A Comparative Study of Four Grass-Legume Mixtures under Three Systems of Management

by

PETER DOLBEY JONES

A Thesis

Submitted to the Faculty of Graduate Studies and Research

In Partial Fulfilment of the Requirements

for the Degree of

MASTER OF SCIENCE

THE UNIVERSITY OF MANITOBA

MAY 1958

ABSTRACT

A comparative study of four grass-legume mixtures for herbage production, consumption and quality under continuous grazing, rotational grazing and hay management was conducted at the University of Manitoba in 1957. The seed mixtures, sown in 1955, were as follows:

Mixture 1 Brome and Alfalfa.

Mixture 2 Brome, Russian Wild Ryegrass and Alfalfa.

Mixture 3 Brome, Meadow Fescue, Alfalfa and Alsike.

Mixture 4 Creeping Red Fescue, Intermediate Wheat Grass, Alfalfa and Alsike.

In 1956 the four mixtures were utilized for hay.

Mixture 4 produced the highest average yield and quality herbage under all systems of management. However, there were no apparent differences in percentage consumption of herbage among the four mixtures. Botanical analyses revealed that the rotational and continuous sections increased and the hay section decreased in percentage cover.

The relatively high percentage of alfalfa present in Mixture 4 may explain its superiority in yield and quality of herbage. Growth stage and grass-legume ratio appeared to have a much greater influence on the protein content of the herbage under all systems of management than did the composition of any one mixture. The herbage from the rotational

section, although inferior in yield to that produced from the continuous section, was of a higher and more constant quality throughout the experiment. The yield of herbage produced from the hay section was intermediate to that produced from the two grazed sections.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF DIAGRAMS

LIST OF GRAPHS

LIST OF PLATES

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Professor J. D. Truscott and Dr. Anna K. Storgaard for their assistance and guidance throughout the course of this study and for their constructive criticisms and suggestions for the improvement of the manuscript.

Thanks are also extended to the Animal Science Department whose cooperation made this project possible and to Mr. J. A. McKirdy for his guidance with the chemical analyses.

The entire project was made possible by a financial grant from the Manitoba Provincial Government.

INTRODUCTION

The range of adapted seed mixtures for Western Canada is limited (32). Pure stands of grasses and legumes are sometimes grown but grass-alfalfa mixtures have a greater yielding capacity due to the overlapping of the growth curves of the component species.

The inclusion of alfalfa with grass species increases the quality and balance of the herbage for livestock in addition to increasing the total yield (32). Thus a well balanced grass-alfalfa mixture produces more herbage of a higher quality and for a longer period than any pure grass or legume stand.

The maintenance of an optimum grass-alfalfa balance is primarily dependent on the system of management it receives. The system of management which best maintains the balance varies according to the seed mixture in question.

The purpose of this study was to measure the influence of three systems of management on the production, consumption, quality and composition of herbage produced from four grass-legume mixtures.

LITERATURE REVIEW

Seed Mixtures

Many agronomists, studying grass and grass-legume mixtures for pasture and hay production in the Prairie Provinces, have found that grass-alfalfa mixtures were definitely superior in yield to pure stands of grasses and alfalfa (6,12,32). Wilsie (47), however, obtained similar yields from alfalfa and grass-alfalfa mixtures when the seeding rate of alfalfa was high. Kilcher _et al_. (32) considered that the inclusion of alfalfa in a mixture with grass increased the yield and quality of herbage substantially. In addition, the utilization of atmospheric nitrogen by alfalfa helped to maintain soil fertility and prevent the grasses from becoming sod-bound.

Wilsie (47), Comstock and Law (14) and Woods (48) agreed that competition between grasses and legumes was most severe in the seeding year. Comstock and Law (14) also reported that frequent cutting of grass-legume mixtures favoured grass species at the expense of legumes and that all mixtures produced more when cut for hay than when clipped frequently to simulate grazing.

A composite general purpose mixture of six grasses and two legumes was compared to a series of one grass, one legume mixtures (30). It was concluded that the greater yield from the simple mixtures was largely due to the higher proportion of alfalfa in the simple mixtures.

According to Jackobs (31), the yield of grass-alfalfa mixtures was influenced by the species of grass present even when alfalfa was the dominant species in the mixture.

Dominion Experimental Farms throughout Western Canada have reported (20) considerable differences in the yield and quality of herbage produced from recommended seed mixtures under simulated pasture, pasture and hay trials. For example, the Experimental Farm at Brandon reported variations in yield among six grass-legume mixtures in a simulated pasture trial over a three year period. Similar results were obtained at Indian Head and Melfort. In a grazing trial at Melfort, differences in grazing days, daily liveweight gains, dry matter (D.M.) and total digestible nutrients (T.D.N.) production and consumption were evident between two grass-legume mixtures. Chemical analyses of the components of the seed mixtures also revealed differences in protein, fibre and ash content.

A general conclusion from the above review is that grass-legume mixtures outyielded pure stands of grasses and legumes and that management becomes more important in handling mixtures.

Systems of Management

All systems of pasture management are based on two fundamental systems, continuous and rotational grazing. Other systems are simply modifications of rotational grazing.

Continuous grazing of a sward at a fixed stocking rate throughout the grazing season, irrespective of the herbage present, has many faults. The sward is overstocked at the beginning of the season and then grossly understocked when herbage is abundant. This naturally leads to a high degree of selective grazing, a weakening of the most rapidly growing species and a considerable drop in the nutritive value of the herbage. Thus herbage production and consumption decline rapidly when this treatment is continued for any length of time.

Rotational grazing involves the division of the grazing area into smaller sections which are grazed in turn. The periods between grazing allow rapidly growing plants to regenerate their vegetative portions and replenish their food reserves. In this way the vigour and persistence of the sown species are enhanced. Meanwhile, this fresh regrowth of herbage provides grazing animals with a more constant and nutritious food supply, maintained over a longer period than is possible under continuous grazing.

Continuous grazing of a sward, despite all its harmful effects, is still a common system of management. Napier in 1598, according to Smith (43), was the first to advocate the basic idea of moving livestock at regular intervals from one enclosure to another. Cole (Smith,43) implied that Dr. Warmbald in Germany, during the first World War, was responsible for the development of modern rotational grazing.

An appreciation of the nutritive value of grass and its products for livestock feed, together with the need for obtaining the most economical use of herbage and labour, led to paddock grazing being considered seriously as an alternative to extensive free range grazing (29). Strip grazing, close folding or ration grazing, all of which are forms of rotational grazing, was the next logical step.

deGeus (19) considered that up to 40% of the gross herbage yield was wasted under continuous grazing, whereas, with rotational grazing, losses were reduced by half. Holmes (28) showed that dairy cattle under rotational grazing utilized only approximately two thirds of the available herbage. Both workers concluded that losses would be reduced by increasing the intensity of stocking or developing a more stringent form of rotational grazing.

Levy (34) pointed out that under New Zealand conditions the production from typically sown swards, rotationally grazed, was greater because the various species within the mixture were given a better chance to achieve their highest production. Rotational daily strip grazing in Minnesota produced almost three times the production per acre, in terms of T.D.N., obtained by continuous grazing of one large paddock (9).

Many workers have shown that the yields of rotationally grazed pasture were not always superior to that from continuously grazed pasture (24,25). Hodgson et al.(26) reported the same number of cow-days of grazing per acre from both systems but an increase of 9% in T.D.N. in favour of the rotational system. It was doubtful if rotational grazing would be worthwhile under those conditions when the extra costs involved were considered. This view is supported by Brown (8) who stated that a similar picture existed in all experiments where rotational grazing of permanent pasture was compared to uncontrolled grazing in Maryland, Michigan, Missouri, Wisconsin and Washington.

It seems evident from this review on systems of pasture management that rotational grazing generally resulted in a greater production or more efficient utilization of herbage than did continuous grazing.

Herbage Production and Consumption

In grazing trials an estimate of growth, yield and consumption of forage by a clipping technique is valuable to relate productivity measured through the use of livestock. Two main clipping techniques are used to obtain these estimates. These are designated as the "difference" and "direct" techniques, the nomenclature being based on procedures followed in each (41).

The "difference" technique, as outlined by Nowosad et al. (41), consists of cutting herbage samples from plots at the beginning and end of each grazing period, and by difference, measure consumption and growth that has taken place during those periods. When the grazing periods exceed two to three days, cages are necessary to protect sampling areas from grazing. In contrast to this , measurements made in the "direct" technique are based on a single cut.

In the "difference" technique, groups of three similar areas designated as A, B and C are located within each plot at the beginning of the grazing period. A is clipped, B is caged, and C is marked for clipping at the end of the period when the caged area is also clipped. With the beginning of the second and subsequent grazing periods, this procedure is repeated and the cages are moved to fresh locations on the pasture.

Growth is determined by subtracting the A cut from the B cut, and consumption, by subtracting the C cut from the B cut. Yield is considered as the total amount of forage which a pasture produces and is calculated by adding to the production of the first clipping, the growth made in the subsequent grazing periods.

This general technique has been used by many workers (36,39,40,41,42) but with considerable variation in the sampling method. The distribution of cages and the selection of sampling areas in particular appears to be a controversial procedure. Klingman _et al_. (33) revealed that when a site was chosen at random and another selected similar to it, variability decreased considerably. Jolly, according to Brown (7), disagreed with this procedure from a statistical viewpoint stating that it could lead to considerable bias in the results.

One group of workers (38) had the B and C cuts adjacent but, according to Brown (7), Donald, Darland and Weaver pointed out that animals graze and trample excessively around the caged areas so that any randomization which placed the C cut alongside the caged area should be disregarded.

Consumption as estimated by the "difference" technique is generally about 30% higher than that calculated on the basis of animal performance (36). Linehan _et al_, (39) showed that clips taken at the beginning or end of a grazing period which exceeded two to three days, cannot be relied on to represent the yield of grass actually available to stock.

Linehan and Lowe (37) concluded that too infrequent cutting, when growth is rapid, may be a major source of error with this technique.

Linehan (36) considered that most trials showed a high correlation between total seasonal yields determined by clipping techniques and those derived from livestock performance data. He concluded therefore, " that where relative rather than absolute yields are sufficient, any of the commonly used techniques have value for comparing certain grass variables ".

Pasture productivity has also been expressed in terms of " grazing days " (21). Castle (10) defines a " grazing day " as a quantitative measurement computed from the product of the number of cattle and the length of the grazing period per unit area of land. He points out that as no account is taken of any form of animal production while on the pasture, an accurate assessment of pasture productivity is not possible. However, comparisons between treatments in any one experiment are reasonably accurate.

Herbage Quality

An appraisal of pasture management is deduced directly from measurements of production and consumption. Production is dependent on the aggressiveness and persistency of a sward, whereas consumption is related to the palatability and nutritive value of the herbage produced. Therefore, in discussing herbage quality, these aspects must be considered.

Chemical analysis is not an absolute measure of the feeding value of a crop, but it does provide a good indication of its nutritive worth (4,15). This is particularly true in relation to the different parts of a grass and to the degree of maturity of those parts (44). Fagan and Jones (22) reported that leaves of grasses contained more protein and ash but less fibre than stems. Osvald, according to Stapledon (44), supported these findings and revealed that differences between stems and leaves of one species tended to be greater than the differences between leaves of different species. Palatability is important and in some instances may be the determining factor in the value of a feed (11).

Stapledon (44) pointed out that, with regard to chemical composition, differences between grass species increase with their age, but far greater differences exist between pasture and hay samples of one species, than between pasture samples of any two different species. Others (5,11,15) have also established that the nutritive value of grasses varies from one stage of development to another within a species and also between species at particular stages.

Stapledon (44) considered that the feeding value of various parts of a grass depends more on the functions they have to perform than on the inherent chemical composition of these parts. Growth stage and leaf to stem ratio are also important factors in determining the feeding value of grasses. It was concluded that the economic value of a grass depends not only on its palatability and nutritive value, but equally on its ability to flourish under the management imposed upon it.

Herbage Composition

A. Point quadrat method

Variations in botanical composition of swards are important when comparing different systems of management because a change in botanical composition often precedes a change in yield and nutritive value of a pasture (46).

The point method expresses botanical composition in terms of ground cover and, as the sampling unit is a point which can be replicated to an unlimited extent, the analysis should be statistically reliable (7). This method of sampling by points was developed by Levy and Madden (35). The points are steel pins held in a frame which is dropped on the sward; the species and bare ground hit by the pins are recorded. Any aerial part of the plant is generally considered as a hit (7). Clarke *et al*.(13), however, recorded only hits on the base of plants when analysing native pastures in Alberta, Saskatchewan and Manitoba. This technique meant that any pin not striking a plant base was recorded as bare ground.

Many workers prefer the pins inclined at an angle of 45° rather than 90° because it tends to equalize the probability of the grass and broadleaved species being hit (7). This inclined point quadrat method has been used in the Prairie Provinces of Canada (13) and the mixed pastures of Minnesota (1).

The literature reveals no standard practice regarding the distribution of the frame within the experimental area (7). Species distribution appears to be the important factor. When the species are distributed evenly, sampling can be at random but if the herbage appears to be stratified, a systematic design should be adopted.

Brown (7) considered that a large variety of species, sparse distribution or base recorded hits, require a large number of readings. The number of points required in South Australia to assure a good assessment of the dominant and lesser important species ranged from three to five hundred points per field (16).

B. Estimation of percentage weight method

This method expresses botanical composition in terms of percentage productivity. The sampling unit is a frame or grid. Each species within the grid is allotted a mark or value according to its estimated proportion by weight. When sufficient samples have been taken, percentage productivity for each species is calculated.

This method is not suitable for pastures composed of species which differ considerably in morphological characters (7). Davies (18) cast a six inch grid ten times per plot. Ten marks were allotted to the species within each sample according to their estimated proportion by weight.

Therefore, the productivity of each species is expressed directly as a percentage of the total. Various modifications of this method have been used by a number of workers (17,18). They concluded that this method is satisfactory for detecting changes in productivity of component species in a sward.

MATERIALS AND METHODS

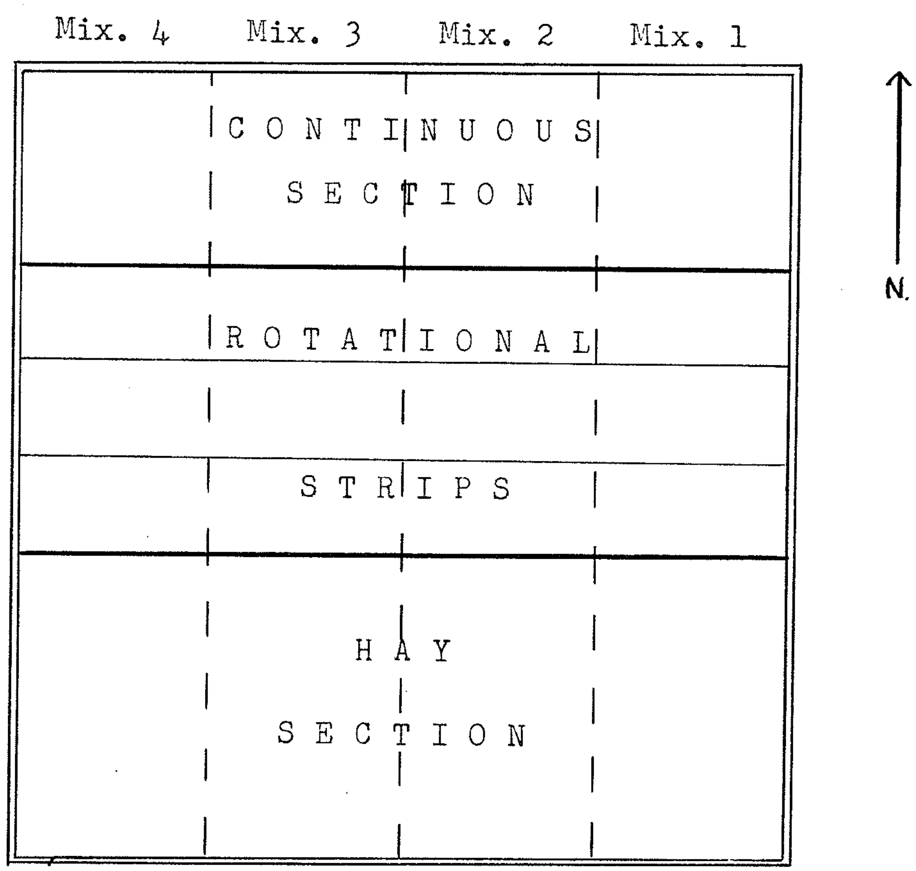
General

The following one-year experiment was conducted at the University of Manitoba, Fort Garry, in 1957. The experimental area consisted of a 16.6 acre field which was seeded in 1955 to four grass-legume mixtures, each occupying approximately 4 acres in area. The four mixtures listed below, were sown in a north-south direction so that by stretching two page-wire fences across in an east-west direction, the area was divided into three sections of 4, 6 and 6.6 acres respectively. In 1956 the entire field was twice cut for hay.

Twenty-eight unbred Holstein-Friesian heifers were the main grazing animals used throughout the experiment. However, from June 7 to June 27, thirty-one unbred Aberdeen Angus and Hereford heifers were introduced to eat off the rapidily maturing herbage before it reached the hay stage. The number of cattle and their duration of grazing, under the continuous and rotational systems of management, were recorded to evaluate herbage production in terms of " grazing days ".

Diagram 1

Plan of Experimental Area



Seed Mixtures

Mixture 1

7 lbs. Brome
2 lbs. Alfalfa

Mixture 2

4 lbs. Brome
4 lbs. Russian Wild Ryegrass
2 lbs. Alfalfa

Mixture 3

4 lbs. Brome
4 lbs. Meadow Fescue
1 lb. Alfalfa
1 lb. Alsike

Mixture 4

3 lbs. Creeping Red Fescue
5 lbs. Intermediate Wheat Grass
1 lb. Alfalfa
1 lb. Alsike

The four acre section was continuously grazed at the rate of 2.9 heifers per acre from June 7 to June 27. Partial flooding of the field due to excessive precipitation during the third week of June caused all grazing to be discontinued from June 27 to July 12. Grazing was resumed on July 12 at the rate of 3.2 heifers per acre. This in effect turned the continuous grazing into a form of rotational grazing.

The six acre section was divided into three, 2 acres strips with electric fences. These strips were rotationally grazed at the rate of 10.2 heifers per acre from June 7 to June 27. Sufficient herbage was produced on two of the rotational strips to allow a crop of hay to be taken from the third before using it in the rotational scheme. On July 12, grazing was resumed at the average rate of 6.9 heifers per acre until the experiment ceased.

Comparisons of herbage production, consumption, nutritive value and composition were made among the four mixtures subjected to these two systems of management.

The remaining 6.6 acres were cut for hay and herbage quantity, quality and compositions comparisons were made among the four mixtures.

Herbage Production and Consumption

The " difference " technique, as outlined previously, was used in this experiment to measure herbage production and consumption. Twenty cages were used, three per mixture on the continuous section and two per mixture on the rotational strips. These cages were placed at random within the mixtures but each group of three cuts were taken from " identical " areas. C cuts were never taken in the immediate vicinity of the cages because of excessive trampling in this area.

The roofed cages consisted of an iron frame network 4' x 6' x 2½'. A single iron grid, 2' x 4½', which outlined one square yard, was placed inside the 4' x 6' cage before the sample was cut with hedge clippers. In this way border effects on the samples were reduced.

The cut samples were transported in paper bags to the drying room. After the green weights were recorded, approximately three hundred grams of each sample were placed in a drying tray and subjected to 100°C. in a Unitherm drier for at least eight hours. The samples were then reweighed and the moisture percentage computed. Growth and consumption were calculated from this data and expressed in pounds of dry matter per acre.

The hay section was cut on July 4, and again on August 14. In both cases, the production was calculated from ten square-yard samples which were cut at random within each mixture just prior to haying.

Herbage Quality

The effects of the different grazing systems on the nutritive value of the four mixtures were assessed by analysing samples for crude fat, crude fibre and crude protein. Representative samples, consisting of approximately one hundred grams of dried herbage, were taken from each of the A cuts, once their dry matter content had been determined.

A series of protein analyses were made on the mixtures in the hay section to reveal what influence the stage of maturity had on the protein content of the herbage. Samples were cut on June 3, 17, July 4 and August 14. The latter two dates coincided with the first and second hay crops.

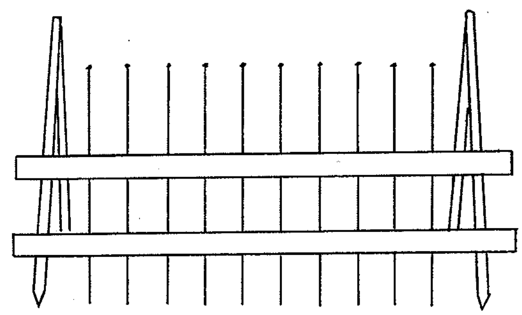
All samples before being analysed, were ground in a Wiley mill fitted with a one millimeter sieve. The methods of chemical analyses used were those recommended by the Association of Official Agricultural Chemists (2).

Herbage Composition

A. Point quadrat method

The apparatus used for this study was developed by Levy and Madden (35). It consisted of a twenty inch frame made of two horizontal bars spaced about three inches apart and mounted on legs. Each horizontal bar contained ten holes, two inches apart, which allowed steel pins, set at a 45° angle, to move up or down in a set course.

Diagram 2 Inclined Point Quadrat Frame



The species within the mixtures appeared to be evenly distributed so the frame was dropped at random twenty times per acre over the entire field. Following the procedure outlined by Clarke *et al*.(13), only the points which hit the base of plants were recorded. Individual species were recorded within each plot but, owing to the sparseness of the sward, were later combined into two groups, grasses and legumes. Comparisons between spring and fall data within and between plots, sections and mixtures were then made.

B. Estimation of percentage weight method

The apparatus used in this technique was a six inch square grid or frame subdivided into four equal parts by two pieces of wire to facilitate estimations. Six classes were used to represent a range in productivity from 1 to 100%. Each species within the grid was given a class according to its estimated proportion by weight. The classes and values are listed in Table 1. No account is taken of bare ground.

Table 1

Productivity Classes and Values

Class	Value %
0	absent
1	0- 1
2	1- 5
3	5- 15
4	15- 25
5	25- 50
6	50-100

The validity of this visual estimate method was tested prior to its application in the field. It was concluded that this method was satisfactory for assessing changes in productivity of the different species.

The grid was thrown sixty times per acre over the field in the spring and fall. Data on the individual species were totalled separately and percentage readings obtained of all plot totals. These readings were combined into two groups, grasses and legumes. This in turn allowed a more accurate assessment of any changes in percentage productivity from spring to fall.

RESULTS

1. Herbage Production

(a) Mixtures

The average yield for each mixture shown in Table 2 indicates that Mixture 4 produced the most herbage. There was little difference in the average yield of the other three mixtures. The computation of all herbage production tables is shown in Appendix A.

Table 2

Herbage Production of Mixtures

Systems of Management	Mixtures 1. (lbs. of D.M. per acre)	2.	3.	4.
Continuous grazing	7607	7827	7236	8450
Rotational grazing+	6141	5767	6515	6451
Hay management	6830	7251	6759	7846
Average	6859	6948	6837	7586

+ Includes hay crop

Mixture 4 outyielded the other mixtures in the continuous grazing and hay sections. Under rotational grazing Mixture 4 yielded more than Mixture 1 and 2, and was approximately equal to Mixture 3. Similarly, Mixture 2 outyielded Mixtures 1 and 3 in the continuous grazing and hay sections but had the lowest yield when grazed rotationally.

1. Herbage Production

(b) Treatments

Herbage production data reported in Table 3 indicates that the continuous section produced the highest yield of dry matter per acre. The yields, in pounds of dry matter per acre, were 7780, 6226 and 7172 respectively, on the continuous, rotational and hay sections.

Table 3

Herbage Production within Treatments

	Continuous section	Rotational section (pasture) (lbs. of D.M. per acre)	Rotational section (hay)	Hay section (1st.cut)	Hay section (2nd.cut)
Mixture 1.	7606	4656		4306	2524
Mixture 2.	7827	4281		4458	2793
Mixture 3.	7236	5030		4058	2701
Mixture 4.	8450	4996		4999	2847
Total	31119	28444	8912+	26731	16199
Average	7780	6226		7172	

+ Only total yield known

A crop of hay was taken from the third rotational strip before using it in the rotational scheme. In total, the six acres produced 37356 lbs. of D.M., 8912 lbs. of which constituted the hay crop.

The first hay crop on the hay section, cut on July 4, produced an average yield of 4455 lbs. of D.M. per acre but the second crop, cut on August 14, only produced 2716 lbs. of D.M. per acre.

(c) Grazing days

The total number of grazing days on the continuous and rotational sections were 715 and 970 respectively, i.e. 179 and 162 grazing days per acre.

11. Herbage Consumption

(a) Mixtures

The average consumption of herbage from each mixture is reported in Table 4. There were considerable differences in the amount of herbage consumed from the four mixtures under both systems of grazing. When the actual consumption was expressed as a percentage of the herbage available, however, the differences became negligible. The computation of all herbage consumption tables is shown in Appendix B.

Table 4

Herbage Consumption of Mixtures

Management Systems	Mixtures 1.	2.	3.	4.
	(lbs. of D.M. per acre)			
Continuous grazing	6946	6825	6473	7796
(% consumption)	91.3	87.2	89.4	92.2
Rotational grazing	3652	3452	4181	4020
(% consumption)	78.4	78.9	83.1	80.5
Average	5299	5139	5327	5908

Mixture 4 had a 92.2% consumption in the continuous section. The amount consumed on Mixture 4, 7796 lbs. was considerably greater than from the other mixtures. A somewhat similar situation existed in the rotational section. Mixture 3 had an 83.1% consumption but the difference in actual consumption between Mixture 3 and the other mixtures was not great.

The percentage consumption of herbage from the four mixtures within grazing periods is listed in Table 5. The data in this table indicate that there is more variation in percentage consumption within the continuous section than there is in the rotational section.

Table 5

Percentage Consumption of Mixtures

Grazing Period	Mixtures 1.	2.	3.	4.
Continuous Section				
1. June 7-19.	27.6	40.6	46.6	38.2
2. June 19-25	61.2	61.7	69.2	66.5
3. July 12-24	47.7	39.7	67.4	59.9
4. July 24- 7	72.7	67.3	77.8	67.4
5. August 7-16	65.0	53.5	50.4	67.1
Rotational Section				
1. June 7-19	69.4	70.5	68.8	61.6
2. June 19-25	73.2	59.0	67.7	80.8
3. July 12-24	66.9	65.6	70.6	66.0
4. July 24- 7	61.4	62.2	74.8	61.7
5. August 7-16	58.5	72.3	71.0	69.3
6. August 16-19	70.6	60.7	63.9	76.5

In the continuous section the percentage consumption for all mixtures was the lowest in period 1 and highest in period 4. This trend was not apparent in the rotational section where the data suggests a slightly more uniform consumption. However, the data in the continuous section and to a lesser extent in the rotational section show that considerable variation did exist in percentage consumption between mixtures at any one grazing period and also between grazing periods within any one mixture.

11. Herbage Consumption

(b) Treatments

The percentage consumption of herbage from the continuous section varied considerably from one grazing period to another in contrast to the more uniform consumption within the rotational section. Table 6 shows that consumption on the continuous section was lowest during the first grazing period, approximately half that which occurred on the rotational section. The highest percentage consumption on the continuous section occurred during the fourth grazing period, when for the first and only time, did it surpass that on the rotational section.

Table 6

	Percentage Consumption within Treatments	
Grazing Period	Continuous Section	Rotational Section
1. June 7-19	37.2	67.7
2. June 19-25	64.2	69.8
3. July 12-24	53.1	67.3
4. July 24- 7	71.0	65.7
5. August 7-16	59.5	67.7
6. August 16-19	-	68.6

111. Herbage Quality

(a) Mixtures

The protein content of the component species of the four mixtures, harvested on June 3, is shown in Table 7. Alfalfa had a protein percentage of 20.9 while the grasses averaged 13.5%. Brome had the highest protein percentage of the grasses, 15.0, and Meadow Fescue the lowest, at 10.6%. The others were intermediate between these two.

Table 7

Protein Content of Component Species (June 3)

Components	Protein Percentage (oven dry basis)	
Alfalfa		20.9
Brome	15.0	
Russian Wild Ryegrass	14.8	
Creeping Red Fescue	14.2	
Intermediate Wheat Grass	11.5	
Meadow Fescue	10.5	
Average	13.5	20.9

The average protein percentages of the mixtures subjected to three systems of management are presented in Table 8. Mixture 4 had the highest average protein percentage throughout the season under all systems of management. Statistical analysis of the protein percentages of the mixtures, shown in Table 9, revealed that Mixture 4 is significantly higher than Mixture 3 ($L.S.D._{.05} = 1.78$) However, there is no significant difference among Mixtures 1, 2 and 4.

Table 8

Protein Percentages of Mixtures

Continuous Section

Sampling Dates	Mixture 1	Mixture 2	Mixture 3	Mixture 4
June 7	19.9	19.3	15.0	16.5
June 19	13.3	14.1	10.6	14.2
June 25	11.5	12.0	11.3	12.2
July 12	22.1	22.8	22.1	25.4
July 24	15.2	14.8	16.7	18.2
August 7	11.7	14.9	13.9	14.8
Average	15.7	16.3	14.9	16.9

Rotational Section

Sampling Dates	Mixture 1	Mixture 2	Mixture 3	Mixture 4
June 7	19.8	18.0	15.4	17.4
June 19	15.3	16.6	15.7	19.8
June 25	15.9	15.9	12.6	18.3
July 12	23.4	23.4	21.7	21.4
July 24	20.8	21.3	18.2	20.4
August 7	19.4	18.0	17.1	21.2
August 16	19.7	22.5	24.0	22.8
Average	19.2	19.4	17.8	20.2

Hay Section

Sampling Dates	Mixture 1	Mixture 2	Mixture 3	Mixture 4
June 3	17.2	16.0	15.8	16.3
June 17	17.5	18.5	13.9	18.4
July 4	12.0	13.2	10.1	13.1
August 14	21.4	21.4	21.4	23.1
Average	17.0	17.3	15.3	17.7

The protein data for specific sampling dates are also presented in Table 8. These data indicate that, under grazing conditions, the protein content of the herbage was highest on July 12. In direct contrast to this, the highest protein content recorded for the hay section occurred on August 14. It should be noted that the averages presented in Table 8 are unweighted, i.e. do not indicate the protein content of the total forage produced.

Table 9

Analysis of Protein Percentages of Mixtures

Source	S.S.	D.F.	M.S.	F.
Total	646.55	47		
Mixtures	38.43	3	12.81	9.78+
Management	85.87	1	85.87	65.55++
Error (a)	3.93	3	1.31	
Dates	400.27	5	80.05	14.19++
Dates x Mixt.	27.74	15	1.85	.33
Dates x Mgt.	5.67	5	1.14	.20
Error (b) Dates x Mixt. x Mgt.	84.64	15	5.64	

+ 5% level
++1% level

111. Herbage Quality

(b) Treatments

The seasonal variation in the nutritive value of the herbage produced on the continuous and rotational sections is shown in Graphs 1 and 2. On June 7, there was little difference in the dry matter content of the herbage from both sections. By August 16, however, the dry matter content of the herbage on the continuous section had increased to 47.1% compared to 31.5% on the rotational section.

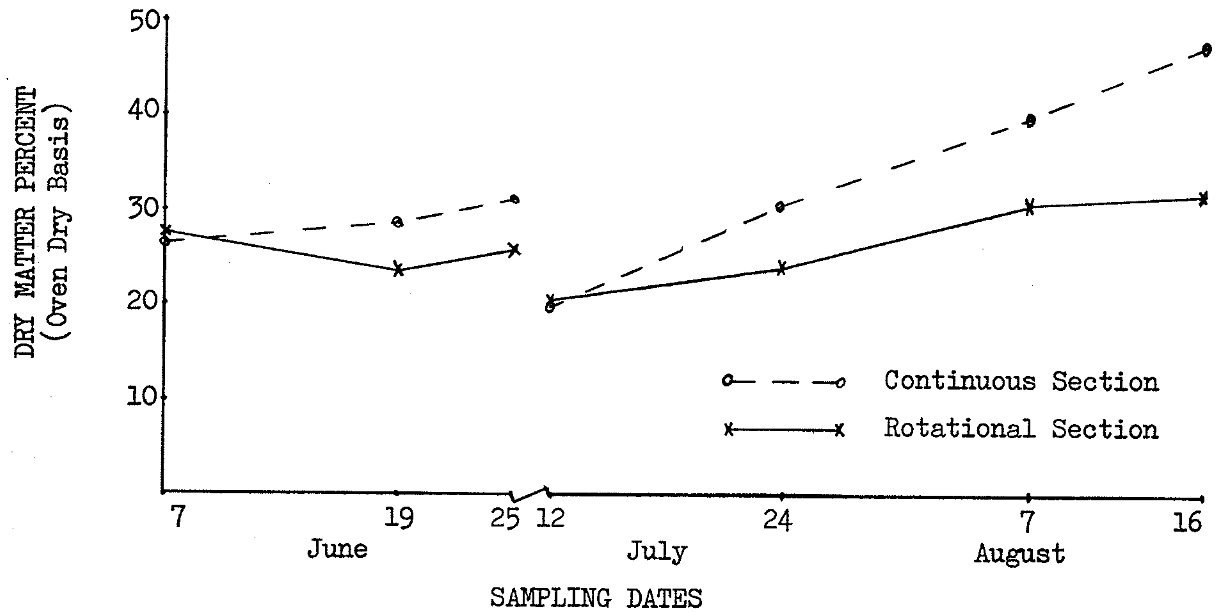
The protein percentages of the herbage on the continuous and rotational sections were identical on June 7. From June 7 to June 25, the protein percentage dropped 2% on the rotational section compared to 5.9% on the continuous section. No samples were taken from June 25 to July 12, because climate conditions caused a temporary suspension of the experiment. When the experiment was resumed on July 12, the protein percentages on both sections were the highest recorded. During the next three grazing periods, the protein percentage fell 3.6% and 9.3% respectively on the rotational and continuous sections. Statistical analysis of the protein percentages of the herbage under both systems of grazing, reported in Table 9, showed that the rotational herbage had a significantly higher protein content ($L.S.D._{.01}=1.05$).

There was no appreciable difference between the fibre contents of the herbage produced on the continuous and rotational sections until the end of July. On August 7, the percentage fibre on the rotational section was 23.1% compared to 28.2% on the continuous section. By August 16, the fibre percentage was down to 20.5% on the rotational section but by this time the cattle had been taken out of the continuous section so no more samples were taken.

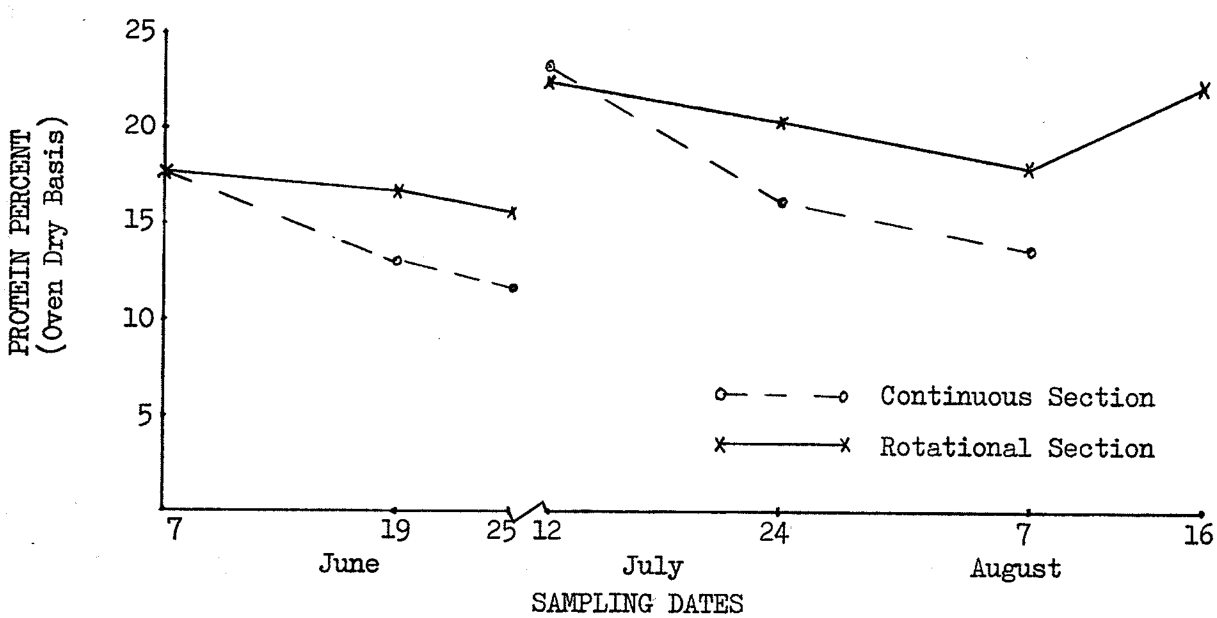
The herbage on the rotational section contained a slightly higher percentage of crude fat throughout the experiment.

The protein percentages of the hay samples cut on June 3 and June 17 were 16.3% and 17.1%, respectively, compared to 12.1% on July 4 when the section was cut for hay. This section was again cut for hay on August 14 when its protein percentage was 21.8%.

Seasonal Variations in Dry Matter Content of Herbage from the Continuous and Rotational Sections

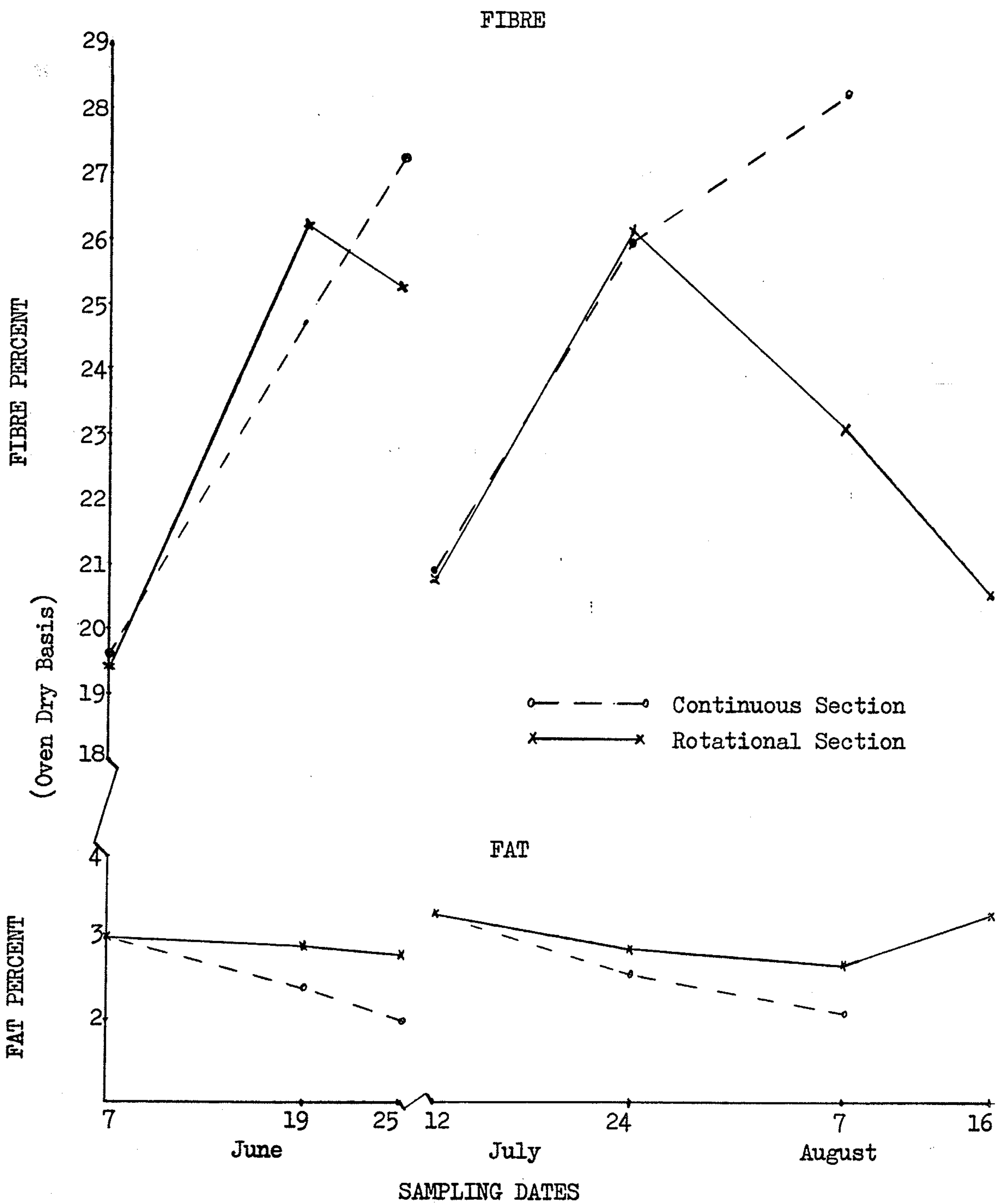


Seasonal Variations in Protein Content of Herbage from the Continuous and Rotational Sections



GRAPH 1.

Seasonal Variations in the Crude Fat and Fibre Content of the Herbage from the Continuous and Rotational Sections



GRAPH 2.

lV. Herbage Composition

(a) Point quadrat method

The percentage cover for the entire field, recorded on May 24 and August 21, is shown in Table 10. Mixtures 1, 2 and 4 showed a small increase in percentage cover from spring to fall. Statistical analysis of this data revealed that the differences were not significant.

Table 10

Percentage Cover of Mixtures

	Spring	Fall
Mixture 1	31.4	33.1
Mixture 2	31.3	36.8
Mixture 3	32.3	32.2
Mixture 4	28.2	33.0
Average	30.8	33.8

The effects of the different treatments on the four mixtures is reported in Table 11. An increase in cover of 7.3% occurred during the season on the rotational section compared to a 1.5% increase on the continuous section. A decrease in cover of 2.9% occurred in the hay section.

Considering the mixtures individually, the rotational treatment again appeared to have the greatest influence on cover. Mixture 3 showed a significant increase (P=.01) in cover under the rotational system of grazing. Mixtures 1, 3 and 4 increased in cover under continuous grazing but not significantly. Only Mixture 2 showed an increase in percentage cover in the hay section whereas Mixtures 1,3 and 4 decreased.

Table 11

Percentage Cover within Treatments

	Continuous Section Spring	Continuous Section Fall	Rotational Section Spring	Rotational Section Fall	Hay Section Spring	Hay Section Fall
Mixture 1	23.0	30.5	35.9	34.8	34.1	31.0
Mixture 2	34.0	27.0	32.0	39.8	28.6	30.4
Mixture 3	22.5	25.5	31.8	43.8	38.0	31.4
Mixture 4	29.5	32.0	25.8	36.4	32.1	30.4
Average	27.2	28.7	31.4	38.7	33.7	30.8

Table 12 shows that a slight decrease in percentage cover of legumes occurred during the growing season. This trend was, however, reversed in Mixture 3.

Table 12

Percentage Grass-Legume Cover of Mixtures

	Spring Grasses	Spring Legumes	Fall Grasses	Fall Legumes
Mixture 1	69.1	28.0	73.4	23.0
Mixture 2	71.2	24.3	79.6	20.4
Mixture 3	79.9	19.1	72.3	26.1
Mixture 4	65.3	32.6	68.2	31.8
Average	71.4	26.0	73.4	25.3

(b) Weight estimation method

The estimated proportion by weight of legumes to grasses are reported in Table 13 and Table 14. The legume values are expressed as a percentage of the weight of the grass components. Table 13 indicates that the proportion by weight of legumes to grasses over the entire field increased from spring to fall. The greatest increases were in Mixtures 3 and 4.

Table 13

Seasonal Variation in Grass-Legume Ratio in Mixtures

	Spring		Fall	
	Grasses	Legumes	Grasses	Legumes
Mixture 1	100	61	100	67
Mixture 2	100	69	100	85
Mixture 3	100	42	100	69
Mixture 4	100	70	100	97
Average	100	61	100	79

The data on each mixture were subdivided into three management sections as shown in Table 14. The data indicate the effects of the different treatments on the grass-legume ratio in each mixture.

The proportion by weight of legumes to grasses decreased in Mixtures 1 and 4 in the continuous section. Only Mixture 1 showed a decrease however, in the rotational section. In the hay section all the mixtures showed an increase in the proportion by weight of legumes to grasses.

Table 14

Seasonal Variation in Grass-Legume Ratio within Treatments

	Spring Grasses	Spring Legumes	Fall Grasses	Fall Legumes
Mixture 1				
Continuous section	100	72	100	50
Rotational section	100	76	100	48
Hay section	100	41	100	108
Mixture 2				
Continuous section	100	51	100	55
Rotational section	100	64	100	88
Hay section	100	98	100	118
Mixture 3				
Continuous section	100	32	100	68
Rotational section	100	49	100	71
Hay section	100	44	100	69
Mixture 4				
Continuous section	100	83	100	76
Rotational section	100	59	100	102
Hay section	100	70	100	97

DISCUSSION

1. Herbage Production

(a) Mixtures

The fact that alfalfa can outyield any of the commonly grown grasses in this region could explain the comparatively high yielding ability of Mixture 4. The point quadrat data revealed that 31.8% of the total vegetation of Mixture 4 consisted of alfalfa. This is in contrast to an average of 23.2% alfalfa in the other mixtures. In addition, the relative proportion of alfalfa to grasses in the fall, as shown by the weight estimation technique (Table 13), was 97:100 in Mixture 4 compared to an average of 74:100 in the other mixtures.

There does not appear to be a reasonable explanation for the apparent superiority of Mixture 3 under rotational grazing especially as it is inferior to the other mixtures under continuous grazing and hay management.

(b) Treatments

The nature of the growth curve of the grasses and legumes is a fact which must be considered in pasture production appraisal (36). Barton-Wright (3) indicated that the curve was typically S shaped. Hence, up to certain limits the more herbage on the sward, the higher will be the growth rate. The importance of this fact is well illustrated by Linehan et al. (39) who measured the active growth of pasture for two seasons. The rate of growth was about .28 cwt. D.M. per day during the first three weeks after resting, and as high as .57 cwt. D.M. per day during the following ten days.

This fact then must surely be the fundamental basis behind all systems of pasture management. The average point where the cuttings or grazings intersect the growth curve determines the yield and quality of the herbage obtained. Cutting or grazing at a point just prior to the flattening out of the curve will secure maximum yield and quality herbage. It was for this reason that rotational grazing was devised and advocated. Levy (34) states, " there is for each species or set of species, a stage between the close and continuously hard grazing and the over lenient grazing where not only is production greatest in quantity but also the food consumed is of the most desirable quality. The system which best fits in with the above ideas is that of rotational grazing ".

Light grazing of the continuous section would allow plants to build up food reserves which in turn would probably have a favourable influence on the final yield (Table 3). Protein data from this section indicated that the grazing was not severe enough to maintain the plants in a highly nutritious state. Had it been so, the final herbage production figures might have been much lower.

In contrast to this, intense stocking of the rotational strips during a period of heavy precipitation resulted in severe damage to the sward, and partially explains its comparatively low yield. It is thus doubtful that the herbage production data recorded for the rotational section was a true picture of its potential under more normal conditions.

(c) Grazing days

It should be noted that, had the hay from the rotational section been available for grazing, the number of grazing days per acre would have increased. The average consumption of dry matter per grazing day on the rotational section was calculated. This figure was subsequently divided into the total quantity of dry matter produced as hay. Thus in effect, the hay yield is expressed as grazing days which is then divided by six to obtain an estimate of grazing days per acre as shown below.

Lbs. of D.M. consumed under rotational grazing	=	22958
No. of grazing days	=	970
Lbs. of dry matter consumed per grazing day 22958/970	=	23.7
Hay yield of rotational section	=	8912
Yield of hay in grazing days per acre 8912/23.7 x 6	=	62.7
Total yield of rotational section in grazing days per acre 161.7 + 62.7	=	224

Thus it appears that production in terms of grazing days is slightly in favour of the rotational section (Appendix B). It should be borne in mind that the estimated sixty two grazing days was calculated indirectly and, that this method as a whole is subject to large sampling errors. Nevertheless, the hay crop from the rotational section should not be overlooked although the differences in estimated grazing days per acre were probably not as great as the above data suggests.

11. Herbage Consumption

(a) Mixtures

Consumption determined by the " difference " technique is represented by the difference between the quantity of grass which was available to stock and that which is left uneaten. Linehan et al. (39) obtained data which indicated that herbage present in cages at the end of prolonged grazing periods is more than was actually available to stock. This may be one of the reasons why the " difference " technique is subject to high sampling errors.

The differences in percentage consumption of herbage from the four mixtures, in Table 4, under both systems of grazing were not enough to suggest any preferential trends between mixtures.

The greater variation in percentage consumption of herbage within grazing periods on the continuous section (Table 5) may have partially resulted from the comparatively light grazing it received during the first part of the experiment. Light grazing at a time when herbage is plentiful naturally leads to a high degree of selective grazing. However, the high sampling error with which the " difference " technique is associated must be borne in mind when making any generalizations.

(b) Treatments

The light stocking on the continuous section may also explain why the percentage consumption for the first grazing period was so much lower than that on the rotational section (Table 6). The high percentage consumption during the fourth grazing period on the continuous section suggested that the sward had been overgrazed. The herbage available during the fifth and last grazing period was at such a mature stage that the cattle found it extremely unpalatable. Hence the drop in percentage consumption for that period.

The rotational system of grazing appears to have reduced some of the variations in percentage consumption between grazing periods. A higher intensity of grazing and more uniform regrowth of herbage during the rest periods may help to explain this.

111. Herbage Quality

(a) Mixtures

Protein analysis of the various components of the mixtures indicated that alfalfa had a considerably higher protein content than any of the grasses. In addition, the point quadrat and weight estimation data showed that Mixture 4 had the highest legume-grass ratio in the spring and fall. It seems highly probable therefore, that the high protein content of Mixture 4 is directly related to its high legume-grass ratio. Mixture 3, which had the lowest legume-grass ratio, also had the lowest protein content.

The fluctuations in protein percentage of the mixtures appeared to be a direct function of the legume-grass ratio at any one time.

(b) Treatments

The grazing intensity on the continuous section was comparatively light especially during the first part of the experiment. This light stocking rate encouraged the cattle to select the most immature herbage first, leaving the rest to become even more mature. In contrast to this, there was comparatively little selective grazing on the rotational section because of the high intensity of grazing on fresh herbage produced during the rest periods. Thus these two systems of management, as applied in this experiment, may largely explain why the dry matter content of the herbage from the continuous section remained at a higher level throughout the experiment.

Sullivan and Garber (45) stated that moisture is high in young rapidily growing plants and, as such, is positively correlated with proteins, sugars and many minerals but negatively correlated with fibrous and ligneous constituents. It would appear therefore, that any management which favours succulent young plants will maintain high protein production while keeping the fibrous and ligneous constituents to a minimum.

The herbage produced on the rotational strips during each rest period was high in moisture and protein but low in fibre. It seems likely then, that this system of management was largely responsible for the uniform production of higher quality herbage compared to that obtained from the continuous system of management.

A small portion of the weight of forage plants consists of crude fat (45). Brouwen, according to Sullivan and Garber (45), states that this portion decreases in grasses as the plants mature. This fact then may account for the slightly lower percentage of crude fat in the continuously grazed herbage.

The results of the protein analyses on the hay samples, cut at three different dates, illustrate how rapidly the protein content of the herbage can drop once the flowering stage is reached.

The high protein percentage, obtained on July 12 in the grazed sections, was largely due to regrowth, whereas in the hay section the plants had not been cut or grazed until July 4. A similar situation explains the very high protein percentage of the second hay crop which only had a forty day growing period. This short growing period meant that only the most rapidly growing species in the mixtures together with the leafy portions of the other species would be the main constituents of the crop. At that time of year, alfalfa was by far the most productive species and this largely explains the crop's high protein content.

lV. Herbage Composition

(a) Point quadrat method

Harlan (23) in discussing the extent of the grazing animal's influence in pasture management concluded that, " the adjustment of the stocking rate and the systematic manipulation of the grazing pressure can be used to control the stage of growth and nutritional value of herbage, can alter the botanical composition of the sward, can control undesirable plants, can assist in obtaining new stands, and can help solve the problem of seasonal surplus and deficit forage production ".

The increase in percentage cover which only occurred in the continuous and rotational sections (Table 11), suggest that the grazing animal might be primarily responsible as the hay section showed a decrease in percentage cover over the same period. The increase in percentage cover was greatest in the rotational section where the rapidly growing plants had an opportunity to replenish their food supplies before being grazed again. Under a system of continuous grazing these plants tend to exhaust their food reserves rapidly and this may weaken their persistency.

Repeated haying of the sward, irrespective of seed mixture, appears to favour tall, early seeding plants. This in turn tends to hamper the competitive ability of the later starting, more prostrate plants so that they become more susceptible to adverse conditions such as low temperature and flooding. Such a sequence of events may possibly explain the decrease in percentage cover on the hay section.

When mixtures are considered individually within treatments, certain trends become apparent despite the presence of an exception in each treatment. The rotational and to a lesser extent the continuous treatments enabled the mixtures to increase in percentage cover, whereas, with the hay treatment the reverse occurred.

The slight increase in percentage cover of grasses at the expense of the legumes was probably due to a combination of events. The flooding and consequent poaching of the grazed area at a time when the legumes in particular were in their critical growth stage may have hampered their development seriously. Under such conditions alfalfa crowns are very susceptible to splitting. High temperatures which followed this crown damage seemed to create an ideal environment for bacterial invasion. This in turn may explain the high incidence of rotting alfalfa plants. This combination of events appeared to affect the alfalfa to a much greater extent than the grasses because of the differences which exist in their morphological characters.

(b) Weight estimation method

It is generally agreed that grasses start growth earlier in the spring than legumes. In the Prairie Provinces alfalfa will surpass the grasses in rate and amount of growth from late June until September. It is possible then that the increase in the proportion of legumes to grasses recorded in the fall was a reflection of the seasonal growth pattern of the grasses and legumes.

Spring sampling occurred on May 16, at which time only the grass species had started active growth. The fall sampling was taken on September 4 and, as the data show (Table 13), the legumes had contributed considerably more at that time than they had contributed in the spring.

In Mixtures 3 and 4, which recorded greater increases in the proportion of legumes to grasses than Mixtures 1 and 2, more than one grass species became well established (Appendix C). Botanical analysis data in the fall showed that Mixture 3 contained 35.7% Brome, 36.6% Meadow Fescue and 26.1% Alfalfa while in Mixture 4 there were 22.7% Creeping Red Fescue, 19.7% Intermediate Wheat Grass and 31.8% Alfalfa. This could mean that competition among grass species in these two mixtures may have reduced the competition between the grass and legume components which would favour the latter's development. In Mixtures 1 and 2, 69.8% and 71.2% of the total vegetation consisted of the vigorous creeping brome grass together with 23.0% and 20.4% alfalfa. Here the grass was competing directly against the alfalfa which may help to explain the smaller legume increase recorded in Mixtures 1 and 2.

Alfalfa when cut or grazed draws on its food reserves to produce fresh foliage more rapidily then most grass species. If this foliage is removed before the plant has time to replenish its food reserves, the plant is seriously weakened. Thus under a system of continuous grazing the most vigorous growing plants tend to be weakened first. For vigorous and persistent growth, alfalfa needs to reach the early flowering stage at least once a year, preferably in the spring, before defoliation occurs. This allows food reserves to be built up in its tap root which in turn are responsible for its high production during the summer months.

Only under the hay treatment did the proportion of alfalfa to grass increase in all the mixtures. This data suggests that alfalfa may be more suited to hay production than as a pasture component. The longer rest periods between defoliation enables the plant to build up its food reserves more effectively and hence, its potential production and persistency.

SUMMARY AND CONCLUSIONS

A comparative study of four grass-legume mixtures for herbage production, consumption and quality under continuous grazing, rotational grazing and hay management was conducted at the University of Manitoba in 1957. The seed mixtures, sown in 1955, were as follows:

Mixture 1. Brome and Alfalfa.

Mixture 2. Brome, Russian Wild Ryegrass and Alfalfa.

Mixture 3. Brome, Meadow Fescue, Alfalfa and Alsike.

Mixture 4. Creeping Red Fescue, Intermediate Wheat Grass, Alfalfa and Alsike.

In 1956 the four mixtures were utilized for hay.

Mixture 4 produced the highest average yield of dry matter per acre under all systems of management. However, there was little difference in the average yield of the other three mixtures. The highest yield of dry matter per acre within the three treatments was obtained from the continuous section. Production in terms of grazing days however, was slightly in favour of the rotational section if the hay crop from the third rotational strip is taken into account.

Although there were considerable differences in the amount of herbage consumed from the four mixtures: these differences became negligible when expressed as a percentage of the herbage available. This percentage consumption of herbage fluctuated more from one grazing period to another within the continuous section than it did on the rotational section.

Protein analyses of the component species of the four mixtures revealed that alfalfa had a considerably higher protein percentage than any of the grasses. This probably explains why Mixture 4 had the highest average protein percentage throughout the season under all systems of management as botanical analyses showed that Mixture 4 contained the most alfalfa. The herbage from the rotational section contained a higher percentage of moisture, protein and fat than that from the continuous section. However, there was little difference in the fibre content until the end of July when it began to increase rapidly in the herbage from the continuous section. Protein analyses of the herbage from the hay section illustrated the importance of cutting at an early growth stage to obtain maximum quality herbage.

The point quadrat data revealed that the percentage cover of the field increased slightly. There was an increase of 7.3% and 1.5% cover in the rotational and continuous sections respectively compared to a decrease of 2.9% in the hay section. Similarly, there was an increase in the percentage cover of grasses to legumes in all but Mixture 3. The weight estimation method showed an increase in the proportion by weight of legumes to grasses over the entire field. The greatest increases were in Mixtures 3 and 4. Within the three treatments, all mixtures showed an increase in the hay section, three mixtures increased in the rotational section but only two mixtures increased in the continuous section.

REFERENCES AND LITERATURE CITED

1. Arny, A. C. and A. R. Schmid. A study of the inclined point quadrat method of botanical analysis of pasture mixtures. J. Am. Soc. Agron. 34:238-247. 1942.

2. Association of Official Agricultural Chemists. Methods of analysis. Eighth edition, 1955.

3. Barton-Wright, E. C. Recent advances in plant physiology. J. and A. Churchill, London. pp. 352. 1930.

4. Bell, J. M., G. H. Bowman, and R. T. Coupland. Chemical composition and digestibility of forages grown in Central Saskatchewan with observations on Kochia species. Sci. Agr. 32:463-473. 1952.

5. Bird, J. N. Stage of cutting studies. I. Grasses. J. Am. Soc. Agron. 35:845-861. 1943.

6. Bowren, K. E. Progress report of the Snowden Gray Soils Substation, Saskatchewan. 1954.

7. Brown, Dorothy. Methods of surveying and measuring vegetation. Bull. 42, Commonwealth Bureau of Pasture and Field Crops, Hurley, Berks. England. 1954.

8. Brown, Marion E. The management of grazing. Yearbook of Agriculture, U. S. Dept. of Agr., Washington 25, D. C. 135-139. 1948.

9. Brundage, A. L. and W. E. Petersen. A comparison between daily rotational grazing and continuous grazing. J. Dairy Sci. 35:623-630. 1952.

10. Castle, M. E. Methods of evaluating grassland production in temperate zones. Herbage Abstracts. 25:1-9. 1955.

11. Christensen, F. W. and T. H. Hopper. Effects of weathering and stage of maturity on the palatability and nutritive value of prairie hay. Bull. 260, Agr. Expt. Sta. Fargo, N. Dakota. 1932.

12. Clarke, K.W. and D. H. Heinrich. Grass-Legume mixture trials. Expt. Sta. Swift Current, Saskatchewan. 1957.

13. Clarke, S. E., J. A. Campbell and J. B. Campbell. An ecological and grazing capacity study of the native grass pastures in Southern Alberta, Saskatchewan and Manitoba. Publ. 738. Tech. Bull. 44. Can. Dept. Agr. 1942.

14. Comstock, V. E. and A. G. Law. The effect of clipping on the yield, botanical composition and protein content of grass-alfalfa mixtures. J. Am. Soc. Agron. 40:1074-1083. 1948.

15. Crampton, E. W. and R. I. C. Jackson. Seasonal variation in chemical composition of pasture herbage and the relation to its digestibility by steers and sheep. J. Animal Sci. 3:333-339. 1944.

16. Crocker, R. L. and N. S. Tiver. Survey methods in grassland ecology. J. Brit. Grassland Soc. 3:1-26. 1948.

17. Davies, J. G. and H. C. Trumble. Grassland research in Australia:Notes on the technique of pasture investigations. Bull. 14. Imp. Bur. of Plant Genetics:Herbage Plants. 1934.

18. Davies, Wm. Methods of pasture analysis and fodder sampling. Rept. 1. Welsh Plant Breeding Sta. Aberystwyth, Wales. 1931.

19. de Geus, J. A note on ration grazing in Holland. J. Brit. Grassland Soc. 5:251-252. 1950.

20. Dominion Experimental Farms. Progress report of pasture investigations. Ottawa, Canada. 1956.

21. Ellison, Wm. The productivity of upland areas in Montgomeryshire. J. Brit. Grassland Soc. 1:54-72. 1946.

22. Fagan, T. W. and T. H. Jones. The nutritive value of grasses as shown by their chemical composition. Bull. H. 3. Welsh Plant Breeding Sta. Aberystwyth, Wales. 1924.

23. Harlan, J. R. Theory and dynamics of grassland agriculture. D. Van Nostrand Company, Inc., Princeton, New Jersey.

24. Harrison, C. H., C. L. Cole and H. C. Rather. Continuous and rotational grazing of alfalfa-bromegrass pasture with ewes and lambs. Soil Sci. Soc. Am. Proc. 6:303-308. 1942.

25. Harrison, C. H., G. Williams and W. N. Fischer. Continuous and rotational grazing of a grass-legume mixture with dairy cows. J. Am. Soc. Agron. 40:357-363. 1948.

26. Hodgson, R. E., J. C. Knott, V. L. Miller and E. V. Ellington. A comparison of rotational and continuous grazing of pasture in Western Washington. Wash. Agr. Expt. Sta. Bull. 294. 1934.

27. Holmes, W., R. Waite, D. L. Fergusson and Jean Campbell. Studies in grazing management. I. A comparison of the production obtained from close-folding and rotational grazing of dairy cows. J. Agr. Sci. 40:381-391. 1950.

28. Holmes, W., R. Waite, D. L. Fergusson and Jean Campbell. Studies in grazing management. II. The amount and chemical composition of herbage eaten by dairy cows under close-folding and rotational grazing. J. Agr. Sci. 40:392-402. 1950.

29. Hosking, Z. D. and C. Line. Comparison of two methods for the controlled grazing of dairy cows. J. Brit. Grassland Soc. 11:190-193. 1956.

30. Hughes, G. P. The comparative seasonal output of ultra-simple and general purpose seed mixtures. J. Agr. Sci. 42:413-421. 1952.

31. Jackobs, J. A. The performance of six grasses growing alone and in combination with legumes and different nitrogen and phosphate fertilization in a Yakima pasture. Agron. J. 44:573-578. 1952.

32. Kilcher, M. R., R. W. Lodge, D. H. Heinrich and J. B. Campbell. Pasture and hay crops for the Southern Canadian Prairies. Swift Current Expt. Sta. Saskatchewan. 1956.

33. Klingman, D. L., S. R. Miles and G. O. Mott. The cage method for determining consumption and yield of pasture herbage. J. Am. Soc. Agron. 35:739-746. 1943.

34. Levy, E. B. Grasslands of New Zealand. Govt. Printers, Wellington, New Zealand. 1955.

35. Levy, E. B. and E. A. Madden. The point method of pasture analysis. New Zealand J. Agr. 46:267-279. 1933.

36. Linehan, P. A. Use of cage and mower strip methods for measuring the forage consumed by grazing animals. Proc. Sixth Intern. Grassland Congr. Pennsylvania, U. S. A. 2:1328-1333. 1952.

37. Linehan, P. A. and J. Lowe. The output of pasture and its measurement. J. Brit. Grassland Soc. 1:7-35. 1946.

38. Linehan, P. A., J. Lowe and R. H. Stewart. The output of pasture and its measurement. J. Brit. Soc. 2:145-168. 1947.

39. Linehan, P. A., J. Lowe and R. H. Stewart. The output of pasture and its measurement. J. Brit. Soc. 7:73-98. 1952.

40. Nevens, W. B. A comparison of sampling procedures in making pasture yield determinations. J. Dairy Sci. 28:171-185. 1945.

41. Nowosad, F. S., S. B. Williams, L. S. Donovan, S. M. Donaldson and R. R. Cairns. Review of literature on methods and techniques employed in pasture research. Can. Dept. of Agr. Ottawa, Canada. 1953.

42. Robinson, R. R., W. H. Pierre and R. A. Ackermann. A comparison of grazing and clipping for determining the response of permanent pastures to fertilization. J. Am. Soc. Agron. 29:349-359. 1937.

43. Smith, J. H. Some early advocates of rotational grazing. J. Brit. Grassland Soc. 11:199-202. 1956.

44. Stapledon, R. G. Characters which determine the economic value of grasses. Part I. Nutritive value and palatability. J. Ministry Agr. 33:1083-1091. 1927.

45. Sullivan, J. T. and R. J. Garber. Chemical composition of pasture plants. Bull. 489. Agr. Expt. Sta. Pennsylvania. 1947.

46. Wagner, R. E. Weight estimation and other procedures for measuring the botanical composition of pastures. Proc. Sixth Intern. Grassland Congr. Pennsylvania, U. S. A. 2:1315-1320. 1952.

47. Wilsie, C. P. Evaluation of grass in legume associations with emphasis on the yields of bromegrass varieties Agron. J. 41:412-421. 1949.

48. Woods, J. E., A. L. Hafenrichter, J. L. Schwendiman and A. G. Law. The effects of grasses on the yield of forage and production of roots by grass-alfalfa mixtures with special reference to soil conservation. Agron. J. 45:590-595. 1953.

APPENDIX A

Growth, Production and Consumption of the Mixtures

CONTINUOUS SECTION

Grazing periods	Total production	Growth by period	Consumption by period	Herbage available	Percentage consumption
	(grams per square yard)				
Mixture 1					
7-18/6/57	227.6	80.1	62.8	227.6	27.6
19-24/6/57	227.6	-	99.9	163.1	61.2
25-11/7/57+	292.7	65.1	-	-	-
12-23/7/57	463.4	170.7	147.3	309.0	47.7
24- 6/8/57	590.9	127.5	210.2	289.2	72.7
7-16/8/57	712.8	121.9	130.6	200.9	65.0
	712.8		650.8		91.3%
Mixture 2					
7-18/6/57	229.8	42.2	93.3	229.8	40.6
19-24/6/57	270.8	41.0	109.6	177.5	61.7
25-11/7/57+	351.3	80.5	-	-	-
12-23/7/57	536.5	185.2	132.5	333.6	39.7
24- 6/8/57	626.2	89.7	195.8	290.8	67.3
7-16/8/57	733.5	107.3	108.3	202.3	53.5
	733.5		639.5		87.2%
Mixture 3					
7-18/6/57	129.7	25.7	60.2	129.7	46.6
19-24/6/57	156.5	26.8	66.3	95.8	69.2
25-11/7/57+	218.5	62.0	-	-	-
12-23/7/57	423.3	204.8	199.6	296.3	67.4
24- 6/8/57	594.2	170.9	208.3	267.6	77.8
7-16/8/57	678.0	83.8	72.1	143.1	50.4
	678.0		606.5		89.4%
Mixture 4					
7-18/6/57	196.6	51.5	75.2	196.6	38.2
19-24/6/57	265.1	68.5	126.3	189.9	66.5
25-11/7/57+	325.0	59.9	-	-	-
12-23/7/57	490.0	165.0	172.7	288.5	59.9
24- 6/8/57	717.1	227.1	231.3	342.9	67.4
7-16/8/57	791.8	74.7	125.0	186.3	67.1
	791.8		730.5		92.2%

+ Break due to bad weather.

The following table expresses the above production and consumption data in pounds of dry matter per acre.

Mixtures	Production	Consumption
1	7607	6946
2	7827	6825
3	7236	6473
4	8450	7796

APPENDIX A

Growth, Production and Consumption of the Mixtures

ROTATIONAL SECTION

Grazing periods	Total production	Growth by period	Consumption by period	Herbage available	Percentage consumption
		(grams per square yard)			
Mixture 1					
Strip 1					
7-18/6/57	236.9	38.9	164.4	236.9	69.4
19-11/7/57	316.8	79.9	-	-	-
12-23/7/57	416.5	99.7	168.7	252.1	66.9
24-15/8/57	421.2	4.7	-	-	-
16-19/8/57	428.9	61.7	105.8	149.8	70.6
Strip 2					
19-24/6/57	311.6	67.2	228.2	311.6	73.2
25-23/7/57	515.1	203.5	-	-	-
24- 6/8/57	558.8	43.7	203.1	330.6	61.4
Strip 3					
7-15/8/57	267.3	63.7	156.3	267.3	58.5
	3/1309.0		3/1026.5		
	436.3		342.2		78.4%
Mixture 2					
Strip 1					
7-18/6/57	211.0	19.5	148.7	211.0	70.5
19-11/7/57	296.5	84.6	-	-	-
12-23/7/57	417.5	121.9	176.4	268.8	65.6
24-15/8/57	417.5	-	-	-	-
16-19/8/57	475.3	57.8	84.3	138.8	60.7
Strip 2					
19-24/6/57	369.6	79.7	217.9	369.6	59.0
25-23/7/57	451.3	81.7	-	-	-
24- 6/8/57	471.8	20.5	157.9	253.9	62.2
Strip 3					
7-15/8/57	256.2	74.2	185.2	256.2	72.3
	3/1203.3		3/ 970.4		
	401.1		323.5		78.9%

APPENDIX A

Growth, Production and Consumption of the Mixtures

ROTATIONAL SECTION

Grazing periods	Total production	Growth by period	Consumption by period	Herbage available	Percentage consumption
	(grams per square yard)				
Mixture 3					
Strip 1					
7-18/6/57	227.7	55.2	156.7	227.7	68.8
19-11/7/57	285.8	58.1	-	-	-
12-23/7/57	451.8	166.0	208.5	295.1	70.6
24-15/8/57	466.7	14.9	-	-	-
16-19/8/57	524.4	57.7	101.7	159.2	63.9
Strip 2					
19-24/6/57	315.4	68.0	213.4	315.4	67.7
25-23/7/57	509.2	193.8	-	-	-
24- 6/8/57	610.5	101.3	297.2	397.1	74.8
Strip 3					
7-15/8/57	278.9	96.2	197.9	278.9	71.0
	3/1413.8		3/1175.4		
	471.3		391.8		83.1%
Mixture 4					
Strip 1					
7-18/6/57	205.5	87.5	126.5	205.5	61.6
19-11/7/57	269.5	64.0	-	-	-
12-23/7/57	454.7	185.2	216.6	328.2	66.0
24-15/8/57	454.7	-	-	-	-
16-19/8/57	568.1	113.4	149.4	195.4	76.5
Strip 2					
19-24/6/57	333.8	72.0	269.8	333.8	80.8
25-23/7/57	495.9	162.1	-	-	-
24- 6/8/57	596.3	100.4	201.6	326.5	61.7
Strip 3					
7-15/8/57	239.8	12.1	166.3	239.8	69.3
	3/1404.2		3/1130.2		
	468.1		376.7		80.5%

The following table expresses the above production and consumption data in pounds of dry matter per acre.

Mixtures	Production	Consumption
I	4656	3652
2	4281	3452
3	5030	4181
4	4996	4020

APPENDIX B

Daily Grazing Diary for Experimental Period

	CONTINUOUS SECTION		ROTATIONAL SECTION	
Dates	(Grazing Days (accumulative)	Stocking Rate per acre	Grazing Days (accumulative)	Stocking Rate per acre
7-13/6/57	28	1	56	4
14-15/6/57	44	2	72	4
16-17/6/57	106	7.7	104	8
18-24/6/57	225	4.2	314	15
25-27/6/57	249	2	428	19
12-13/7/57	265	2	444	4
14-16/7/57	-	-	492	8
17-18/7/57	289	3	500	2
19-25/7/57	415	4.5	570	5
26-14/8/57	695	3.5	850	7
15-16/8/57	715	2.5	886	9
17-19/8/57	-	-	970	14
Grazing Days per Acre		4/715 178.8	6/970 161.7	

APPENDIX C

Botanical Composition in 1957

	Entire field Spring	Entire field Fall	Continuous section Spring	Continuous section Fall	Rotational section Spring	Rotational section Fall	Hay section Spring	Hay section Fall
Mixture 1								
Bare ground	68.6%	66.7%	77.0%	69.5%	64.1%	65.0%	65.8%	68.9%
Vegetation++	31.4%	33.3%	23.0%	30.5%	35.9%	35.0%	34.2%	31.1%
Brome	62.4	69.8	60.9	73.8	63.0	72.6	57.2	54.2
Alfalfa	28.0	23.0	26.1	19.7	29.5	22.3	31.1	28.7
Wild Barley	6.7	3.6	10.9	6.6	4.2	1.4	10.3	8.0
Other weeds	2.9	3.6	2.2	-	3.3	3.1	1.4	-
Mixture 2								
Bare ground	68.6%	63.2%	66.0%	73.0%	68.0%	60.0%	71.5%	69.6%
Vegetation++	31.4%	36.8%	34.0%	27.0%	32.0%	40.0%	28.5%	30.4%
Brome	52.4	71.2	50.0	64.8	57.5	73.1	48.6	50.6
Russian Wild Ryegrass	5.4	3.0	4.4	3.7	6.2	2.3	5.6	4.6
Alfalfa	24.3	20.4	17.7	11.1	25.6	22.6	24.8	44.7
Wild Barley	13.4	5.4	23.5	20.3	9.1	2.0	14.3	-
Other Weeds	4.5	-	4.4	-	1.6	-	6.6	-
Mixture 3								
Bare ground	67.6%	67.8%	77.5%	74.5%	68.2%	56.2%	62.0%	68.6%
Vegetation++	32.4%	32.2%	22.5%	25.5%	31.8%	43.8%	38.0%	31.4%
Brome	40.6	35.7	33.3	25.5	32.7	29.7	48.9	47.7
Meadow Fescue	35.3	36.6	28.9	25.5	45.9	42.9	28.9	31.9
Alfalfa	19.1	26.1	11.1	29.4	20.4	26.0	22.1	20.4
Wild Barley	4.0	-	24.4	15.7	-	-	-	-
Other weeds	.9	1.6	2.2	3.9	.9	1.4	-	-
Mixture 4								
Bare ground	71.8%	67.0%	70.5%	68.0%	74.2%	63.6%	67.9%	69.6%
Vegetation++	28.2%	33.0%	29.5%	32.0%	25.8%	36.4%	32.1%	30.4%
Intermediate Wheat Grass	28.4	19.7	42.4	10.9	14.7	21.2	31.5	27.0
Creeping Red Fescue	17.4	22.7	10.2	32.8	21.3	15.4	21.5	21.1
Brome and Meadow Fescue	5.7	7.3	6.8	1.6	2.7	3.6	6.8	17.8
Alfalfa	32.6	31.8	35.6	28.1	30.6	40.1	32.4	25.6
Wild Barley	13.8	18.5	3.4	26.6	28.7	19.8	6.2	8.2
Other weeds	2.1	-	1.6	-	1.9	-	1.6	.3

++ Species expressed as a percentage of the total vegetation

Plate 1

Continuous section on July 24. Note the uneven or selective grazing in the foreground.

Plate 2

Rotational section on June 19. Note the excessive trampling around the field cage.

Plate 3

Hay section on August 10. Note the high proportion of alfalfa present.