PASTURE MANAGEMENT;

A COMPARISON BETWEEN

ROTATIONAL AND CONTINUOUS GRAZING

WITH DAIRY COWS

by

RAGNAR HILLESTAD

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ABSTRACT

An experiment comparing continuous and rotational systems of pasture management was conducted in the summer of 1957. A 26 acre field was divided into two 13 acre sections. One half section was further sub-divided into five paddocks which were grazed rotationally. The other half was continuously grazed. Comparable herds of Holstein-Friesian milking cows were used under both systems of management. Two of the rotational fields were cut for hay at the end of June and one of them again in August. The latter field was not grazed. Hence, the rotational herd grazed an area four-fifths of the size of the continuous field.

The system of grazing did not influence milk production per cow day. The total milk production was 15.9 percent higher for the rotational than for the continuous herd. This increase is directly attributable to the longer grazing season of the experimental area under the rotational system of grazing. The milk production per acre for the grazing period, May 30 to August 16, was 24.7 percent greater for the rotational system of grazing. The total yield of herbage estimated as pounds of dry matter per acre was 21.3 percent higher for the rotational than for the continuous field for the entire grazing season.

Results of surveys made in the spring and fall, on the botanical composition showed that the percentage of legume persisting in the swards was higher in the rotational pastures.

The crude protein content of the herbage from the rotational fields was higher than that from the continuous field. Crude fibre, fat, ash and nitrogen-free extract content of the herbage were very similar within both systems of grazing.

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INTRODUCTION

Investigations over the last thirty years have shown that controlled grazing can play an important part in improving the productivity of grassland. The evidence indicates that yield, nutritive quality and palatability can be improved by proper management of the pasture. Pasture management can also have a beneficial effect on the botanical composition of the sward.

Brown (8) stated that the chief problem to be solved in pasture management is the appropriate disposal of excess forage during the flush period in spring and early summer. In addition a complex of other factors affecting forage is involved. The herbage will vary in digestibility and nutritive value according to the stage of growth and time in the growing season. Long-term productivity depends on the degree of success in excluding weeds and inferior plants and keeping a desirable ratio between the grass and legume components.

Continuous grazing involves keeping animals on a pasture for an entire season. Rotational grazing in contrast to continuous, involves dividing pasture land into small paddocks, usually four or more, and grazing each in turn. By the time the herd is brought back to the first paddock, a uniform growth should have developed. This system largely eliminates the problem of spot grazing and the admixture of old growth with young growth, a feature characteristic of continuously grazed pasture. Rotational grazing gives excellent opportunity to cut one or more of the paddocks for hay or silage.

Cole, according to Smith (45), implied that the system of rotational grazing, known as the Hohenheim system of pasture management, originated in Germany during the first World War. Smith (45) claimed, however, that this basic idea was advocated in Scotland in the Sixteenth Century.

The variations in techniques used for evaluation of pasture productivity create problems in comparing results from different experiments. The importance of this problem has been fully recognized by several American agricultural organizations which have appointed a study committee to collaborate in investigations of pasture research techniques (2).

Results of research in pasture management may be influenced by many factors including number of fields in the rotational system of grazing, botanical composition of the sward, kind of animals utilizing the pasture, geographical area, climatic and soil conditions.

The objective of this thesis was to study and compare rotational and continuous systems of grazing. The primary aspect of the study was the measurement of pasture productivity. The other chief aspect for study was the determination of the effect on the sward of the two systems of grazing. Chemical analyses supported the evaluation of nutritive value.

LITERATURE REVIEW

A. Pasture Management

Rotational grazing has been practiced to a great extent in England and other European countries. These countries and New Zealand and the United States have conducted most of the research in this particular field.

Hodgson et al. (22) reported the same number of cow pasture days per acre from rotational and continuous systems of grazing, but an increase of nine percent in total digestible nutrients (T.D.N.) in favour of rotational grazing. They doubted that rotational grazing is worthwhile considering the costs involved.

Brundage and Petersen (9) in Minnesota used four sets of identical twins of dairy cattle, to compare daily rotational and continuous grazing. The experiment was carried out over a complete season. They obtained in terms of T.D.N. nearly three times the production per acre with daily strip grazing over that from continuous grazing in one large paddock.

One aspect of grazing deserving attention is the efficiency of grazing. It has been estimated in England, as reviewed by Holmes et al. (24) that the produce from dairy cattle grazing rotationally was only 60 percent of that of similar grassland cut and preserved for drying. This may be attributed largely to wastage of grass by treading, dunging and selective grazing by the stock. De Geus (14) stated that in Holland losses up to 40 percent of the gross yield were possible with continuous grazing. However, under the modern system of rotational grazing with nine adult cows per acre, losses decreased to 20 - 25 percent of the gross yield. He further said that although rotational grazing is a considerable improvement over continuous grazing the losses are still significant. De Geus (14) showed that as the stocking rate on a field increased, the losses decreased because less grass was trampled down. In addition, each rotational field has a longer period for recovery because the forage is consumed in a shorter period of time at the higher stocking rate.

Hosking and Line (27) stated that the logical development from paddock grazing was close-folding, an extreme form of rotational grazing encouraged by the economics of tethering and advances in electric fencing techniques. It is generally agreed that the overall yield of milk and live-weight changes of milking cows are not materially affected by different grazing systems (9, 24, 25), although milk yield is more stable from day to day under a system of daily folding. According to workers in New Zealand and Scotland (27) differences in the grazing behaviour and health of the cows on close-folding and paddock grazing were small, although the latter method was generally associated with the higher consumption of herbage dry matter.

De Geus (14), Holmes et al. (24) and Procter et al. (39) found that higher production per acre and more efficient pasture utilization was possible under the close-folding method. They reported increases in output per acre of 15 to 40 percent.

Not all experiments, however, show the advantage of rotational grazing (19, 20).

B. Experimental Procedures

1. Animal Production

Harlan (18) reported that the measurement of animal products is generally considered to be the most significant method for evaluation of pasture productivity. There are many reports concerning the evaluation of swards in terms of live weight changes or meat production but relatively few dealing with milk output (10). Milk production can be affected by many factors totally unconnected with the supply of nutrients. The paucity of critical grassland evaluation in terms of milk yield can thus be understood.

Cox et al. (12) suggested the possibility of pasture evaluation in terms of milk production using individually-grazed cows. They obtained a significant linear relationship between mean milk yield and estimated dry matter intake over a three week period.

One of the difficulties encountered in describing pastures in terms of animal productivity is the development of a unit of measurement that is simple, accurate, yet general enough to be applicable to all kinds of stock (7). Gain in live weight or milk production are terms easily understood by the farmers, but they are not general enough to be applied to all kinds of stock, and they do not take into account the maintenance of the animals.

Brown and Slate (5) in reporting pasture results with steers, used net energy values. The method is also discussed by Ivins (28).

The net energy system originated with Kellner's studies of the fat producing power of feeds and with Armsby's respiration calorimeter experiments. Net energy is the portion of the ingested energy which is actually utilized to produce such items as meat, milk or work, but excludes the portion used for metabolic processes (34). Although probably the most accurate in principles, not enough data are available to apply this method to all kinds of stock.

Pasture productivity is more commonly expressed in terms of total digestible nutrients (16, 21, 30, 36). However, determination of total digestible nutrients is only one step in arriving at the useful portion of a ration because losses in urine, combustible gases and heat elimination are not taken into account. The calculated fecal loss is large and usually exceeds all other losses, especially in the case of roughages. Digestible nutrients are easily determined, and digestion coefficients are available for most of the common feeds (35).

The requirements of the grazing animal in terms of T.D.N. are calculated both for maintenance and for gain by the reverse use of feeding standards. Because the requirements of animals are estimated in metabolism cages or stalls, the value obtained does not include the extra maintenance fraction required for movements on pasture in search for food. This is perhaps not serious in comparative trials, since the absolute level of production is not critical as long as a valid comparison can be obtained (46).

Supplementary food introduces uncertainty into the results of an animal production experiment and should be avoided as far as possible (2). Watson and Kauter, as reviewed by Brown (7), have shown that supplementary feeding increases the difference between results obtained by the agronomic method (actual weight of cut herbage) and the animal grazing method. This is particularly apparent when the results are expressed in starch equivalent. Knott et al. (30) believed that if the rate of growth of herbage is fairly uniform throughout the season, less error would be introduced by maintaining the same number of animals and increasing the supplementary feed so long as just enough is given to prevent loss in body weight or an abnormal decline in milk production.

2. Carrying Capacity

Pasture productivity may be expressed in terms of "cow days". "Cow days" are simply the product of the number of grazing days and the number of animals carried on a unit pasture area. Castle (10) reviewed many experiments where the results have been expressed in this manner. This is only a rough measure of pasture productivity, and the main disadvantage is that no credit is given for meat or milk production and feeding of supplementary food can seriously affect the results.

3. Measurement of Herbage Production

In nearly all pasture experiments it is desirable to supplement actual grazing results with some estimation of herbage production. When the animals are on the pasture for so long a period that the amount of herbage which has grown during that period cannot be ignored, small enclosures are employed to prevent the animals from grazing certain areas. The enclosures or cages are placed in one position for a whole season (permanent cages) or they are moved around to different positions several times during the season. At periodic intervals the forage growth within the caged area is clipped and weighed in order to estimate total production. The permanent cage technique suffers from many defects of continuous clipping and is not strictly comparable with grazing by animals (5, 43). According to Robinson et al. (43) the permanent cage method is satisfactory enough when the work does not justify the time and expense of the movable cage system, provided that the cages are moved each season.

The term "difference method" has been employed to describe those cage techniques in which a subtraction or "difference" is employed. In one case it is herbage growth which is estimated, in another herbage consumption. The techniques employed by various workers have varied considerably. These variations are found chiefly in sampling procedures as number, size and location of the cages, types of apparatus used in harvesting the forage, heights and frequency of cuttings, size and shape of the paddocks and the handling and drying of samples (24, 32, 33, 37, 43, 48).

When estimating growth and consumption by the "difference method" three corresponding areas have to be located. One of these areas is clipped at the beginning of the grazing period; the second will be covered by the cage, and the third staked or marked out. The second and third areas are clipped at the end of the grazing period. Growth of forage is estimated at the end of the grazing period by finding the difference between the weight of forage from the caged area and that from the area clipped at the commencement of grazing. The difference between the caged and uncaged areas both clipped at the end of the grazing period expresses consumption.

Many workers (7, 32, 49) have these sampling units adjacent. Klingmann et al. (29) showed that in estimating consumption, it was more efficient to choose one area at random and to select corresponding areas similar in plant composition, amount of growth and soil characteristics. Brown (7) indicated that there is a lack of complete agreement as to selection of the three areas to be clipped. Some workers disregard any randomization which places the grazed sampling area immediately adjacent to the caged area. A reason for this practice is that animals tend to congregate more closely around cages and to graze that area more intensively.

4. Botanical Composition

Recording of changes in botanical composition over a period of time is of great importance when different systems of pasture management are compared. Crocker and Tiver (13) stated that botanical composition expressed in terms of cover, is one of the best means of studying ecological changes and trends in development of a pasture. They quoted Levy as saying that the percentage of ground covered rather than percentage composition of the sward represents the true position relative to gain or loss by each species. Brown (7) described a number of methods which have been used for estimating botanical composition.

The vertical point quadrat method developed by Levy and Madden (31) is essentially a method for expressing botanical composition in terms of cover. The apparatus which is used consists of ten pins linearly placed at two inch intervals in a line or row in a metal frame. This frame is dropped at random on the pasture and the species hit are recorded. Thus, groups of ten readings are made at each randomization over the field. As the pin is moved towards the ground a record is made of either the first hit or all the plants hit (11, 47). Staples in a written communication to Brown (7) suggested counting only hits made on vegetation present in the first inch above the surface of the ground. Where no vegetation is hit bare ground is recorded.

Tinny et al. (47) introduced the inclined point quadrat method where the pins are set at an angle of 45°, as a desirable modification of Levy's vertical quadrat method. This modification has since been used in the prairie provinces of Canada (11) and in the United States (3, 15). Tinny et al. (47) considered the inclined point quadrat method to be more accurate because a greater area is covered per reading.

There is no standard practice regarding the distribution of points. Some workers use a line transect across the pasture (31) while others prefer to distribute the point quadrat frame within plots or quadrats (17).

The necessary number of points does not depend to any extent on the size of the field but rather on the nature of the vegetation. A large variety of species or a sparse distribution requires a large number of readings. For a pasture where information on dominant species only is required Levy and Madden (31) considered 100 points to be sufficient and for the less abundant species, 400 to 500 points. Crocker and Tiver (13) claimed that for dominant species only a slight increase in accuracy is obtained when the number of readings exceeds the range of 200 to 400.

MATERIALS AND METHODS

A. General

The experimental field comprised an area of 26.62 acres which was divided into two equal portions. One-half was further subdivided into five paddocks (numbered I to V), each containing 2.66 acres. In the spring of 1954 the total pasture had been seeded in a nurse crop of wheat, to a uniform stand of alfalfa, meadow fescue and brome grass. The seed mixture used was as follows:

Brome grass	8 lbs. per acre
Meadow fescue	4 lbs. per acre
Alfalfa	6 lbs. per acre

However, at the time the experiment started some Kentucky bluegrass and timothy had invaded the sward. The pasture area was used in 1955 for hay and in 1956 for the first year of the continuous versus rotational trial.

The entire field was fertilized in the spring of 1957 with barnyard manure at ten tons per acre.

Each half of the total field was grazed by comparable herds of Holstein-Friesian milking cows. The herd assigned to the continuous field grazed the same area during the whole pasture season. The herd under the rotational system of grazing alternated on the small paddocks.

B. Animals Used

The milking cows in the University dairy herd were divided into two groups as similar as possible in age, stage of lactation, weight and current and potential milk production. One cow was removed from the rotational group on June 27 because of illness; two cows after calving were added to this group, one on July 9 and the second on July 24. To the continuous group it had been intended to add one fresh cow on July 10; however, an injury to the cow prevented this addition.

It should be noted that in the initial allotment subsequent increases in the size of each group were taken into account. During the early part of the season the continuous group was slightly more productive due to higher yielding ability per cow and the greater number of animals in the group. However, this discrepancy was intended to be removed during the season. When taking the entire period into consideration, the two groups were believed to have very similar potential production.

Averages for milk production, weight, age and stage of lactation of the two groups prior to the test are shown in Table 1. Average daily milk production was evaluated over a period of one week before the experiment started.

Table 1. Preliminary Evaluation of the Experimental Groups.

	Rotational	Continuous
Milk production per cow (daily)	31.6 lbs.	34.0 lbs.
Weight per cow	1146 "	1156 "
Age per cow	5.9 years	5.8 years
Stage of lactation (Ave. no. days from calving)	112.9	125.9 days

The continuous group consisted of 16 animals during the whole grazing season. The rotational group varied from 14 to 16 animals as follows: from May 30 to June 27, 15 animals; from June 28 to July 8, 14 animals; from July 9 to July 24, 15 animals and from then on 16 animals. Thus, the individual rotational fields had a stocking rate varying from 5.7 to 6.1 cows per acre and the continuous field was constantly stocked at 1.2 cows per acre.

The cattle were on the pasture day and night and were brought into the barn for milking twice a day, each time for approximately 3 hours. The distance from the pasture field to the barn was half a mile.

During the trial the two groups grazed on their respective pastures for 5.5 days each week except for two weeks in the middle of June when they grazed 7 days a week. On Sundays and holidays both groups were placed together on a non-test field. In practice, the cows grazed on the non-test field from the completion of the Saturday afternoon milking until the Monday morning milking, after which they were re-grouped and returned to the experimental field.

The amount of supplementary feed given daily was determined from the quality of the pasture and daily milk production per cow (35). The quality of the pasture both in the continuous and rotational fields was considered "excellent" until the middle of July and between "excellent" and "good" thereafter.

The composition of the supplementary feed; i.e., concentrate mixture, was as follows:

Oats	60.0 percent
Barley	29.5 "
Soybean oil meal	7.5 "
Salt (Cobalt iodized)	1.5 "
Bonemeal	1.5 "
Total	100.0 percent

The chemical composition of a representative sample of the concentrate ration was determined to be: moisture 12.36 percent; crude protein 12.82 percent; fat 4.25 percent; crude fibre 6.93 percent; ash 4.69 percent and N-free extract 58.95 percent.

Cows in both groups had constant access to water and a mineral mixture containing equal parts of bonemeal and iodized salt.

The animal products measured were milk production while the animals were on the test and live weight changes. The milk produced by each cow was weighed to the closest half pound after each milking. The percentage of fat in milk of each cow was determined monthly and weighted according to milk production to give an average fat test for the experimental period.

Although weighing of cattle on three consecutive days has frequently been practiced, it has recently been demonstrated that single weighings are equally satisfactory (1, 4, 38). Therefore, single weighings were made at monthly intervals. Initial and final weights were also recorded. All weights were taken just after morning milking.

The days of grazing and number of animals under each system of grazing were recorded for the whole grazing season and expressed as "cow days".

C. Measurement of Herbage Production and Consumption

In conjunction with the grazing test, estimates of the yield, growth and consumption of forage for each grazing period were obtained in pounds of dry matter per acre by the "difference method". The procedure used is outlined as follows: At the beginning of the first grazing period, groups of three similar areas were located within the paddock. One was clipped, one caged and the third marked for clipping at the end of the grazing period, at which time the caged area was also cut. At the beginning of the second and subsequent periods similar areas were located. Growth was calculated by subtracting the production of the unprotected area cut at the beginning of the grazing period from that of the caged area at the end of the grazing period. Determination of consumption was calculated by subtracting the figure for the unprotected area from the figure for the protected area, both clippings taken at the end of the grazing period.

Ten cages were allotted to the rotational field and 20 cages to the continuous field. The cages were placed to sample adequately the area grazed. The cages were moved in both fields when the cows were rotating to a new pasture field under the rotation system of grazing. The cages, 4' x 6' x 2.5' (Fig. 1), were made of an iron frame with wire netting. Within each cage a cut of one square yard (2' x 4.5') was made. This eliminated border effect and possible grazing just inside the cage. Similar cuttings of one square yard were made outside the cages. The cuttings were made by hand with a hedge clipper and as close to the ground as possible. The herbage cut within each cage was collected in paper bags and weighed. Approximately 300 grams were taken out of each sample and dried separately in a preheated Unitherm oven for at least six hours (41) to determine dry matter and moisture percentages.

D. Botanical Composition

The effect of the two grazing systems on the botanical composition of the sward was determined by the inclined point quadrat method (Fig. 2). Data were collected in the fall of 1956 and in the spring and fall of 1957. In each of the rotational fields 300 hits were recorded, which meant that the frame was placed at 30 different places in the field. In the continuous field 1,500 hits were recorded. This is equivalent to the amount which was taken in the five rotational fields. All portions of each field were sampled.

Readings were made at ground level. The different grass species were not distinguished but all recorded as "grass". The other groups read were legumes (mostly alfalfa), weeds and bare ground.

It was noticed in the fall of 1956 that the rotational fields were not completely uniform in their botanical composition. Field I was higher in legume amount than any of the others, with comparatively little grass and a relatively high percentage of bare ground. The amount of weeds was also especially high in this field. Field III showed least legumes while field II had the highest amount of grass. Field II showed, however, the most uneven growth, due mainly to some low spots within this area, which probably had been under water in previous periods.

E. Chemical Composition

The chemical composition of the pasture mixture throughout the grazing period was evaluated for crude protein, fat, crude fibre, N-free extract and ash. As mentioned earlier, moisture percentage was determined in connection with yield determination. The samples for chemical analyses were taken from the rotational fields at the beginning of each grazing period, using the same samples collected for yield determination. Samples were also taken in the continuous field at the same date. The dried samples within each field were mixed thoroughly and a representative sample of approximately 200 g. was taken for chemical analyses. The samples were ground to a fine flour in a Wiley mill.

The methods of chemical analysis used were those recommended by the Association of Official Agricultural Chemists (26).

The improved Kjeldahl method was used for determination of crude protein. "Kel-packs", which contain a pre-packed specific amount of HgO and K_2SO_4, were used instead of weighing out the amounts separately.

Samples for fat determination must be completely moisture-free. The samples were stored in jars with tight lids for some time before chemical analyses were carried out. These samples were able to pick up some moisture during handling of the material. Consequently, the samples used for fat determination were dried in vacuum at 95-100^{o} C. for five hours prior to the chemical analysis. The moisture content varied from three to ten percent. The other chemical components were corrected for this amount of moisture. They were thus all expressed on a completely dry matter basis.

F. Climatic Conditions

A brief review of average daily temperature (^{o}F) and rainfall (inches) for the four summer months in 1957 compared with long time averages for the same feature is presented in Table 2. These data were recorded at Stevenson Field Airport, adjacent to Winnipeg.

Table 2. Temperature and Rainfall in the Summer of 1957 compared to a "Normal" Year.

	May	June	July	August
Temperature				
1957	55.1	58.5	72.3	65.3
Normal	51.9	62.0	67.1	64.5
Rainfall				
1957	1.73	5.00	1.68	3.50
Normal	2.07	3.20	2.90	2.54

Climatic conditions in the summer of 1957 were rather unusual. May was warm with rainfall slightly below normal. June was cool and wet. This provided a very good start for the pasture and resulted in heavy growth in late June. July was very warm, the third warmest July on record, and rainfall was only 58 percent of normal. The last two-thirds of the month were extremely hot and dry. August had a normal temperature with an excess of rain which gave favourable conditions for pasture growth.

RESULTS AND DISCUSSION

A. Management

The experiment commenced May 30, 1957 for both the rotational and the continuous group. The growth in the continuous field was almost two weeks behind that of the rotational field. This was probably due to heavy grazing of the continuous field during the previous year.

The continuous group grazed the same area until August 16, at which time lack of herbage made it necessary to remove this herd. The rotational fields, however, were able to produce sufficient herbage for another two weeks grazing. The experiment terminated on August 31 for the rotational group.

It was soon clear that with the number of animals used, the five rotational fields would produce an excess of forage during the intensive growth period early in the summer. When grazing of three fields was completed, the first field was again ready for grazing. Two of the fields (I and V) were then cut for hay on June 27. Later in the season it was obvious that four rotational fields would produce enough herbage for the stock. Field V was cut for hay a second time on August 17. Thus, the rotational group grazed an area only four-fifths as large as that grazed by the continuous herd.

It is now generally believed that pasture species should not be grazed shorter than 1 to 2 inches (8). However, due to growth differences between species, no simple measure for best defoliation heights is practicable (44). Hay type grasses and legumes especially will not withstand heavy grazing. Lenient grazing is required for brome grass and alfalfa. Consequently, the management of a brome grass alfalfa mixture is governed by the requirements of alfalfa. In order to maintain a well-balanced mixture of alfalfa and brome grass through three or four seasons in Michigan, it was considered advisable to maintain a growth 8 to 10 inches tall during May and June and not less than 4 inches high during the summer (8). Recent work in New Zealand, as reviewed by Sears (44), has demonstrated by sequential yield and leaf area that the growth increment curve is sigmoid with a very slow initial recovery after close grazing.

An attempt was made to avoid overgrazing of the rotational fields. High producing dairy cows are not able to obtain enough nutrients for profitable production when the vegetation is too short. It may be argued that it is necessary to graze the pasture sufficiently hard to force the stock to eat unpalatable herbage and weeds but this results in a decrease in production. Another factor is that certain valuable pasture plants may be destroyed by heavy grazing. In this experiment visual estimation and decrease in milk production towards the end of the grazing period were the main factors which determined when the rotational herd was to be moved (Fig. 3).

No precise measurements are available to indicate exactly when to move a herd from one rotational field to the next, how close to graze a pasture to achieve maximum utilization without damage to the sward and when to terminate grazing for the season. This means that subjective judgment must be used to reach such decisions.

The rotational fields were mowed when necessary after the grazing period to establish an even regrowth and to keep weeds from setting seed. In contrast to the rotational fields, the continuous field was heavily invaded by weeds, especially Canada thistle and wild barley (Fig. 4) but was not mowed until the end of the grazing season.

No palatability studies were conducted, but from observations it appeared that the legume components were most appreciated and timothy least appreciated by the herd.

B. Carrying Capacity

Table 3 shows the rotation of the sub fields, grazing periods for each of the rotational fields and the number of cow days within each system of grazing for corresponding periods.

The length of each grazing period varied during the season. As could be expected, the periods were shorter at the end of the season. The continuous field supplied 1,017.5 cow days for the entire season. When the continuous group was removed on August 16 the rotational fields had supplied 968.5 cow days or 49 less than the continuous field. Expressed on per acre basis the continuous field

Table 3. Carrying Capacity

Grazing Period	Continuous Pasture Grazing days	Continuous Pasture Cow days	Rotational Pasture Grazing days	Rotational Pasture Cow days	Field No.
May 30 - June 8	8	128	8	120	III
June 8 - June 19	10.5	163.5	10.5	154.5	IV
June 19 - July 3	10	160	10	146	II
July 3 - July 15	9	144	9	131.5	III
July 15 - July 25	8.5	136	8.5	128.5	IV
July 25 - Aug. 6	9	144	9	144	I
Aug. 6 - Aug. 16	9	142	9	144	II
Aug. 16 - Aug. 26			6.5	104	III
Aug. 26 - Aug. 29			3.5	56	IV
Aug. 29 - Aug. 31			2	32	I
Total	64.0	1017.5	76.0	1160.5	

supported 79.7 cow days and the rotational fields 91.2 cow days. When the extra two weeks' grazing of the rotational fields were included, this system of management had an excess of 143 cow days over the continuous field. Hence, for the entire season the rotational fields had 109.0 cow days per acre or 36.8 percent more than the continuous field. This means that the rotational fields were more heavily stocked than the continuous field.

C. Animal Production

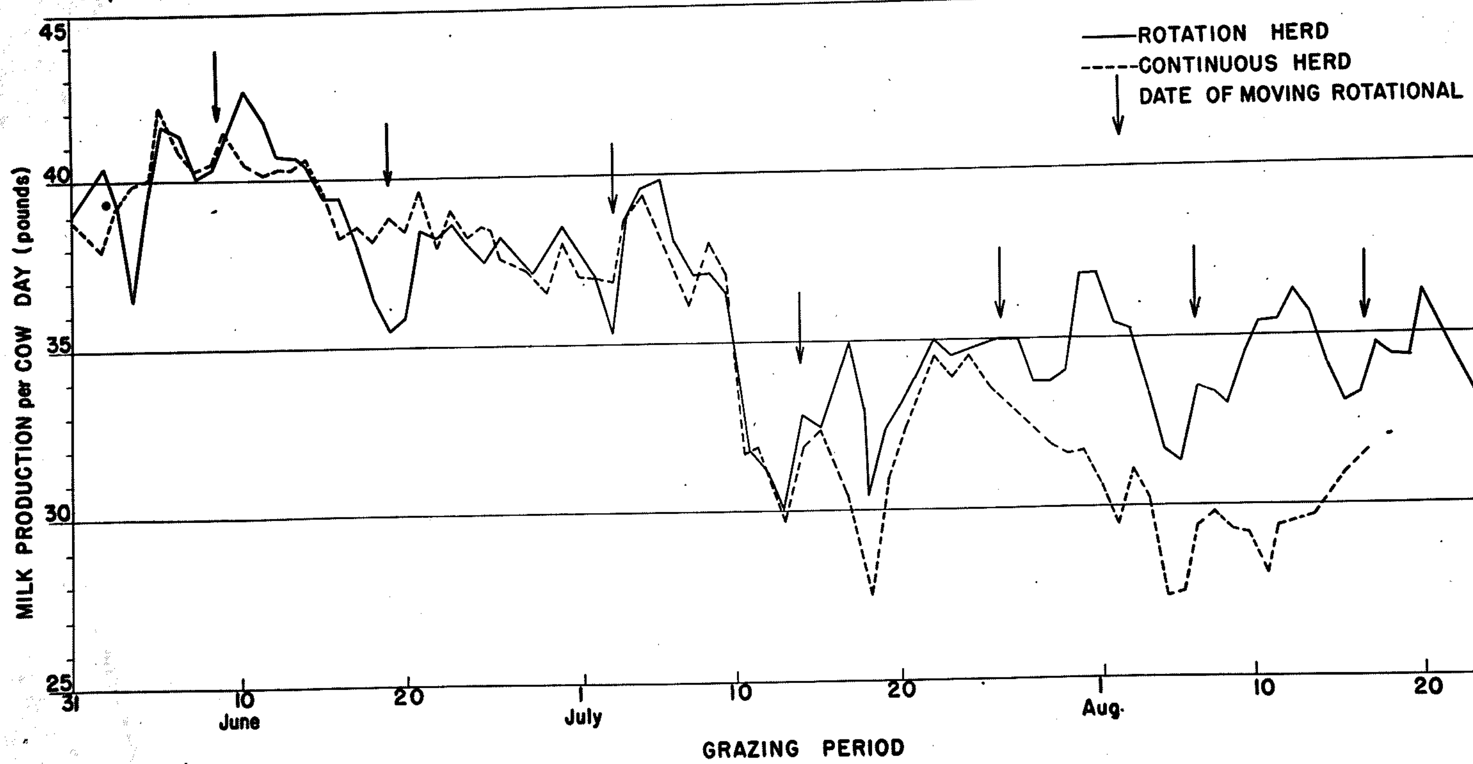
Milk production per cow day for the entire season is given in Graph 1. It shows that from the beginning of the season and until the middle of July there was little difference between the two groups. The sudden decrease in production after July 10 may be attributed to the physiological effect on the herd of the very high temperature at that time. Experiments at the University of Missouri (40) with

Holstein-Friesian milking cows have shown that high temperature has a depressing effect on milk production, feed consumption and body weight. This becomes evident at 75 to 80° F. and rapidly increases with higher temperature. The extreme example of this phenomenon is illustrated on the graph for the days July 10 and 11. The drop in milk production at this time was about 5 lbs. per cow.

From the middle of July onwards, there was an obvious difference in milk production in favour of the rotational group. This can be explained by a decreasing amount of herbage available for the continuous group but other factors must be considered. The herd under continuous grazing consisted of the same animals throughout the entire season and they had all calved before the experiment started. Because of the nature of the lactation curve, a gradual decrease in milk production must be expected. This is clearly indicated by the graph. The herd under rotational grazing varied in number of animals. During July this group was increased by two newly-calved animals which helped to keep up the production and accounts, in part, for the difference in production between the two groups. However, the fact that the continuous group had to be removed from the pasture two weeks before the rotational group, because of lack of herbage, should indicate that rotational grazing makes higher production possible from a specified acreage.

Although there are fluctuations in the milk production from

Graph I.


ROTATION HERD
CONTINUOUS HERD
DATE OF MOVING ROTATIONAL
MILK PRODUCTION per COW DAY (pounds)
45
40
35
30
25
31
10
June
20
1
July
10
20
1
Aug.
10
20
GRAZING PERIOD

day to day, it may be noticed from the graph that the rotational group had a decrease in production towards the end of each grazing period. This may indicate that the herd was kept on each of the rotational fields for too long a period. The fields were, however, not grazed extremely hard. It seems to be difficult to keep an even milk production under a rotational system of grazing.

Because the herbage under both systems of management was utilized as far as possible, the milk production per cow day tended to decrease both under rotational and continuous grazing towards the end of the season.

Table 4 presents averages for milk production, concentrate feeding and live weight changes during the whole season for both systems of management. The milk production was almost the same for both groups when compared for equal time. From May 30 to August 16 the rotational and continuous groups produced 34,863.5 lbs. and 35,512.0 lbs. respectively. For the total season on the experimental fields, the rotational group produced 15.9 percent more milk. This is, however, due to the longer period of grazing. The table also shows that the rotational group consumed more concentrates than the continuous group. This could account, in part, for the slightly higher production of milk by the rotational herd, on a cow day basis. During the last two weeks' grazing for the rotational herd the milk production per cow day decreased 3.2 lbs. compared with the

Table 4. Milk production, Concentrate Ration and Live Weight changes

	Rotational May 30 to Aug. 16	Continuous May 30 to Aug. 16	Rotational Aug. 16 to 31.
Ave. No. of animals per day	15.1	15.9	16.0
Total milk production (lbs.)	34863.5	35512.0	6297.5
Milk production per animal (lbs.)	2278.7	2233.5	393.6
Ave. daily milk production per cow (lbs.)	36.0	34.9	32.8
Milk production per acre (lbs.)	3326.7	2668.1	600.9
Total concentrates fed (lbs.)	8113.0	7837.5	1408.0
Ave. daily concentrates per cow (lbs.)	8.4	7.7	7.3
Total concentrates per cow (lbs.)	537.3	492.9	88.0
Ave. live weight changes per cow (lbs.)	78.3	91.6	-27.8

production during the previous period.

Although both groups increased in body weight until August 16, the greatest increase was recorded for the continuous group. During the latter part of the grazing season, average weight of the cows under rotational grazing decreased.

The milk production per acre was 24.7 percent higher for the rotational than for the continuous herd for the same grazing period. It has to be kept in mind that the rotational herd grazed on a smaller area. When the additional two weeks' grazing in the rotational fields are included, the milk production was 47.2 percent higher per acre for the rotational herd.

It can thus be concluded that the system of grazing does not seem to have influence on the milk production as such. The rotational system of grazing has advantages attributable to a longer grazing season and an excess of herbage, which can be cut for hay, during the early part of the season. This statement is in good agreement with results obtained by other workers (9, 24, 25).

D. Animal Production and Maintenance calculated as T.D.N.

A method summarized by Sylvestre and Williams (46) was used for estimation of T.D.N. requirements of the experimental herd. This method consists of calculating the gross T.D.N. necessary for animal maintenance, for production of a given amount of milk and for changes in live weight. The T.D.N. of supplementary feeds are subtracted from the gross T.D.N. The difference is that which is furnished by grazing.

The maintenance requirement is that of the Morrison's standard (35) reduced to 100 lbs. live weight. For example, a 1200 lbs. cow requires 0.774 lbs. T.D.N. per 100 lbs. weight for one day maintenance. For milk production, 0.324 lbs. T.D.N. is required for the production of one pound of milk testing four percent fat. The following formula is used to convert milk to four percent fat corrected milk:

Fat corrected milk = 0.4 x milk prod. + 15 x fat percent.

The figures that are available on the requirements for gain in live weight have been derived from experiments with growing animals or fattening steers and may not be entirely accurate for use in the case of mature lactating dairy cows. Knott et al. (30) calculated that 3.53 lbs. of T.D.N. are required per pound of gain in body weight. In the absence of more accurate or applicable information, this factor was used in the calculations.

T.D.N. in supplementary feed was calculated by using results obtained from chemical analyses of the concentrate mixture in conjunction with digestion coefficients listed in Morrison's feeding standards (35).

Results of T.D.N. calculations are given in Table 5. For the period May 30 to August 16 the rotational and continuous groups

Table 5. T.D.N. Requirements for Animal Production and Maintenance

	Rotational May 30-Aug.16	Continuous May 30-Aug.16	Rotational Aug.17-31
Fat percent	3.61	3.60	--
Fat corrected milk (lbs.)	32557.2	33168.5	5885.9
T.D.N. required for maintenance (lbs.) *	9061.4	9450.9	1823.8
T.D.N. required for milk prod. (lbs.)	10548.5	10746.6	1907.0
T.D.N. required for gain in live weight(lbs.)	4419.6	5171.5	--
Total T.D.N. required (lbs.)	24029.5	25369.0	3730.8
T.D.N. in concentrates (lbs.)	5481.6	5295.6	951.4
T.D.N. from pasture (lbs.)	18547.9	20073.4	2779.4
Percent nutrients from pasture	77.2	79.1	74.5
T.D.N. per animal from pasture (lbs.)	1228.3	1262.5	173.7
T.D.N. per cow day from pasture (lbs.)	19.2	19.7	14.5
T.D.N. per acre pasture (lbs.)	1769.8	1508.1	265.2

* Body weight of each cow used to estimate T.D.N. requirement was average of weights at beginning and end of monthly intervals. Monthly requirements were totaled.

obtained from pasture approximately 18547 lbs. T.D.N. and 20073 lbs. T.D.N. respectively. The rotational group thus consumed 92.4 percent as much T.D.N. as the continuous group obtained by grazing. The requirement for the rotational group was, however, obtained from an area four-fifths the size of the continuous field. On a per acre basis the rotational group consumed 17.4 percent more than did the continuous group. It should be kept in mind that one of the four rotational fields was cut for hay once before any grazing was made. This is not taken into account when estimating the consumption per acre. Consequently, the result should actually be more favourable for the rotational fields than is indicated. When the additional two weeks grazing are included, the consumption from the rotational fields was 34.9 percent higher per acre than that from the continuous field.

The results obtained by T.D.N. calculation are in good agreement with results obtained by milk production. It will be noticed in Table 5 that the amount of T.D.N. consumed per cow day from the pasture until August 16 was 0.5 lbs. higher for the continuous than for the rotational group. It was previously found that the milk production per cow was a little higher for the rotational than for the continuous group. This may appear to be contradictory althought the difference is not big enough to be worthy of emphasis. Some reasons can be advanced to explain this discrepancy.

The weights of the animals in the two groups were approximately the same at the beginning of the experiment (Table 1). The continuous group gained, however, 13.3 lbs. more per cow than the rotational group during the experimental period until August 16. This higher amount of T.D.N. requirements is approximately enough to level out the difference of 0.5 lbs. T.D.N. per day. It should also be kept in mind that some uncontrolled factors are not included in the calculation. The fact that maintenance requirements for movement on pasture are not included is probably not serious in a comparative trial. However, it is probable that the continuous herd was moving around more in search for food than the rotational herd because of the bigger area and less herbage available per acre. This necessitates higher requirements for maintenance. Although probably not of great importance, it decreases the amount of energy available for milk production.

For the last two weeks of grazing, when only the rotational group was on the experimental area, the T.D.N. amount consumed was 4.7 lbs. less than for the previous period. That this had a definite effect on the animals is indicated by a decrease in milk production and loss in body weight during this period. The loss in body weight during the last two weeks of grazing is not taken into account when calculating the T.D.N. requirements. Less herbage was thus consumed than the calculation indicates.

Allowance for loss in body weight is a problem that is difficult to solve and there is no definite information on the efficiency of conversion of body weight to milk production (30). Visual estimation during the last part of the experiment indicated that the amount of herbage available was adequate but, after considering the loss in body weight and decreasing milk production, the herd appeared to have been on the pasture for too long a period. Consequently, in evaluating the total productivity of the two management systems, it may be advisable not to put too much emphasis on the production from the rotational fields during the last two weeks of grazing.

E. Herbage Production and Consumption determined by Clippings

The clipping method for determination of herbage production and consumption is widely used despite its limitations. The aim is to take the cuts in such a way that the harvested herbage will be in a condition similar in amount, botanical composition and chemical composition to that available to the grazing animal. The fact that selective grazing by the animal is not taken into account is perhaps the most important criticism (42).

Table 6 shows the total yield, growth and consumption for each grazing period within all fields. Calculation of growth and consumption is explained under "Materials and Methods". Total yield is calculated by adding to the herbage present at the beginning of the grazing season, growth during the successive grazing periods. In the rotational fields the growth periods include both grazing and rest periods.

Data obtained for growth by subtracting yield of protected area at the end of the grazing period from yield at the beginning of the grazing period are probably overestimated. Growing conditions should be more favourable inside the cage than outside. The animals select the leafy and highly digestible parts first and reduce the amount of productive organs. This error will also overestimate consumption. Another factor is that the microclimate inside the cage differs from that outside the cage. However, these errors should not be significantly different for the two systems of management so comparisons can be made.

Average yield for all the four rotational fields which were grazed (hay cut of field I included) was 5974 lbs. of dry matter per acre. The continuous field produced 4925 lbs. of dry matter per acre. Thus, the rotational fields produced 21.3 percent more per acre than the continuous field. Field V, which was cut for hay twice, produced 4923 lbs. per acre. The yield of the rotational fields varied considerably. Three of the fields (I, III and IV) produced more than six thousand pounds of dry matter per acre while the other two (II and V) produced less than five thousand pounds of dry matter per acre. As part of field II was on a relatively low area which probably had been under water in previous periods, production

Table 6. Yield, Growth and Consumption of Forage in Pounds Dry Matter per Acre as Determined by the Difference Method

Continuous Field

Date of Clipping	Yields from protected areas	Yields from unprotected areas	Growth by periods	Consumption by periods		Total yields to date
				Weight	%	
May 30		1013	1013			1013
June 8	1511	1041	498	470	31.1	1511
June 19	1470	789	429	681	46.3	1940
July 3	1268	540	479	728	57.4	2419
July 15	1587	755	1047	832	52.4	3466
July 25	1682	1186	927	496	29.5	4393
Aug. 6	1562	957	376	605	38.7	4769
Aug. 16	1113	544	156	569	51.1	4925

Rotational Field I

Date of Clipping	Yields from protected areas	Yields from unprotected areas	Growth by periods	Consumption by periods (Weight)	Consumption by periods (%)	Total yields to date
July 25		2608	2608			2608
Aug. 6	2608	594		2014	77.2	2608
Aug. 29		1284	690			3298
Aug. 31	1284	472		812	63.2	3298

Continued

Table 6. (continued) Yield, Growth and Consumption of Forage in Pounds Dry Matter per Acre as Determined by the Difference Method

Date of Clipping	Yields from protected areas	Yields from unprotected areas	Growth by periods	Consumption by periods Weight	%	Total yields to date
Rotational Field II						
June 19		2859	2859			2859
July 3	3304	679	445	2625	79.4	3304
Aug. 6		1987	1308			4612
Aug. 16	2291	628	304	1663	72.6	4916
Rotational Field III						
May 30		1879	1879			1879
June 8	2278	661	399	1617	71.0	2278
July 3		1889	1228			3506
July 15	3415	1032	1526	2383	69.8	5032
Aug. 16		1689	657			5689
Aug. 26	2425	799	736	1626	67.1	6425
Rotational Field IV						
June 8		1882	1882			1882
June 19	2919	448	1037	2471	84.7	2919
July 15		2370	1922			4841
July 25	3100	1476	730	1624	52.4	5571
Aug. 26		2035	559			6130
Aug. 29	2035	572	-	1463	71.9	-

was very uneven. This was the last grazed field the previous fall and overgrazing may have been the reason for slow growth in the spring of 1957.

High temperature and abundant moisture in the ground resulted in the most intensive growth during the first three weeks of July. Rotational field III showed the highest growth intensity during the period July 3 to 15 with an average daily production of 127.2 lbs. of dry matter per acre. During the period July 15 to 25 the continuous field produced on an average 92.7 lbs. dry matter per acre daily. The field under rotational grazing produced on an average 73.0 lbs. dry matter per acre daily, during the same period.

Data in Table 6 also shows the proportion of herbage production which is consumed by the grazing animals. This is calculated for each grazing period for both systems of grazing. The percentage consumption calculated on herbage cut in the protected area at the end of each grazing period varied considerably. For the continuous field the consumption rate varied from 29.5 to 57.4 percent and for the rotational fields from 52.4 to 84.7 percent.

F. Botanical Composition

The results of three surveys made to determine the botanical composition of the sward are shown in Table 7.

No significant change occurred in the grass group under either of the management systems. During the winter period 1956 - 57 the

Table 7. Botanical Composition

Date	Point Quadrat Data (expressed as percent) Ground	Weeds	Grass	Legumes
Continuous Field				
Fall, 1956	55.3	2.2	35.3	7.2
Spring, 1957	57.5	2.3	36.8	3.3
Fall, 1957	58.1	2.0	37.1	2.9
Rotational Fields				
Fall, 1956	44.9	2.3	37.2	15.5
Spring, 1957	59.9	2.1	31.6	6.3
Fall, 1957	58.9	1.1	32.7	7.3

rotational fields decreased and the continuous field increased slightly in the percentage of grass. The grazing period in 1957, apparently had no effect on the grass components.

The most striking change is a decrease in the legume components under both systems of management. Although no point quadrat data are available previous to the fall of 1956, the two fields had been uniformly managed in 1954 and 1955 and appeared to be similar. The difference in legume content of the two fields in the fall of 1956 may be attributable to the 1956 management. The main decrease in the legume components occurred, however, during the winter of 1956-57. This was a winter of very light snowfall and the decrease in legumes was most likely caused by winter-killing. The legume content in the continuous field decreased from 7.2 to 3.3

percent and in the rotational fields from 15.5 to 6.3 percent. The proportion killed was about the same for both systems of management, 45.8 percent for the continuous field and 40.6 percent for the rotational fields. The management during the summer of 1957 had little effect on the legume stand. The 0.4 percent decrease for the continuous field and 1.0 percent increase for the rotational fields are too small to permit any conclusions as to changes in legume content due to management during the summer of 1957.

The point quadrat data can be studied with consideration given to grass and legume species only. On the basis of the total grass and legume components being 100 percent, the relative changes in grasses and legumes can be tabulated as in Table 8.

Table 8 Grass and Legume Components of the Sward

	Fall 1956		Spring 1957		Fall 1957	
	Cont.	Rot.	Cont.	Rot.	Cont.	Rot.
Grass %	83.1	70.6	91.8	83.4	92.7	81.7
Legume %	16.9	29.4	8.2	16.6	7.3	18.3

The important factor of the sward is the legume species, it being important for its nutritional value, forage yield and contribution to the continued fertility of the sward. At the completion of the 1956 grazing season, the rotational fields contained more legume than the continuous field. The rotational fields had more legume surviving after the winter 1956-57 and the difference in legume content between the two fields had widened. After the 1957 grazing season, the difference in legume content of the two management systems was again wider. It would appear that the rotational system of grazing resulted in the maintenance of a higher proportion of legume.

Another factor which has to be kept in mind is that the proportion by weight of grass to legume changes during the growing season. It is well-known that the legume components of a pasture sward grow better in the middle of the summer in dry areas than do the grass components. The point quadrat analyses taken in the spring and the fall do not take this phenomenon into consideration, and consequently are unable to detect possible changes in the botanical composition which might affect quality. Even a survey taken in the middle of the summer would not have detected this change because of the nature of the technique used. Readings were taken at ground level and different growth intensities would not have any influence on the result. Readings of all hits on the plants would probably have given a more satisfactory result for this specific purpose.

It should be emphasized that weight estimation of grass and legumes separately would be the best method to express the importance of species according to the amount they produce. This is, however, a more expensive method but ought to be considered when analysing grassland of high economic value.

As shown in Table 7 the percentages of weeds under both systems were small. A decreasing amount of weeds occurred under rotational grazing. This may be due to the system of management.

G. Chemical Composition

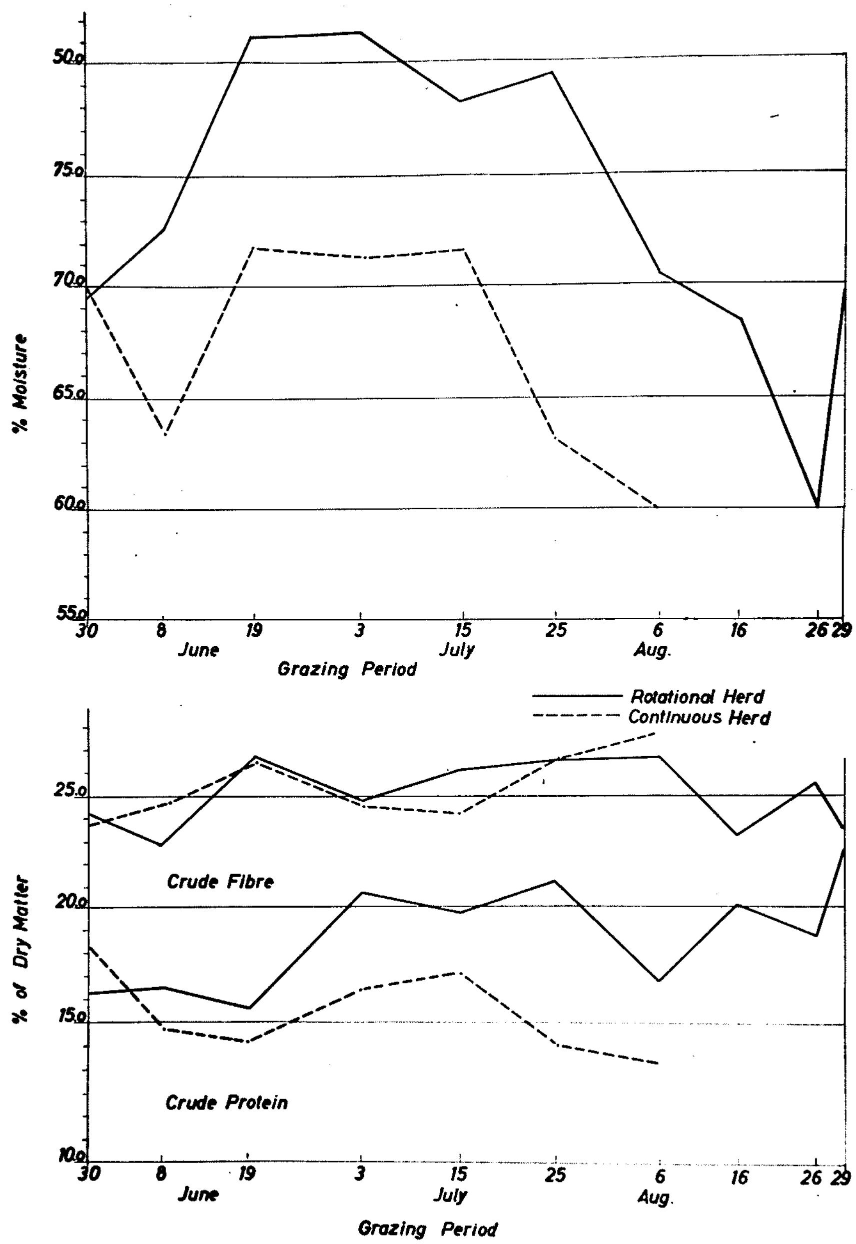
A complex of factors have to be considered when determining the quality of forages. Different species vary in chemical composition. It is, however, generally believed that variation in quality depends more on the stage of growth than botanical composition of the forage (18). Chemical analyses are only the first step in evaluating the quality of herbage and must be considered as a rough guide only. Digestibility of the herbage varies according to stage of growth, class of livestock utilizing the pasture, the balance of the ration, amount of herbage consumed and other factors. The ultimate forage evaluation, therefore, must consist of feeding trials with experimental animals.

Graph 2 shows the results of moisture, crude protein and crude fibre determinations of the herbage within the two systems of management. The moisture content of the herbage within the rotational fields varied from 60.0 to 81.2 percent with an average of approximately 73 percent. Within the continuous field the variation was from 60.1 to 71.5 percent with an average of approximately 67 percent. Except for the samples taken at the beginning of the grazing season, the moisture content was higher within the rotational than within the continuous field throughout the whole summer. An unpaired t-test showed, however, no significant difference in the moisture content of the forage from the two systems of management. Plants are highest in moisture content when they are at a young and leafy stage. The higher moisture content of the herbage from the rotational fields indicates that the herbage was more immature and in a more intensive stage of growth than that from the continuous field. Under both systems of grazing the moisture content was higher in the latter part of June and in July than at the beginning and end of the grazing season. It was previously found that this was the most intensive growth period and most likely explains this phenomenon.

Moisture content may be influenced by many factors such as humidity in the air, recent rainfall and time of the day the cutting is made. Samples of the herbage within the two systems of grazing were taken at different times of the day and no attempt was made to correct for environmental influences.

When the experiment started, the protein content was slightly higher in the continuous than in the rotational field. This could be expected because the herbage was at a more advanced stage in the rotational field at this time. During the remainder of the grazing season the protein content was higher in the rotational fields. The protein content in the rotational fields varied from 15.7 to 21.9 percent of dry matter and within the continuous field from 13.3 to 18.4 percent of dry matter. An unpaired t-test showed that the

Graph 2 **Chemical Composition**

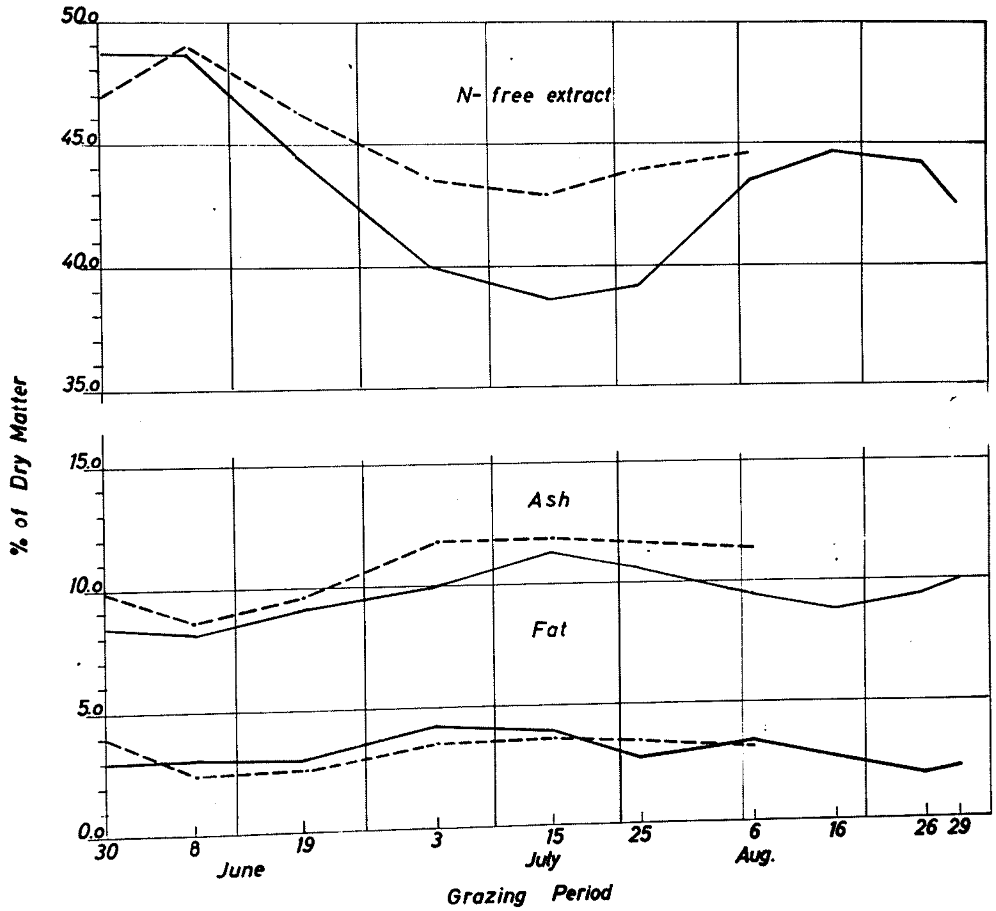


protein content of the herbage within the rotational fields was significantly higher than that of the herbage within the continuous field ($P<0.01$). In the beginning of July the protein content increased under both systems of grazing. This may be partly attributable to an increasing proportion by weight of legumes compared to grass. In the continuous field the amount of protein decreased towards the end of the season. Except for the samples analysed on August 6 the rotational fields maintained a relatively high protein content. Samples taken on July 25 and August 29 showed the highest protein content. This high protein value may be explained in part by the fact that both of these samples were taken from rotational field I, which had a relatively high proportion of legumes.

The fibre content varied less throughout the season than the protein content for both systems of management. The difference between the two systems was also small. The fibre content in the rotational fields varied from 22.9 to 26.9 percent of the dry matter. Within the continuous field the variation was from 23.7 to 27.7 percent of the dry matter. It will be noticed from the graph that in most cases the crude protein content was inversely proportional to the crude fibre content of the same sample.

Graph 3 shows nitrogen-free extract, ash and fat content of the herbage as percentage of dry matter under the two systems of grazing. There is little difference in the fat and ash content of the forage from the rotationally and continuously grazed fields. The forage from the continuous field showed a slightly higher content of ash and a little lower content of fat. Nitrogen free extract is calculated by subtracting the sum of crude protein, crude fibre, ash and fat from one hundred. The lower nitrogen free extract content for the rotational system of grazing is mainly due to the differences in crude protein content at that time.

Graph 3. **Chemical Composition**



SUMMARY AND CONCLUSIONS

An experiment comparing continuous and rotational systems of pasture management was conducted at the University of Manitoba in the summer of 1957. A 26 acre field was divided into two equal portions. One-half was further sub-divided into five paddocks and grazed rotationally. The other half was continuously grazed. Comparable herds of Holstein-Friesian milking cows were used for pasturing. The experiment commenced May 30 for both groups and terminated August 16 for the continuous herd and August 31 for the rotation herd.

One of the advantages of rotational grazing is that one or more of the paddocks can be cut for hay or silage during the period of intensive growth early in the summer. Two of the rotational fields were cut for hay at the end of June and one of them again in August. The latter field was not grazed. Hence, the rotational herd grazed an area four-fifths the size of the continuous field.

The number of grazing days per acre was 36.8 percent higher under rotational than under continuous grazing. The system of grazing did not influence the milk production per cow day. The rotational herd produced 15.9 percent more milk from an experimental area which was four-fifths the area available to the continuous herd. This increase is directly attributable to the longer grazing season under the rotational system of grazing. The rotational herd produced 24.7 percent more milk per acre than the continuous herd for the grazing period May 30 to August 16. When the entire grazing season is considered, the rotational herd produced 47.2 percent more milk per acre. This increase is attributable both to the longer grazing season and the smaller area which was grazed under the rotational system of management.

The rotational herd obtained 34.9 percent more total digestible nutrients from the pasture than the continuous herd. Theoretically, this should be the most accurate method for estimation of herbage consumption from pasture because maintenance requirements, milk production, live weight changes and supplementary feed given are taken into account.

The rotational fields produced 21.3 percent more dry matter of herbage per acre than the continuous field estimated by clippings.

Results of surveys made in the spring and fall on the botanical composition showed that the percentage of legumes persisting in the sward was higher in the rotational pastures. At the end of the experiment there were more weeds in the continuous than in the rotational fields. This is probably due to the fact that some of the rotational fields were mowed after the grazing period to establish an even regrowth and to keep weeds from setting seed.

Chemical analyses of the herbage showed higher protein content under rotational than under continuous grazing. Crude fibre, fat, ash and nitrogen-free extract content of the herbage were very similar for both systems of management.

The results of different methods used for measurement of pasture and productivity are not completely identical. This must be expected due to limitations of the techniques used. All the methods show, however, the advantages for the rotational system of grazing. This experiment indicates that when dairy cattle graze a productive sward, at least 20 - 30 percent increase in productivity is possible under rotational compared to continuous grazing.

It must be emphasized that this paper presents one year's results only and the value of the data, therefore, is obviously limited.

FIGURES

Figure 1.
Cage (4' x 6' x 2.5') used to prevent grazing by the cattle.

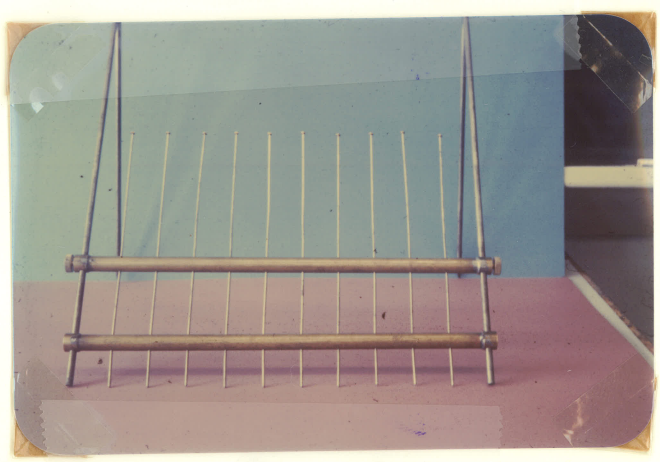


Figure 2.
Apparatus for determining botanical composition of pasture by the inclined point quadrat method.

Figure 3.
Rotational field IV at the end of a grazing period, June 19. Rotational field V to the left. Note the fairly even grazing.

Figure 4.
Continuous field at the end of the grazing season, August 16. Note the uneven grazing and the amount of weeds.

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