1979). The growth pattern of this grass in western Oregon generally follows the hypothetical curve described by Dawson and McGuire (1973): In normal years, dormant ryegrass plants start to grow when fall rains begin in September or October. Rate of growth subsequently declines as temperature decreases in winter, and increases slowly again as air and soil temperatures increase in the early spring. Growth accelerates quickly in March and peaks in May. Perennial ryegrass plants go dormant after maturing in July. Maturation coincides with the onset of summer drought.

When soil moisture is not limiting, soil and/or air temperature is probably the most limiting factor for growth. Keating et al. (1979) found that during the period from March to September, air temperature and soil water potential had a great influence on leaf extension rates in perennial ryegrass swards. They also noticed that winter growth was linearly related to soil temperature. Thomas and Norris (1982) reported that temperature, rather than light, was limiting plant growth. This was particularly true from mid-February to mid-March.

Temperature not only greatly affects winter growth rates, but also may dictate inflorescence development. Although date of flower initiation was found to be largely affected by day length, subsequent growth and development toward ear emergence was mainly related to temperature (Beddows 1968, Keating et al. 1979).

Another important factor in perennial ryegrass growth is the nitrogen available in the soil. This plant has a high nitrogen requirement and is very responsive to increased levels of this element. Cowling and Locker (1970) found that ryegrass had a positive linear response to N fertilizer up to 330 kg/ha. This response was most pronounced during the first portion of the growing season and prior to inflorescence emergence. Read (1972, 1978) also found an almost linear relationship between dry matter yield and nitrogen fertilization up to 336 kg/ha.

High nitrogen affinity makes perennial ryegrass well adapted to grow and compete with clovers such as subterranean clover.

b) Subterranean clover (Trifolium subterraneum L.)

Subterranean clover (subclover) is a winter annual legume, adapted to (Mediterranean) climates with mild winters and dry summers. It is a prostrate, tap rooted plant which puts out runners which may extend as much as 45 cm (Smetham 1977b). Rapid growth, high yields, superior nutritive value for ungulates, and a wide adaptability to grow with both annual and perennial grasses make this plant an important forage species for dryland pasture improvement in western Oregon.

Subclover is able to fix atmospheric nitrogen through a symbiotic relationship with N-fixing bacteria. The amount of atmospheric nitrogen fixed by subclover depends on the soil organic nitrogen pool, soil carbon content, availability of mineral nitrogen in soil, and the presence and effectiveness of symbiosis between subclover and the associated rhizobia. Therefore, the annual rate of nitrogen fixation/unit area of land may be different from place to place. Hogland et al. (1979) reported a total of 183 kg N/ha/year was fixed by subclover in New Zealand. They also cited annual nitrogen fixation levels of 650 kg N/ha in New Zealand, 163 kg in Ireland, 246 kg in south England, and 268 kg in North Ireland.

The annual growth cycle of subclover is similar to that of perennial ryegrass. Subclover starts growth with seed germination in the fall. Growth, at a very slow rate continues throughout the winter up to April, when the period of rapid growth begins. Growth

rate peaks in mid-May and declines afterwards to plant senescence and seed formation in mid-July.

Subclover produces some seed with a hard seed coat which prevents germination. Dry summer and high soil surface temperature are essential to break subclover seed dormancy, if good seed germination is expected in the fall (Young et al. 1970, Caminos et al. 1973).

In grass-clover swards, subclover has to compete with grass for light and nutrients. Light is essential for successful growth, flower initiation and seed formation of subclover (Stern and Donald 1962, Rossiter 1972, Collins 1978, Collins et al. 1978). Morley (1961) in a detailed review on subclover, stated that grass-clover swards would experience a natural cycling in species composition if proper management of the sward was missing. Perennial ryegrass would overshadow and reduce subclover. Then, due to intra-species competition for light and nutrients, a significant die out of perennial ryegrass would occur. This would open the space for dormant subclover seeds to germinate and make a clover dominated sward. High N-fixation of subclover and nitrogen accumulation in the soil encourage perennial ryegrass to come back and repeat the cycle. Proper management of defoliation and fertilization is therefore essential to achieve an optimum grass-clover mixture. For an optimum quality and quantity of forage, a ratio of 30-40% clover and 60-70% grass is recommended (Harris and Thomas 1973, Smetham 1977b, Curll 1981).

B. Effect of defoliation on pasture dry matter production

Defoliation, as a means of harvesting forage, can be done by grazing animals or with mowing machines. The effect of pasture defoliation on the quality and quantity of dry matter produced depends upon both the frequency and the intensity of defoliation.

Defoliation frequency (DF) is determined by the period of non-use between two consecutive defoliations, i.e., the longer the period of non-use, the less frequently a pasture is defoliated. There is, in general, a positive relationship between dry matter accumulation and length of the regrowth period. This generalization holds true for grass-clover swards in temperate zones (Brougham 1959, Appadurai and Holmes 1964, Hedrick 1964, Boswell 1977, Wilman and Asiegbu 1982), temperate, pure grass swards (Anslow 1967, Knutti and Hidioglou 1967, Binnie and Harrington 1972, Chestnutt et al. 1977, King et al. 1979, Ollerenshaw and Incol 1979), and pure clover swards (Davidson and Brich 1972). More light interception due to accumulation of leaf area under longer defoliation intervals is often cited as a factor to explain higher dry matter production. There is however, an upper limit beyond which increased defoliation interval does not increase forage production.

Bland (1967) in west Scotland found that the average dry matter yield of grass-clover pasture, defoliated two times/year for three years, was lower than pastures defoliated four or six times/year. Death and decay of some forage due to prolonged shading and slower

regrowth of less frequently defoliated plots were the causative factors. Brougham (1970) reported that a grass-clover pasture in New Zealand, defoliated three times within eighteen weeks in winter, produced 70% more yield than a pasture defoliated only once during that period.

Defoliation Intensity (DI) or defoliation height is defined as "the vertical distance between mean ground level and the cut ends of the stubble" (Thomas 1980).

There is generally more agreement on the effect of DF, rather than DI on pasture dry matter production. Researchers working on pastures of temperate zones, reported that higher dry matter yield were obtained when pastures were defoliated more intensively (Reid 1959, Appadarai and Holmes 1964, Reid 1966, Reid 1967, Binnie and Harrington 1972, Boswell 1977). Cooper (1959) did not find any effect of cutting height on dry matter yield. Other workers (Brougham 1959, Weeda 1965), in contrast, reported more dry matter yield with higher defoliation heights. To understand this apparently contradictory evidence, one must consider the specific morphological and physiological characteristics of the pasture plants involved. Pasture plant varieties and cultivars may respond differently to defoliation intensity. For instance, Simons et al. (1972) found that with two clones of a ryegrass variety, the clone with faster leaf appearance, produced more new growth below cutting level and had higher yield when it was cut at 2 cm rather than 5 cm. Reid (1968) noticed that orchardgrass (Dactylis glomerata L.) was less sensitive

to defoliation height than perennial ryegrass or timothy (Pleum par-
tense L.) were. Finally, a prostrate growing cultivar of perennial
ryegrass recieved less harm, and produced more yield, when defoliated
at 3 cm rather than 6 or 9 cm (Ollerenshaw and Hodgson 1977). In
addition, some pasture plants may adapt themselves to withstand
severe defoliation. Growth form of subclover plants was observed to
adapt to close (DI = 1.5 cm) and frequent (every week) defoliation
(Davidson and Brich 1972). The plants developed a prostrate network
of stolons which led to more leaf production, higher photosynthesis
and rapid canopy development as compared to non-defoliated swards.
Briseno and Wilman (1981) found that white clover (Trifolium ripense
L.), in the second year of their experiment, reduced the length of
its stolons, and leaflets, as an adaptive survival mechanism to sheep
grazing. Close defoliation may be beneficial to adapted plants by
removing old and senescent material and making room for new growth.
More stems and dead matter (Reid 1959, Harris 1971), and more
flowering shoots (Reid 1967) were found in laxly defoliated, as com-
pared to closely defoliated swards. The new foliage of closely defo-
liated plots was found (Ollerenshaw and Incoll 1979) to be more effi-
cient in photosynthesis than was older tissue.

C. Regrowth after defoliation

Pasture regrowth after defoliation depends on plant carbohydrate
reserves, leaf area remaining and its photosynthetic efficiency .

(Ludlow and Charles-Edwards 1980).

A detail review of the effects of defoliation on carbohydrate reserves is not proposed here. Several recent reviews on this subject are available (Alberda 1966, Humphreys 1966, White 1973, Dahl and Hyder 1977, Moser 1977). It is helpful, however, to look at some general conclusions.

Organic carbon compounds, which are stored mainly in stem bases, stolones, and underground plant parts of perennial plants are used for respiration during dormance, initiation of growth, and regrowth after defoliation (White 1973). Non-structural carbohydrates were found (Alberda 1966) to be of great importance in perennial ryegrass regrowth after defoliation. Humphreys (1966) considered sward vigor and plant persistence in pastures to be closely related to the amount and percent of organic reserve material in the plants. May (1960) stated that too heavy, too early or too frequent pasture defoliation generally lead to yield reduction and carbohydrate reserve exhaustion. Reserved organic material in the lower regions of stems is known to be related to the rate of plant regrowth for the first 2 to 7 days after defoliation. Plant regrowth following this period primarily depends on other factors such as leaf area, photosynthesis and nutrient uptake (Alberda 1966, White 1973, King et al. 1979). Finally, since the carbohydrate synthesis and translocation are sink related (Moser 1977), lowering carbohydrate reserve through defoliation may stimulate plant photosynthetic activities.

Another important factor in pasture regrowth after defoliation is effective light interception and photosynthesis of the sward. Solar radiation, the source of photosynthetic energy in field plants, has a pronounced seasonal variation in the temperate zones. Cooper (1970) mentioned a range of 500 to 50 cal/cm²/day for solar radiation in the summer to winter, respectively. Other variables such as angle of incidence, light duration and distribution also have great impacts on daily photosynthetic rate and energy conversion of plants (Cooper, 1970).

Brougham (1956) considered light interception by foliage as the major factor in pasture regrowth. He measured the light interception of a grass-clover sward during a 32-day regrowth period and concluded that 95% light interception occurred much faster when 12.5 cm, as opposed to 2.5 cm, stubble remained after defoliation. Simons et al. (1972) also measured light interception of perennial ryegrass. They, too, recorded higher light interception in swards defoliated at 5 cm rather than 2 cm. However, dry matter production did not increase as the cutting height increased. More herbage weight loss due to respiration and less efficient photosynthesis were believed to be the causative factors. Brown and Blaser (1968) mentioned three requirements for efficient use of sunlight by plants: a) 95% interception of the incidental light, b) Favorable distribution of the intercepted light within the canopy, and c) high photosynthetic efficiency of leaves.

The relationship between incidental light and its utilization by plants can be better understood using the "Leaf Area Index" concept.

Leaf Area Index (LAI) is the area of green herbage per unit area of ground (Thomas 1980). The use of LAI, as a measurement tool for light interception appears to be a useful tool for understanding forage growth, developing better plant varieties, and more successful management practices.

Brown and Blaser (1968) made a detail review on the use of LAI in pasture studies. There is a positive relationship between LAI and light interception. More sunlight will be absorbed when more leaf area is present on the pasture. Under favorable conditions, this increases dry matter production up to a point when 95% or more of incidental light is intercepted. Above this point, growth rate is dictated by phenological conditions of plants and edaphic and environmental factors. The growth rate, being independent from LAI, may level off at high LAI due to less photosynthesis and more respiration of shaded leaves.

Photosynthesis and respiration of shaded leaves is another complicating factor in pasture regrowth. Shading may have a temporary depressing effect on photosynthesis by young leaves. However, it permanently retards the photosynthetic efficiency of older leaves (Brown and Blaser 1968). There is some controversy in the literature concerning whether or not older leaves may become "parasitic" by consuming a portion of the produced assimilate from younger leaves. Older, shaded leaves actually lose weight due to respiration (Brown and Blaaser 1968). Presumably, as a mature organ, they may not be able to receive assimilate from other plant parts (Moser 1979).

Shaded leaves may have less chlorophyll content. This is another important factor in determining the rate of pasture regrowth after defoliation. Differences in chlorophyll content of several crop and pasture species was observed to result in different photosynthetic efficiencies and dry matter production (Brougham 1960b).

D. Forage quality

Knowledge of pasture growth as affected by defoliation treatments, is helpful to maximize forage production. The produced forage however, must be judged by its quality if it is used for animal consumption. Forage quality factors (mainly percent digestibility and crude protein) have been clearly shown to be significant in limiting the growth of herbivores (Humphreys 1966, Ellis 1978). There may be one or several factors effective in altering forage quality.

Morphological stage of pasture plants and time of use in the growing season are important determinants of forage quality. Usually when plants grow toward maturity, they lose their quality due to lignification of cell walls and dilution of essential nutrients such as nitrogen compounds. For instance Minson et al. (1960) concluded that the rate of digestibility of orchard grass and perennial ryegrass were constant from the beginning of the growing season until head emergence, after which digestibility decreased rapidly. Edelsten and Corral (1979) found that decreased digestibility of perennial ryegrass was caused by the presence of flowering stems and

by the age of forage components. They also reported that digestibility of cut herbage was high in spring, decreased in summer and increased towards autumn. Swift and Edwards (1980), working with perennial ryegrass and orchardgrass, found that 50% head emergence roughly corresponded to the time when digestibility dropped below a minimum desirable percentage. Seasonal variation of forage quality is probably dictated by herbage accumulation rate (Kg dry matter accumulated/day/ha) of the sward. Rapid spring growth coincides with high forage quality. Rapidly growing vegetative stems may be as digestible as leaf lamina (Minson et al. 1960, Davies 1973).

Forage plant variety is another factor influencing forage quality. For instance, in any stage of growth, orchardgrass was less digestible than perennial ryegrass (Minson et al. 1960, Waite 1970). Herbaceous legumes, such as clovers, are generally considered to be more digestible and to have higher protein content than compatible grasses (Smetham 1977b).

Defoliation treatments may be effective in determining forage quality. Extensive investigations of the effect of defoliation treatments on forage quality have been reported. Generally, when the interval between defoliation increases, percent digestibility and crude protein of forage decreases (Humphreys 1966, Reid 1968, Waite 1970, Binne and Harrington 1972, Clark et al. 1974, Wilman et al. 1976).

There are not many reports of defoliation intensity as it affects forage quality. Clark et al. (1974) found that DI of 3, 6

and 10 cm had no significant effect on percent digestible organic matter and crude protein of grass-clover swards. Reid (1967) concluded that cutting heights of 2.5 or 6.25 cm had no effect on percent crude protein of a perennial ryegrass-white clover sward. Binnie and Harrington (1972) obtained partly similar results when they cut Italian ryegrass at 2.5, 5 or 12.5 cm cutting heights. Percent digestibility was not different but crude protein was lowest in 2.5 cm cutting regime.

Finally, another factor which may effect forage quality is soil fertility and soil nitrogen content. A fertile soil probably encourages pasture plants to grow faster and produce more succulent forage which is more digestible. Wilman et al. (1976a) found that applied nitrogen should be accompanied by shorter periods of non-use if a high percent of digestibility is to be obtained. Waite (1970) found that nitrogen fertilizer increased the number of cuts per season in orchard grass and perennial ryegrass, and therefore improved forage digestibility. Available soil nitrogen may also increase plant nitrogen content and improve crude protein. Reid (1972) applied 0 to 897 Kg/ha nitrogen to perennial ryegrass pasture and found that crude protein responded linearly up to 673 Kg N/ha. He also said that the average response up to 336 Kg N/ha was 4.2 Kg crude protein for every Kg of nitrogen applied on perennial ryegrass. Bartholomew and Chestnutt (1977) also reported a similar linear relationship between nitrogen application and forage nitrogen yield.

E. Plant persistence, pasture species composition and root growth

Use and management of pasture are strong determinants of pasture persistency. We are concerned about persistency of perennial pasture plants because "Persistence and yield potential are complementary and essential attributes of all perennial herbage species of value in agriculture" (Calmin and Stewart 1976). Lack of persistency was found (Rhodes 1975) to be the major causes of lower yield in perennial ryegrass pasture.

The life expectancy of perennial ryegrass plants varies in different conditions. Generally, a perennial ryegrass plant lives for five to six years. However, longevity could be extended for up to 17 years under excellent growth conditions and good management (Calmin and Stewart 1976). Several factors may be involved in the longevity of perennial ryegrass plants.

Soil moisture deficits and high summer temperatures were found effective in eliminating perennial ryegrass plants from pastures (Lucanus et al. 1960, Pook and Costin 1970). Brougham (1960a) reported a higher summer survival of this grass where moisture was conserved in the site with proper grazing management. Cultivars (Harris and Thomas 1970, Vartha 1978) and even populations of a cultivar (Charles 1973) may differ in resistance to summer drought or other unfavorable conditions.

Pasture defoliation could be another important factor in the longevity of perennial ryegrass plants. A prominent effect of

defoliation is evident in the root systems of perennial plants. Crider (1955) noticed that root growth stopped immediately following foliage removal in almost all of the several grass species examined. Davidson and Milthrope (1965) found that severe defoliation effectively terminated root extension in orchard grass. Mineral nutrient absorption, which was closely related to root extension, stopped even when the roots were continually bathed in nutrient solutions.

Growth conditions and defoliation pattern are not the only factors in root persistency. Plant species differ in the extent of their root systems and in root longevity. Although the root system is included as a main perennial organ of perennial ryegrass plants, each individual root may last only a few months to one year (Stucky 1941, Garwood 1967). Throughton (1981) found that among several cultivated grass species, perennial ryegrass had the shortest lived roots. This natural weakness along with unfavorable growth conditions and defoliation may cause reduction or elimination of this desirable pasture plant. Sharrow et al. (1981) noticed a marked change in species composition of the swards grazed by different intensity of sheep stocking: In ryegrass-subclover pastures under light sheep grazing (7.4 ewes/ha), the proportion of ryegrass-subclover became less over time and the sward became grass dominated. In heavy sheep stocking (12.4 ewes/ha), perennial ryegrass was replaced by annual grasses and subclover. A better balance of grass-clover and a higher yield was obtained from pastures under medium sheep stocking (9.9 ewes/ha). In pastures with mixed swards, a good

balance of main plant species is essential, if optimum quality and quantity forage is to be produced.

Botanical composition of mixed swards may also change due to the effect of defoliation regimes on tiller development and basal area of perennial grasses. For instance, shorter (3-6 weeks), as opposed to longer (8-12 weeks) periods between defoliations were found to increase the number of tillers and weight per tiller for some cultivars of perennial ryegrass (Wilman et al. 1976b, Wilman et al. 1977, Wilman and Asiegbu 1982). Bartholomew and Chestnutt (1977) found less ryegrass cover at less frequent defoliation and higher rate of nitrogen application. Baker (1957) observed more perennial ryegrass plants and tillers per unit area under more frequent defoliation, although root weight per plant and per tiller decreased under such treatments. Defoliation may not only remove apical dominance and, therefore, encourage new tiller development (Dahl and Hyder 1977), but also provide light at the base of perennial grasses such as ryegrass. Lack of adequate light at the base of this plant was found to cause tiller death and to prevent initiation of new tillers (Wilman et al. 1976b, Ong 1978, Ong et al. 1978).

As discussed above, defoliation of a pasture by grazing livestock or by using a mower may have great effects on pasture species composition, especially in mixed stands. Mechanical clipping or cutting, however, may not adequately simulate livestock grazing of pastures in some respects. For instance, livestock tend to graze selectively, regardless of the proposed defoliation plan (Morris 1969, Gammon and Roberts 1978). Uprooting of seedlings and trampling

are other problems associated with using livestock in grazing trials. Such factors which are significant on changes of pasture species composition, plant performance, and pasture durability may prevent using the results of clipping studies in livestock grazing plans. The following points, however, may encourage one to do so:

Mechanical defoliation trials:

- are fairly economical in saving time and money;
- use less space and increase homogeneity between experimental units;
- eliminate a difficult-to-control factor (livestock) from the ecosystem to make isolation of individual treatment factors easier.

Similar performance of pastures, defoliated by mowing or grazing by cattle or sheep, have been reported (Matches 1968). An exception is nutrient cycling in which livestock play a major role (Cuykendall and Martin 1968). The similarity, however, holds true if the grazing pressure is high enough to prevent selective grazing by livestock.

CHAPTER 2

EFFECT OF FREQUENCY AND INTENSITY OF DEFOLIATION ON FORAGE
DRY MATTER PRODUCTION OF A LOLIUM PERENNE (L.) - TRIFOLIUM
SUBTERRANEUM (L.) PASTURE¹

Iraj Motazedian and Steven H. Sharrow²

FOOTNOTES

¹This article was submitted as Technical Paper No. . Oregon Agricultural Experiment Station, Corvallis.

²Authors are graduate student and associate professor, Department of Rangeland Resources, Oregon State University, Corvallis, respectively.

Abstract

Effects of defoliation treatments on the dry matter production of a typical perennial ryegrass (Lolium perenne L.) - subterranean clover (Trifolium subterraneum L.) hill pasture were studied in western Oregon. A combination of four defoliation intervals (clipped every 7, 21, 35 or 49 days) and three stubble heights (70, 55, and 40 mm of stubble remaining) were applied. Data from the 1980, 1981, and 1982 growing seasons were analyzed as a split plot in time. Data within each year were a factorial arrangement of treatments in a randomized complete block design.

Total annual dry matter production in all three years increased as defoliation interval increased from one to seven weeks. Effect of stubble height on dry matter yield was probably dictated by forage plant type and sward species composition. Erect growing ryegrass, which was the major pasture component in 1980, produced more dry matter with lax defoliation; while the more prostrate subclover, which dominated the sward in 1982, yielded more with close defoliation. The grass-dominated pasture of 1980 produced more dry matter than the clover-dominated pasture of 1982.

The results of this experiment suggest that short duration grazing which provides a period of nonuse for pasture regrowth should produce more dry matter than does continuous grazing.

CHAPTER 2

EFFECT OF FREQUENCY AND INTENSITY OF DEFOLIATION ON FORAGE
DRY MATTER PRODUCTION OF A LOLIUM PERENNE (L.) - TRIFOLIUM
SUBTERRANEUM (L.) PASTURE

Introduction

A common goal of pasture management is to maximize the yield of forage produced and harvested without inducing pasture deterioration. Carrying capacity and grazing pressure (Humphreys 1966), along with the quantity and quality of herbage consumed by herbivores (Hamilton et al. 1973, Gibb and Treacher 1978) are largely determined by the amount of forage standing crop present at any point in time. Forage production and, therefore, forage standing crop is strongly affected by defoliation regimes (Ollerenshaw and Hodgson 1977, Binnie and Harrington 1972). Therefore, knowledge of the effects of defoliation frequency and intensity on forage yield is crucial if a successful pasture management scheme is to be planned. While many authors have evaluated defoliation intensity or frequency, few levels of each factor have generally been applied within a study. In addition, both defoliation frequency and intensity are rarely applied simultaneously in such a way that their interaction may be evaluated. These limitations greatly reduce the usefulness of such data for planning pasture management systems where a continuous range of possible defoliation events rather than a few discrete options must be considered.

Recent work in western Oregon (Sharrow and Krueger 1979, Warner

1983) indicate both pasture production and livestock performance may be higher under short duration than under continuous grazing. Because of the expense and difficulty of conducting large scale pasture trials, few grazing frequencies and intensities have been examined. This study was initiated in 1980 to elucidate the effects of defoliation frequency and intensity over the range of combinations likely to be considered for short duration grazing systems.

Materials and Methods

The study area was located one kilometer northwest of Corvallis, Oregon. The soil is a Hazelair silt loam (Ultic Haploxeroll) with approximately 12% south slope. The elevation is 100 meters above sea level. The climate is maritime with mild, wet winters and warm, dry summers. Average annual precipitation is approximately 1,000 mm (NOAA 1978). Vegetation consisted of a perennial ryegrass (Lolium perenne L.) - subclover (Trifolium subterraneum L.) stand (Table 1), typical of nonirrigated improved hill pastures in the Willamette Valley.

A 20 x 40 m enclosure was built in March 1980 to protect plots from sheep grazing. The study area was moderately stocked with sheep in previous years prior to enclosure. Thirty-six 2 x 2 m permanently marked plots were assigned randomly to defoliation treatments. Defoliation treatments included all possible combinations of four defoliation intervals (DI = 7, 21, 35 or 49 days between two

consecutive defoliations), and three stubble heights (SH; High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation). A 1 m wide buffer strip, which was defoliated as adjacent plots, was left around every plot to provide access and to reduce edge effects. Each treatment was replicated three times. In addition, there were three control plots which remained undefoliated until final harvest each growing season.

A rear-bagging rotary mower was used to defoliate the plots on their assigned dates and heights. The entire contents of the mower bag from each plot was weighed and a grab sample obtained for dry matter determination. Total phytomass harvested for each plot was corrected to an oven-dry matter basis using the percent dry matter calculated from field weights and oven-dry weights of grab samples dried for 48 hours at 50° C. Defoliation treatments commenced each spring when pasture height reached 15 cm. Following this criterion, defoliation treatments began on April 5, March 24, and April 7 in 1980, 1981 and 1982, respectively. All the plots were defoliated at the same (40 mm) height at the beginning and at the end of the spring growing season each year.

All plots were fertilized with 150 kg/ha of superphosphate in September each year. In addition, 0.8 kg/ha of sodium molybdate was applied in March 1980 to remove possible Mo deficiency.

At the initiation of the experiment in March 1980, canopy cover and species composition data gathered from 40 randomly placed ten-point frames (Sharrow and Tober 1979) were used to typify the study area.

Canopy cover and species composition of the study area were also estimated by examination of 160 randomly placed ten-point frames prior to defoliation treatments in 1981 and 1982.

Data were analyzed separately for each year as a factorial arrangement of treatments in a randomized complete block design (Steel and Torrie 1980). The means, where appropriate, were separated using the Student-Newman-Keul's test (Steel and Torrie 1980). Significant treatment effects were partitioned into orthogonal polynomial components and response surfaces were fitted by least squares regression procedures (Neter and Wasserman 1974). Polynomials up to cubic terms for DI and up to quadratic terms for SH treatments, together with their interactions (DI x SH) were introduced as independent variables against dry matter yield in a "stepwise" regression procedure. Models with highest r^2 and the lowest mean square error were selected as the "best" models (Neter and Wasserman 1974). Regression coefficients of all independent variables in the selected model were tested against zero (t test). Only those regression coefficients which were significantly ($P < .05$) different from zero remained in the model.

Results and Discussion

Data from a weather station, 16 kilometers northeast of the study area (NOAA 1980, 1981, 1982) indicated the yearly mean soil and air temperatures were near average in 1980, 1981 and 1982. Precipitation, however, was above normal in all three years. Average

precipitations and their deviations from the 30-year average were: 1050 (+60) mm, 1170 (+180) mm and 630 (+50) mm for 1980, 1981 and January-August 1982, respectively. Because of the climatic similarities between years, differences in species composition and pasture production between years were not believed to reflect differences in weather conditions.

With similar defoliation treatments, yearly dry matter production of pasture differed ($P < .01$) between years. Averaged over all treatments, total dry matter yields were: 7,824, 7,223 and 6,771 kg/ha for 1980, 1981 and 1982, respectively. The decline in dry matter yield over this period appeared to reflect a shift in species composition of the pasture as subclover increased from year to year (Table 2-1). Stands of clover, usually, produce less dry matter than pure stands of perennial grasses (Cocks 1974; Smetham 1973).

Three-year, as well as individual year, dry matter production increased ($P < .01$) as the period of nonuse between two consecutive defoliations increased from one to seven weeks (Table 2-2). Authors working on a variety of different pasture species including short-rotation ryegrass (Lolium perenne x L. multiflorum) - clover pasture (Brougham 1959), Italian ryegrass (Lolium multiflorum L.) sward (Binnie and Harrington 1972), and perennial ryegrass - white clover (Trifolium repens L.) pasture (Wilman and Asiegbu 1982) have reported similar results.

Stubble height (SH) treatments also affected dry matter production. Three-year average dry matter yield from plots with high SH

Table 2-1. Species composition (SC) and canopy cover (CC) of the study area estimated at the initiation of defoliation treatments in March 1980, 1981, and 1982.

Source	Year	Ryegrass	Clover	Tall Fescue	Other Perennial Grasses	Forbs	Annual Grasses	Total (%)
SC	1980	54.5c ¹	24.5a	11.6b	5.1b	2.2	2.2	100.0
(%)	1981	37.1b	51.5b	5.4a	2.4a	2.5	1.1	100.0
	1982	25.0a	66.2c	4.0a	2.3a	2.0	0.5	100.0
CC	1980	43.3c	22.3a	17.0b	4.7b	2.0	1.7	91.0
(%)	1981	34.0b	48.0b	5.0a	2.0a	2.4	0.6	92.0
	1982	30.0a	55.0c	4.7a	2.2a	1.9	0.2	94.0

¹Means in a column for each source not sharing a common letter differ (P<.05).

Table 2-2. Total annual dry matter yield (kg/ha) of pasture under four different defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) in 1980, 1981 and 1982.

DI Treatments (days)	Yearly Means ¹			Three-Years Average Means
	1980	1981	1982	
7	6,043 ^a	5,130 ^a	5,768 ^a	5,647 ^a
21	6,551 ^b	6,470 ^b	6,227 ^a	6,416 ^b
35	8,090 ^c	6,868 ^b	6,937 ^b	7,298 ^c
49	10,612 ^d	10,477 ^c	8,153 ^c	9,737 ^d
	$\bar{S}_y = 117$	$\bar{S}_y = 212$	$\bar{S}_y = 186$	$\bar{S}_y = 125$

¹Means in a column not sharing a common letter differ (P<.05).

was greater ($P < .01$) than those with medium or low SH (Table 2-3). However, the results between years were not as consistent for SH as they were for DI treatments. Similar to the three-year average, the sward of 1980 produced more ($P < .01$) dry matter under high, than under medium or low SH. These results agree with those reported by other authors (Brougham 1959; Weeda 1965). There was no statistical difference ($P < .05$) in dry matter production attributable to SH treatments in 1981. However, treatment means numerically followed the same trend as in 1980. In contrast to the previous two years, more dry matter yield ($P < .01$) in 1982 was obtained from closely defoliated plots than from high or medium SH treatments. This is in agreement with several other reports (Reid 1967; Binnie and Harrington 1972; Boswell 1977).

To understand the apparently "conflicting" response of pasture dry matter yield to SH treatments in different years of this study and in the literature (Binnie and Harrington 1972), one must consider the growth habits of the stand. The pasture of 1980 was dominated by perennial ryegrass (Table 2-1), which is an erect grower compared to subclover. Grass in this type of sward responds better to high clipping heights (Brougham 1959), since intensive cutting may remove all or more of the green foliage which is necessary for the initiation of regrowth (Brougham 1956). By 1982, the pasture had become dominated by subclover. This resulted in a more prostrate stand. Ryegrass plants also appeared to become more prostrate in their growth habit, perhaps as an adaptation to the defoliation treatments

Table 2-3. Total annual dry matter yield (kg/ha) of pasture under three stubble height treatments (SH = 70, 55 or 40 mm stubble remained after defoliation) in 1980, 1981 and 1982.

SH Treatments (mm)	Yearly Means ¹			Three-Years Average Means
	1980	1981	1982	
70 (High)	8,928 ^b	7,362 ^a	6,530 ^a	7,556 ^b
55 (Medium)	7,150 ^a	7,106 ^a	6,623 ^a	7,048 ^a
40 (Low)	7,394 ^a	7,212 ^a	7,160 ^b	7,220 ^a
	$\bar{S}_y = 101$	$\bar{S}_y = 183$	$\bar{S}_y = 161$	$\bar{S}_y = 108$

¹Means in a column not sharing a common letter differ ($P < .05$).

(Kydd 1966). Pastures with prostrate growing plants have been observed to produce more dry matter when defoliated to lower stubble heights (Ollerenshaw and Hodgson 1977).

The DI x SH treatment interaction was not significant ($P < .05$) for three-year average dry matter yield. This reflected lack of a DI x SH interaction in 1981 and 1982 ($P < .05$). A meaningful ($P < .01$) interaction did occur in 1980, however.

The response surface model for 1980 (Figure 2-1) has up to quadratic terms for both DI and SH treatments and their linear interaction term. The lowest and highest points of this surface correspond with treatments, 1 Low and 7 High, respectively. Dry matter increased in a curvilinear fashion as DI increased and SH decreased.

The regression model for 1981 dry matter yield was also a power curve as in 1980. But it had only DI as an independent variable. The cubic relationship between dry matter yield and DI treatments is illustrated by the response surface of this model (Figure 2-2). The two tails of this curve indicate a rapid response of dry matter yield to increasing defoliation interval, while the flat middle portion reflects a similarity between means of DI = 21 and 35 (Table 2-2). A linear component of SH, plus a quadratic element of DI were independent variables in the 1982 model. The response surface, therefore, consisted of parallel straight lines for SH and power curves for DI treatments (Figure 2-3). The lowest and the highest corners of this surface corresponded to treatments 7 Low and 49 High, respectively.

Figure 2-1. Relationship ($r^2 = 0.88$) of total pasture dry matter (DM) yield with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble heights (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1980. Dry matter yield = $18139.70 - 102.21 (DI) - 447.05 (SH) + 2.57 (DI)^2 + 4.49 (SH)^2 + 1.22 (DI \times SH)$.

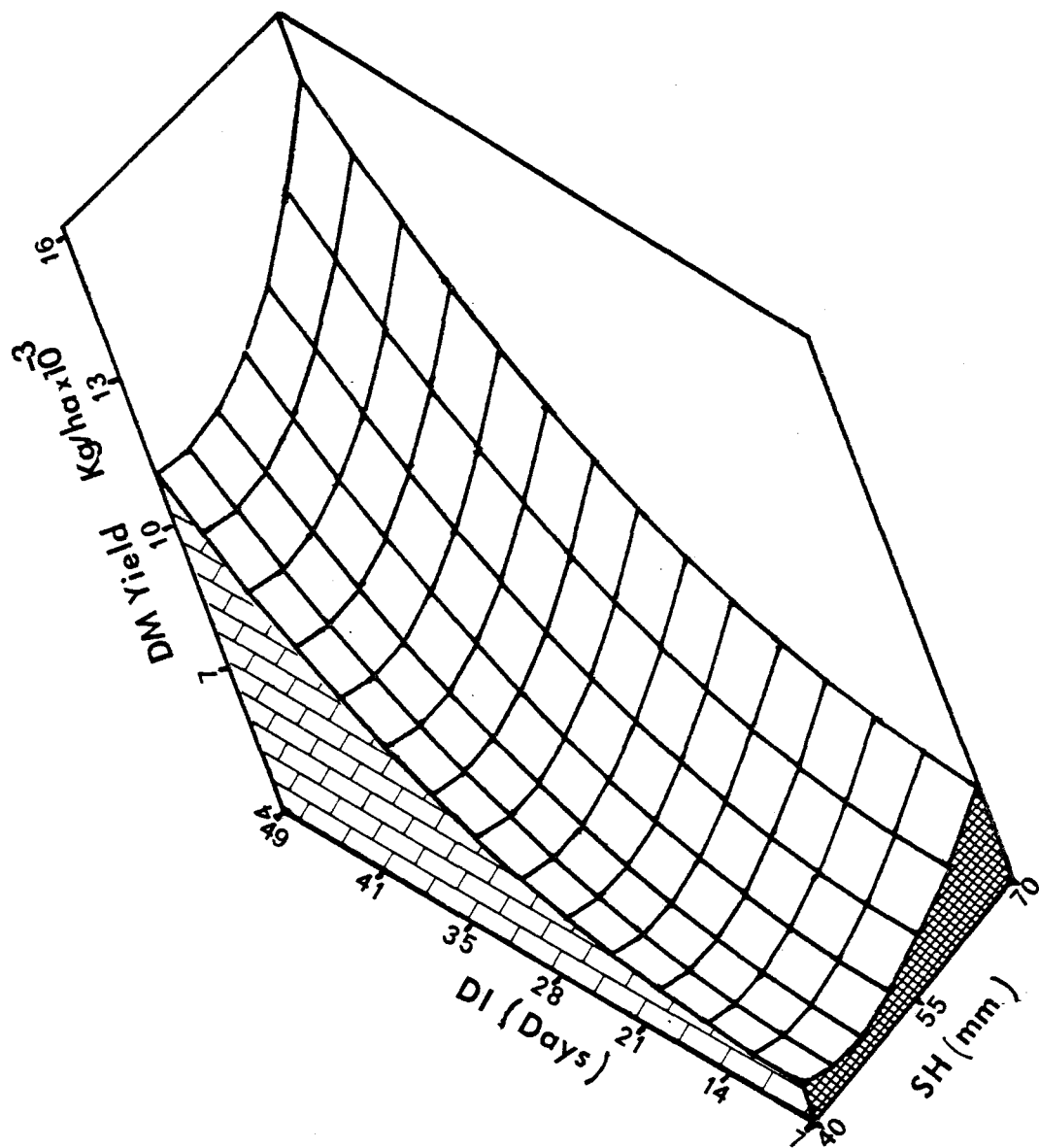


Figure 2-1

Figure 2-2. Relationship ($r^2 = 0.91$) of total pasture dry matter (DM) yield with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes in 1981. Dry matter yield = $2820.04 + 444.94 (DI) = 18.17 (DI)^2 + .25 (DI)^3$.

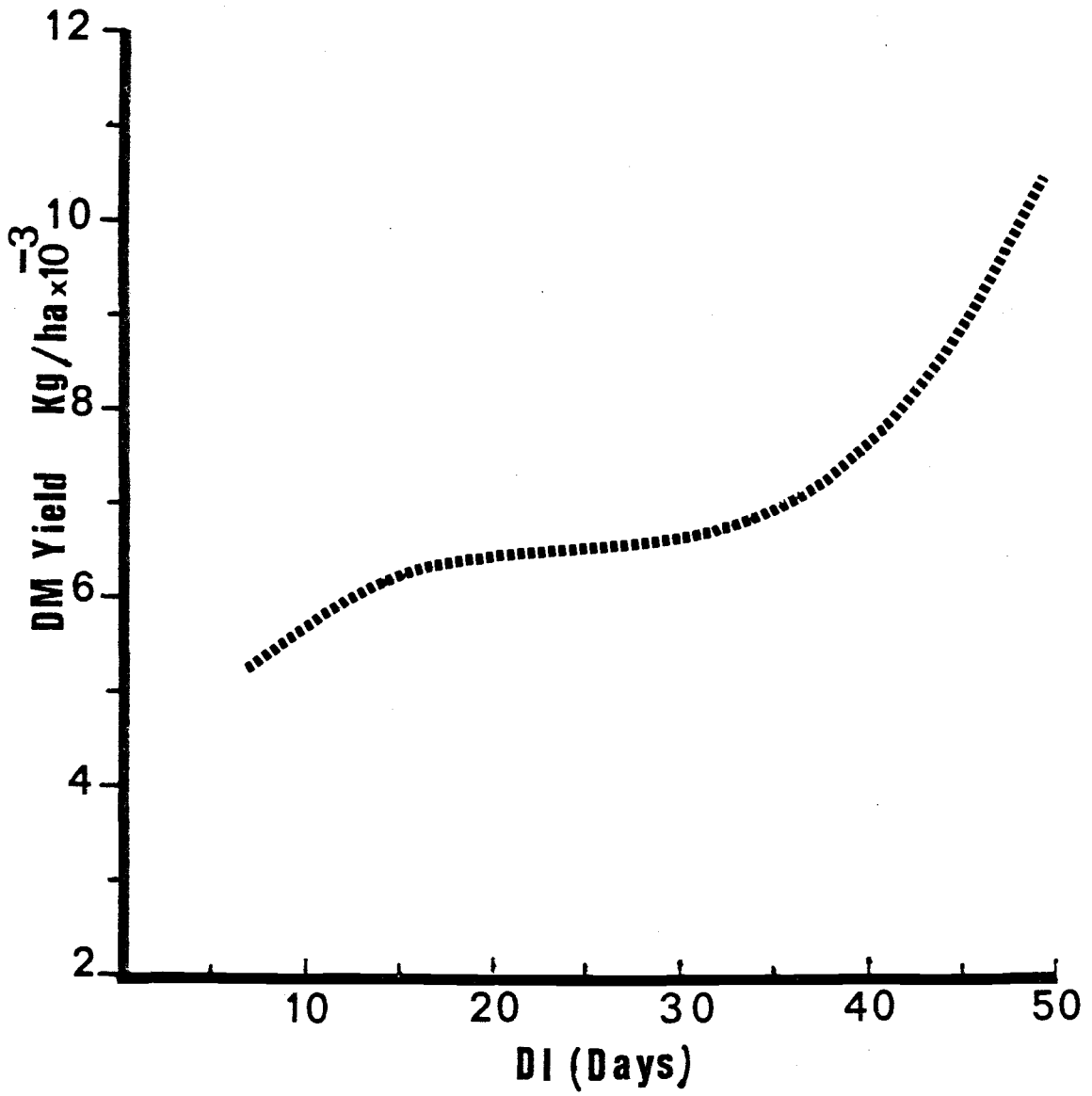


Figure 2-2

Figure 2-3. Relationship ($r^2 = 0.76$) of total pasture dry matter (DM) yield with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1982. Dry matter yield = $6894.41 - 20.99 (SH) + (DI)^2$.

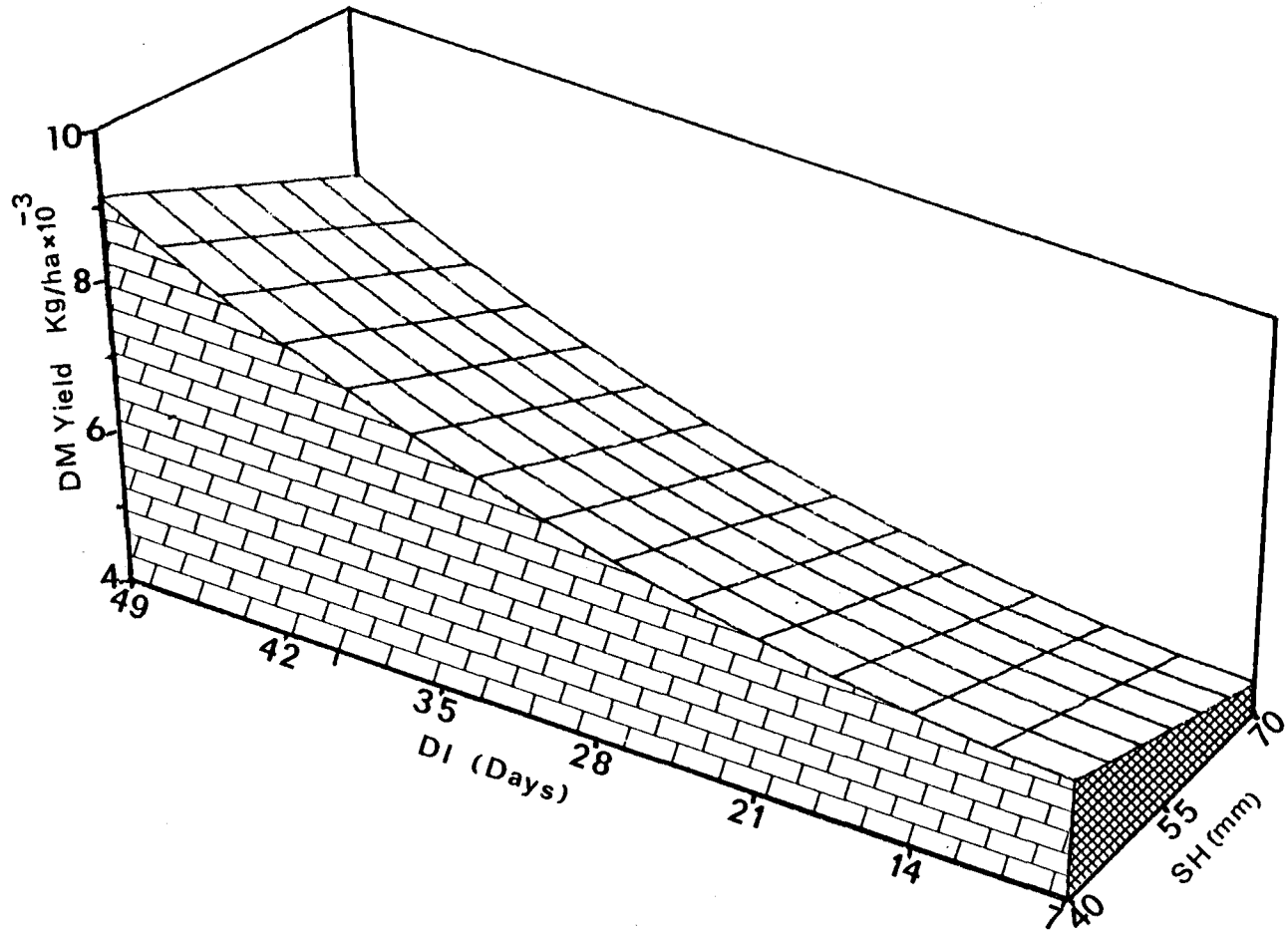


Figure 2-3

In all three years, defoliation interval had a more dramatic impact on total dry matter yield than did stubble height intensity over the levels examined. This implies that increasing the defoliation interval even if a corresponding decrease in stubble height occurs, may result in increased forage production. For example, switching from 1 High to 5 Low defoliation regimes increased forage production by approximately 1,400 kg/ha. Furthermore, the power curve relationship between defoliation interval and dry matter yield indicates that each additional day of regrowth between defoliations contributed proportionately more to dry matter production than did the preceding day. In 1982, for example, increasing DI from 21 to 22 or from 48 to 49 days where SH was 70 mm increased forage yield by 43 kg/ha and 97 kg/ha, respectively. This points out the large impact of seemingly minor adjustments in DI as DI increases beyond three weeks. Highest dry matter yields were consistently obtained from defoliation every seven weeks. We did not try intervals greater than seven weeks. It is not clear if longer periods between defoliations would result in proportionately larger forage yields. The steep slopes of the dry matter response surfaces suggest that it would. However, dry matter yields of control plots which were defoliated once at the end of the growing season (DI \approx 100 days) were similar ($P < .05$) to those of the DI 49 plots. These observations, while certainly not definitive, are in keeping with Morley's (1968) mathematical model of pasture growth which predicts maximum spring growth will occur between a DI of 35-70 days.

Conclusions

Dry matter yield was directly related to defoliation interval. The relationship between dry matter yield and DI was generally a power curve with yield increasing rapidly as the period between defoliation events increased from one to seven weeks.

The effectiveness of stubble height treatments on dry matter production was probably dictated by pasture plant type and species composition, a variable which changed visibly during the experiment. The erect growing perennial ryegrass dominated sward in 1980, had its highest yield under High SH. The more prostrate subclover-dominated pasture of 1982 produced more when defoliated closer to the ground. It appears that dry matter yield is more sensitive to the interval between defoliations than it is to severity of defoliation, provided that some photosynthetic tissue remains to support regrowth. This was especially true for defoliation intervals greater than three weeks. These data suggest the short duration grazing practice of increasing the interval between grazings at a cost of increased severity of each defoliation event is compatible with high forage production. Our mathematical models suggest that highest dry matter production will be obtained when defoliation interval is seven weeks or greater. The effects of such a long regrowth period on forage quality is the subject of a companion paper.

Literature Cited

- Binnie, R. C. and F. J. Harrington. 1972. The effect of cutting height and cutting frequency on the productivity of an Italian ryegrass sward. *J. British Grass. Soc.* 27:177-182.
- Boswell, C. C. 1977. Effect of cutting regime on pasture production. *New Zealand J. of Exp. Agric.* 5:403-408.
- Brougham, R. W. 1956. Effect of intensity of defoliation on regrowth of pasture. *Australian J. Agric. Res.* 7:377-387.
- Brougham, R. W. 1959. The effect of frequency and intensity of grazing on the productivity of a pasture of short-ration ryegrass and red and white clover. *New Zealand J. Agric. Res.* 2:1232-1248.
- Cocks, P. S. 1974. Potential production of grass and clover monocultures in a Mediterranean-type environment--an experimental approach. *Australian J. Agric. Res.* 25:835-846.
- Gibb, M. J. and T. T. Treacher. 1978. The effect of herbage allowance on herbage intake and performance of ewes and their twin lambs grazing perennial ryegrass. *J. Agr. Sci., Camb.* 90:139-147.
- Hamilton, B. A., K. J. Hutchinson, P. C. Annis and J. B. Donnelly. 1973. Relationships between the diet selected by grazing sheep and the herbage on offer. *Aust. J. Agr. Res.* 24:271-277.
- Humphreys, L. R. 1966. Pasture defoliation practice: A review. *J. Aust. Instit. of Agric. Sci.* 32:93-105.
- Kydd, D. D. 1966. The effect of intensive sheep stocking over a five-year period on the development and production of the sward. *J. British Grass. Soc.* 21:284-288.
- Ludlow, M. M. and D. A. Charles-Edwards. 1980. Analysis of regrowth of a tropical grass/legume sward subjected to different frequencies and intensities of defoliation. *Aust. J. Agric. Res.* 31:673-692.
- Morley, F. H. W. 1968. Pasture growth curves and grazing management. *Aust. J. Exp. Agr. Anim. Husb.* 8:40-43.

- National Oceanic and Atmospheric Administration (NOAA). 1978, 1980, 1981 and 1982. Oregon climatological data. Annual Summary. (Corvallis, State Univ.) Dept. of Commerce, National Climatic Center, Asheville, North Carolina.
- Neter, J. and W. Wasserman. 1974. Applied Linear Statistical Model. Richard D. Irwin, Inc. Homewood, Illinois.
- Ollerenshaw, J. H. and D. R. Hodgson. 1977. The effects of constant and varying heights of cut on the yield of Italian ryegrass (Lolium multiflorum L.) and perennial ryegrass (Lolium perenne L.) J. Agric. Sci. 89:425-435.
- Reid, D. 1967. Studies on the cutting management of grass-clover swards. II. The effect of changes in the closeness of cutting at different times in the season on the yield and quality of herbage from a perennial ryegrass-white clover sward. J. Agric. Sci. 68:249-254.
- Sharrow, S. H. and D. A. Tober. 1979. A simple lightweight point frame. J. Range Manage. 32:75-76.
- Sharrow, S. H. and W. C. Krueger. 1979. Performance of sheep under rotational and continuous grazing on hill pastures. J. Anim. Sci. 49:893-899.
- Smetham, M. L. 1977. Pasture legume species and strains. p. 85-127. In R. H. M. Langer (editor), Pastures and pasture plants. A. H. and A. W. Reed, London.
- Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics. Second Edition. McGraw-Hill Book Co., New York.
- Warner, J. R. 1983. Evaluation of three sheep-grazing systems on western Oregon hill pastures. M.S. Thesis. Oregon State Univ. Corvallis, Oregon. 124 numb. leaves.
- Weeda, W. C. 1965. The effect of frequency and severity of grazing by cattle on the yield of irrigated pastures. New Zealand J. Agric. Res. 8:1060-1069.
- Wilman, D. and J. E. Asiegbu. 1982. The effect of clover variety, cutting interval and nitrogen application on herbage yields, proportions and heights in perennial ryegrass-white clover swards. Grass and Forage Sci. 37:1-13.

CHAPTER 3

EFFECT OF PERIOD AND INTENSITY OF DEFOLIATION
ON FORAGE QUALITY OF A LOLIUM PERENNE (L.) -
TRIFOLIUM SUBTERRANEUM (L.) PASTURE¹

Iraj Motazedian and Steven H. Sharrow²

FOOTNOTES

¹This article was submitted as Technical Paper No. . Oregon
Agricultural Experiment Station, Corvallis.

²Authors are graduate student and associate professor, Department of
Rangeland Resources, Oregon State University, Corvallis, respec-
tively.

Abstract

Forage digestibility and crude protein content of a perennial ryegrass (Lolium perenne) - subclover (Trifolium subterraneum) pasture under twelve different defoliation treatments were determined. Treatments consisted of all possible combinations of four defoliation intervals (clipped every 7, 21, 35 or 49 days) and three stubble heights (High = 70, Medium = 55, or Low = 40 mm stubble remaining). A rear bagging rotary mower was used to defoliate the plots and to collect the phytomass at the assigned dates and heights. Grab samples of the forage produced from different treatments were analyzed to determine their digestibility and crude protein content. Data from 1980, 1981 and 1982 were collected and analyzed as a factorial arrangement of treatments in a randomized complete block design with three replications.

Forage digestibility and crude protein content of the forage produced decreased as the period between defoliation events and the intensity of defoliation increased. Forage quality, however, was generally adequate on all treatments to meet the needs of most classes of livestock.

The yield of digestible forage and crude protein were mostly dictated by the amount of forage produced rather than by percent nutrient content. Compensation between forage yield and quality did, however, reduce the range of differences in digestible forage yield and crude protein yield between treatments. The results of this

study suggest that defoliation schemes which maximize forage production may also maximize the amount of digestible nutrients available for livestock production. The defoliation interval, which optimized both forage production and forage quality was 5 and 7 weeks between defoliation events for grass dominated and clover dominated pastures, respectively.

CHAPTER 3

EFFECT OF FREQUENCY AND INTENSITY OF
DEFOLIATION ON FORAGE QUALITY OF A LOLIUM PERENNE (L.) -
TRIFOLIUM SUBTERRANEUM (L.) PASTURE¹

Introduction

Forage quality must be considered along with total dry matter yield in designing pasture management systems for livestock production. Low quality forage, even if abundant, may be associated with low forage intake and poor performance of livestock (Humphreys 1966, Ellis 1978). An ideal pasture management system would maximize both the quantity and quality of forage available for consumption by livestock. This is not always possible, however, as infrequent or lax defoliation which maximizes forage production (Brougham 1959, Ludlow and Charles-Edwards 1980, Wilman and Asiegbu 1982) may reduce percent crude protein and digestibility of the forage produced (Allinson et al. 1969, Woodman and Stewart 1932, Chestnutt et al. 1977). In practice, a balance must be sought between the quality and quantity of forage produced. Short duration grazing systems seek to achieve this balance through control of the frequency and intensity of defoliation events. While a substantial body of information exists concerning the effects of frequency or intensity of defoliation on forage yield (see Humphreys 1966, Smetham 1977), much less is known about the effects of these factors on forage quality.

The purpose of this paper is to describe the effects of different frequencies and intensities of defoliation on the percent protein, dry matter digestibility, crude protein yield, and digestible dry matter yield of forage obtained from perennial ryegrass-subclover pastures.

Materials and Methods

The study area was located one kilometer northwest of Corvallis, Oregon. The climate is maritime with mild, wet winters and warm, dry summers. Average annual precipitation is approximately 1,000 mm (NOAA 1973). Vegetation consisted of a perennial ryegrass (Lolium perenne L.) - subclover (Trifolium subterraneum L.) stand, typical of nonirrigated, improved hill pastures in the Willamette Valley.

A 20 x 40 m enclosure was built in March 1980 to protect plots from sheep grazing. Thirty-six 2 x 2 m permanently marked plots were assigned randomly to defoliation treatments. Defoliation treatments included three replications of all possible combinations of four defoliation intervals (DI = 7, 21, 35, or 49 days of nonuse between two consecutive defoliations), and three stubble heights (SH, High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation).

A rear-bagging rotary mower was used to defoliate plots on their assigned dates and heights. The entire contents of the mower bag from each plot was weighed and a grab sample obtained for dry matter

determination. Total phytomass harvested from each plot was corrected to an oven-dry matter basis using the percent dry matter calculated from field weights and oven-dry weights of grab samples dried for 48 hours at 50°C. The grab samples were ground to pass 1 mm sieve and saved in sealed plastic bags for chemical analysis. Defoliation treatments commenced each spring when pasture height reached 15 cm. Following this criterion, defoliation treatments began April 5, March 24, and April 7 in 1980, 1981 and 1982, respectively. Defoliation treatments and data collection continued throughout the spring to summer growing season. Work was terminated in July each year when the sward dried up due to summer drought.

All plots were fertilized with 150 kg/ha of superphosphate in September each year. In addition, 0.8 kg/ha of sodium molybdate was applied March 1980 to remove possible Mo deficiency.

The two-stage in vitro rumen fermentation technique (Tilley and Terry 1969) was used to determine digestibility of the forage samples. Rumen liquor was obtained from rumen-fistulated sheep fed ryegrass hay. Crude protein (NX6.25) was determined by microKjeldal method (AOAC 1970). All the collected samples of each treatment were used for chemical analysis and an unweighted average was determined.

The yields of digestible forage and crude protein were calculated by multiplying percent digestibility and percent crude protein by the corresponding dry matter yield.

Data were analyzed as a factorial arrangement of treatments in a randomized complete block design with three replications for each

individual year. Information from all three years was evaluated as a split plot in time with defoliation treatments as main plots and years as subplots (Steel and Torrie 1980). Where appropriate, means were separated by the Student-Newman-Keul's test (Steel and Torrie 1980). Significant treatment effects were partitioned into orthogonal polynomial components and response surfaces were fitted by least squares regression procedures (Neter and Wasserman 1974). Polynomials up to cubic terms for DF and up to quadratic term for DI treatments, together with their interaction (DF X DI) were introduced as independent variables against yields of digestible forage and crude protein in a "stepwise" regression procedure. Models with the highest r^2 and lowest mean square error were selected as the "best" models. Regression coefficients of all independent variables in the selected model were tested against zero (t test). Only those regression coefficients which were significantly ($P < .05$) different from zero remained in the model (Neter and Wasserman 1974).

Results and Discussion

Yearly average percent crude protein and dry matter digestibility of the forage produced increased ($P < .01$) by 5% each year during the three years of this study (Table 3-1). Total crude protein yield also increased during the interval from 1980 to 1982. Total digestible dry matter yield however, decreased ($P < .05$) during this period. Changes in forage crude protein and dry matter digestibility

Table 3-1. Yearly mean in vitro dry matter digestibility (IVDMD), crude protein content (CPC), digestible dry matter yield (DDM) and crude protein yield (CPY) of the forage produced averaged overall treatments in 1980, 1981 and 1982.

Source	Year			\bar{S}_y
	1980	1981	1982	
IVDMD (%)	63.4a ¹	65.3b	68.4c	0.25
CPC (%)	14.6a	18.1b	19.6c	0.14
DDM (kg/ha)	4930.0b	4705.5a	4623.7a	64.68
CPY (kg/ha)	1100.2a	1244.0b	1298.8c	18.56

¹Means in a row followed by different letters differ ($P < .05$).

over time may be explained by an observed shift in species composition of the sward from grass to clover dominance (Chapter 4) during the course of the study. Clovers generally have higher dry matter digestibility and crude protein than do associated grasses at similar stages of maturity (Smetham 1977). Nitrogen fertilized perennial ryegrass monocultures, however, may produce higher total dry matter yields than do perennial ryegrass-clover stands (Harris and Thomas 1973). The higher crude protein and dry matter digestibility of ryegrass-clover pastures may compensate for their lower total dry matter yields (Ulyatt, 1970). These concepts are consistent with our observations that increased clover dominance of the sward was associated with higher crude protein yield but lower digestible dry matter yield. Apparently, digestible dry matter yield was strongly influenced by changes in total dry matter yield between years while crude protein yield reflected differences in both crude protein content of the forage and total dry matter produced in different years.

Both the average crude protein and average dry matter digestibility of forage varied among the defoliation regimes each year (Table 3-2). Percent crude protein declined ($P < .01$) rapidly as defoliation interval (DI) increased from one (DI7) to seven (DI49) weeks between defoliation events. Averaged over all three years, this decrease was approximately 0.2% less crude protein for each additional day between defoliations. A similar rate in the decline of percent crude protein with decreasing defoliation frequency was reported by Woodman and Stewart (1932). Response of dry matter digestibility to DI was less

Table 3-2. Mean forage digestibility, digestible dry matter, crude protein content, and crude protein yield of pasture under four different defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) in 1980, 1981 and 1982.

DI treatments (days)	1980	1981	1982	1980	1981	1982
	Forage digestibility (%)			Crude protein content (%)		
7	63.5d ¹	66.5b	69.0a	18.8d	22.2d	22.8b
21	61.0c	65.1b	68.4a	16.2c	19.8c	22.7b
35	64.8b	66.3b	68.1a	13.1b	16.9b	16.5a
49	62.4a	63.5a	68.1a	10.7a	13.4a	16.2a
\bar{S}_y	0.19	0.48	0.76	0.15	0.28	0.34
	Digestible dry matter (kg/ha)			Crude protein yield (kg/ha)		
7	3838a ¹	3410a	3974a	1035a	1140a	1313b
21	4077b	4213b	4256a	1070a	1279b	1413b
35	5262c	4555b	4719b	1066a	1162a	1146a
49	6600d	6645c	5555c	1131b	1395c	1323b
\bar{S}_y	70.0	150.9	142.0	16.3	33.8	48.2

¹Means in each column within categories followed by different letters differ ($P < 0.05$).

consistent than that of crude protein. Digestibility of the forage produced by DI49 was numerically lower than that of DI7 each year. This difference between DI49 and DI7 was significant ($P < .05$) in 1980 and 1981 but not ($P > .05$) in 1982. No differences ($P > .05$) in dry matter digestibility between treatments DI7, DI21 or DI35 were evident in 1981 and 1982. The numerically low dry matter digestibility of DI21 in 1980 resulted from low digestibility of forage only on plots under Low defoliation. The reasons for this phenomenon are not clearly understood. Field observations suggest that relatively low subclover phytomass on these plots may have contributed to their low digestibility values. These findings are in general agreement with other reports (Binnie and Harrington 1972), Clarke et al. 1974, Wilman et al. 1976) that both crude protein and digestibility of forage declines as defoliation interval increases. The difference in dry matter digestibility resulting from defoliation every week compared to defoliation every seven weeks is not large, being only about 1, 3 and 1% in 1980, 1981 and 1982, respectively. This decline is less than the 8% lower digestibility reported for DI42 compared to DI14 treatments for a perennial ryegrass stand by Chestnutt et al. (1977) but similar to the 1% difference in digestible organic matter on DI7 vs DI35 treatments noted by Woodman and Stewart (1932).

The effects of defoliation interval on the yield of digestible dry matter closely paralleled differences in total forage dry matter yields among treatments each year. Forage dry matter yields increased sharply as the interval between defoliations increased from

one to seven weeks (Chapter 2). Lower dry matter yields of frequently defoliated plots were, to some extent, compensated for by higher crude protein and digestibility of the dry matter produced compared to less frequently defoliated plots. Compensation was more evident in crude protein yield than it was for digestible dry matter yield. Apparently differences in percent crude protein among DI treatments were sufficiently large to influence differences in total crude protein yields. Increasing defoliation interval from one to five weeks did not depress ($P < .05$) crude protein yields. In fact decreasing the period between defoliation events from five to three weeks slightly increased ($P < .05$) crude protein yield. Highest crude protein yields were obtained from DI49 plots in 1980 and 1981. In 1982, however, DI21 plots yielded the numerically greatest harvest of crude protein, largely as a result of their high percent crude protein content that year.

Stubble height treatments were also effective in altering forage quality (Table 3-3). Generally, both digestibility and crude protein content of forage decreased ($P < .05$) as stubble height decreased during all three years of this study. Forage digestibility was apparently more sensitive to stubble height than was the crude protein content of forage. Averaged over all three years, forage digestibility decreased by approximately 0.16% per 1 mm decrease in stubble height while crude protein decreased by only 0.03% per 1 mm as defoliation height varied from 70 to 40 mm. These results are consistent with observations that digestibility of perennial

Table 3-3. Mean forage digestibility, digestible dry matter crude protein content and crude protein yield of pasture under three different stubble heights (SH; High = 70 mm, Medium = 55 mm, and Low = 40 mm stubble remaining after defoliation) in 1980, 1981 and 1982.

Stubble height	1980	1981	1982	1980	1981	1982
	Forage digestibility (%)			Crude protein content (%)		
High	65.1c ¹	66.6c	70.9b	15.2b	18.6b	20.3b
Medium	64.8b	65.4b	69.0b	14.6a	18.2b	19.9b
Low	58.8a	64.0a	65.3a	14.2a	17.3a	19.5a
\bar{S}_y	0.13	.41	0.65	0.13	0.24	0.29

	Digestible dry matter (kg/ha)			Crude protein yield (kg/ha)		
	High	5783c ¹	4776a	4618a	1238c	1288b
Medium	4687b	4804a	4562a	1053b	1271b	1293a
Low	4389a	4537a	4691a	1010a	1173a	1302a
\bar{S}_y	60.6	130.7	123.0	14.1	29.2	83.5

¹Means in each column within categories followed by different letters differ (P<0.05).

ryegrass (Taylor and Rudman 1966) and legumes (Mowat et al. 1965) declined as harvest height declined. Several authors, however, have reported no difference in either percent crude protein or digestibility of forage from plots harvested at different heights (Clark et al. 1974, Reid 1967). Binnie and Harrington (1972), while observing no difference in the digestibility of Italian ryegrass (Lolium multiflorum) harvested at 2.5 compared to 6.5 cm heights, reported lower crude protein content of forage at the lower height. Clearly more work relating the components of pasture yield and the age of plant organs harvested at different stubble heights needs to be done before the effects of SH on forage quality will be understood.

Digestible dry matter yield did not differ ($P < .05$) between SH treatments in both 1981 and 1982. The only treatment difference in crude protein yield during these two years was 115 Kg/ha less production on closely defoliated plots as compared to plots with high SH during 1981. In 1980, both crude protein yield and digestible dry matter yield decreased ($P < .05$) as stubble height decreased. Crude protein and digestible dry matter yields were 228 and 1394 Kg/ha less, respectively, for Low vs High SH treatments. The difference in response between years is believed to reflect changes in species composition of the sward over time, as previously discussed.

Interactions occurred between stubble height and defoliation interval treatments in 1980 (Figure 3-1). The response surface relating digestible dry matter yield to intensity and period of defoliation consisted of power curves for both DI and SH and a linear DI

Figure 3-1. Relationship ($r^2 = 0.91$) between digestible dry matter yield, defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble heights (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1980. Digestible dry matter = $7674.51 - 194.692 (SH) + 2.078 (SH)^2 + .016 (DI)^3 + 0.449 (DI \times SH)$.

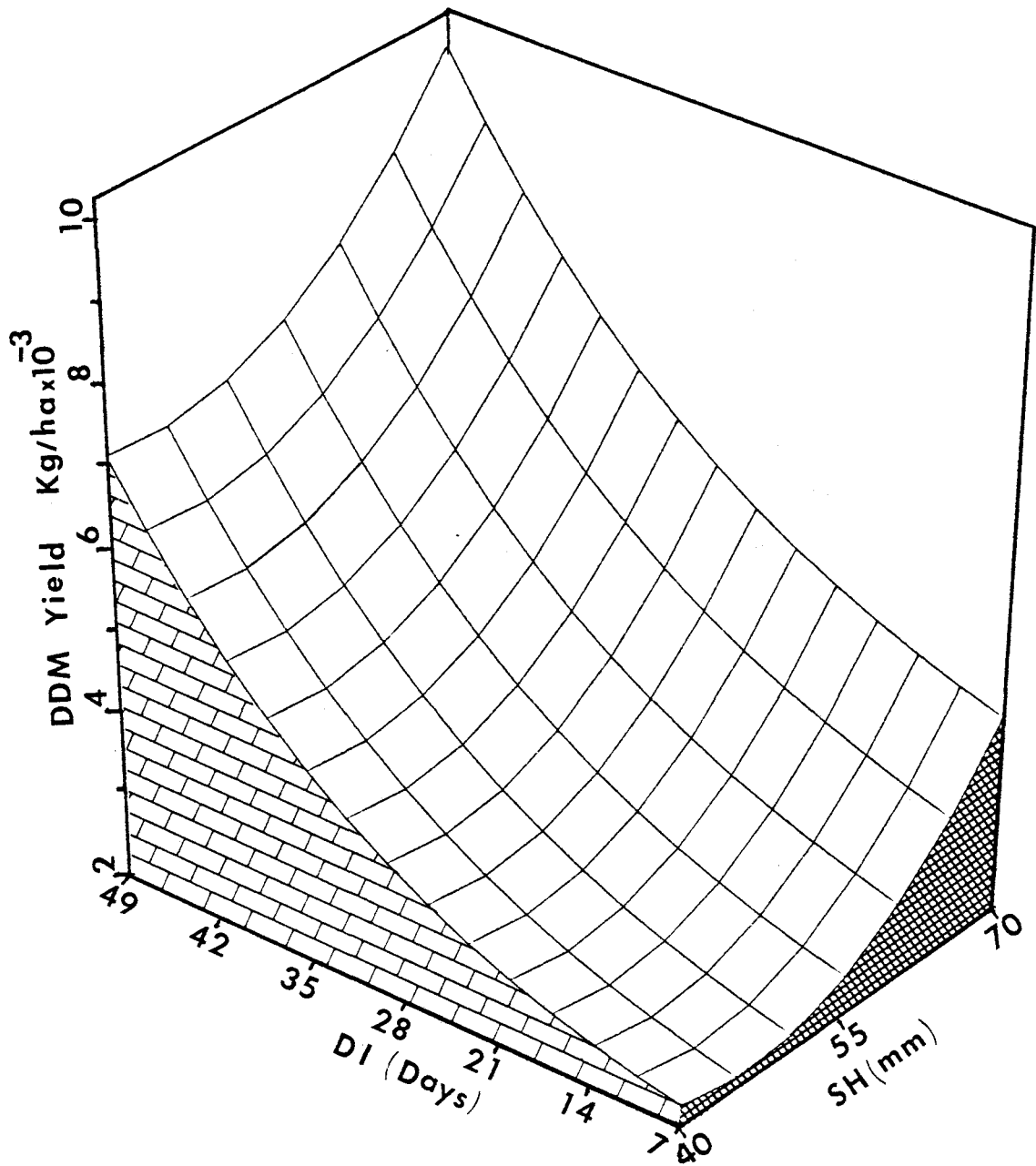


Figure 3-1

x SH interaction term. Like 1980, response surfaces in 1981 and 1982 (Figure 3-2) consisted of power curves relating DI to digestible dry matter yield. Unlike 1980, however, neither SH nor the DI x SH interaction were useful as predictors of digestible dry matter yield in either 1981 or 1982.

Similar to models for digestible dry matter yield, the response surface relating DI and SH to crude protein yield in 1980 contained power curves for both DI and SH and a linear DI x SH interaction component (Figure 3-3). Crude protein yield responded linearly to both DI and SH in 1981. No interaction was apparent that year (Figure 3-4). Analysis of variance indicated that SH treatments did not significantly effect crude protein yields in 1982. The corresponding regression model, however, contained SH and DI x SH as significant components (Figure 3-5). These response surfaces suggest that digestible dry matter yield and crude protein yield of perennial ryegrass dominant swards are responsive to changes in either DI or SH. These parameters, however, were less responsive to management in clover-dominant than ryegrass-dominant stands. Presumably, differences in response to defoliation reflect differences between digestibility and crude protein content of grass and clover as they mature.

Management Implications

The general trend presented by our response surfaces is for both

Figure 3-2. Relationship between digestible dry matter yield and defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes in 1981 ($r^2 = 0.88$) and 1982 ($r^2 = 0.69$). Digestible dry matter (1981) = $969.050 + 267.957 (DI) - 9.634 (DI)^2 + 0.134 (DI)^3$. Digestible dry matter (1982) = $4039.530 + 0.820 (DI)^2$.

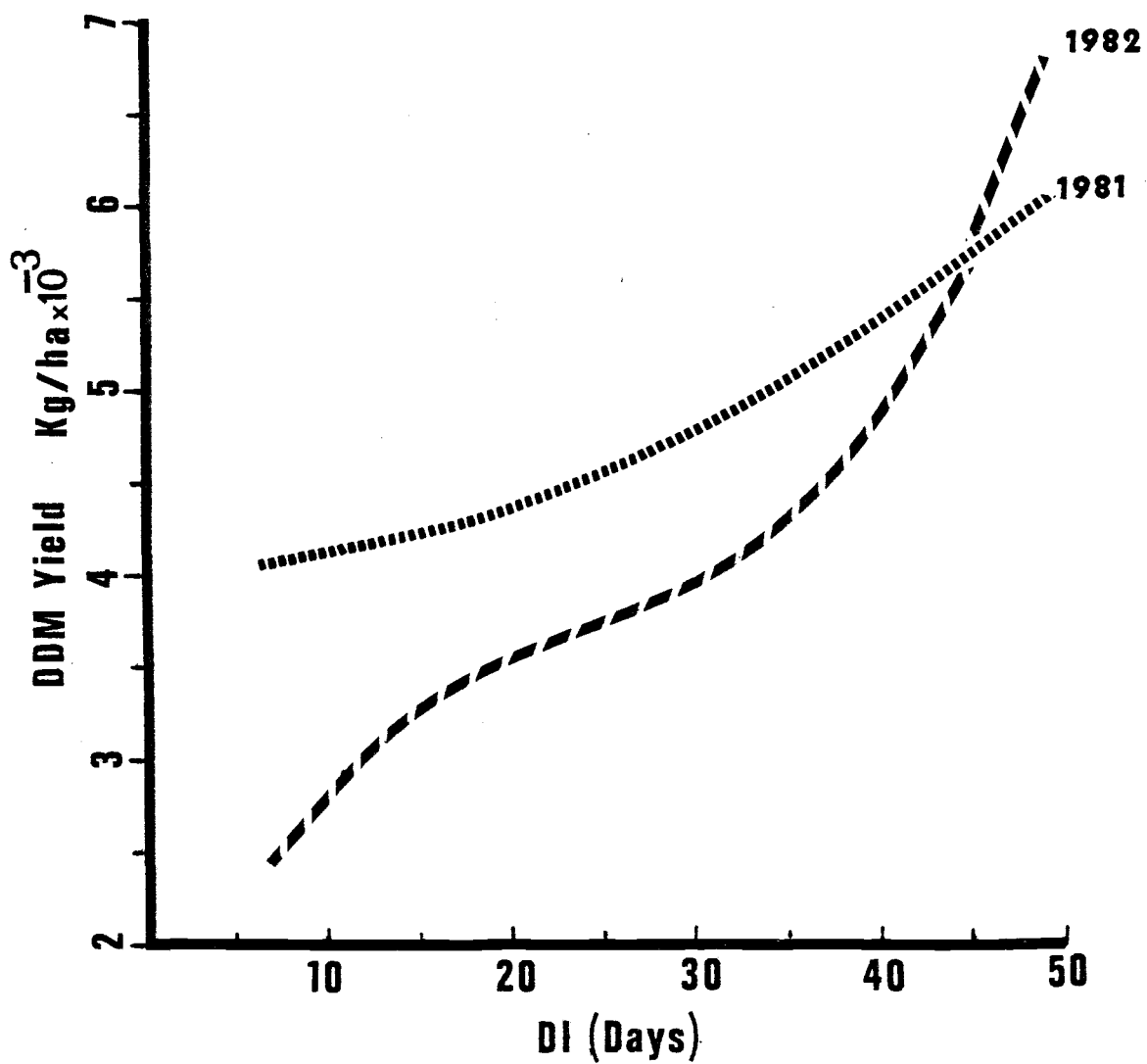


Figure 3-2.

Figure 3-3. Relationship ($r^2 = 0.67$) between crude protein yield (CPY), defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1980. Crude protein yield = $1508.040 + 0.002 (DI)^3 + 0.316 (SH)^2 - 0.099 (DI \times SH)$.

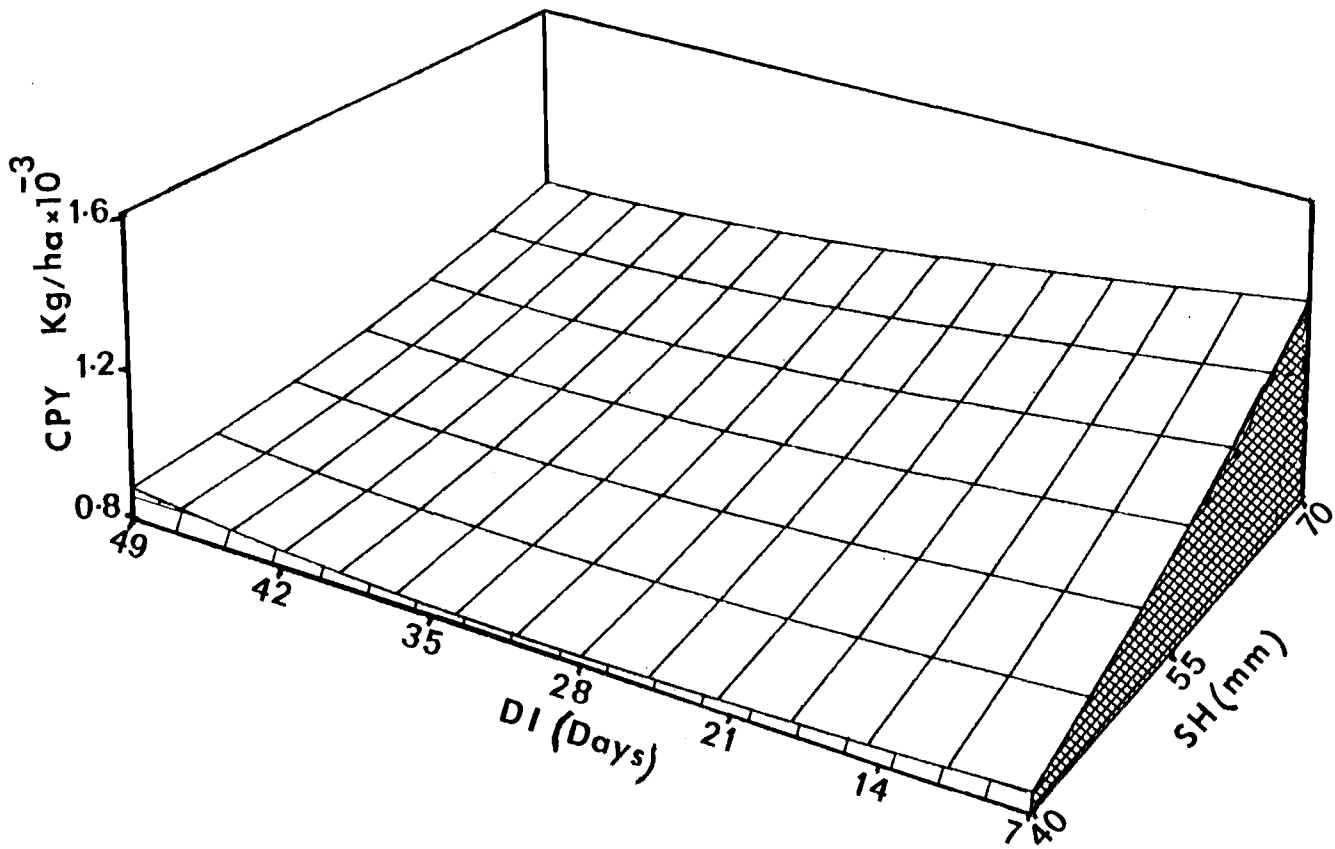


Figure 3-3

Figure 3-4. Relationship ($r^2 = 0.95$) between crude protein yield (CPY), defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1981. Crude protein yield = $19.459 - 0.110 (DI) + 0.071 (SH)$.

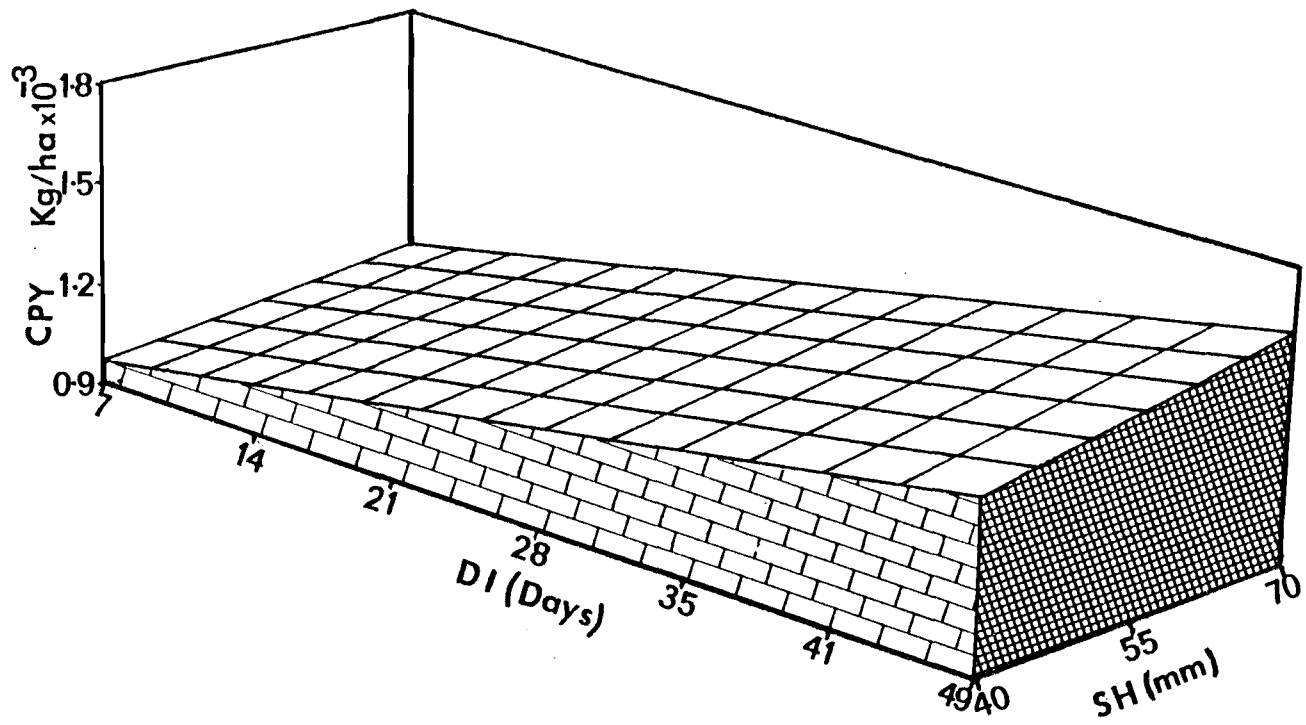


Figure 3-4

Figure 3-5. Relationship ($r^2 = 0.40$) between crude protein yield (CPY), defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in 1982. Crude protein yield = $616.136 + 106.318 (DI) - 4.050 (SH)^2 + 0.049 (DI)^3 + 0.079 (SH)^2 + 0.312 (DI \times SH)$.

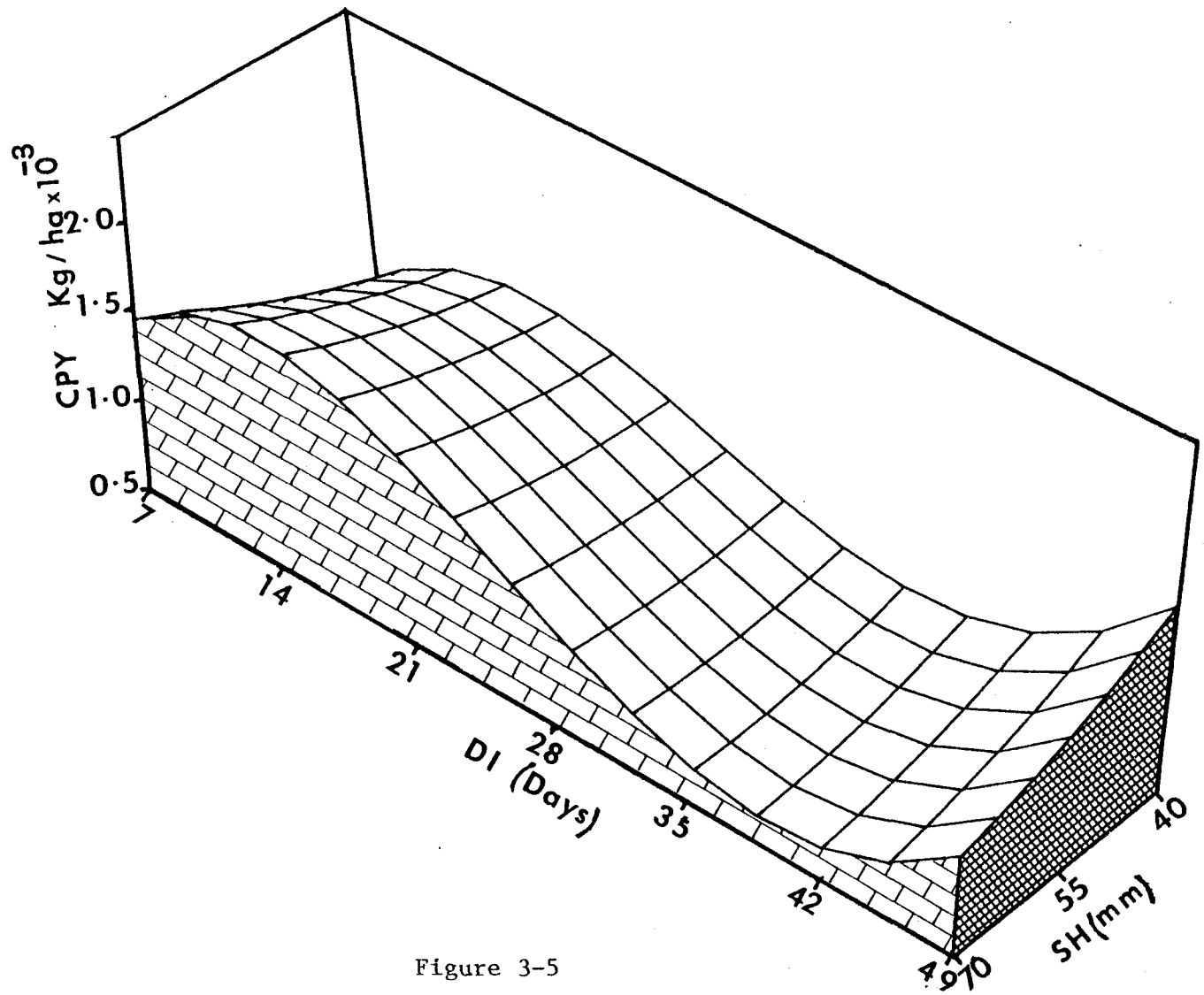


Figure 3-5

crude protein yield and digestible dry matter yield to increase as both DI increases and SH decreases over the range of values evaluated. Increased crude protein yields and digestible dry matter yields as DI increases from 7 to 49 days between defoliations is often achieved at a cost of lower percent crude protein and, to a lesser degree, reduced digestibility of the dry matter harvested. In no case did percent crude protein content drop below 10% of the dry matter. In the clover dominant swards of 1981 and 1982, more over, the lowest crude protein value recorded was 13%. If one allows for slightly higher forage quality in an animal's diet compared to that of the general value of the forage on offer (Bedell 1971), it is unlikely that low dietary crude protein content will limit livestock performance under any of the defoliation regimes tested. It is more likely as Smetham (1977) suggests that livestock production on grass-clover pastures will be limited by digestible energy intake rather than by crude protein of the feed. He goes on to speculate that increased digestible energy yield may be a primary cause of superior livestock performance under rotational grazing systems. This view is consistent with our observations that the short duration grazing practice of increasing defoliation interval, which necessitating a corresponding increase in defoliation intensity, produces pronounced increases in the yield of digestible dry matter. Increased yield of digestible dry matter under infrequent defoliation appears to result from dry matter yield increasing at a faster rate than its digestibility decreases with time since defoliation.

There obviously is a critical point at which forage digestibility is inadequate to achieve livestock production goals. The exact value of this critical point is somewhat arbitrary as it varies with the class and type of livestock as well as with the level of livestock performance expected. Average daily gains of 290 g/hd/day may be achieved by lambs grazing perennial ryegrass-subclover pastures of 66% dry matter digestibility and 9-10% crude protein content (Thetford 1976). Using these values as a guide, a 5 week interval between grazing events appears to optimize the quality and quantity of forage produced from the grass-dominant pasture in 1980. This defoliation interval is also near optimum for maintaining perennial ryegrass in the sward (Chapter 5). Clover dominant pastures decline in quality more slowly with age than do grass dominant pastures (Smetham, 1977). Our data suggest that defoliation intervals of 7 weeks or even longer may be optimum for clover dominant swards such as our 1982 sward.

Literature Cited

- Allinson, D. W., M. B. Teser, and J. W. Thomas. 1969. Influence of cutting frequency, species, and nitrogen fertilization on forage nutritional value. *Crop Sci.* 9:504-508.
- Association of Official Analytical Chemists (AOAC). 1970. Official methods of analysis (11th edition). Washington, D.C.
- Bedell, T. E. 1971. Nutritive value of forage and diets of sheep and cattle from Oregon subclover-grass mixtures. *J. Range Mgt.* 24:125-133.
- Binie, R. C. and F. J. Harrington. 1972. The effect of cutting height and cutting frequency on the productivity of an Italian ryegrass sward. *J. British Grass. Soc.* 27:177-182.
- Brougham, R. W. 1959. The effect of frequency and intensity of grazing on the productivity of a pasture of short-rotation ryegrass and red and white clover. *New Zealand J. of Agric. Res.* 2:1232-1248.
- Chestnutt, D. M. B., J. C. Murdoch, F. J. Harrington, and R. D. Binnie. 1977. The effect of cutting frequency and applied nitrogen on production and digestibility of perennial ryegrass. *J. British Grass. Soc.* 32:177-183.
- Clark, J., C. Kat, and K. Santhirasegaram. 1974. The effects of changes in heights of cutting and growth on the digestible organic matter production and botanical composition of perennial pasture. *J. British Grass. Soc.* 29:269-273.
- Ellis, W. C. 1978. Determinants of grazed forage intake and digestibility. *J. Dairy Sci.* 61:1828-1840.
- Harris, W. and V. J. Thomas. 1973. Competition among pasture plants. III. Effects of frequency and height of cutting on competition between white clover and two ryegrass cultivars. *New Zealand J. of Agric. Res.* 16:49-58.
- Humphreys, L. R. 1966. Pasture defoliation practice: A review. *The J. Aust. Instit. of Agric. Sci.* 32:93-105.
- Ludlow, M. M. and D. A. Charles-Edwards. 1980. Analysis of regrowth of a tropical grass, legume sward subjected to different frequencies and intensities of defoliation. *Aust. J. Agric. Res.* 31:673-692.

- Mowat, D. N., R. S. Fulkerson, W. E. Tossell, and J. E. Winch. 1965. The in vitro digestibility and protein content of leaf and stem portions of forages. *Canadian J. Plant Sci.* 45:321-331.
- National Oceanic and Atmospheric Administration (NOAA). 1973. Monthly normals of temperature, precipitation, and heating and cooling degree days 1941-70. U.S. Dept. of Commerce. National Climatic Center. Asheville, North Carolina.
- Neter, J. and W. Wasserman. 1974. Applied linear statistical models. Richard D. Irwin, Inc., Homewood, Illinois.
- Reid, D. 1967. Studies on the cutting management of grass-clover swards. V. The effect of changes in closeness of cutting at different times in the season on the yield and quality of herbage from a perennial ryegrass - white clover sward. *J. Agric. Sci.* 68:249-254.
- Smetham, M. L. 1977. Grazing management. P. 179-228. In R. H. M. Langar editor. Pastures and pasture plants. A. H. and A. W. Reed Publishing, Sydney.
- Steel, R. G. O. and J. H. Torrie. 1980. Principles and procedures of statistics. Second edition. McGraw-Hill book company. New York.
- Taylor, J. C., and J. E. Rudman. 1966. Height and method of cutting or grazing in relation to herbage consumption and live-weight gain. Proc. 9th Intern. Grassland Congress Sao Pawo pp. 1639-1644.
- Thetford, F. O. 1976. Responses of vegetation and sheep to three grazing pressures. Ph.D. Dissertation. Oregon State University, Corvallis, Oregon. 157 numb leaves.
- Tilley, J. M. A., and R. A. terry, 1969. The relationship between the soluble constituents of herbage and their dry-matter digestibility. *J. British Grass. Sco.* 24:290-295.
- Ulyatt, M. J. 1970. Evaluation of pasture quality under New Zealand conditions. *Proc. N.Z. Grassld. Assoc.* 32:61-68.
- Wilman, D. and J. E. Asiegbu. 1982. The effects of clover variety, cutting interval and nitrogen application on herbage yields. Proportions and heights in perennial ryegrass-white clover swards. *Grass and Forage Sci.* 37:1-13.

Wilman, D., A. Koocheki, and A. B. Lwoga. 1976. The effect of interval between harvests and nitrogen application on the proportion and yield of crop fractions and on the digestibility and digestible yield and nitrogen content and yield of two perennial ryegrass varieties in the second harvest year. *J. Agric. Sci.* 87:59-74.

Woodman, H. E., and J. Stewart. 1932. The mechanism of cellulose digestion in the ruminant organism. III. The action of cellulose-splitting bacteria on the fibre of certain typical feeding stuffs.

CHAPTER 4

EFFECT OF DEFOLIATION TREATMENTS ON PASTURE REGROWTH
AS RELATED TO LEAF AREA INDEX AND THE REMAINING STUBBLE¹

Iraj Motazedian, and Steven H. Sharrow²

FOOTNOTES

¹This article was submitted as Technical Paper No. . Oregon Agricultural Experiment Station, Corvallis.

²Authors are graduate student and associate professor, Department of Rangeland Resources, Oregon State University, Corvallis, respectively.

Abstract

The relationships between leaf area index, the remaining stubble, and herbage accumulation rate of a grass-clover hill pasture under twelve different defoliation treatments were studied in western Oregon. Treatments consisted of all possible combinations of four defoliation intervals (clipped every 7, 21, 35, or 49 days) and three stubble heights (High = 70 mm, Medium = 55 mm, and Low = 40 mm of stubble remaining).

Leaf Area Index of the herbage produced, plus chlorophyll content of the remaining stubble after defoliation were measured in the first seven weeks of 1981 and 1982 growing seasons. Herbage accumulation rate (Kg dry matter produced/ha/day) were calculated in both 1981 and 1982 growing seasons using the phytomass produced under each defoliation treatment. Collected data were analyzed as factorial arrangement of treatments in a randomized complete block design.

It was found that greater herbage accumulation rate on less frequently defoliated plots was associated with increases in leaf area index with time since defoliation. The chlorophyll content of the remaining stubble, however, decreased as the interval between defoliations increased from one to seven weeks. Apparently lower initial photosynthetic capacity of the stubble on infrequently defoliated plots was less important in determining total forage production than was the higher accumulated leaf area.

Herbage accumulation rate was not sensitive to changes in defoliation treatments during the second half of the growing season, mainly because plants were in the reproductive stage of growth.

Higher herbage accumulation rate of closely defoliated plots, plus the overwhelming effect of leaf area duration over the stubble chlorophyll content suggested that forage production may be maximized by Low SH regime, to remove the old inefficient tissue, followed by sufficiently long recovery period.

CHAPTER 4

EFFECT OF DEFOLIATION TREATMENTS ON PASTURE REGROWTH
AS RELATED TO LEAF AREA INDEX AND THE QUALITY OF
THE REMAINING STUBBLE

Introduction

Plants in natural communities as well as sown crops compete with each other for environmental factors such as water, nutrients and light. When water and nutrients are adequate, growth can be determined by the solar radiation and its efficient use by pasture plants. Brown and Blaser (1968) mentioned three requirements for efficient use of light by pasture plants: 1) At least 95% interception of the incidental light by foliage, 2) favorable distribution of the intercepted light, and 3) high photosynthetic efficiency of leaves. The relationship between incidental light and its interception by plant canopy is expressed by Leaf Area Index (LAI), which is defined as the area of green herbage per unit area of ground (Thomas 1980).

Extensive literature indicates a positive relationship exists between LAI and dry matter production. More dry matter accumulates as LAI increases up to a point (Optimum LAI) at which almost all of the incidental light is captured by the foliage. The rate of herbage accumulation is believed to be maximum at this point.

While LAI is useful to describe the amount of photosynthetic tissue present, it alone may not be adequate to predict plant growth

(Brown and Blaser 1968). Internal plant factors are also involved in use of incoming radiation for photosynthesis. For instance, age (Ollerenshaw and Incol 1979), and chlorophyll content (Brougham 1960b) of the photosynthetic areas are two qualitative factors which may be important in plant regrowth especially after defoliation.

The effect of defoliation regimes on subsequent LAI and pasture regrowth have been widely studied (Grant et al. 1981, Ludlow and Charles-Edwards 1980). There is, however, relatively little information relating the remaining stubble following defoliation treatments to subsequent pasture regrowth.

Materials and Methods

The study area was located one kilometer northwest of Corvallis, Oregon. The climate is maritime with mild, wet winters and warm dry summers. The 30-year-average annual precipitation is near 1000 mm (NOAA 1978). Vegetation at the beginning of the study in March 1980 consisted mainly of 55% perennial ryegrass (Lolium perenne L.), 25% subclover (Trifolium subterraneum L.), and 12% Tall fescue (Festuca arundinacea).

A 20 x 40 m exclosure was built in March 1980 to protect plots from sheep grazing. Thirty six 2 x 2 m permanently marked plots were assigned randomly to three replication of 12 different defoliation treatments. Defoliation treatments were a combination of four defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive

defoliations), and three stubble heights (SH, High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation). A 1 m wide buffer strip, which was defoliated the same as the adjacent plots, was left on each side of every plot to provide access and to reduce edge effects.

A rear-bagging rotary mower with adjustable cutting height was used to defoliate the plots on their assigned dates and heights. The entire contents of the mower bag from each plot was weighed and a grab sample obtained for dry matter determination. Total harvested phytomass for each plot was corrected to an oven-dry matter basis using the percent dry matter calculated from the field weights and oven-dry weights of grab samples dried for 48 h at 50°C. Defoliation treatments commenced each spring when pasture height reached 15 cm and ceased when pastures dried in summer. Following this criterion, defoliation treatments began on April 5, March 24, and April 7 and ended on July 12, July 21 and July 7 in 1980, 1981 and 1982 respectively. All plots were defoliated at the same (Close) height at the beginning and at the end of the spring growing season each year.

All plots were fertilized with 150 Kg/ha of superphosphate in September of each year. In addition, 0.8 Kg/ha of sodium molybdate was sprayed on the plots in March 1980 to remove possible Mo deficiency.

Samples of green herbage for determination of averaged terminal LAI of the forage produced, and LAI, dry weight and chlorophyll content of the remaining stubble were taken during the first seven weeks

of the 1981 and 1982 growing seasons. A 40 x 20 cm rectangular quadrat, with adjustable legs, was used to sample forage produced on plots at the assigned dates and heights of defoliation, immediately prior to mowing the plot. Forage clipped from within the quadrat was placed in plastic bags and taken to laboratory where leaf area was determined using an electronic planimeter. The entire sample was then dried in an oven at 50°C for 48 hours, then weighed.

Stubble remaining after mowing of plots was clipped at ground level in a 0.1 m² quadrant from the buffer strip of each plot in 1981 only. Dry weight and LAI of these samples were also determined using the methods described above.

Chlorophyll content of the stubble was determined immediately after defoliation of each plot. Samples were chopped into small pieces from which a 1 ± 0.01 g subsample was drawn. The procedure described by Brougham (1960b) was used to prepare extracts for the final measurements. Percent light absorbency (100-transparency) of the solution, as a scale to compare chlorophyll content, was measured with a spectrophotometer dialed on 663 and 645 m) wave lengths for chlorophyll A and B, respectively.

Pasture herbage accumulation rate (HAR) under different defoliation treatments was calculated as Kg dry matter accumulated per day per ha during the 1981 and 1982 growing seasons. The total phytomass collected from mowed plots was divided by the number of days since the last mowing to estimate HAR.

Data were analyzed separately for each year as a factorial arrangement of treatments in a randomized complete block design (Steel and Torrie 1980). The means, where appropriate, were separated by Student-Newman-Keuls' test (Steel and Torrie 1980). Significant treatment effects were separated into orthogonal polynomial components and appropriate response surfaces were fitted by least square regression procedures (Neter and Wasserman 1974).

Results and Discussions

The amount of leaf area and therefore LAI differed ($P < 0.01$) between DI and SH regimes in both the 1981 and 1982 growing seasons. Generally, as the period of nonuse increased more leaf area accumulated on the plots. Greater leaf area was also measured on plots clipped to Low, rather than High SH (Figure 4-1). Swards with greater LAI have been reported (Donald and Black 1958, Brown and Blaser 1968, Cocks 1974, Ludlow and Charles-Edwards 1980) to use incoming solar radiation more completely and to produce more dry matter. Therefore, a positive relationship between LAI values and canopy assimilate production (Brown and Blaser 1968, King et al. 1979), or pasture dry matter (Brougham 1956) may occur up to the point at which optimum LAI is reached. The herbage accumulation rate (HAR) in this trial, which was calculated as the total herbage accumulated per unit area of soil per unit of time, plus the efficiency of the sward (E) calculated as herbage accumulation per unit area of

Figure 4-1. Averaged terminal Leaf Area Index (LAI) measured on plots under different defoliation interval (DF = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH; High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation) regimes during first seven weeks of the 1981 and 1982 growing seasons.

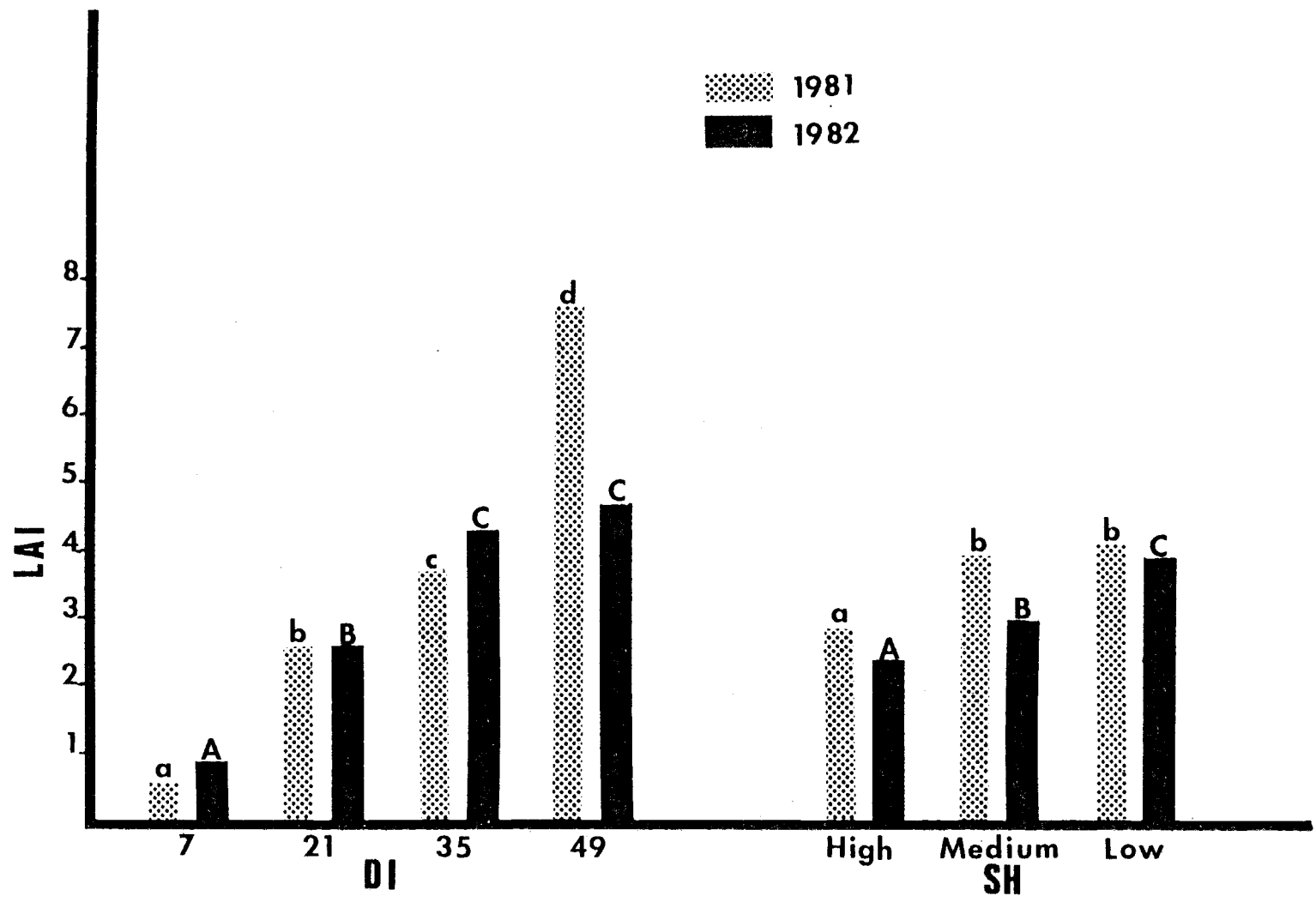


Figure 4-1

leaf per unit of time ($HAR = LAI \times E$) (Brown and Blaser 1968), were determined to find their relationships with LAI. In both the 1981 and 1982 growing seasons the general relationships of LAI with HAR and E were positive and negative, respectively. The HAR model of 1981 (Figure 4-2) was linear indicating that the rate of herbage production increased as LAI increased over time. The efficiency of herbage production, however, decreased up to LAI of 6.5 then stopped decreasing (Figure 4-2). Similar results were obtained during 1982. In this year, however, the positive relationship between HAR and LAI, was best described by a power curve (Figure 4-3). As in 1981, a curvilinear relationship was observed between LAI and E in 1982. The lowest E in this year corresponded to LAI of 3.6 (Figure 4-3).

Differences in the LAI at which minimum E was observed between years is believed to reflect differences in the grass/clover balance of the pasture between years. Plots consisted of 52% clover and 37% perennial ryegrass in 1981, 66% clover and 25% perennial ryegrass in 1982 (Chapter 2). Maximum herbage production occurs at relatively lower LAI for clover than grass (Davidson and Donald 1958, Cocks 1974).

The initial trend of E to decline as LAI declines in our data was consistent with the literature reviewed by Brown and Blaser (1968). They said that due to the old age and mutual shading, the sward efficiency in dry matter production decreases as LAI increases. The slight increase in E at relatively high LAI in our study is unique. High LAI in our trial was associated with long periods

Figure 4-2. Relationships between LAI, Herbage Accumulation Rate (HAR), and the efficiency of pasture dry matter production (E) in the first seven weeks of 1981 growing season. $HAR(r^2 = 0.99) = -1.99 + 0.08(LAI)$.

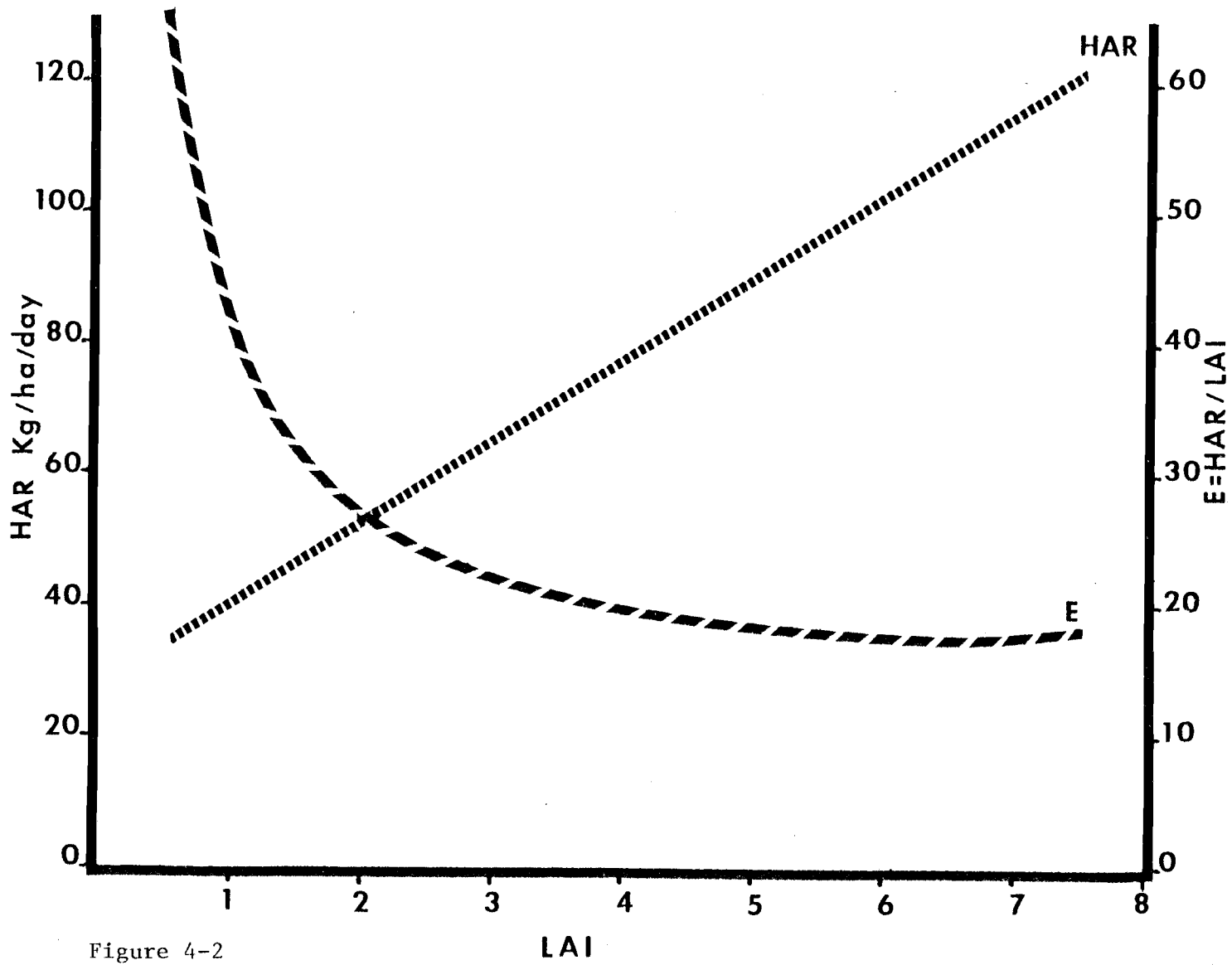


Figure 4-2

Figure 4-3. Relationships between LAI, Herbage Accumulation Rate (HAR), and the efficiency of pasture dry matter production (E) in the first seven weeks of 1982 growing season. $HAR(r^2 = 0.91) = 65.03 - 21.10(LAI) + 5.77(LAI)^2$.

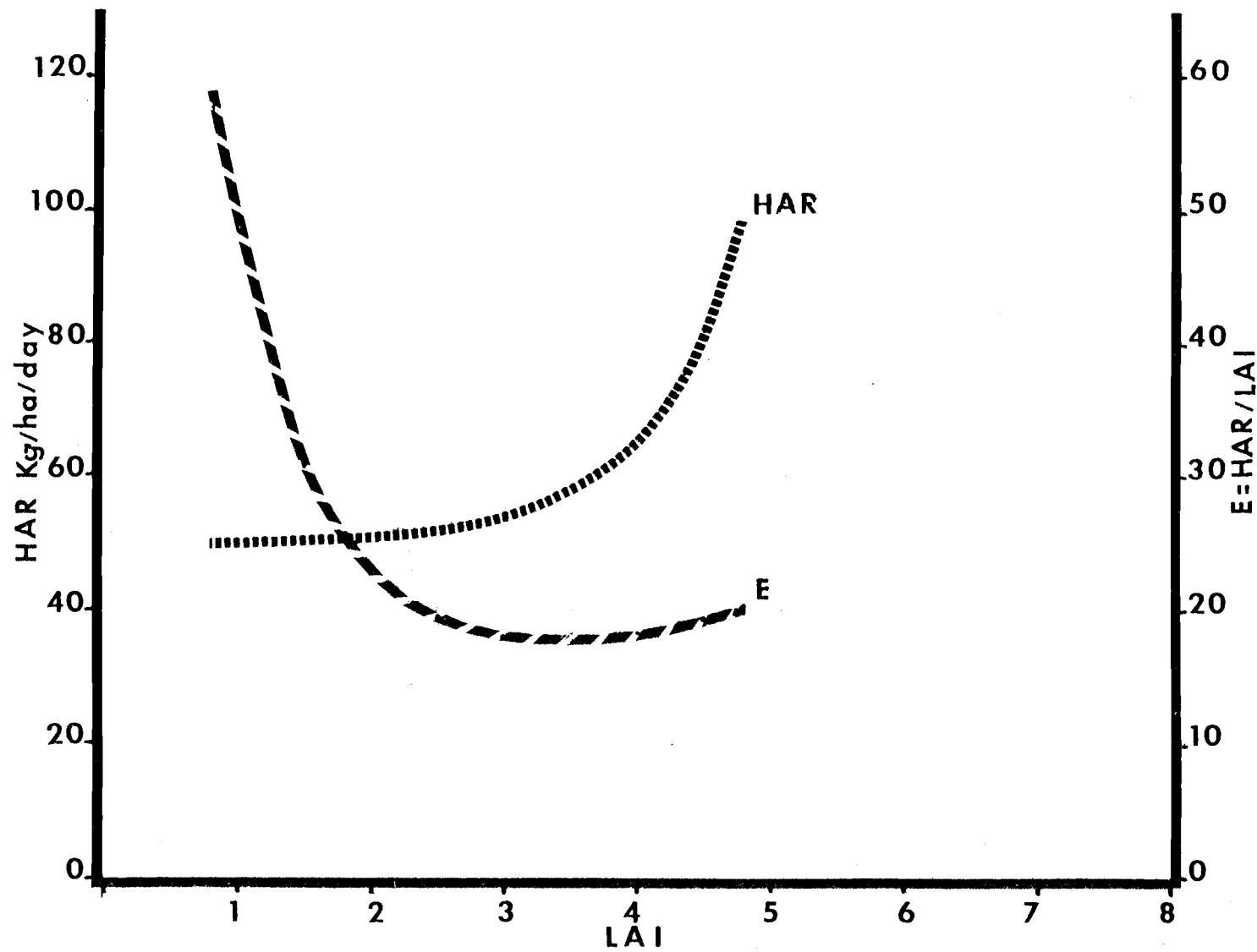


Figure 4-3

between defoliation events. Under these conditions, stands tended to become reproductive. The accompanying change in stand structure as grass plants produced culms may explain the observed increase in E as LAI increased on these plots.

Treatments with longer periods of regrowth had lower ($P < 0.01$) LA/DW for the forage produced (Table 4-1). This suggests that herbage in such treatments was less leafy when compared to herbage from shorter defoliation intervals. Less leafy forage may mean less relative LAI per unit dry weight but may also be associated with different stand structure, and more efficient display of the leaf area present.

The 1981 and 1982 HAR models do not lead us to believe that the optimum LAI was achieved in grass-clover pastures of these two years (Figures 4-4 and 4-5). Herbage accumulation rate did not begin to decline as one would expect if optimum LAI were approached. In fact HAR was still increasing from day 48 to 49 in each year. Nevertheless both models indicate high forage production was associated with greater LAI values which accumulated on less frequently defoliated plots. This explains the higher ($P < 0.01$) HAR of plots under longer periods of regrowth, especially those of DI35 and DI49 in the first period of the growing season (Table 4-2). Comparisons of HAR values between DI49 and DI7 indicate that plots under DI49 treatments had nearly 3.5 and 2.0 times more production in the first period of 1981 and 1982 growing seasons, respectively.

Table 4-1. Leaf area/Dry matter weight (cm^2/g) for plots under different defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) treatments measured in first seven weeks of growing season, 1981 and 1982.

Source DI (days)	LA/DW	
	Years	
	1981	1982
7	214.4d ¹	191.5c
21	195.6c	184.1c
35	134.0b	133.9b
49	127.3a	97.9a
$\bar{S}_y =$	2.21	3.83
SH (mm)		
70	169.9b	159.4b
55	170.0b	146.0a
40	163.6a	150.1a
$\bar{S}_y =$	1.91	3.31

¹Means in each column and for each source followed by different letters differ ($P < 0.05$).

Table 4-2. Mean Herbage Accumulation Rate (HAR) for the first and second seven week periods of the 1981 and 1982 growing seasons for plots under four defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and three stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes.

Source	HAR (Kg/ha/day)			
	1981		1982	
	First period	Second period	First period	Second period
DI (days)				
7	35.7a ¹	34.4a	50.2a	17.8a
21	59.5b	33.9a	52.4a	17.9a
35	72.4c	31.3a	72.3b	19.1a
49	122.8d	49.9b	99.0c	16.5a
\bar{S}_y	2.73	3.25	3.02	2.06
SH (mm)				
70	57.9a	34.3a	55.7a	18.9a
55	78.0b	39.5a	67.5b	16.3a
40	81.9b	39.9a	82.3c	18.4a
\bar{S}_y	2.36	2.82	2.61	1.78

¹Means in each column and for each source followed by different letters differ ($P < 0.05$).

The stubble height regimes were also effective ($P < 0.01$) in changing HAR. Based on what was removed, plots under close defoliation had higher HAR than those defoliated laxly in the first period of 1981 and 1982 growing seasons (Table 4-2).

The interaction of DI x SH was not significant ($P > 0.05$) in analysis of variance tables for both years. This component, however, was significant in the 1982 regression model. Both DI and SH participated as power curves in the 1981 HAR model. Therefore the 1981 surface had sharply raising curves as both DI and SH increased. The lowest and the highest corners of this surface were 7 High and 49 Low, respectively (Figure 4-4). The DI x SH interaction and DI^2 were the components of 1982 response surface. However, the lowest and the highest points were associated with the same treatments as in 1981 (Figure 4-5).

Differences between HAR of DI49 and DI7 became rather small or non-significant in the second period of the growing seasons in both years. At this time, plots under DI49 in 1981 had higher ($P < 0.01$) HAR than the other DI regimes. The DI49/DI7 ratio, however, was nearly 1.5 which was half of the same ratio in the first seven week period (Table 4-2). The HAR values obtained for the second growing period in 1982 did not differ among DI regimes ($P > 0.05$).

The SH treatments were also not effective ($P > 0.05$) in changing HAR in the second period of both growing seasons (Table 4-2). The second period of the growing season began on May 19 and May 31 in 1981 and 1982, respectively. Usually, this is a time of

Figure 4-4. Relationship ($r^2 = 0.93$) of Herbage Accumulation Rate (HAR) with defoliation interval (DF = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH; High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation) regimes during first seven weeks of the 1981 growing season. $HAR = -28.445 + 0.041 (DI)^2 + 0.036(SH)^2$.

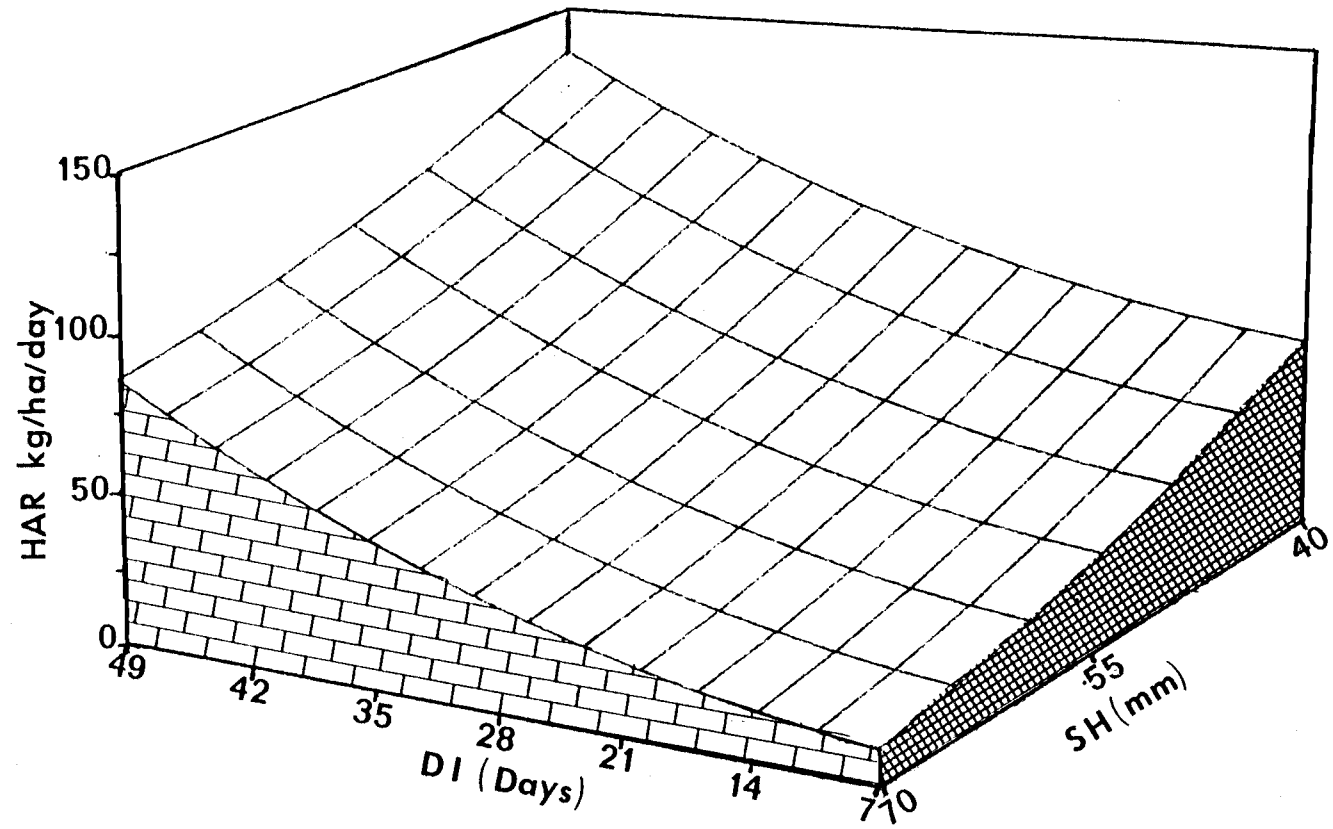


Figure 4-4

Figure 4-5. Relationship ($r^2 = 0.89$) of Herbage Accumulation Rate (HAR) with defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH; High = 70 mm, Medium = 55 mm, or Low = 40 mm stubble remaining after defoliation) regimes during first seven weeks of the 1982 growing season. $HAR = 64.430 + 0.071 (DI)^2 - 0.027 (DI \times SH)$.

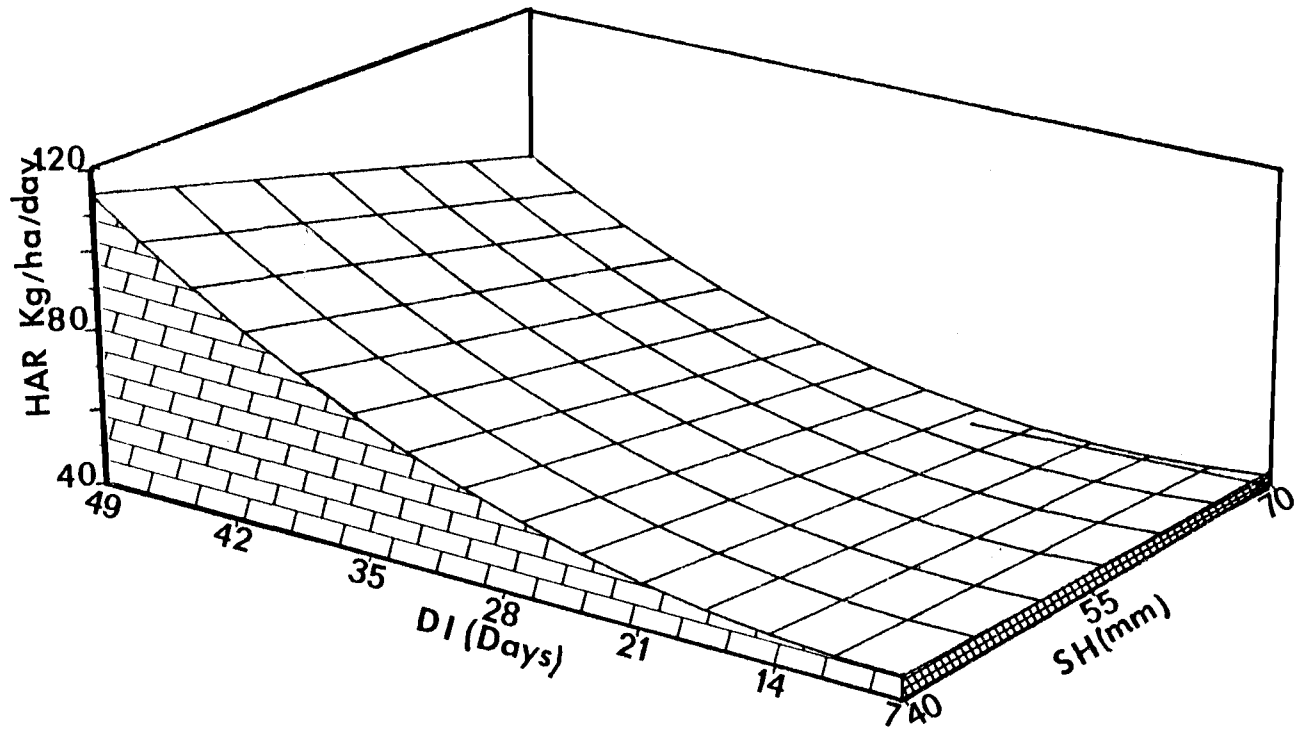


Figure 4-5

inflorescence initiation for grass and clover in our area. Plots which were defoliated frequently such as DI7 were slower to flower than less defoliated plots. A similar observation was made by Korte et al. (1982). Rate of dry matter production often declines as plants shift from vegetative to reproductive stages (Sheehy et al. 1979). The developing inflorescence of grass and clover plants are strong sinks drawing upon both reserves and currently produced photosynthate (Moser 1977). As a result of internal allocation of resources within plants, fewer resources may be available for initiation of new leaves and tillers in reproductive plants. This is believed to have played a role in holding back production of plants on DF5 and DF7 treatments. Apparently, the relatively lower LAI on frequently defoliated plots was, to a large extent, offset by the plants remaining more physiologically active during the second regrowth period compared to the more mature, reproductive plants present on DI49 and DI35 plots.

Condition of the stubble remaining after defoliation is another factor which may impact regrowth and initiation of photosynthesis. The amount of stubble is important in light interception (Brougham 1956) but its photosynthetic efficiency should also be considered (Simons et al. 1972). The quality of the remaining stubble is, therefore, important in efficient use of the captured light. In many prostrate growing stands, closer defoliation, which leaves less stubble behind, may produce more dry matter (Reid, 1967, Binnie and Harrington 1972) mainly because the aged material was removed to be

replaced by young, more efficient foliage (Harris 1971, Ollerenshaw and Incol 1979). On the contrary, more upright growing plants may benefit from less intense defoliation which leaves more green material behind (Vickery et al. 1971). In both cases, the photosynthetic capacity of the stubble is an important factor for regrowth after defoliation.

Dry weight and LAI of the stubble remaining after defoliation treatments in 1982 differed ($P < 0.01$) between defoliation regimes. More frequently defoliated plots had more residual stubble dry weight and more LAI as compared to less defoliated plots (Table 4-3). Plots under High SH regime also had more ($P < 0.01$) stubble weight and leaf area, as compared to Low defoliation. The chlorophyll A and B of the stubble material, measured in the first period of 1981 and 1982 growing seasons, also decreased ($P < 0.01$) as the period of regrowth and intensity of defoliation increased (Table 4-4).

Plots under longer periods of regrowth had less leaf material and less chlorophyll content after defoliation. Such stubble may display slow initiation of new growth, at least for the first few days after defoliation. The pattern of regrowth is complicated, however, by the tendency of less frequently or severely defoliated plants to have higher levels of stored carbohydrate and other reserved material. Plants richer in such material may produce new foliage faster (Brown and Blaser 1968) following defoliation. Nutrient reserve may therefore, compensate for lower stubble quality. No difference in dry matter production, estimated by use of a disk

Table 4-3. Dry matter (g/m^2) and leaf area index (LAI) of the stubble remaining after defoliation of plots under defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes in the first 7 weeks of growing seasons, 1981.

<u>Source</u>	<u>Dry weight</u>	<u>Leaf Area Index</u>
DI (days)		
7	2366b ¹	2.85b
21	2323b	2.34b
35	1691a	1.76a
49	1481a	1.56a
$\bar{S}_y =$	181.0	0.01
SH (mm)		
70	2463b	2.84b
55	1873a	1.88a
40	1560a	1.57a
$\bar{S}_y =$	156.75	0.01

¹Means in each column for each source followed by different letters differ ($P < 0.05$).

Table 4-4. Percent light absorbency of wavelengths 663 and 645 nm as a measurement of chlorophyll A and B respectively for the stubble materials of plots defoliated at different defoliation intervals (DI = 7, 21, 35, or 49 days between two consecutive defoliations) and stubble heights (SH; 70, 55, or 40 mm stubble remaining after defoliation) during the first 7 weeks of the 1981 and 1982 growing seasons.

Source	Year			
	1981		1982	
DI (days)	Chlorophyll A	Chlorophyll B	Chlorophyll A	Chlorophyll B
7	74.6c ¹	55.5c	81.0d	61.4d
21	58.0b	34.6b	66.1c	43.5c
35	61.0b	39.6b	56.6b	31.7b
49	38.1a	24.7a	34.9a	29.9a
$\bar{S}_y =$	2.36	1.91	0.66	0.87
SH (mm)				
70	65.6b ¹	45.4b	60.8b	41.4a
50	55.2b	35.4b	59.9ab	40.2a
40	53.1a	34.8a	58.2a	40.2a
$\bar{S}_y =$	2.05	1.65	0.57	0.75

¹Mean in each column and for each source followed by different letters differ ($P < 0.05$).

meter (Baker et al. 1981), was noticed between plots under DI7 and DI49 treatments, one week after defoliation of these plots.

Contrary to the fact that Low, as opposed to High, SH left less leaf material and chlorophyll behind, plots under Low defoliation had higher and similar HAR in the first and second periods of both growing seasons, respectively. Apparently, the prostrate stands benefited from Low defoliation which removed more of the old leaf and stem material.

In general, longer periods of nonuse seem to be more important in pasture regrowth and HAR than the quality of the stubble remaining after defoliation. Regrowth may be slow immediately after defoliation because light interception and photosynthesis are not efficient. This, however, may be followed by a rapid phase of growth and dry matter production as leaf area accumulates on the pasture.

Management Implications

Total annual forage production was more responsive to changes in defoliation intensity than to stubble height regimes (Chapter 2). Greater forage production on less frequently defoliated plots was associated with increases in leaf area index and Herbage Accumulation Rate with time since defoliation. The amount and chlorophyll content of stubble remaining immediately after defoliation events, however, decreased as the interval between defoliations increased from one to

seven weeks. Apparently, lower initial photosynthetic capacity of stubble on infrequently defoliated plots was less important in determining total forage production than was the higher leaf area index on these plots. This phenomenon could be explained by greater duration of leaf area as well as greater leaf area itself under less frequent defoliation. In addition, regrowth of less frequently defoliated plants may be accomplished using stored nutrient reserves (Brown and Blaser 1968), making stubble quantity and quality less important.

These data suggest that forage production may be maximized by defoliation regimes employing close defoliation to remove old inefficient tissue followed by sufficiently long recovery periods to allow accumulation of relatively high LAI. The optimum LAI for a stand can be expected to vary with species composition, latitude and climatic conditions. The highest LAI recorded in this study were 7.6 and 4.7 observed on DI49 plots in 1981 and 1982, respectively. There is little evidence to suggest that longer regrowth periods allowing accumulation of leaf area beyond these levels would not result in further increases in forage production. One potential problem encountered in employing long defoliation intervals is the tendency of plants to produce reproductive culms which are lower in quality as feed for livestock than is vegetative growth. Herbage Accumulation Rate was not very sensitive to changes in defoliation interval during the second half of the growing spring season when plants were becoming reproductive. Therefore, defoliation interval could be decreased during this period to suppress perennial ryegrass culm

development without greatly reducing forage production. Care must be exercised, however, to ensure that more frequent defoliation during the late spring-early summer period does not reduce the root system of the plants (Chapter 5) and increase summer mortality (Brougham 1960a).

Literature Cited

- Baker, B.S., T.V. Eynden, and N. Boggess. 1981. Hay yield determinations of mixed swards using a disk meter. *Agron. J.* 73:67-69.
- Binnie, R. C. and F. J. Harrington. 1972. The effect of cutting height and cutting frequency on the productivity of an Italian ryegrass sward. *J. British Grass. Soc.* 27:177-182.
- Brougham, R. W. 1956. Effect of intensity of defoliation on regrowth of pasture. *Australian J. Agric. Res.* 7:377-387.
- Brougham, R. W. 1960a. The effect of frequent hard grazings at different times of the year on the productivity and species yields of a grass-clover pasture. *New Zealand J. Agric. Res.* 3:125-136.
- Brougham, R. W. 1960b. The relationship between the critical leaf area, total chlorophyll content and maximum growth rate of some pasture and crop plants. *Ann. of Botany* 24:463-473.
- Brown, R. H., and R. E. Blaser. 1968. Leaf area index in pasture growth. *Herb. Abst.* 38:1-9.
- Cocks, P. S. 1974. Potential production of grass and clover monocultures in a Mediterranean-type environment--an experimental approach. *Australian J. Agric. Res.* 25:835-846.
- Davidson, J. L., and C. M. Donald. 1958. The growth of swards of subterranean clover with particular reference of leaf area. *Aust. J. Agric. Res.* 9:53-72.
- Donald, C. M., and J. N. Black. 1958. The significance of leaf area in pasture growth. *Herb. Abst.* 28:1-7.
- Grant, S. A., G. T. Barthram, and L. Trovell. 1981. Components of regrowth in grazed and cut *Lolium perenne* swards. *Grass and Forage Sci.* 36:155-168.
- Harris, W. 1971. The effect of density, cutting height and white clover (*Trifolium repens* L.) on the structure of a ryegrass (*Lolium* spp.) population. *J. Agric. Sci.* 77:385-395.

- King, J., W. I. C. Lamb, and M. T. McGregor. 1979. Regrowth of ryegrass swards subject to different cutting regimes and stocking densities. *Grass and Forage Sci.* 34:107-118.
- Korte, C. J., B. R. Watkins and W. Harris. 1982. Use of residual leaf area index and light interception as criteria for spring-grazing management of a ryegrass-dominated pasture. *N.Z.J. of Agric. Res.* 25:309-319.
- Ludlow, M. M. and D. A. Charles-Edwards. 1980. Analysis of regrowth of a tropical grass, legume sward subjected to different frequencies and intensities of defoliation. *Aust. J. Agric. Res.* 31:673-692.
- Moser, L. E. 1979. Carbohydrate translocation in range plants P. 47-71. In: *Rangeland Plant Physiology*. R. E. Sosebee (editor). Society for Range Management, Denver, Colorado.
- National Oceanic and Atmospheric Administration (NOAA). 1973. Oregon climatological data. Monthly normals of temperature, precipitation, and heating and cooling degree days. 1941-1970. U.S. Department of Commerce, National Climatic Center. Asheville, North Carolina.
- Neter, J., and W. Wasserman. 1974. *Applied linear statistical models*. R. D. Irwin, Inc. Homewood, Illinois.
- Ollerenshaw, J. H. and L. D. Incol. 1979. Leaf photosynthesis in pure swards of two grasses (*Lolium perenne* and *Lolium multiflorum*) subjected to contrasting intensities of defoliation. *Ann. Applied Biology.* 92:133-142.
- Reid, D. 1967. Studies on the cutting management of grass-clover swards. V. The effect of changes in closeness of cutting at different times in the season on the yield and quality of herbage from a perennial ryegrass - white clover sward. *J. Agric. Sci.* 68:249-254.
- Sheehy, J. E., J. M. Cobby, and G. J. A. Ryle. 1979. The growth of perennial ryegrass: A model. *Ann. Bot.* 43:335-354.
- Simons, R. G., A. Divies, and A. Troughton. 1972. The effect of the height of defoliation on two clones of perennial ryegrass. *J. Agric. Sci.* 79:509-514.
- Steel, R. G. O. and J. H. Torrie. 1980. *Principles and procedures of statistics*. Second edition. McGraw-Hill book company. New York.

Thomas, H. 1980. Terminology and definitions in studies of grass-land plants. *Grass and Forage Sci.* 35:13-23.

Vickery, P. J., Brink, V. C. and Ormrod. 1971. Net photosynthesis and LAI relationships in swards of *Dactylis glomerata* under contrasting defoliation regimes. *J. British Grass. Soc.* 26:85-90.

CHAPTER 5

SPECIES COMPOSITION OF A LOLIUM PERENNE
(L.) - TRIFOLIUM SUBTERRANEUM (L.) PASTURE UNDER
DIFFERING DEFOLIATION TREATMENTS¹

Iraj Motazedian, Steven H. Sharrow²

FOOTNOTES

¹This article was submitted as Technical Paper No. . Oregon Agricultural Experiment Station, Corvallis.

²Authors are graduate student and associate professor, Department of Rangeland Resources, Oregon State University, Corvallis, respectively.

Abstract

Pasture species composition was monitored and some components related to persistence of perennial ryegrass were measured in a perennial ryegrass (Lolium perenne L.) - subclover (Trifolium subterraneum L.) pasture in western Oregon under 12 different defoliation regimes for three consecutive years. Defoliation treatments were a combination of four defoliation intervals (clipped every 7, 21, 35 or 49 days), and three stubble heights (70, 55, and 40 mm of stubble remaining). Species composition and canopy cover were estimated prior to defoliation treatments each year. Plant density, basal area and root phytomass of perennial ryegrass plants were determined at the completion of the experiment. Data were analyzed as a factorial arrangement of treatments in a randomized complete block design with three replications.

Species composition and canopy cover of both defoliated and non-defoliated plots changed with time over the trial. Perennial ryegrass, in defoliated plots, lost nearly 25% of its cover to subclover each year. Thus, the sward changed from grass dominance to clover dominance. Both perennial ryegrass and subclover disappeared from non defoliated plots. As a result, these plots were composed mainly of annual grasses after three years. There were no differences in plant cover and species composition among defoliated plots for all of the pasture plant species.

Plots defoliated every 1 or 7 weeks, as compared to 3 or 5 weeks, had fewer ryegrass plants at the end of the experiment. The basal area, however, was similar for all defoliation treatments. Root phytomass significantly decreased as defoliation frequency increased. The stubble height regimes did not have an appreciable effect on any of the parameters measured. Some management implications regarding the results are discussed.

Chapter 5

SPECIES COMPOSITION OF A LOLIUM PERENNE (L.) -
TRIFOLIUM SUBTERRANEUM (L.) PASTURE
UNDER DIFFERING DEFOLIATION TREATMENTS

Introduction

Perennial ryegrass (Lolium perenne L. and subclover (Trifolium subterraneum L.) are commonly seeded for pasture improvement on non-irrigated hill lands in western Oregon. Once established, grass-clover pastures require careful grazing management if a favorable ratio of grass to clover is to be maintained. Infrequent or lax defoliation of the sward, while allowing high dry matter production (Wilman and Asiegbu 1982), favors erect growing grasses over the more prostrate clovers (Brougham 1960). Conversely, frequent or intense defoliation may result in reduction of perennial grasses (Baker 1957) and a shift towards clover dominance of the sward (Cameron and Cannon 1970). These effects are well illustrated by a stocking rate study conducted by Sharrow et al. (1981). They observed that perennial ryegrass - subclover pastures which were lightly stocked with sheep became grass dominant over a six year period. During this same period, perennial ryegrass was largely replaced by annual grasses and subclover in heavily stocked pastures. These shifts in species composition were reflected in substantially more herbage production being obtained from moderately stocked than from either lightly or heavily stocked pastures.

Although the general principles of grass-clover pasture management are well understood (see Smetham 1977, Harris 1978), much of the past work had been done using perennial ryegrass-white clover (Trifolium repens L.) pastures. The effect of concurrent changes in both defoliation interval and stubble height on the species composition of perennial ryegrass-subclover pastures are currently not well documented.

This study seeks to gather information concerning the effects of interval and intensity of defoliation on species composition and the persistence of ryegrass in perennial ryegrass-subclover stands. Both defoliation interval and stubble height were simultaneously varied over a range of values likely to be encountered under short duration grazing systems during the spring growing season. The purpose of this experiment was to generate a base of information upon which hypotheses concerning the effects of short duration grazing systems on similar pastures could be formed. Such hypotheses would, of course, require further testing by an actual grazing trial.

Materials and Methods

The study area was located one kilometer northwest of Corvallis, Oregon. Vegetation consisted of a non-irrigated perennial ryegrass (Lolium perenne L.)-subclover (Trifolium subterraneum L.) stand, typical of improved hill pastures in the Willamette Valley. The

climate is maritime with mild, wet winters and warm, dry summers. The 30 year-average annual precipitation is approximately 1000 mm which falls mostly as rain from September to July (NOAA 1973).

A 20 x 40 m exclosure was built on the study area in March 1980 to protect plots from sheep grazing. Thirty six 2 x 2 m permanently marked plots were assigned randomly to defoliation treatments. Defoliation treatments were a combination of four defoliation intervals (DI = 7, 21, 35, or 49 day periods of nonuse between two consecutive defoliations), and three stubble heights (SH; High = 70 mm, Medium = 55 mm, and Low = 40 mm stubble remaining after defoliation). Each treatment was replicated three times. In addition to defoliation treatments, there were three control plots which remained undefoliated until the end of the growing season.

A rear-bagging rotary mower was used to defoliate the plots on their assigned dates and heights. Defoliation treatments commenced each year when pasture height reached 15 cm. Following this criterion, defoliation treatments began on April 4, March 24, and April 7 in 1980, 1981 and 1982, respectively. All of the plots, including control plots were defoliated closely at the beginning and at the end of each season.

All plots were fertilized with 150 kg/ha of superphosphate in September of each year. In addition, 0.8 kg/ha of sodium molybdate was sprayed onto the plots in March 1980 to remove Mo deficiency.

At the initiation of the experiment in March 1980, canopy cover and species composition data gathered from 40 randomly placed ten-

point frames (Sharrow and Tober 1979) were used to typify the study area. Canopy cover and species composition of the study area were also estimated by examination of 160 randomly placed ten-point frames prior to defoliation treatments in 1981 and 1982.

Basal area, density, and root weight per plant of perennial ryegrass were measured in July 1982, after three years of defoliation treatments. Basal area and density of perennial ryegrass plants were measured inside of a 1 m^2 quadrant which was randomly placed on each plot. Basal area of each individual plant was calculated using the formula $\text{area} = \pi R_1 R_2$ where R_1 and R_2 are one half of the longest and shortest diameters, respectively.

Two plants per plot were chosen for root sampling using two criteria 1) that the sample plant be at least 6 cm from its nearest neighbor and 2) that its basal area be near the population average of 14 cm^2 . A 17 cm diameter loop was centered over each sample plant and all soil within the loop was excavated to a depth of 30 cm. Excavated soil was soaked for 24 hours, then the root washed free of soil and collected on a 1 mm^2 screen. The collected root material from each plant was oven dried at 50°C for 48 h to determine total root dry matter. In order to investigate the distribution of root phytomass with soil depth, six additional ryegrass plants were randomly chosen for sampling. A core of 227 cm^2 by 60 cm depth was divided into four vertical segments of 15 cm each. Root phytomass of each soil segment was washed and dried separately for each plant.

Data were analyzed as a factorial arrangement of treatments in a

randomized complete block design (Steel and Torrie 1980). Where appropriate, the means were separated by student-Newman-Keuls' test (Steel and Torrie 1980). Significant treatment effects were separated into orthogonal polynomial components and appropriate response surfaces were fitted by least squares regression procedures (Neter and Wasserman, 1974).

Results and Discussion

The initial survey in March 1980 indicated that canopy cover of perennial ryegrass, subclover, tall fescue (Festuca arundinacea L.) and other plant species at the site of experiment were 43, 22, 17 and 9%, respectively.

Total canopy cover of the sward in March varied little between years (Table 5-1). Species composition of the canopy, however, changed markedly during the course of experiment. Canopy cover of perennial ryegrass declined steadily from its initial value of 43% in 1980 to 30% in 1982. Tall fescue and other perennial grasses also declined during this period. The resources which become available as the amount of perennial grasses declined were apparently used by subclover which increased from its initial value of 22% in 1980 to a value of 55% in 1982. Weather data from a station approximately 16 kilometers northeast of the study area (NOAA 1980, 1981, 1982) indicated no noteworthy differences between years in soil temperatures, air temperatures, or precipitation. Therefore, differences in

Table 5-1. Mean canopy cover (%) of perennial ryegrass (LOPE), tall fescue (FEAR), subclover (TRSU), and other plants under defoliation interval (DI = 7, 21, 35 or 49 days between two consecutive defoliations), stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes and nondefoliated and control plots in 1981 and 1982.

Year	Plant Species	Defoliation regimes							
		DI (days)				Control	SH (mm)		
		7	21	35	49		70	55	40
1981	LOPE	32.3b ¹	32.7b	34.9b	36.1b	6.7a	33.9a	34.7a	33.4a
	FEAR	4.5a	4.9a	4.9a	5.7a	3.6a	5.1a	5.2a	4.7a
	TRSU	46.2b	50.1b	47.3b	48.4b	15.0a	48.0a	47.3a	48.7a
	Others ²	4.1a	4.9a	5.3a	5.7a	43.6b	4.8a	5.0a	5.2a
1982	LOPE	30.0b	29.7b	31.2b	29.1b	1.0a	31.9a	29.7a	28.4a
	FEAR	4.5a	4.0a	4.9a	5.4a	5.0a	4.6a	4.3a	5.2a
	TRSU	57.2b	50.9b	56.3b	55.6b	4.5a	54.2a	55.0a	55.8a
	Others ²	4.1a	4.9a	4.3a	3.9a	47.5b	4.0a	4.1a	4.5a

¹Means in each row and within each category followed by different letters differ (P<.05).

²Mainly consisted of annual grasses.

species composition of the plots between years are believed to reflect treatment, rather than climatic effects over time.

Defoliation treatments had no effect ($P > .05$) on species composition of the defoliated plots within years (Table 5-2). However, differences were apparent ($P < .01$) between all defoliated plots and the undefoliated control plots. Control plots became dominated by annual grasses. They contained only about half as much perennial ryegrass and subclover as did the defoliated plots ($P < .05$) in both 1981 and 1982. Similar effects have been reported for underutilized pastures (Sharrow et al. 1981). All defoliation treatments were apparently equally effective in maintaining subclover and in preventing annual grass dominance of the sward. Low amounts of annual grasses and other weeds on defoliated plots likely resulted from competition by the vigorous stand of subclover on these plots (Evers 1983). Loss of subclover from underutilized stands such as our control plots is often attributed to the presence of an overburden of unharvested forage which hampers germination and establishment of subclover in the fall (Hedrick 1964). Both control and defoliated plots were mowed to a 4 cm stubble height and harvested material removed at the end of spring growing season each year. It is unlikely, therefore, that differences in species composition between the control and defoliation treatments reflect differences in fall seedbed conditions. It is more likely that reduced shading (Collins et al. 1978) and/or stimulation of flower production as a result of defoliation (Collins 1978) allowed production of a larger subclover

Table 5-2. Mean species composition (%) of perennial ryegrass (LOPE), Tall fescue (FEAR), subclover (TRSU), and other plants under defoliation interval (DI = 7, 21, 35 or 49 days between two consecutive defoliations), stubble height (SH = 70, 55, or 40 mm stubble remaining after defoliation) regimes and nondefoliated and control plots in 1981 and 1982.

Year	Plant Species	Defoliation regimes							
		DI (days)				Control	SH (mm)		
		7	21	35	49		70	55	40
1981	LOPE	39.6b ¹	38.9b	34.2b	35.7b	20.2a	37.3a	38.0a	36.0a
	FEAR	5.1a	5.7a	6.0a	4.8a	4.3a	5.2a	5.0a	6.0a
	TRSU	47.9b	54.3b	49.7b	54.1b	20.1a	51.2a	50.5a	51.9a
	Others ²	7.4a	1.1a	10.1a	5.4a	55.4b	6.3a	6.5a	6.1a
1982	LOPE	22.1b	24.7b	27.0b	28.2b	10.4a	26.1a	24.8a	24.1a
	FEAR	3.8a	3.0a	4.7a	4.5a	2.1a	4.0a	4.0a	4.1a
	TRSU	70.3b	63.4b	62.9b	68.2b	8.3a	67.9a	66.0a	64.7a
	Others ²	3.8a	8.9a	5.4a	4.2a	79.2b	2.0a	5.2a	7.1a

¹Means in each row and within each category followed by different letters differ (P<.05).

²Mainly consisted of annual grasses.

seed crop on defoliated plots. Such an effect would be especially significant for annual clovers such as subclover which must be reestablished from seed each year.

Similar reductions in the canopy cover of perennial ryegrass among all defoliation treatments during the 1980 to 1982 period suggested that this phenomenon was not related to severity of defoliation. The average life expectancy of perennial ryegrass plants is approximately 5 years (Calmin and Stewart 1976). Thus, in the absence of reproduction, one would expect a 20% reduction in perennial ryegrass each year due to natural mortality events. This is approximately what we observed. Seed production was largely prevented by harvesting of plots prior to seed formation on all defoliation treatments. While perennial ryegrass plants on control plots produced seed, few seedlings became established. A general chlorotic appearance of the grass seedlings in the control, as compared to those on the defoliated plots in early spring was investigated by microKjeldal analysis (AOAC 1970) for comparison of tissue nitrogen content of these seedlings. The average nitrogen concentration of ryegrass plants inside the treated plots was 4.2%. This was significantly ($P < 0.01$) different from the 2.8% nitrogen content of ryegrass seedlings in control plots. Nitrogen deficiency is believed to have contributed to seedling mortality in control plots.

Lower density of perennial ryegrass plants at the end of the experiment on control plots compared to all defoliation treatments (Table 5-3) suggests that a higher rate of mortality occurred for

Table 5-3. Mean density, basal area, plant, basal area/m², and root weight, plant in plots under defoliation interval (DI = 7, 21, 35 or 49 days between two consecutive defoliations) and stubble height (SH = 70, 55, or 40 mm stubble remaining) treatments and in control plots measured at end of experiment in 1982.

Source	DI treatments (days)				Control	SH treatments (mm)		
	7	21	35	49		70	55	40
Density (plants/m ²)	29.8b	42.1c	42.0c	30.0b	9.0a	39.3a	35.0a	33.7a
Basal area (cm ² /plant)	14.0b	14.0b	15.9b	13.5b	9.6a	13.6a	16.6a	12.9a
Basal area (cm ² /m ²)	417.2b	584.4c	667.8c	405.0b	86.4a	534.5b	581.0b	434.7a
Root weight (g/plant)	2.3a	4.2b	6.7c	6.9c	11.5d	5.5a	5.2a	4.5a

¹Means in each row and within each category followed by different letters differ (P<.05).

undefoliated than for defoliated plants. The extent to which increased mortality of undefoliated plants may be attributed to lower soil nitrogen on control plots due to reduction of the nitrogen-fixing clover component, and/or to shading effects within undefoliated swards is unclear. Average basal areas of perennial ryegrass plants from defoliated plots were consistently greater ($P < .05$) than those from control plots. Survival and basal area expansion of existing perennial ryegrass plants may have been reduced on control plots by lack of sufficient light at the plant bases to stimulate production of new tillers. Lack of adequate light at the base of perennial ryegrass plants has been reported to hasten tiller death and to prevent the initiation of new tillers (Wilman et al. 1976, Ong 1978, Ong et al. 1978).

In contrast to canopy cover and species composition which did not differ between defoliation treatments, differences in plant density were evident between DI treatments (Table 5-3). The relationship between plant density and DI was parabolic (Figure 5-1) with maximum density occurring at a DI of 29 days. Similar to control plots, reduction in perennial ryegrass density as DI increased beyond 29 days likely reflects inhibition of tillering due to low light levels under the dense canopy present on these plots. Reduced perennial ryegrass density as DI was reduced below 29 day is believed to result from an inability of frequently defoliated plants to maintain adequate leaf area to accumulate necessary carbohydrate reserves and to support a strong root system (El Hassan 1979). The stubble height

Figure 5-1. Relationship ($r^2 = 0.65$) between density of perennial ryegrass plants and defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes at the end of experiment in 1982. Density = $19.23 + 1.72 (DI) - 0.03 (DI)^2$.

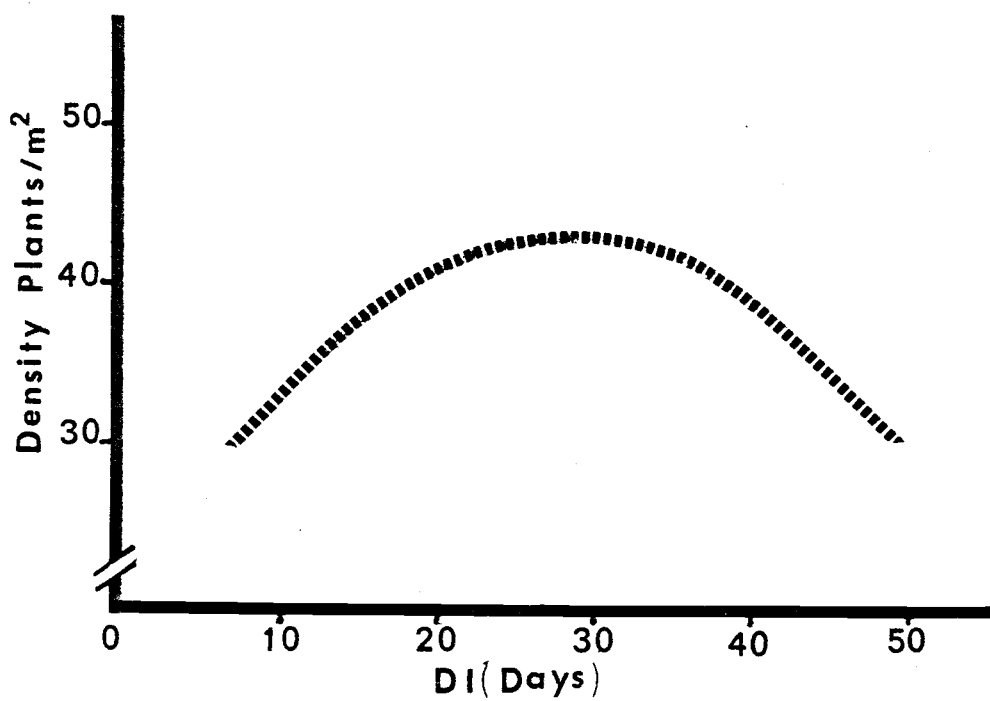


Figure 5-1

regimes had no ($P > .05$) apparent effect on the persistence of perennial ryegrass. In addition, no DI x SH interaction was evident.

Average basal area per perennial ryegrass plant did not differ ($P > .05$) among DI or SH treatments. Total basal area of perennial ryegrass plants per m^2 , however was greater ($P < .05$) for DI21 and DI35 than for DI7 or DI49 treatments. This difference reflected the greater plant density of DI21 and DI35 plots. Total basal area per m^2 was less under Low than under Medium or High SH defoliations. Treatment differences in plant density and total basal area per m^2 were not reflected in percent canopy cover. This suggests that lower total basal areas of DI7 and DI49 treatments were compensated for by the display of more canopy cover per unit of basal area.

Root weights of perennial ryegrass plants at the end of the trial in July 1982 are presented in Table 5-3. Perennial ryegrass appears to be a relatively shallow rooted species. Our preliminary survey of root distribution indicated that 95% of perennial ryegrass roots biomass occurred in the surface 15 cm of soil. Only 4.5% and 0.5% of the total root biomass harvested were contained in the 15 to 30 and 30 to 45 cm soil depths, respectively. Therefore, our 30 cm deep soil cores should have been adequate to capture almost all of the root system.

Varying SH from 40 to 70 mm of stubble remaining after defoliation had no effect ($P > .05$) on root biomass. Root biomass was sensitive to DI, increasing linearly by 0.11 gram per day as days between defoliation events increased from 7 to 49 (Figure 5-2).

Such sensitivity is not surprising as defoliation may temporarily stop root growth (Crider 1955). Reduction in root growth would be especially detrimental to a plant such as perennial ryegrass whose roots live only a few months to a year (Stucky 1941, Garwood 1967, Troughton 1981) before they must be replaced. The greatest root biomass occurred on control plots. Extrapolation from the equation relating root biomass to DI (Figure 2) predicts a root biomass of 11.1 grams per plant for control plots. This is reasonably close to the actual value obtained from these plots. Many authors have attributed observed reductions in the size and longevity of grass root systems to severe defoliation treatments (Crider 1955, Baker 1957, Hodgkinson and Baas Becking 1977). Brougham (1970) stressed the importance of defoliation induced reductions in perennial ryegrass root systems as a factor contributing to plant mortality during the summer period. Presumably increased mortality due to a reduction of root biomass as DI decreased contributed to the observed decline in plant density as DI was reduced below 29 days between defoliation events.

Management Implications

Percent canopy cover of perennial ryegrass decreased while that of subclover increased steadily over the three years of this trial on all defoliation treatments. Decline of perennial ryegrass and its replacement by subclover, to a certain extent, is desirable as it

Figure 5-2. Relationship ($r^2 = 0.84$) between mean root weight at the end of experiment in 1982 of perennial ryegrass plants and defoliation interval (DI = 7, 21, 35, or 49 days between two consecutive defoliations) regimes. Mean root weight = $1.85 + 0.11$ (DI).

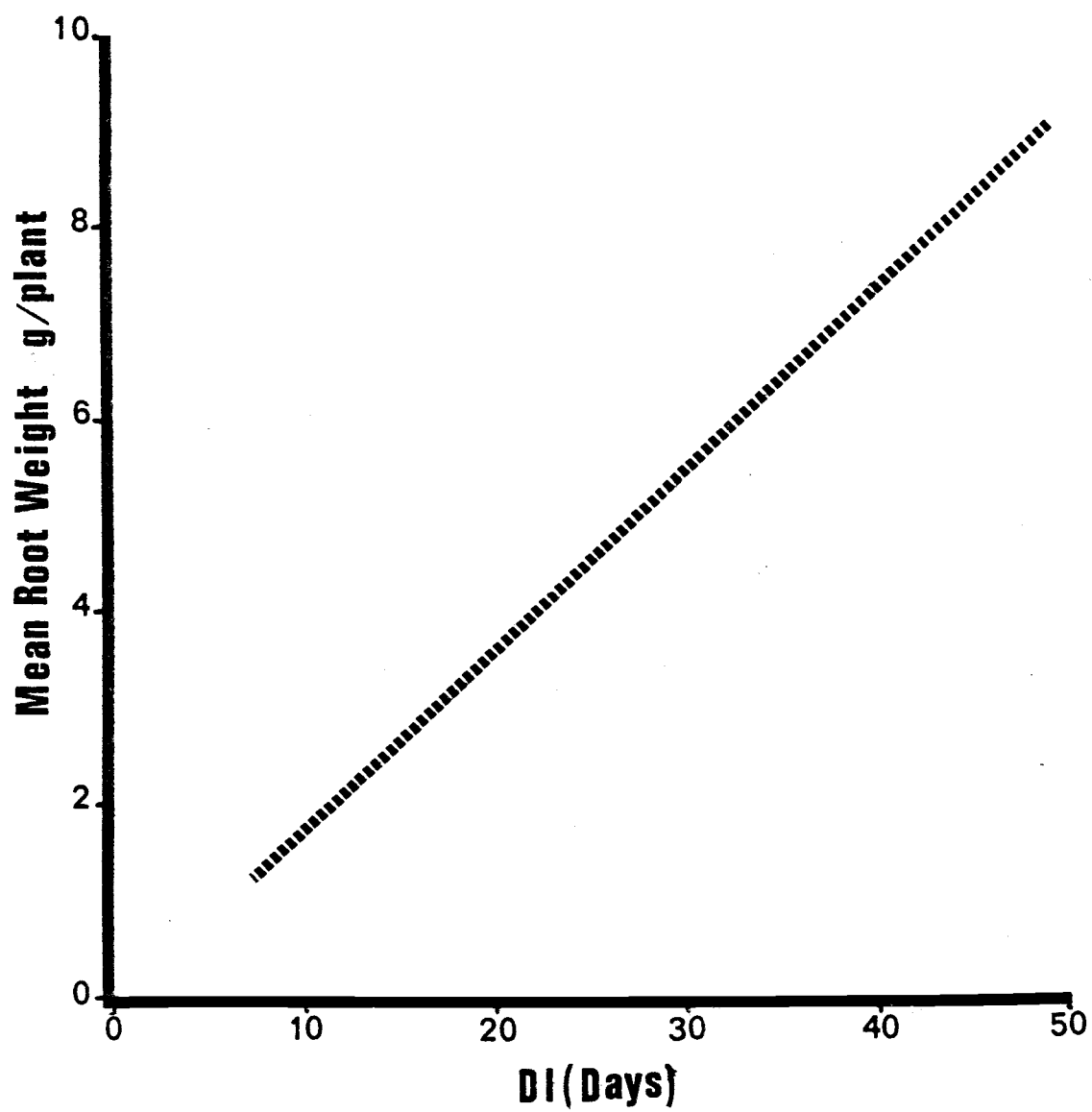


Figure 5-2

tends to improve forage quality. A ratio of 60-70% grass and 30-40% clover is generally considered to be optimum for production of both quantity and quality of forage in livestock production systems (Harris and Thomas 1973, Curll 1981). By the second year of our study, perennial ryegrass was already well below optimum levels on all defoliation treatments. If the observed rate of decline continued, perennial ryegrass would be practically eliminated from the plots within five years. Clearly, if a favorable grass-clover balance is to be achieved and maintained factors affecting plant natality and mortality must be considered in designing production systems.

The data presented here suggest the following points which may be useful in designing pasture management systems:

- 1) Some defoliation during the growing season is necessary to maintain subclover in high producing swards. The exact timing and intensity of defoliation over the range of values tested was not particularly important in this regard. However, simply removing the overburden of old unharvested forage prior to the advent of fall rains was not sufficient to perpetuate the clover stand.

- 2). Perennial ryegrass is a short lived perennial which appears to be highly dependent upon seed production for perpetuation of the stand over time. In the absence of seed production, it will disappear from the stand within 5 to 6 years.

- 3). Mortality of perennial ryegrass plants is affected by defoliation regime. Density of perennial ryegrass plants at the end of

the experiment was not affected by SH regimes. Defoliation interval, however, did affect plant density. Decreased plant density, presumably reflecting increased mortality of perennial ryegrass plants under frequent defoliation was associated with reduced root biomass. Mortality was also high on plots which were defoliated infrequently, presumably due to lack of new tiller formation as evidenced by low plant basal areas. Evidently, defoliation plays a role in maintaining adequate root/top ratios of perennial ryegrass plants. Deviation from the optimum DI of 29 days resulted in decreased plant density. The actual effects of DI on the proportion of perennial ryegrass in the stand over time, however, are believed to be small compared to changes induced by lack of seed production.

These data indicate that canopy cover and species composition of perennial ryegrass-subclover stands are not particularly sensitive to either DI or SH treatments. The short duration grazing practice of increasing defoliation interval at the expense of reduced stubble height, in order to increase forage production, appears to be possible without affecting species composition. Long periods between defoliation events ($DF > 29$ days) may tend to reduce density of perennial ryegrass plants. This effect, however, is minor compared to that due to inability of perennial ryegrass to produce seed under all of our defoliation patterns. If perennial ryegrass is to be maintained in a pasture, defoliation regimes must be modified to ensure that seed production occurs. This could be accomplished in practice by adjustments in either the speed of rotation from paddock

to paddock, or by reducing the stocking rate slightly. More information concerning the population dynamics of grasses and clovers growing together in mixed swards is required before precise grazing management strategies can be planned and management recommendations made.

Literature Cited

- Association of official analytical chemists (AOAC). 1970. Official methods of analysis (11th edition). Washington, D.C.
- Baker, H. K. 1957. Studies on the root development of herbage plants. III. The influence of cutting treatments on the root, stubble and herbage production of a perennial ryegrass sward. J. British Grass. Soc. 12:197-208.
- Brougham, R. W. 1960. The effect of frequent hard grazings at different times of the year on the productivity and species yields of a grass-clover pasture. New Zealand J. Agric. Res. 3:125-136.
- Brougham, R. W. 1970. Frequency and Intensity of grazing and their effects on pasture production. Proceedings N.Z. Grass. Assoc. 32:137-144.
- Calmin, M. S., and R. H. Stewart. 1976. The assessment of persistence and its application to the evaluation of early perennial ryegrass cultivars. J. British Grass. Soc. 13:1-6.
- Cameron, I. H., and D. J. Cannon. 1970. Changes in botanical composition of pasture in relation to rate of stocking with sheep, and consequent effects on wood production. Proc. XI Int. Grassland Congr. 640-643.
- Collins, W. J. 1978. The effect of defoliation on inflorescence, production, seed yield and hard-seededness in swards of subterranean clover. Aust. J. Agric. Res. 29:789-901.
- Collins, W. J., R. C. Rossiter, and A. R. Monreal. 1978. The influence of shading on seed yield in subterranean clover. Aust. J. Agric. Res. 29:1167-1175.
- Crider, F. J. 1955. Root-growth stoppage resulting from defoliation of grass. USDA Tech. Bull. 1102, 22 pages.
- Curll, M. L. 1981. The effect of grazing by set-stocked sheep on a perennial ryegrass, white clover pasture. Thesis abstract. In. herbage abstract: 51 #355.
- El Hassan, B. A. 1977. The impact of three stocking intensities and four grazing treatments on the carbohydrate reserve of perennial ryegrass (Lolium perenne L.). Ph.D. dissertation. Oregon State Univ., Corvallis, OR. 91 numb. leaves.

- Evers, G. W. 1983. Weed control on warm season perennial grass pastures with clovers. *Crop Sci.* 23:170-171.
- Garwood, E. A. 1967. Seasonal variation in appearance and growth of grass roots. *J. British Grass. Soc.* 22:121-129.
- Harris, W. 1978. Defoliation as a determinant of the growth, persistence, and composition of pasture, P. 67-94. In: J. R. Wilson (editor), *Plant relations in pastures*. CSIRO, Melbourne, Australia.
- Harris, W. and V. J. Thomas. 1973. Competition among pasture plants. III. Effects of frequency and height of cutting on competition between white clover and two ryegrass cultivars. *N.Z. J. Agric. Res.* 16:49-58.
- Hedrick, D. W. 1964. Response of an orchardgrass-subclover mixture in western Oregon to different clipping and fertilizing practice. *J. Range Mgmt.* 17:148-152.
- Hodgkinson, K. C., and H. G. Baas Becking. 1977. Effect of defoliation on root growth of some arid zone perennial plants. *Aust. J. Agric. Res.* 29:31-42.
- National Oceanic and Atmospheric Administration (NOAA). 1973. Oregon monthly normals of temperature, precipitation, and heating and cooling degree days. 1941-1970. U.S. Department of Commerce, National Climatic Center. Asheville, North Carolina.
- National Oceanic and Atmospheric Administration (NOAA). 1980, 1981, 1982. Oregon climatological data. Annual Summary. (Corvallis, State Univ.). Dept. of Commerce, National Climatic Center, Asheville, North Carolina.
- Neter, J., and W. Wasserman. 1974. *Applied linear statistical models*. R. D. Irwin, Inc. Homewood, Illinois.
- Ong, C. K. 1978. The physiology of tiller death in grasses. I. The influence of tiller age, size and position. *J. British Grass. Soc.* 33:197-203.
- Ong, C. K., C. Marshall, and G. R. Sager. 1978. The physiology of tiller death in grasses - 2. Causes of tiller death in a grass sward. *J. British Grass. Soc.* 33:205-211.
- Sharrow, S. H., W. C. Krueger, and F. O. Thetford. 1981. Effect of stocking rate on sheep and hill pasture performance. *J. Animal Sci* 52:210-217.
- Sharrow, S. H., and D. A. Tober, 1979. A simple lightweight point frame. *J. Range Mgmt.* 32:75-76.

- Smetham, M. L. 1977. Grazing management, p. 178-228. In. R. H. M. Langer (editor), Pastures and pasture plants. A. H. and A. W. Reed, London.
- Steel, R. G. O., and J. H. Torrie. 1980. Principles and procedures of statistics. Second edition. McGraw-Hill Book Company, New York.
- Stuckey, Irene H. 1941. Seasonal growth of grass roots. American J. Bot. 28:486-491.
- Troughton, A. 1981. Length of life of grass roots. Grass and Forage Sci. 36:117-120.
- Wilman, O.; A. Koocheki, and A. B. Lwoga. 1976. The effect of interval between harvests and nitrogen application on the proportion and yield of crop fractions and on the digestibility and digestible yield and nitrogen content of two perennial ryegrass varieties in the second harvest year. J. Agric. Sci. 87:59-74.
- Wilman, D., and J. E. Asiegbu. 1982. The effect of clover variety, cutting interval and nitrogen application on herbage yields proportions and heights in perennial ryegrass-white clover swards. Grass and Forage Sci. 33:1-13.

LITERATURE CITED

- Alberda, Th. 1966. The influence of reserve substances on dry-matter production after defoliation. Proceedings of the 10th International Grassland Congress: 140-147.
- Allinson, D. W., M. B. Teser, and J. W. Thomas. 1969. Influence of cutting frequency, species, and nitrogen fertilization on forage nutritional value. *Crop Sci.* 9:504-508.
- Anslow, R.C. 1967. Frequency of cutting and sward production. *J. Agric. Sci.* 68:377-384.
- Appadurai, R. R., and Holmes. 1964. The influence of stage of growth, closeness of defoliation, and moisture on the growth and productivity of ryegrass-white clover sward. I. Effect on herbage yields. *J. Agric. Sci.* 62:327-332.
- Association of Official Analytical Chemists (AOAC). 1970. Official methods of analysis (11th edition). Washington, D.C.
- Baker, H. K. 1957. Studies on the root development of herbage plants. III. The influence of cutting treatments on the root, stubble and herbage production of a perennial ryegrass sward. *J. British Grass. Soc.* 12:197-208.
- Baker, B.S., T.V. Eynden, and N. Boggess. 1981. Hay yield determinations of mixed swards using a disk meter. *Agron. J.* 73:67-69.
- Bartholomew, P.W., and D.M.B. Chestnutt. 1977. The effect of a wide range of fertilizer nitrogen application rates and defoliation intervals on the dry-matter production, seasonal response to nitrogen, persistence and aspects of chemical composition of perennial ryegrass (*Lolium perenne*, CV.S.24) *J. Agric. Sci.* 88:711-721.
- Beddows, A.R. 1968. Head emergence in forage grasses in relation to February-May temperature and the predicting of early or late springs. *J. British Grass. Soc.* 23:88-97.
- Bedell, T. E. 1971. Nutritive value of forage and diets of sheep and cattle from Oregon subclover-grass mixtures. *J. Range Mgt.* 24:125-133.

- Binnie, R. C. and F. J. Harrington. 1972. The effect of cutting height and cutting frequency on the productivity of an Italian ryegrass sward. *J. British Grass. Soc.* 27:177-182.
- Bland, B.F. 1967. The effect of cutting frequency and root segregation on the yield from perennial ryegrass-white clover association. *J. Agric. Sci.* 69:391-397.
- Boswell, C. C. 1977. Effect of cutting regime on pasture production New Zealand *J. of Exp. Agric.* 5:403-408.
- Briseno De La Hoz, V.M., and D. Wilman. 1981. Effects of cattle grazing, sheep grazing, cutting and sward height on a grass-white clover sward. *J. Agric. Sci.* 97:699-706.
- Brougham, R. W. 1956. Effect of intensity of defoliation on regrowth of pasture. *Australian J. Agric. Res.* 7:377-387.
- Brougham, R. W. 1959. The effect of frequency and intensity of grazing on the productivity of a pasture of short-rotation ryegrass and red and white clover. *New Zealand J. of Agric. Res.* 2:1232-1248.
- Brougham, R. W. 1960a. The effect of frequent hard grazings at different times of the year on the productivity and species yields of a grass-clover pasture. *New Zealand J. Agric. Res.* 3:125-136.
- Brougham, R. W. 1960b. The relationship between the critical leaf area, total chlorophyll content and maximum growth rate of some pasture and crop plants. *Ann. of Botany* 24:463-473.
- Brougham, R. W. 1970. Frequency and Intensity of grazing and their effects on pasture production. *Proceedings N.Z. Grass. Assoc.* 32:137-144.
- Brown, R. H., and R. E. Blaser. 1968. Leaf area index in pasture growth. *Herb. Abst.* 38:1-9.
- Calmin, M. S., and R. H. Stewart. 1976. The assessment of persistence and its application to the evaluation of early perennial ryegrass cultivars. *J. British Grass. Soc.* 13:1-6.
- Cameron, I. H., and D. J. Cannon. 1970. Changes in botanical composition of pasture in relation to rate of stocking with sheep, and consequent effects on wool production. *Proc. XI Int. Grassland Congr.* 640-643.

- Caminson, Juan, C. A. Raguse, and D. C. Summer. 1973. Effects of seed aggregation, nutrient availability, and temperature on germination of subterranean clover (Trifolium subterraneum L.) Agron. J. 65:1002-1003.
- Charles, A. H. 1973. A comparison of ryegrass populations from intensively managed permanent pasture and leys. J. Agric. Sci. 81:99-106.
- Chestnutt, D. M. B., J. C. Murdoch, F. J. Harrington, and R. D. Binnie. 1977. The effect of cutting frequency and applied nitrogen on production and digestibility of perennial ryegrass. J. British Grass. Soc. 32:177-183.
- Clark, J., C. Kat, and K. Santhirasegaram. 1974. The effects of changes in heights of cutting and growth on the digestible organic matter production and botanical composition of perennial pasture. J. British Grass. Soc. 29:269-273.
- Cocks, P. S. 1974. Potential production of grass and clover monocultures in a Mediterranean-type environment--an experimental approach. Australian J. Agric. Res. 25:835-846.
- Collins, W. J. 1978. The effect of defoliation on inflorescence, production, seed yield and hard-seededness in swards of subterranean clover. Aust. J. Agric. Res. 29:789-901.
- Collins, W. J., R. C. Rossiter, and A. R. Monreal. 1978. The influence of shading on seed yield in subterranean clover. Aust. J. Agric. Res. 29:1167-1175.
- Cooper, C. S. 1959. The effect of time and height of cutting on the yield, crude protein content and vegetative composition of a native flood meadows in eastern Oregon. Agron. J. 48:257-258.
- Cooper, J. P. 1970. Potential production and energy conversion in temperate and tropical grasses. Herb. Abst. 40:1-15.
- Cowling, D. W., and D. R. Locker. 1970. The response of perennial ryegrass to nitrogen in various periods of the growing season. J. Agric. Sci. 75:539-546.
- Crider, F. J. 1955. Root-growth stoppage resulting from defoliation of grass. USDA Tech. Bull. 1102, 22 pages.
- Curll, M. L. 1981. The effect of grazing by set-stocked sheep on a perennial ryegrass, white clover pasture. Thesis abstract. In. herbage abstract: 51 #355.

- Cuykendall, C. H., and G. C. Marten. 1968. Defoliation by sheep-grazing versus mower-clipping for evaluation of pasture. *Agron. J.* 60:404-408.
- Dahl, B. E., and D. N. Hyder. 1977. Developmental morphology and management implications. P. 257-290. In: *Rangeland Plant Physiology*. R. E. Sosebee (editor). Society for Range Management. Denver, Colorado.
- Davidson, J. L., and J. W. Brich. 1972. Effects of defoliation on growth and carbon dioxide exchange of subterranean clover swards. *Aust. J. Agric. Res.* 23:981-993.
- Davidson, J. L., and C. M. Donald. 1958. The growth of swards of subterranean clover with particular reference of leaf area. *Aust. J. Agric. Res.* 9:53-72.
- Davidson, J. L., and F. L. Milthrope. 1965. Carbohydrate reserves in the regrowth of cocksfoot (*Dactylis glomerata* L.) *J. British Grass. Soc.* 20:15-18.
- Davies, W. E. 1973. The potential contribution of forage legumes to the nitrogen-protein-energy crisis. Report of the Welsh plant breeding station: 103-110.
- Dawson, M. D. and W. S. McGuire. 1973. Grass-clover pastures and livestock production in Oregon. Summary of reports 1973 sheep and wool day. Special report 382. Agric. Experiment Sta. Oregon State Univ. Corvallis. 13 pages.
- Donald, C. M., and J. N. Black. 1958. The significance of leaf area in pasture growth. *Herb. Abst.* 28:1-7.
- Edelsten, P. R., and A. J. Corrall. 1979. Regression models to predict herbage production and digestibility in a non-regular sequence of cuts. *J. Agric. Sci.* 92:575-585.
- El Hassan, B. A. 1977. The impact of three stocking intensities and four grazing treatments on the carbohydrate reserve of perennial ryegrass (*Lolium perenne* L.) Ph.d. dissertation, Oregon State Univ., Corvallis, OR. 91 numb. leaves.
- Ellis, W. C. 1978. Determinants of grazed forage intake and digestibility *J. Dairy Sci.* 61:1828-1840.
- Evers, G. W. 1983. Weed control on warm season perennial grass pastures with clovers. *Crop Sci.* 23:170-171.

- Gammon, D. M., and B. R. Roberts. 1978. Patterns of defoliation during continuous and rotational grazing of the matops sandveld of Rhodesia. 1. Selectivity of grazing. *Rhod. J. Agric. Res.* 16:117-131.
- Garwood, E. A. 1967. Seasonal variation in appearance and growth of grass roots. *J. British Grass. Soc.* 22:121-129.
- Gibb, M. J. and T. T. Treacher. 1978. The effect of herbage allowance on herbage intake and performance of ewes and their twin lambs grazing perennial ryegrass. *J. Agr. Sci., Camb.* 90:139-147.
- Grant, S. A., G. T. Barthram, and L. Trovell. 1981. Components of regrowth in grazed and cut *Lolium perenne* swards. *Grass and Forage Sci.* 36:155-168.
- Hamilton, B. A., K. J. Hutchinson, P. C. Annis and J. B. Donnelly. 1973. Relationships between the diet selected by grazing sheep and the herbage on offer. *Aust. J. Agr. Res.* 24:271-277.
- Harris, W. 1971. The effect of density, cutting height and white clover (*Trifolium repens* L.) on the structure of a ryegrass (*Lolium spp.*) population. *J. Agric. Sci.* 77:385-395.
- Harris, W. 1978. Defoliation as a determinant of the growth, persistence, and composition of pasture, P. 67-94. In. J. R. Wilson (editor), *Plant relations in pastures*. CSIRO, Melbourne, Australia.
- Harris, W., and V. J. Thomas. 1970. Competition among pasture plants. I. Effects of frequency and height of cutting on competition between two ryegrass cultivars. *N.Z. J. Agric. Res.* 13:833-861.
- Harris, W. and V. J. Thomas. 1973. Competition among pasture plants. III. Effects of frequency and height of cutting on competition between white clover and two ryegrass cultivars. *New Zealand J. of Agric. Res.* 16:49-58.
- Heath, M. E., D. S. Metcalfe, and R. F. Barnes. 1973. *Forages*. The Iowa State University Press, Ames, Iowa.
- Hedrick, D. W. 1964. Response of an orchardgrass-subclover mixture in western Oregon to different clipping and fertilizing practices. *J. Range Mgt.* 17:148-152.
- Hodgkinson, K. C., and H. G. Baas Becking. 1977. Effect of defoliation on root growth of some arid zone perennial plants. *Aust. J. Agric. Res.* 29:31-42.

- Hogland, J. H., J. R. Crush, J. L. Brock, and R. Ball. 1979. Nitrogen fixation in pasture. XII. General discussion. N.Z. J. of Exp. Agric. 7:45-51.
- Humphreys, L. R. 1966. Pasture defoliation practice: A review. J. Aust. Instit. of Agric. Sci. 32:93-105.
- Ludlow, M. M. and D. A. Charles-Edwards. 1980. Analysis of regrowth of a tropical grass/legume sward subjected to different frequencies and intensities of defoliation. Aust. J. Agric. Res. 31:673-692.
- Keatinge, J. D.H., R. H. Stewart, and M. K. Garrett. 1979. The influence of temperature and soil water potential on the leaf extension rate of perennial ryegrass in N. Ireland. J. Agric. Sci. 92:175-183.
- King, J., W. I. C. Lamb, and M. T. McGregor. 1979. Regrowth of ryegrass swards subject to different cutting regimes and stocking densities. Grass and Forage Sci. 34:107-118.
- Knutti, H. J., and M. Hidioglou. 1967. The effect of cutting and nitrogen treatments on yield, protein and certain morphological characteristics of timothy and smooth brome grass. J. British Grass. Soc. 22:35-41.
- Korte, C. J., B. R. Watkins and W. Harris. 1982. Use of residual leaf area index and light interception as criteria for spring-grazing management of a ryegrass-dominated pasture. N.Z.J. of Agric. Res. 25:309-319.
- Kydd, D. D. 1966. The effect of intensive sheep stocking over a five-year period on the development and production of the sward. J. British Grass. Soc. 21:284-288.
- Lucanus, R., K. J. Mitchell, G. G. Pritchard, and D. M. Calder. 1960. Factors influencing survival of strains of ryegrass during the summer. N. Z. J. Agric. Res. 3:185-193.
- Ludlow, M. M. and D. A. Charles-Edwards. 1980. Analysis of regrowth of a tropical grass, legume sward subjected to different frequencies and intensities of defoliation. Aust. J. Agric. Res. 31:673-692.
- Matches, A. G. 1968. Performance of four pasture mixtures defoliated by mowing or grazing with cattle or sheep. Agron. J. 60:281-285.

- May, L. H. 1960. The utilization of carbohydrate reserves in pasture plants after defoliation. *Herb. Abst.* 30:239-245.
- Minson, D. J., W. F. Raymond, and C. E. Harris. 1960. Studies in the digestibility of herbage. VIII. The digestibility of S37 Rocksfoot, S23 ryegrass and S24 ryegrass. *J. British Grass. Soc.* 15:174-180.
- Morley, F. H. W. 1961. Subterranean Clover. *Advances in Agron.* 13:58-117.
- Morley, F. H. W. 1968. Pasture growth curves and grazing management. *Aust. J. Exp. Agr. Anim. Husb.* 8:40-43.
- Morris, R. M. 1969. The pattern of grazing in continuously grazed swards. *J. British Grass. Soc.* 24:65-70.
- Moser, L. E. 1977. Carbohydrate translocation in range plants P. 47-71. In: *Rangeland Plant Physiology*. R. E. Sosebee (editor). Society for Range Management, Denver, Colorado.
- Mowat, D. N., R. S. Fulkerson, W. E. Tossell, and J. E. Winch. 1965. The in vitro digestibility and protein content of leaf and stem portions of forages. *Canadian J. Plant Sci.* 45:321-331.
- National Oceanic and Atmospheric Administration (NOAA). 1973. Oregon monthly normals of temperature, precipitation, and heating and cooling degree days. 1941-1970. U.S. Department of Commerce, National Climatic Center. Asheville, North Carolina.
- National Oceanic and Atmospheric Administration (NOAA). 1980, 1981, 1982. Oregon climatological data. Annual Summary. (Corvallis, State Univ.). Dept. of Commerce, National Climatic Center, Asheville, North Carolina.
- Neter, J., and W. Wasserman. 1974. *Applied linear statistical models*. R. D. Irwin, Inc. Homewood, Illinois.
- Ollerenshaw, J. H. and D. R. Hodgson. 1977. The effects of constant and varying heights of cut on the yield of Italian ryegrass (*Lolium multiflorum* L.) and perennial ryegrass (*Lolium perenne* L.) *J. Agric. Sci.* 89:425-435.
- Ollerenshaw, J. H. and L. D. Incol. 1979. Leaf photosynthesis in pure swards of two grasses (*Lolium perenne* and *Lolium multiflorum*) subjected to contrasting intensities of defoliation. *Ann. Applied Biology.* 92:133-142.

- Ong, C. K. 1978. The physiology of tiller death in grasses. I. The influence of tiller age, size and position. J. British Grass. Soc. 33:197-203.
- Ong, C. K., C. Marshall, and G. R. Sager. 1978. The physiology of tiller death in grasses - 2. Causes of tiller death in a grass sward. J. British Grass. Soc. 33:205-211.
- Pook, E. W., and A. B. Costin. 1970. Changes in pattern and density of perennial grasses in an intensively grazed sown pasture influenced by drought in southern New South Wales. Aust. J. Exp. Agric. and Anim. Husb. 10:286-292.
- Reid, D. 1959. Studies on the cutting management of grass-clover swards. I. The effect of varying the closeness of cutting on the yields from an established grass-clover swards. J. Agric. Sci. 53:299-312.
- Reid, D. 1966. Studies on the cutting management of grass-clover swards. IV. The effect of close and lax cutting on the yield of herbage from swards cut at different frequencies. J. Agric. Sci. 66:101-106.
- Reid, D. 1967. Studies on the cutting management of grass-clover swards. V. The effect of changes in closeness of cutting at different times in the season on the yield and quality of herbage from a perennial ryegrass - white clover sward. J. Agric. Sci. 68:249-254.
- Reid, D. 1968. Studies on the cutting management of grass-clover swards. VI. The effects of different closeness and frequency of cutting treatments on the yield and quality of herbage from a cocksfoot/white clover sward. J. Agric. Sci. 70:59-64.
- Reid, D. 1972. The effects of the long-term application of a wide range of nitrogen rates on yield from perennial ryegrass swards with and without clover. J. Agric. Sci. 79:281-301.
- Reid, D. 1978. The effects of frequency of defoliation on the yield response of a perennial ryegrass sward to a wide range of nitrogen application rates. J. Agric. Sci. 90:447-457.
- Rhodes, I. 1975. The relationship between productivity and some components of canopy structure in ryegrass (*Lolium* spp.). IV. Canopy characters and their relationships with sward yields in some intra population selections. J. Agric. Sci. 84:345-351.
- Rossiter, R. C. 1972. The effect of defoliation on flower production in subterranean clover. Aust. J. Agric. Res. 23:427-435.

- Sharrow, S. H., and D. A. Tober, 1979. A simple lightweight point frame. *J. Range Mgmt.* 32:75-76.
- Sharrow, S. H. and W. C. Krueger. 1979. Performance of sheep under rotational and continuous grazing on hill pastures. *J. Anim. Sci.* 49:893-899.
- Sharrow, S. H., W. C. Krueger, and F. O. Thetford. 1981. Effect of stocking rate on sheep and hill pasture performance. *J. Animal Sci* 52:210-217.
- Sheehy, J. E., J. M. Cobby, and G. J. A. Ryle. 1979. The growth of perennial ryegrass: A model. *Ann. Bot.* 43:335-354.
- Simons, R. G., A. Divies, and A. Troughton. 1972. The effect of the height of defoliation on two clones of perennial ryegrass. *J. Agric. Sci.* 79:509-514.
- Smetham, M. L. 1977a. Grazing management. P. 179-228. In R. H. M. Langer editor. *Pastures and pasture plants*. A. H. and A. W. Reed Publishing, Sydney.
- Smetham, M. L. 1977b. Pasture legume species and strains. p. 85-127 In R. H. M. Langer (editor), *Pastures and pasture plants*. A. H. and A. W. Reed, London.
- Steel, R. G. O. and J. H. Torrie. 1980. Principles and procedures of statistics. Second edition. McGraw-Hill book company. New York.
- Stern, W. R., and C. M. Donald. 1962. Light relationships in grass-clover sward. *Aust. J. Agric. Res.* 13:599-614.
- Stuckey, Irene H. 1941. Seasonal growth of grass roots. *American J. Bot.* 28:486-491.
- Swift, G., and R. A. Edwards. 1980. Effect of spring grazing on the yield and quality of perennial ryegrass (*Lolium perenne*) and cocksfoot (*Dactylis glomerata*) cut for conservation. *Grass and Forage Sci.* 35:301-309.
- Taylor, J. C., and J. E. Rudman. 1966. Height and method of cutting or grazing in relation to herbage consumption and live-weight gain. *Proc. 9th Intern. Grassland Congress Sao Pawo* pp. 1639-1644.
- Thetford, F. O. 1976. Responses of vegetation and sheep to three grazing pressures. Ph.D. Dissertation. Oregon State University, Corvallis, Oregon. 157 numb leaves.

- Thomas, H. 1980. Terminology and definitions in studies of grassland plants. *Grass and Forage Sci.* 35:13-23.
- Thomas, H., and I. B. Norris. 1981. The influence of light and temperature during winter on growth and death in simulated swards of Lolium perenne. *Grass and Forage Sci.* 36:107-116.
- Tilley, J. M. A., and R. A. Terry, 1969. The relationship between the soluble constituents of herbage and their dry-matter digestibility. *J. British Grass. Soc.* 24:290-295.
- Troughton, A. 1981. Length of life of grass roots. *Grass and Forage Sci.* 36:117-120.
- Ulyatt, M. J. 1970. Evaluation of pasture quality under New Zealand conditions. *Proc. N.Z. Grassld. Assoc.* 32:61-68.
- Vartha, E. W. 1978. Annual and seasonal growth of grasslands 4710, and Aberystwyth S. 170 tall fescues and grasslands Ariki ryegrass at Lincoln and Kirwee, Canterbury. *N.Z. J. Exp. Agric.* 6:157-160.
- Vickery, P. J., Brink, V. C. and Ormrod. 1971. Net photosynthesis and LAI relationships in swards of *Dactylis glomerata* under contrasting defoliation regimes. *J. British Grass. Soc.* 26:85-90.
- Waite, R. 1970. The structural carbohydrates and the in vitro digestibility of a ryegrass and cocksfoot at two levels of nitrogen fertilizer. *J. Agric. Sci.* 74:457-462.
- Warner, J. R. 1983. Evaluation of three sheep-grazing systems on western Oregon hill pastures. M.S. Thesis. Oregon State Univ. Corvallis, Oregon. 124 numb. leaves.
- Weeda, W. C. 1965. The effect of frequency and severity of grazing by cattle on the yield of irrigated pastures. *New Zealand J. Agric. Res.* 8:1060-1069.
- Wilman, D. and J. E. Asiegbu. 1982. The effect of clover variety, cutting interval and nitrogen application on herbage yields, proportions and heights in perennial ryegrass-white clover swards. *Grass and Forage Sci.* 37:1-13.
- Wilman, D., D. Droushiotis, M. N. Mzamane, and J. S. Shim. 1977. The effect of interval between harvests and nitrogen application on initiation, emergence and longevity of leaves, longevity of tillers and dimensions and weights of leaves and stems in *Lolium*. *J. Agric. Sci.* 89:65-79.

- Wilman, D., A. Koocheki, and A. B. Lwoga. 1976a. The effect of interval between harvests and nitrogen application on the proportion and yield of crop fractions and on the digestibility and digestible yield and nitrogen content of two perennial ryegrass varieties in the second harvest year. *J. Agric. Sci.* 87:59-74.
- Wilman, D., A. Koocheki, A. B. Lwoga, D. Droushiotis, and J. S. Shim. 1976b. The effect of interval between harvests and nitrogen application on the numbers and weights of tillers and leaves in four ryegrass varieties. *J. Agric. Sci.* 87:45-57.
- Woodman, H. E., and J. Stewart. 1932. The mechanism of cellulose digestion in the ruminant organism. III. The action of cellulose-splitting bacteria on the fibre of certain typical feeding stuffs.
- Young, J. A., B. L. Kay, and R. A. Evans. 1970. Germination of cultivars of Trifolium subterraneum L. *Agron. J.* 62:638-641.

APPENDICES

Appendix A

Mean dry matter (Kg/ha) harvested at the assigned dates of the 1980 growing season from plots under 7, 21, 35, or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.

Date	Treatments											
	7H	7M	7L	21H	21M	21L	35H	35M	35L	49H	49M	49L
4/ 5/80	1624	2182	2264	1504	2257	2175	1954	2151	2423	1865	1702	2368
4/12/80	430	342	371									
4/19/80	614	385	411									
4/26/80	263	302	350	1588	1387	1197						
5/ 3/80	305	305	327									
5/10/80	335	240	246				4471	3209	3588			
5/17/80	249	320	291	998	962	1384						
5/24/80	240	265	278							7646	5653	6914
5/31/80	167	107	185									
6/ 7/80	122	167	167	590	755	698						
6/14/80	142	140	168				581	692	865			
6/21/80	142	125	167									
6/28/80	83	97	117	257	406	500						
7/ 5/80	75	83	75									
7/12/80	1939	653	211	1919	727	349	2618	1196	527	2991	1729	966

Appendix B

Mean dry matter (Kg/ha) harvested at the assigned dates of the 1981 growing season from plots under 7, 21, 35, or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.

Date	Treatments											
	7H	7M	7L	21H	21M	21L	35H	35M	35L	49H	49M	49L
3/24/81	614	583	794	788	641	497	601	770	644	425	658	666
3/31/81	36	177	178									
4/ 7/81	83	120	402									
4/14/81	144	322	217	417	820	1102						
4/21/81	205	349	293									
4/28/81	233	284	311				2101	2873	3467			
5/ 5/81	277	284	312	1530	2143	1752						
5/12/81	308	278	286							4904	6568	6574
5/19/81	289	309	380									
5/26/81	386	402	352	830	945	1178						
6/ 2/81	271	288	278				2088	1684	1736			
6/ 9/81	241	285	289									
6/16/81	153	166	174	740	942	761						
6/23/81	118	146	128									
6/30/81	105	137	156							1940	2826	2572
7/ 7/81	84	105	169	284	352	373	441	352	383			
7/14/81	83	82	75									
7/21/81	1552	671	267	2132	972	463	2098	903	465	2178	1150	613

Appendix C

Mean dry matter (Kg/ha) harvested at the assigned dates of the 1982 growing season from plots under 7, 21, 35, or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.

Date	Treatments											
	7H	7M	7L	21H	21M	21L	35H	35M	35L	49H	49M	49L
4/ 7/82	2103	2455	2182	2412	2344	2756	2204	2056	2338	2413	2437	2078
4/14/82	59	101	532									
4/21/82	178	480	323									
4/28/82	480	327	332	958	1646	1715						
5/ 5/82	294	318	288									
5/12/82	535	446	635				2454	3117	4059			
5/19/82	265	463	401	1174	918	851						
5/26/82	256	274	333							3796	4623	6124
6/ 2/82	96	140	174									
6/ 9/82	80	106	127	349	367	627						
6/16/82	120	156	159				888	1000	690			
6/23/82	125	157	146									
6/30/82	113	100	75	591	167	145						
7/ 7/82	752	343	251	877	442	344	1047	626	327	1514	869	607

Appendix D

Mean percent dry matter in vitro digestibility of herbage harvested at different dates of 1980, 1981, and 1982 growing seasons from plots under 7, 21, 35 or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.

Treatments and dates															
Date	7H	7M	7L	Date	21H	21M	21L	Date	35H	35M	35L	Date	49H	49M	49L
4/12/80	73	73	72	4/26/80	70	70	63	5/10/80	69	69	69	5/24/80	62	63	62
5/ 3/80	68	69	67	5/17/80	67	69	57	6/14/80	66	63	53				
5/17/80	67	68	60	6/ 7/80	68	67	47								
5/24/80	60	59	53	6/28/80	62	54	42								
6/28/80	54	55	55												
4/14/81	76	73	72	4/14/81	72	72	71	4/28/81	70	71	72	5/12/81	70	70	70
5/12/81	65	62	63	5/ 5/81	69	66	65	6/ 2/81	68	68	66	7/14/81	57	57	57
6/ 2/81	68	65	65	5/26/81	66	67	60	7/ 7/81	63	60	58				
6/23/81	66	63	61	6/16/81	67	64	62								
				7/ 7/81	64	59	52								
4/21/82	77	77	72	4/28/82	76	72	69	5/12/82	74	73	75	5/26/82	70	68	67
5/ 5/82	74	68	63	5/19/82	72	69	64	6/16/82	66	64	58				
5/26/82	69	65	66	6/ 9/82	69	67	59								
6/ 9/82	66	61	57												

Appendix E

Mean percent crude protein of forage harvested at different dates of the 1980, 1981, and 1982 growing seasons from plots under 7, 21, 35 or 49 day periods of defoliation interval and High (H), Medium (M), or Low (L) stubble height regimes.

Treatments and Dates															
Date	7H	7M	7L	Date	21H	21M	21L	Date	35H	35M	35L	Date	49H	49M	49L
4/12/80	24	23	20	4/26/80	19	20	20	5/10/80	12	14	14	5/24/80	10	11	11
5/ 3/80	22	22	10	5/17/80	19	17	17	6/14/80							
5/17/80	21	22	18	6/ 7/80	15	15	15								
5/24/80	17	18	15	6/28/80	13	14	12								
6/28/80	13	14	13												
5/12/80	25	24	21	4/14/81	22	22	21	4/28/81	22	20	19	5/12/81	17	17	16
5/26/81	23	23	20	5/ 5/81	20	20	20	6/ 2/81	18	18	18	5/14/81	11	10	10
6/23/81	21	22	21	5/26/81	24	22	20	7/ 7/81	14	12	12				
				6/16/81	19	18	18								
				7/ 7/81	17	16	18								
5/ 5/82	29	29	19	4/28/82	27	27	25	5/12/82	21	20	20	5/26/82	16	17	16
5/26/82	23	22	22	5/19/82	25	25	22	6/16/82	13	12	13				
6/ 9/82	22	20	19	6/ 9/82	18	18	17								

Appendix F

The Combined analysis of variance table consists of dry matter (DM), in vitro dry matter digestibility (IVDMD), digestible dry matter yield (DDM), percent crude protein (PCP), and crude protein yield (CPY) of forage produced under defoliation interval (DI) and stubble height (SH) regimes in 1980, 1981 and 1982.

Year	Source	DF	Mean squares				
			DM	IVDMD	DDM	PCP	CPY
1980	Block	2	387182.0	0.3	270891.0	0.1	145715.0
	DI	3	37912900.0	15.6	13759500.0	74.8	17221100.0
	SH	2	11142100.0	98.7	8668460.0	2.0	814227.0
	DI x SH	6	1514610.0	23.2	540073.0	1.8	368875.0
	Error	21	123163.1	0.2	87338.8	0.1	44052.5
	Total	35					
1981	Block	2	506062.0	4.1	141359.0	0.1	24984.0
	DI	3	46409000.0	16.6	17113200.0	129.6	125366.0
	SH	2	211039.0	21.5	257997.0	5.4	46283.3
	DI x SH	6	721493.0	5.0	398869.0	1.3	25487.4
	Error	21	402822.5	2.1	204843.6	0.7	10258.2
	Total	35					
1982	Block	2	830653.0	6.4	389744.0	1.5	83621.0
	DI	3	9713600.0	1.7	4250520.0	122.6	111924.0
	SH	2	1386630.0	96.0	50325.2	11.7	349.5
	DI x SH	6	222890.0	6.6	287825.0	5.5	33544.4
	Error	21	312128.3	5.1	181537.1	1.0	20912.7
	Total	35					