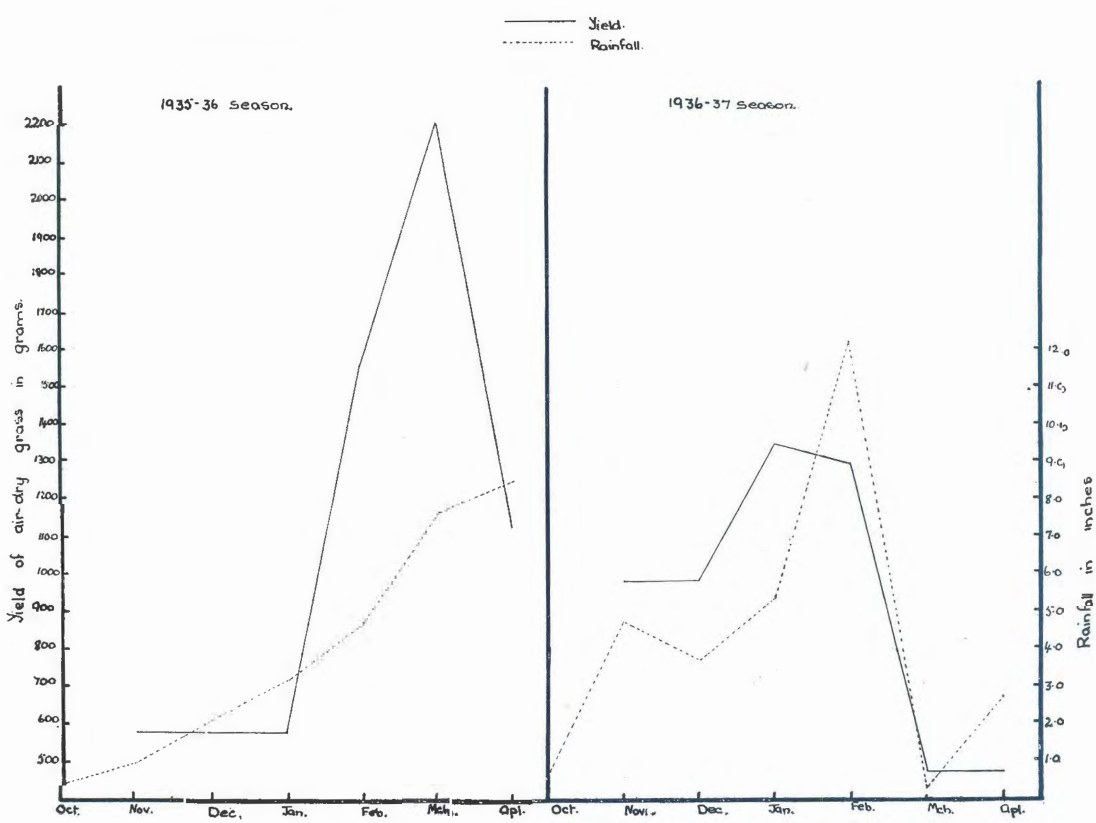
TABLE 7.

Showing seasonal production of dry matter in grams.

1936-37 *Season.*

Species.	December.	January.	February.	April.
Chloris gayana	1,950	1,187	1,153	1,043
Setaria Lindenbergiana	3,163	1,770	1,796	1,111
Cenchrus ciliaris	938	943	855	1,062
Digitaria Pentzii Pta. Sm	1,179	1,211	1,135	397
Panicum maximum	2,611	1,624	1,532	1,094
TOTAL	9,841	6,735	6,471	4,707
Mean	1,968	1,347	1,294	942

Figure 2. Showing effect of rainfall on the seasonal yield of grasses.



The monthly yields of dry herbage for the two seasons are represented in graphical form in conjunction with the monthly rainfall in figure 2. The total rainfall for the month preceding a cut has been made to coincide with the point representing the yield of grass from that particular cut. Generally speaking, the curve describing the yield of dry matter may be considered to vary in a manner similar to that depicting the rainfall for both seasons. In connection with remarks made earlier in this section there are, however, certain features in the graphs which deserve to be mentioned. For the 1935-36 season the period preceding the first cut in January was characterised by a low rainfall associated with high average day temperatures (cf. Fig. 1). During this period only about 26 per cent. (cf. Table 6) of the total growth for the season took place. Good rains during January and February resulted in active growth, the grasses reaching maximum seasonal production with the cut made early in March. In spite of the fact that the best rainfall for the season was recorded for the month following the cut early in March the production of herbage decreased by fully 50 per cent.

Turning now to the data for the 1936-37 season it is found that with climatic conditions approximating the normal about 60 per cent. of the total seasonal production of herbage was obtained with the two cuts in December and January. The yield in February was practically the same as for January but the next two months contributed only about 17 per cent. towards the total for the season. The rainfall during this final period was decidedly low, especially during March, and the average day temperatures were high. At the time of the February cut the soil was over-saturated with moisture as the result of the heavy downpours experienced a few days earlier. Nevertheless, growth was observed to be extremely slow, even while the soil was still wet. The effect of the drastic treatment (monthly cuts) on the vitality of the plants may have been partly responsible for poor growth directly after the February cuts. However, the yield of dry matter under more lenient systems of cutting was also greatly reduced during this final period of the season. For instance, the indices for average seasonal yield of dry matter for species combined for the 2-monthly cutting treatment were 2,439, 3,338, and 1,360 for December, February, and April ,respectively.

In any case, it would appear that, while during seasons of normal rainfall the period of optimum growth is independent of the rainfall, it does depend on rainfall during dry seasons. For the 1935-36 season this period of most active growth occurred at a later date than during the following season. The evidence here produced and from the previous publication (1935) seems to suggest that in the case of the species studied the period of optimum growth is December-January (cf. 1936-37 season and previous results), but that in the event of negligible rain prior to December or January it may occur later in the season (cf. 1935-36 season).

In this connection the results of Trumble and Cornish (1936) are of interest. From a statistical analysis of data pertaining to the influence of rainfall on the yield of natural pasture at the Waite Institute, Australia, a region of winter-rainfall, these workers found the correlation between yield and rainfall to be strongest in the period April to June, which coincides with the early stages of seasonal growth.

(3) The Influence of Frequency of Cutting on Chemical Composition.

The detailed analyses of the herbage samples obtained under different frequencies of cutting for the whole of the experimental period are given in the appendix by Tables A to I. The last columns in the tables giving a description of the grasses as cut require explanation. These notes aim at giving a brief description with reference to the general appearance and the stage of growth obtained at the time of cutting. Height measurements were not actually made. However, when the grass was estimated to have grown to a height of only 6 inches and less the term " short ", and when to a height of more than 12 inches the term " long " has been used to describe the appearance. No descriptive term was applied for estimated heights between 6 and 12 inches. Furthermore, an attempt has been made to indicate the stage of growth reached by the herbage by using the terms " pre-flowering ", " a few flowerheads appearing ", " flowering ", " with flowerheads ", " seeds falling out ", and " seeds fallen out, inflorescences and some leaves browning ", to indicate the advancing stages of maturity.

In connection with the arrangement of results into separate tables for different cutting treatments it should be pointed out that the cuts of the 6th April in table C are in reality monthly cuts and not 3-monthly cuts; also, the April cuts in table H are 2-monthly and not 4-monthly cuts. Furthermore, since there was no difference between 4- and 6-monthly treatments in the 1935-36 season the analysis given in table D is that for a single final cutting for each species.

From the tables in the appendix tables 8-12 giving the average composition of the dry matter obtained under the different systems of cutting have been compiled. Figures for total ash have been included. These are not reliable owing to the unavoidable inclusion of traces of soil which cannot be removed in the cleaning of the sample. However, the values for silica-free ash form a reliable index of the total minerals present in the herbage.

It is not intended to discuss the chemical composition of the herbage in detail as this has been done for similar data in previous publications by du Toit and his associates. The salient features which have a direct bearing on the present investigation may, however, again be indicated briefly.

(*a*) *Phosphorus.*—While the magnitude of the decrease differs with species the phosphorus content of the herbage diminishes on the whole uniformly from monthly cuts to 6-monthly cuts, the relative amount in the single cut at the end of the season being only about 50 per cent. of that present in the monthly cut herbage. In all cases the figures are low compared with the figures of European investigators but are similar to values obtained previously at Onderstepoort and by Taylor (1922, 1929), and compare favourably with data secured by Australian workers (Richardson et al, 1931, 1932) for grasses at the same stage of growth.

(*b*) *Calcium and Magnesium.*—The percentages of these constituents do not show appreciable variation with stage of growth. With the exception of *Chloris gayana* and *Setaria Lindenbergiana* there appears to be a tendency for these minerals to decrease with decreased frequency of cutting. Petrie (1934) pointed out that the relative amount of calcium declines during adolescence and thereafter remains constant or rises.

(*c*) *Potassium and Chlorine.*—Both these constituents are influenced to a considerable extent by the stage of maturity of the herbage. With few exceptions (cf. K-values in 4-monthly cuts for the 1936-37 season) a fall in the content of potassium and chlorine has been observed with advancing stage of maturity.

(*d*) *Sodium.*—Whilst fluctuating somewhat in some species the general tendency for this element is also to decrease with age in the plant.

(*e*) *Crude protein.*—Generally speaking, the variations due to the influence of cutting treatment in the content of crude protein of the herbage are similar to those for phosphorus, the relative amount falling rapidly with decreased frequency of cutting.

(*f*) *Crude Fibre.*—The crude fibre content of the herbage varies more or less inversely with the crude protein content, the highest percentage of the former constituent corresuonding with the lowest value for the latter.

(*g*) *The Ether-soluble extract* of different species shows different variations with age in the plants. In the case of *Panicum maximum* and *Cenchrus ciliaris* there is a definite drop in the percentgae ether-soluble extract with increasing degree of maturity for both seasons of the experiment. The same tendency is noticeable for the other species studied for the 1935-36 season, but during the following season the values for ether-extract show irregular fluctuations with the different treatments.

(*h*) *Silica-free Ash.*—Since all the mineral elements determined are constituents of the silica-free ash and whereas with few exceptions the relative amounts of these elements decrease with decreasing frequency of cutting it may be expected that the percentage of silica-free ash will vary in a similar manner. A glance at the tables shows this to be the case.

(*i*) *Nitrogen-free extract.*—The percentage content of this constituent in the herbage of varying degree of maturity varies very little and shows no definite tendency. It should, however, be pointed out that the accuracy of the figure for this fraction is dependent upon the accuracy with which the fractions on which its calculation is based have been determined. As previously stated the figure for total ash, one of the relevant fractions, is unreliable owing to the unavoidable inclusion of soil particles in the samples analysed.

TABLE 8.

Average percentage composition of the dry matter of Chloris gayana.

Period of growth.	Season.	P.	Ca.	Mg.	K.	Na.	Cl.	Crude protein.	Crude fibre.	Ether soluble extract.	Total Ash.	N-free extract.	Silica free Ash.	Percentage dry matter of herbage as cut.
1 month.............	1935–36	·13	·37	·25	·76	·56	·90	8·3	31·8	2·55	10·52	46·96	4·15	30·7
	1936–37	·12	·43	·29	·77	·38	·67	6·4	32·5	2·27	11·06	47·77	3·75	32·4
2 months............	1935–36	·12	·36	·22	·71	·49	·84	6·4	33·6	2·26	10·29	47·45	3·74	30·8
	1936–37	·11	·39	·23	·75	·32	·65	6·5	31·7	2·63	10·52	48·55	3·25	33·7
3 months............	1935–36	·094	·32	·20	·66	·40	·72	4·8	35·2	2·02	9·28	48·70	3·25	31·5
	1936–37	·088	·42	·25	·55	·31	·64	5·2	32·2	2·46	10·05	50·09	3·10	35·5
4 months............	1935–36	·074	·36	·23	·51	·32	·56	4·4	33·6	2·09	9·86	50·05	2·95	34·1
	1936–37	·077	·37	·23	·64	·27	·55	4·3	32·7	2·14	10·00	50·86	3·09	36·0
6 months............	1936–37	·065	·44	·31	·43	·23	·49	3·9	34·3	2·64	11·25	47·91	3·06	41·0

TABLE 9.

Average percentage composition of the dry matter of Setaria Lindenbergiana.

Period of growth.	Season.	P.	Ca.	Mg.	K.	Na.	Cl.	Crude protein.	Crude fibre.	Ether soluble extract.	Total Ash.	N-free extract.	Silica free Ash.	Percentage dry matter of herbage as cut.
1 month.............	1935–36	·16	·39	·41	2·25	·046	·96	10·9	35·7	3·22	11·72	38·46	5·35	31·3
	1936–37	·15	·44	·41	1·58	·27	·60	9·7	35·2	3·35	11·03	40·72	4·68	33·0
2 months............	1935–36	·13	·44	·41	1·58	·043	·77	7·6	37·4	3·01	11·75	40·24	4·49	33·2
	1936–37	·13	·50	·47	1·23	·092	·59	7·6	35·2	3·46	11·59	42·15	4·12	34·4
3 months............	1935–36	·11	·41	·36	1·36	·044	·60	5·9	38·3	3·55	11·31	41·94	3·82	33·6
	1936–37	·09	·50	·42	1·05	·040	·46	5·8	37·3	3·18	11·37	42·35	3·90	39·6
4 months............	1935–36	·088	·39	·32	1·16	·020	·51	5·2	39·3	2·62	11·25	41·63	3·52	37·6
	1936–37	·091	·43	·36	1·05	·036	·46	4·9	39·4	2·81	11·15	41·74	3·67	38·9
6 months............	1936–37	·078	·55	·37	·84	·057	·38	4·8	35·3	3·62	13·10	43·18	3·82	51·7

TABLE 10.

Average percentage composition of the dry matter of Cenchrus ciliaris.

Period of growth.	Season.	P.	Ca.	Mg.	K.	Na.	Cl.	Crude protein.	Crude fibre.	Ether soluble extract.	Total Ash.	N-free extract.	Silica free Ash.	Percentage dry matter of herbage as cut.
1 month.............	1935–36	·17	·34	·42	2·45	·077	·84	11·2	29·4	2·88	15·50	41·02	5·69	27·6
	1936–37	·13	·36	·39	1·63	·28	·56	9·3	30·1	2·79	14·95	42·86	4·58	31·3
2 months............	1935–36	·14	·32	·40	2·15	·065	·66	9·2	33·4	2·39	15·25	39·76	5·19	30·0
	1936–37	·12	·35	·38	1·57	·091	·54	8·6	31·6	2·74	14·82	42·24	4·35	32·2
3 months............	1935–36	·12	·30	·40	1·89	·059	·67	7·1	35·4	2·09	14·53	40·88	4·64	29·7
	1936–37	·11	·39	·41	1·49	·060	·56	8·2	31·3	2·80	15·22	42·48	4·44	35·8
4 months............	1935–36	·097	·26	·32	1·39	·020	·45	7·0	35·5	2·03	13·66	41·81	3·82	35·8
	1936–37	·093	·25	·29	1·57	·059	·52	6·4	36·0	2·38	12·15	43·07	3·87	33·7
6 months............	1936–37	·066	·36	·36	·97	·063	·46	5·3	36·6	2·21	14·40	41·49	3·53	44·5

TABLE 11.

Average percentage composition of the dry matter of Digitaria Pentzii Pretoria Small.

Period of growth.	Season.	P.	Ca.	Mg.	K.	Na.	Cl.	Crude protein.	Crude fibre.	Ether soluble extract.	Total Ash.	N-free extract.	Silica free Ash.	Percentage dry matter of herbage as cut.
1 month.............	1935–36	·14	·51	·45	2·00	·051	·83	9·1	33·9	3·17	10·75	43·08	5·21	35·6
	1936–37	·13	·51	·44	1·57	·27	·63	8·2	33·9	3·30	10·80	43·80	4·61	32·0
2 months............	1935–36	·13	·52	·45	1·86	·040	·78	7·8	34·3	2·88	10·98	44·04	5·11	30·8
	1936–37	·11	·55	·43	1·35	·062	·59	7·3	34·8	3·27	11·86	42·77	4·15	34·2
3 months............	1935–36	·12	·46	·39	1·94	·047	·78	6·7	37·2	2·66	10·74	42·70	4·85	28·1
	1936–37	·11	·56	·42	1·24	·042	·54	6·5	35·6	3·60	11·17	43·13	4·30	37·2
4 months............	1935–36	·092	·45	·39	1·38	·022	·64	5·7	37·9	2·71	10·53	43·16	4·04	33·0
	1936–37	·098	·46	·36	1·69	·061	·63	5·8	37·3	3·26	10·40	43·24	4·29	32·4
6 months............	1936–37	·077	·54	·43	·80	·032	·40	5·0	38·5	2·93	11·20	42·37	3·72	47·7

TABLE 12.

Average percentage composition of the dry matter of Panicum maximum.

Period of growth.	Season.	P.	Ca.	Mg.	K.	Na.	Cl.	Crude protein.	Crude fibre.	Ether soluble extract.	Total Ash.	N-free extract.	Silica free Ash.	Percentage dry matter of herbage as cut.
1 month.............	1935–36	·17	·41	·46	1·41	·66	·98	10·1	30·5	2·30	13·72	43·38	5·29	29·0
	1936–37	·17	·41	·42	1·09	·52	·70	8·3	30·7	2·38	12·68	45·94	4·59	29·6
2 months.............	1935–36	·12	·40	·43	1·13	·55	·87	7·0	33·7	2·26	13·62	43·42	4·68	27·6
	1936–37	·16	·42	·42	·96	·48	·59	7·2	32·1	2·35	13·45	44·90	4·15	31·3
3 months.............	1935–36	·089	·35	·34	1·17	·42	·80	5·5	37·2	1·71	12·35	43·24	3·98	29·0
	1936–37	·15	·41	·41	1·03	·36	·67	6·2	33·4	2·31	12·70	45·39	4·28	33·2
4 months.............	1935–36	·091	·34	·36	·87	·44	·67	4·5	38·7	1·57	12·56	42·67	3·80	31·1
	1936–37	·12	·38	·30	·82	·40	·65	6·0	34·7	2·14	10·55	46·61	3·85	33·8
6 months.............	1936–37	·12	·32	·34	·93	·33	·54	4·4	39·2	1·78	11·05	43·57	3·64	41·9

(*j*) *Dry matter of herbage as cut.*—On the whole there is a tendency for the dry matter content to increase with age in the plant. With one exception, viz., the final cut for the *Digitaria species* in April, 1936, the highest percentage of dry matter was obtained in the herbage which grew undisturbed until the end of the season, i.e. the 6-monthly cuts. The rise to the highest value does not, however, proceed uniformly with decreasing frequency of cutting. Rigg and his associates (1932) referred to the profound influence of climatic conditions on the percentage of dry matter found in green pasture mown at the growth stage of 2½ inches to 3 inches in length. Drought and low temperatures retarded pasture-production and were invariably associated with high percentages of dry matter in the growth. With suitable moisture and temperature conditions, pasture production was highest, and this was accompanied by low percentages of dry matter. The influence of climate on the dry matter content of herbage in the present investigation is best illustrated by reference to tables 6 and 7, giving the seasonal production of the grasses and to tables A and E in the appendix giving the seasonal dry matter content of the herbage. A study of these tables reveals the fact that the most active growth in March, 1936, and in January and February, 1937, is associated with the lowest values for dry matter content in the course of the respective growing seasons. On the other hand, the highest percentages of dry matter are found in the herbage of the periods of drought as is evident from the figures for dry matter in the herbage cut in January, 1936, and in April, 1937. It would thus appear that while the process of drying off of mature herbage towards the end of the growing season is responsible for high values for dry matter, the amount of this constituent in the fresh herbage in the course of the growing season is largely influenced by the prevailing climatic conditions.

With reference to the seasonal composition of the grasses (see tables A and E in the appendix) the conclusion arrived at in a previous publication (1935) that " in the absence of soil and climatic deficiencies stage of growth is the main factor influencing the mineral and protein content of pasture species " appears to apply equally well to the data for this investigation. Low values for phosphorus and a relatively high level for calcium and magnesium contents are again in evidence during periods of dry weather. At the same time, the protein content does not appear to be affected adversely by unfavourable climatic conditions. In any case, the composition of monthly cut herbage cannot be considered to show marked seasonal variations. During some months a slightly more or less advanced stage of growth is attained by a species when compared with its growth of the previous month and resulting in a slight decrease or increase in the percentage content of the constituents, but, on the whole, the monthly growths of the grasses studied must be looked upon as herbage of a comparatively high composition at a comparatively early stage of growth.

In regard to the more essential constituents from the standpoint of animal nutrition the grasses studied do not show outstanding differences after the same period of growth. On the whole, for monthly cuts, *Panicum maximum* has the highest average phosphorus content, *Setaria Lindenbergiana* and *Cenchrus ciliaris* top the list for protein content, while the lowest values for these constituents are found in *Chloris gayana*. A more marked contrast in the chemical composition of these grasses lies in their potassium and sodium contents. *Chloris gayana* and *Panicum maximum* are characterised by comparatively low potassium and high sodium values, while the very opposite condition obtains in the case of the other species studied. The percentage content of potassium is up to twice as high as, and of sodium only 10 to 20 per cent. of the figures for the two species mentioned.

The average calcium-phosphorus ratio in the monthly cut herbage varies from about 2·3 in *Cenchrus ciliaris* to 3·8 in the Digitaria species, while, as may be expected from a consideration of the relative rates of decrease of the percentage of calcium and phosphorus in ageing herbage, the ratio is increased considerably with decreased frequency of cutting.

A comparison of the data for the two seasons (see tables 8 to 12) reveals some definite differences. Phosphorus, potassium, and crude protein values are lower during the second than during the first season of the experiment. On the other hand, the figures for calcium are consistently, though sometimes not markedly, higher during the 1936-37 than during the previous season. These differences may be ascribed mainly to differences in the climatic conditions obtaining during the two seasons of the experiment, and resulting chiefly in variations in the stage of growth attained by a species after the same interval of growth.

(4) The influence of frequency of cutting on the production of crude protein and phosphorus.

The aggregate production of dry matter, crude protein, and phosphorus for all the species combined, but for cutting treatments separately, is given by table 13 in lb. per acre. The statistically significant features in the results relating to the effect of cutting treatment on the production of dry matter have previously been indicated. Briefly stated, they are to the effect that while there may be no difference in the yield of dry matter from certain lenient treatments the depressing influence on yield under a monthly system of cutting is significant in all cases. Due to the fact that the herbage

Table 13.

Total seasonal production of dry matter, crude protein, and phosphorus in lb. per acre.

	Season.	Cutting Treatment.				
		1 month.	2 months.	3 months.	4 months.	6 months.
Dry matter.......	1935–36	1,932·0	2,286·0	2,270·0	2,520·0	2,520·0
	1936–37	1,612·0	2,073·0	1,847·0	2,292·0	2,322·0
Crude protein.....	1935–36	201·0	202·0	169·0	138·0	138·0
	1936–37	136·0	149·0	116·0	123·0	102·0
Phosphorus (P)....	1935–36	2·86	2·56	2·44	1·87	1·87
	1936–37	1·79	2·16	1·82	1·98	1·63

from individual replications was not analysed separately the statistical method employed in the analysis of the yield data could not be applied to the results of the chemical analysis. The figures in table 13 giving the yield of crude protein and phosphorus will thus be taken at their face value.

The general tendency for the production of crude protein and phosphorus with different cutting treatments is just the opposite of that for the yield of dry matter, the highest yield for crude protein and phosphorus occuring in the more drastic systems of cutting. While there is no difference in protein production by the monthly and the 2-monthly systems for the 1935-36 season a steady decrease is indicated as the intervals between cuts become longer. A similar state of affairs obtains in the data for the following season except that under the monthly system of cutting the production of crude protein is actually less than under the 2-monthly system of cutting. The comparatively low production of dry matter for the three-monthly system, to which reference has been made previously, is mainly responsible for the deviation from the general tendency shown by the figures for this system in the 1936-37 season. The remarks made in regard to protein production apply equally well to the production of phosphorus, except that the highest production of phosphorus was obtained by the monthly system during the 1935-36 season.

The results for the present investigation then, confirm the conclusion reached by du Toit and his associates (1935) in a previous publication from this Institute in that, under the conditions of the experiment, the highest yield of crude protein and phosphorus is obtained when grass species are cut at intervals of two months during the growing season. Whether it may be advisable to forfeit this advantage for the sake of a higher yield of dry matter which may be obtained under more lenient systems of cutting will depend on the results of the digestibility trials to be considered later in this publication. It should be pointed out that by a monthly system of cutting the total production of crude protein and phosphorus may be of the same magnitude as that from the 2-monthly system, but the significant decrease in dry matter production and the effect of the severe treatment on the vitality of the plants remove this system from the realm of practical considerations.

To conclude this section, the markedly lower production of the nutrients under discussion for the 1936-37 season in comparison with the figures for the previous season may be briefly referred to, The tendency for lower values for phosphorus and protein in the herbage of the 1936-37 season has already been indicated. From a consideration of the data for the yield of dry matter during this season (see table 13) it appears that the decreased production of dry matter is mainly responsible for the diminished yield of crude protein and phosphorus.

In comparison with grazing by animals whose droppings are left behind to enrich the soil the utilisation of pasture as hay or silage suffers from the disadvantage that the soil is continually being depleted of nutrients whereas nothing is returned to it. It is realised that other factors may have influenced production during the 1936-37 season; the soil may not have been the most suitable for the species studied, and the climatic conditions may not have been "ideal" for maximum production. However, from purely theoretical considerations the application of fertilisers to pasture which is utilised as hay or silage becomes a necessity if continued production at a high level is aimed at. At the same time, as pointed out by Hall (1932), it may not be economically desirable to fertilise certain types of veld when the more productive and desirable grasses do not occupy 18-25 per cent. of the area.

Section B.—The Influence of Frequency of Cutting on the Digestibility and Nutritive Value of Grasses.

VII. EXPERIMENTAL DETAILS.

(*a*) The Grass Samples.

The amount of material available did not permit of feeding trials with the herbage of different cutting rotations from each grass species separately. Accordingly, the aggregate yield of herbage for the season from any one cutting treatment where the period of growth was actually that indicated by its designation, for all species combined was mixed and treated as one sample for the purpose of determining digestibility. Furthermore, since the plot experiment was continued for only four months during the 1935-36 season those portions of the plots which normally should have been harvested after six months were cut on the same date as the 4-monthly portions, so that for the said season herbage of only four different degrees of maturity was obtained. The materials may be designated as monthly, 2-monthly, 3-monthly, and 4-monthly cuts. During the 1936-37 season cutting was commenced earlier in the season with the result that herbage of five different degrees of maturity became available, namely 1, 2, 3, 4, and 6-monthly cuts. In all nine digestion trials had, therefore to be conducted.

(*b*) The Animals.

Three full-grown Merino wethers weighing on an average 70 lb. at the commencement of the investigation were employed. These animals were selected from a group of six sheep which were shorn on the 30th November, 1936, and which served from this date until the 24th December in a digestion experiment with lucerne hay. The sheep were fed at the rate of 600 grams air-dry material per day and the faeces were collected in a canvas bag, which was attached by a webbing harness, during the last nine days of the trial. The three sheep selected for the grass hay experiments continued to receive the same amount of lucerne hay until the 19th January, 1937. For ten days prior to this date the animals were placed in specially constructed metabolism crates where faeces and urine were collected daily. In this way the animals became used to the crates and, at the same time, a duplicate set of values for the digestibility of the same lucerne hay became available, namely, by collecting the faeces in a bag attached to a harness and, on the other hand, by collecting the faeces on a wire screen in a metabolism crate. The coefficients of digestibility obtained by the two methods are given below:—

	Organic matter.	Crude protein.	Ether extract.	N-free extract.	Crude fibre.
Bag collection	63·7	76·6	42·2	72·1	46·2
Screen collection	65·7	76·9	43·5	73·7	49·2

In general good agreement between the results is indicated.

(c) The Equipment.

The metabolism crates used in the experiments were constructed locally in accordance with those employed amongst other places at the Illinois Eperimental Station for sheep and pigs. Some of the features in the construction of the crates may be briefly mentioned. The inside area on which the animal can move about is ($5\frac{2}{3}$ × 4) square feet. One end opens out into a detachable, galvanized iron feed manger. Water is supplied in a trough attached on the inside away from the feed manger. There are two false bottoms to the crate, an upper wire screen of half-inch mesh on which the animal stands and which permits the excreta to pass through. About four inches below the first floor is a second wire screen of $^1/_{16}$ inch mesh which catches the faeces and allows the urine to pass through on to the funnel-shaped real bottom, and so into a receptacle below the crate. When collections of faeces and urine have to be made the upper part and the animal are moved over on to a cleaning table hooked on the crate and supplied with screens and a funnel-shaped bottom similar to those of the crate proper. During the preliminary periods the sheep are kept in separate feeding pens measuring about (16 × 5) square feet and of which only about a third is under cover with the result that the animals may enjoy sufficient direct sunlight during all preliminary feeding periods.

(d) General Scheme of the Trials.

Table 14 shows the order in which the digestibility of the nine samples of herbage was tested together with the duration of the preliminary and collection periods.

TABLE 14.

Period.	Herbage sample.	Preliminary period.	Collection period.
1	4-monthly cuts, 1935–36 season........	19.1.37– 6.2.37	6.2.37–16.2.37
2	3-monthly cuts, 1935–36 season........	16.2.37–24.2.37	24.2.37– 6.3.37
3	2-monthly cuts, 1935–36 season........	6.3.37–14.3.37	14.3.37–24.3.37
4	1-monthly cuts, 1935–36 season........	24.3.37– 1.4.37	1.4.37–11.4.37
5	6-monthly cuts, 1936–37 season........	19.4.37– 2.5.37	2.5.37–12.5.37
6	4-monthly cuts, 1936–37 season........	12.5.37–20.5.37	20.5.37–30.5.37
7	3-monthly cuts, 1936–37 season........	30.5.37– 7.6.37	7.6.37–17.6.37
8	2-monthly cuts, 1936–37 season........	17.6.37–25.6.37	25.6.37– 5.7.37
9	1-monthly cuts, 1936–37 season........	5.7.37–13.7.37	13.7.37–23.7.37

In period 1 when the diet of the animals had to be changed from a protein-rich lucerne hay to a grass hay of an advanced stage of maturity the preliminary feeding interval lasted 18 days. On the 19th January the three animals, sheep 4, 5, and 6, were weighed, and from this date until the 24th of the month each animal was allowed a ration of 800 grams of air-dry hay per day, offered in two equal portions at 9 a.m. and at 3 p.m. Although none of the animals seemed to like the ration, sheep 5 and 6 consumed all the feed offered while sheep 4 refused on an average 200 grams per day, consisting of hard, fibrous portions.

The general experience on this Station has been that mature sheep, averaging 70 lb. in body weight, will not consume continuously more than about 2lb. of hay per day when they have the run of spacious camps. On the other hand, when serving in experiments and confined to small feeding pens the daily consumption was found to be in the neighbourhood of only 600 grams of hay per head. For this reason it was doubted whether the animals would continue to consume 800 grams of poor hay per day and the ration was accordingly reduced to 700 grams on the 25th January. Until the 29th sheep 4 continued to refuse from 50-100 grams of feed daily. However, from this date until the conclusion of the preliminary period on February 6 the amount left uneaten by this animal never exceeded 20 grams per day, while the other two sheep continued to consume all the feed offered. This amount, namely, 700 grams air-dry material per day, remained constant for all the digestion periods concerned in this investigation and was always offered in two equal portions in the morning and in the afternoon. Excepting periods 1, 2, 5 and 6, when sheep 4 refused small amounts of feed, clean consumption of this quantity of hay was effected.

At the conclusion of period 4 the sheep were fed for 8 days on a ration consisting of 2 parts of Teff hay and one part of lucerne hay at the rate of 700 grams per day. With the change-over from this ration, on the 19th April, to the poorest grass hay cut at the end of the 1936-37 season difficulties were again encountered with regard to consumption of the material. The sheep were obviously averse to feeding on this new ration, number 5, especially, protested violently by bleating and by kicking against the door of the feeding pen. For the next five days as much as 250 grams of hay were refused by sheep 6 per day while numbers 4 and 5 left about 100 grams per day uneaten. From the 25th April until the conclusion of the preliminary feeding period on May 2 sheep 5 and 6 consumed their rations of 700 grams daily completely, but number 4 continued to refuse about 10 grams per day. It should, however, be mentioned that the animals did not appear to relish this ration as well as that offered during the succeeding period (6). From then on until the conclusion of the trials with period 9 no difficulties were experienced and the sheep appeared to like the feed offered.

With the exception then of periods 1 and 5 when the prliminary periods lasted 18 and 14 days, respectively, the duration of these feeding intervals was 8 days and the collection of excreta was continued for 10 days for all experiments.

A preliminary period has to be of such length that the excreta can be presumed to represent the experimental ration. For this purpose a period of 8 to 10 days is generally accepted to be of sufficient duration in the case of the ruminant. Lenkeit (1932) determined the time interval taken by an experimental feed, coloured with fuchsin, to pass completely through the alimentary tract of various animals. In the case of the sheep he found that after 7 to 9 days 97 per cent. and more of the experimental feed had been passed, while complete excretion of the small amount of remaining coloured feed took 16 to 21 days with grains and 12 to 13 days with coarser fodders. Insufficient ingestion of roughage had the effect of further retarding the complete passage of an experimental ration. In view of these findings and since on the whole the difference in chemical composition between grass samples fed in successive periods in the present series of trials was small, a preliminary period of 8 days may be considered to have been of sufficient length. In any case, the amount of material available did not permit of longer preliminary periods.

(*e*) Sampling of Herbage.

Prior to commencing a digestion trial the air-dry herbage to be used in the experiment was chopped into approximately one-inch lengths with a hand forage-cutting machine. The material was then thoroughly mixed and three samples taken for chemical analysis. On two of these, weighing about 300 grams each, dry matter was determined by drying to constant weight at 100° C. in an electric oven. These samples together with the third one of about 600 grams were then finely ground in a high-speed mill, the resultant material thoroughly mixed and a representative sample taken for chemical analysis on the absolutely dry basis. At the time of taking samples for chemical analysis and dry matter determination of the hay as fed the daily rations for the whole of the preliminary and experimental periods were weighed out into paper bags. In this way fluctuations in the dry matter intake from day to day were obviated.

(*f*) Collection and sampling of the excreta.

The sheep were weighed at the beginning and at the conclusion of each experimental period. Before starting a collection period the crates were thoroughly cleaned and care was taken to remove any faecal matter adhering to the wool and hoofs of the animals before entering the crates. The exact time of day when each animal was put into its cleaned crate was noted, and taken to be the beginning of the collection period which was also concluded at the same hour.

Excreta were collected daily at 9 a.m., except for the final collection which depended on the time the animals were put into the crates at the commencement of the period.

A clean bottle was placed under the funnel of the cleaning table and the upper part of the crate and the animal moved over on to the cleaning table. After brushing down any faeces adhering to it the upper screen was removed. The lower screen with all the faeces on it was then carefully taken out and placed on clean brown paper spread on the floor of the metabolism room. Here the faeces were transferred with a scoop and brush to a large enamal tray. Bits of feed scattered by the animal were sorted out carefully and put back into the feed manger to be eaten with the next ration. Particles of crushed faeces which had passed through the lower screen were also collected and added to the main bulk of faeces. The urine receptacle under the crate was removed and replaced by a clean five-litre flask. The screens were put back into position and rinsed with about $2\frac{1}{2}$ litres of distilled water using an ordinary watering can. The upper part of the crate and the animal were then pushed back on to the crate. Excreta passed by the animal while on the cleaning table were likewise collected and added to the main collections.

The urine and " washings " were mixed and 25 cc. 10 per cent. (by volume) sulphuric acid added to the mixture which was filtered through glass wool. All containers were rinsed with a little distilled water and these washings added to the main urine mixture which was made up to a definite volume, usually four litres, with distilled water. Both screens and the bottom of the crate were thoroughly scrubbed with a clean hard brush and rinsed with distilled water on the final day of collection to remove any urinary matter which might have adhered to the screens during the experimental period in spite of the daily rinsing of the screens with water. The urine and washings were usually 8 litres on the last day.

One-twentieth of the total volume of thoroughly mixed urine and washings was taken each day and stored in a glass-stoppered bottle containing a few crystals of thymol. This composite sample was analysed for nitrogen and mineral constituents at the end of the trial.

The urine container was replaced under the crate when the flask with screen washings was removed. A few thymol crystals were placed in the container as a preservative. At first acid (sulphuric or hydrochloric) was used, but as it was found to cause the precipitation of some hippuric acid its use was dispensed with.

Records were kept of water consumption as the tap water supplied to the animals contained a certain amount of lime for which a correction had, therefore, to be made in the lime intake of the animals. The sheep were fed in the morning directly after the completion of the collection of excreta.

The faeces from a daily collection were spread out on the enamel tray and left exposed in the metabolism room for 24 hours after which they were found to contain not more than about 12 per cent. moisture. They were then taken to the laboratory where an aliquot equal to one-tenth of the total weight of faeces was weighed out into a linen bag which was hung up in a suitable place in the laboratory. This process was repeated each day during the collection period and the daily aliquots of one-tenth of the total weight mixed in the same bag. This composite sample was weighed two or three days after the conclusion of the experiment and a sub-sample of unground faeces taken to determine its dry matter content. The main bulk of the composite sample was finely ground, thoroughly mixed, and a representative sub-sample taken for chemical analysis. Due to the fact that the moisture content of air-dry faeces may alter during the grinding process, dry matter had again to be determined on the ground material in order to have all analyses on the absolute dry basis.

Feed refused by an animal in the course of a collection period was left in the manger until the end of the trial, when it was collected, weighed, and chemically analysed. As stated previously, it was only during four of the nine digestion periods that it was found necessary to collect food residues in the case of one of the three animals.

A small quantity, about 3 grams, of table salt was scattered on the feed of each animal every morning.

VIII. RESULTS.

(*a*) The influence of frequency of cutting on Digestibility.

The chemical composition of the dry matter of the nine samples of grass hay fed during the different digestion trials is shown in table 15.

The general tendency in the variations of individual constituents with differences in the stage of growth of the herbage discussed in Section A of this paper is faithfully reflected in the composite samples, crude protein and phosphorus contents increasing with periods 1 to 4 and again with periods 5 to 9, corresponding in each case with herbage of decreasing degree of maturity.

The live-weights of individual sheep at the commencement of the trials and before and after each collection period of the series of experiments are shown in table 16.

There appears to be a slight tendency for the animals to loose weight for a short period after 12th May. This tendency is, however, not maintained and the weights registered at the conclusion of period 9 are from 5 to 7 lb. higher than those obtaining at the commencement of the trials on 19th January. There may have been a real loss in body weights due to deficiencies in the diet consumed in periods 5 and 6, but the length of time the animals were on these diets was too short to permit of definite conclusions.

TABLE 15.

Composition of dry matter of hay samples.

Period.	Hay sample.	Percentage Organic matter.	Percentage Crude protein.	Percentage Crude fibre.	Percentage Ether soluble extract.	Percentage ash.	Percentage N-free extract.	Percentage P.	Percentage Ca.	Percentage dry matter in hay. as fed.
1	4-monthly cuts, 1935–36 season	89·43	5·50	38·6	1·98	10·57	43·35	0·074	0·310	91·0
2	3-monthly cuts, 1935–36 season	89·10	6·90	37·3	2·21	10·90	42·69	0·100	0·342	92·4
3	2-monthly cuts, 1935–36 season	88·60	8·84	35·0	2·35	11·40	42·41	0·112	0·393	92·4
4	1-monthly cuts, 1935–36 season	88·98	10·42	33·9	2·82	11·02	41·84	0·148	0·330	91·1
5	6-monthly cuts, 1936–37 season	87·90	4·37	36·5	2·19	12·10	44·84	0·070	0·411	91·6
6	4-monthly cuts, 1936–37 season	89·18	5·00	36·8	2·51	10·82	44·87	0·083	0·367	92·0
7	3-monthly cuts, 1936–37 season	88·13	6·28	34·0	3·00	11·87	44·85	0·099	0·441	91·7
8	2-monthly cuts, 1936–37 season	88·62	7·18	34·0	2·52	11·38	44·92	0·104	0·415	92·6
9	1-monthly cuts, 1936–37 season	88·42	8·40	34·2	2·52	11·58	43·30	0·111	0·424	90·7

TABLE 16.

Body weight record (expressed in pounds).

Period.	1			2		3		4		5		6		7		8		9	
Sheep No.	19.1.37	5.2.37	16.2.37	24.2.37	6.3.37	14.3.37	24.3.37	1.4.37	11.4.37	2.5.37	12.5.37	20.5.37	30.5.37	7.6.37	17.6.37	25.6.37	5.7.37	13.7.37	23.7.37
4	71	72	71	72	71	72	73	73	74	75	75	72	73	71	73	73	77	77	78
5	70	71	72	71	72	72	73	73	74	75	74	74	72	71	72	72	75	75	77
6	69	71	70	70	70	70	70	72	72	73	72	72	71	70	71	71	73	73	74

The amounts of the different nutrients eaten, diegsted, and voided daily by each sheep together with the co-efficients of apparent digestibility during the nine trials, when feeding the materials described in table 15 appear in table J of the appendix, table K showing the composition of the faeces. An inspection of table J reveals the fact that whilst the agreement amongst the results for the three sheep is not perfect, it may, nevertheless, be considered to be satisfactory for this type of work. On the whole sheep 4 digested its food somewhat more efficiently than did the other two animals.

In order to facilitate comparison the average coefficients of digestibility obtained for the nine samples of grass hay are summarised in table 17.

TABLE 17.

Summary of digestion coefficients (mean for 3 sheep).

Period.	Hay sample.	Organic matter.	Crude protein.	Ether extract.	N-free extract.	Crude fibre.
1	4-monthly cuts, 1935–36 season	49·2	41·3	25·6	45·0	56·3
2	3-monthly cuts, 1935–36 season	55·0	51·4	31·3	51·6	61·2
3	2-monthly cuts, 1935–36 season	58·3	60·4	30·6	55·0	64·2
4	1-monthly cuts, 1935–36 season	64·3	63·5	41·4	60·7	70·8
5	6-monthly cuts, 1936–37 season	48·7	32·4	30·9	46·5	54·2
6	4-monthly cuts, 1936–37 season	52·3	39·6	35·0	50·7	57·3
7	3-monthly cuts, 1936–37 season	58·3	50·4	39·4	57·6	62·4
8	2-monthly cuts, 1936–37 season	62·2	55·1	35·5	61·4	66·7
9	1-monthly cuts, 1936–37 season	65·8	60·3	39·4	63·6	71·9

The influence of the stage of growth on the digestibility of grasses is at once obvious from a glance at table 17. With the exception of the ether extract every constituent shows steadily improving digestibility from the herbage of the most advanced stage of maturity tested in period 1 down to the herbage at the youngest stage of growth fed in the fourth digestion period. The coefficients for the materials of the 1936-37 season vary similarly, a progressive increase taking place from digestion periods 5 to 9, corresponding with herbage of highest to lowest degree of maturity. Ether extract reveals, in general, the same tendency indicated for the other constituents but shows certain irregular fluctuations due probably to varying amounts of ether-soluble material of a metabolic character usually present in the faeces.

For the hay samples of the 1935-36 season the digestion coefficient for organic matter increases from 49·2 for 4-monthly grass through 55·0 and 58·3 for 3- and 2-monthly herbage, respectively, to the comparatively high value of 64·3 for the monthly cuts. Also, for the samples of the following season the digestibility of this constituent improves from 48·7 for the herbage cut after a growth interval of 6 months through 52·3, 58·3, and 62·2 for the intermediate systems of increasing frequency of cutting to 65·8 for the monthly cuts, the highest value obtained for the digestibility of organic matter during this series of trails.

The constituent parts of the organic matter, namely, crude protein, crude fibre, nitrogen-free extract, and, to a lesser extent, ether extract show the same variations in digestibility with stage of growth of the herbage, although differing at times in magnitude. Thus, the apparent digestibility of the crude protein appears to be influenced to a greater extent than the other constituents by the maturity of the grass. The figures for the monthly and 4-monthly herbage of the 1935-36 season differ by as much as 22·2 per cent. in favour of the herbage cut according to the former system. The improvement in digestibility with increasing frequency of cutting is as pronounced in the samples for the following season, the lowest value being 32·4 for the 6-monthly cuts as against 60·3 for the monthly cuts. The composition of the crude fibre content of the herbage samples may have influenced the apparent digestibility of the crude protein in that, although the crude fibre content as determined for two different grass samples may be of the same magnitude, there may be differences in the amounts of indigestible, encrusting materials, such as lignin, which would protect portions of the protein in some measure from enzymatic activity. Nevertheless, from a comparison of the relevant figures in tables 15 and 17 there appears to be a closer relationship between the crude protein content of a sample and its apparent digestibility with constant dry matter intake. In any case, the apparent digestibility of the crude protein of the herbage samples tested remains an index of maturity.

Comparing again table 15 giving the percentage composition of the dry matter of the grass samples tested with table 17 it would appear that there is no consistent relation between the percentage of crude fibre in the hay consumed and the coefficient of digestibility. For digestion periods 1 to 4 the digestibility of the crude fibre improves progressively with decreasing percentage of crude fibre in herbage obtained under increasing frequency of cutting. But, for digestion periods 5 to 9, whilst the digestibility increases in the same progressive manner with the shortening of intervals between cuts, the crude fibre content of the herbage remains the same for periods 5 and 6, then drops somewhat but is again constant for the three final periods. It appears, therefore, that for the climatic conditions obtaining during the two seasons of the plot experiment the figure for crude fibre content as determined by the conventional method does not as such indicate the extent to which it will be digested. More knowledge is needed in regard to the actual chemical composition of the crude fibre moiety. The results of work recently undertaken by Norman (1936) show that " the cellulosic structure of a plant is underestimated in an irregular manner in the fibre determination ". Whereas in young herbage the crude figure accounted for about 90 per cent. of the cellulose, in more mature herbage only 72 per cent. was estimated. A contributary factor in this was found to be the increase of xylan in the cellulose with increasing age. Lignin was also found to increase with maturity.

Whilst, therefore, as stated when discussing the digestibility of the crude protein, the actual figure for crude fibre may be of a similar magnitude in two different herbage samples, the changes taking place in the structural materials of plants with age will result in decreased digestibility of the crude fibre.

The digestion coefficients for the nitrogen free extract show the same tendency with the stage of growth in the samples as indicated for the other constituent parts of the organic matter. However, the nitrogen-free extract is distinctly less digestible than the crude fibre, the coefficients being on an average 10·0 per cent. and 6·6 per cent. higher for the latter than for the former constituent in the hay samples of the 1935-36 and the 1936-37 seasons, respectively.

Woodman (1930) found a similar result for a mineral-deficient herbage tested by him. He remarked that " although this finding emphasizes the important rôle played by bacteria in the digestion of roughages by ruminants, it is difficult to understand why the nitrogen-free extractives in such herbage should run off more quickly than the fibrous constituents into an indigestible and unavailable condition ". The result is perhaps not so surprising when considered in conjunction with the possibility that fermentation in the animal may change crude fibre so as to be partly soluble in 1·25 per cent. acid or alkali, thereby causing it to appear in the nitrogen-free extract of the faeces, according to the conventional method of calculating the so-called " nitrogen-free extractives ". Low figures for the crude fibre content of the faeces will consequently be partly responsible for high values for computed nitrogen-free extract content of the faeces (see table K, appendix), and this in turn will cause the coefficients of digestibility for nitrogen-free extract to be low.

Fraps (1930) studied the digestibility by sheep of the constituents of the nitrogen-free extract of feeds. He found, for instance, that the nitrogen-free extract of roughages contained high percentages of pentosans and other residues not included under sugars, starches and pentosans determined; and that these pentosans and residues of the nitrogen-free extract were digested considerably less efficiently than those occurring in the N-free extract of concentrates. In any case, it seems evident that the nature of the constituents of the N-free extract and the crude fibre of roughages offers a field for extensive investigation.

The coefficients of digestibility for the ether extract, the remaining constituent in table 17, do not show consistent variations with degree of maturity of the herbage, and are comparatively low. These low values and a certain degree of lack of uniformity may be ascribed to the low percentage of ether extract in the hays studied and to the fact that the faeces always contain ether-soluble material of a metabolic character, as previously stated.

Due to the intimate relationship existing between the stage of growth of the herbage and its digestibility comparisons between the results of this investigation and those obtained by other workers are complicated. However, in table 18 a few such comparisons are made with the results obtained in period 4 of the present series of trials.

TABLE 18.

Showing the coefficients of digestibility of roughages.

Roughage.	Percentage Crude Protein.	Percentage Crude Fibre.	Percentage digested.				
			Organic Matter.	Crude Protein.	Ether Extract.	N-free Extract.	Crude Fibre.
Teff hay (Ross, et al, 1927)	9·8	31·9	—	61·2	22·9	57·8	67·1
Rhodes grass hay (Iyer, 1935)	11·4	37·5	63·7	59·4	24·8	55·3	74·4
Prairie hay (Christensen, 1932)	9·6	28·3	64·3	52·2	33·6	67·5	66·8
Mineral-deficient hay (Woodman, 1930)	13·0	35·1	48·0	52·0	5·8	41·8	57·1
Period 4 (This investigation)	10·4	33·9	64·3	63·5	41·4	60·7	70·8

TABLE 19.

Showing percentages digestible nutrients and starch equivalent in dry matter of hay samples fed during digestion periods 1 to 9.

Period.	Hay sample.	Dig. Crude Protein.	Dig. Organic Matter.	Dig. Ether Extract.	Dig. Crude Fibre.	Dig. N-free Extract.	P.S.E.	Nutritive ratio.
1	4-monthly cuts, 1935–36 season	2·27	44·00	0·51	21·72	19·50	21·92	1 : 18·6
2	3-monthly cuts, 1935–36 season	3·55	49·00	0·69	22·80	22·02	27·88	1 : 13·0
3	2-monthly cuts, 1935–36 season	5·34	51·65	0·72	22·47	23·32	31·89	1 : 8·8
4	1-monthly cuts, 1935–36 season	6·61	57·22	1·17	24·00	25·40	38·18	1 : 7·8
5	6-monthly cuts, 1936–37 season	1·42	42·80	0·68	19·78	20·87	22·11	1 : 29·6
6	4-monthly cuts, 1936–37 season	1·98	46·52	0·88	21·10	22·75	26·04	1 : 23·0
7	3-monthly cuts, 1936–37 season	3·17	51·40	1·18	21·20	25·83	32·54	1 : 15·6
8	2-monthly cuts, 1936–37 season	3·96	55·15	0·89	22·68	27·60	35·98	1 : 13·1
9	1-monthly cuts, 1936–37 season	5·07	58·20	0·99	24·60	27·52	38·92	1 : 10·6

A South African, an Indian, a European, and an American roughage have been selected, and the crude protein and crude fibre contents have been included in the table to indicate the approximate stage of growth.

A distinct feature in the table is, with the exception of the prairie hay, the higher coefficients of digestibility for crude fibre in relation to those for the N-free extract. The ether extract values are comparatively low in all cases, crude protein has been digested somewhat more efficiently in the South African roughages, and the digestibility of the organic matter is distinctly low in the European mineral deficient hay in comparison with that for other hays reported in the table. In any case, the digestibility of the South African fodders compares favourably with that of materials of a somewhat similar stage of growth in other countries.

(*b*) The influence of frequency of cutting on nutritive value.

Table 19 gives a summary of the percentages of digestible nutrients and starch equivalent in the dry matter of the herbage samples tested in digestion periods 1 to 9. The starch equivalent has been calculated by the usual formula, namely (digestible protein × 0·94) plus (digestible fat × 1·91) plus (digestible crude fibre) plus (digestible nitrogen-free extract). Since "true" protein has not been determined the figure for digestible crude protein has been employed. To the value obtained according to the above formula the customary correction for roughages (Kellner, 1915) of a deduction of 0·58 of a starch equivalent for each 1 per cent. of total crude fibre in the hay sample concerned has been applied to arrive at the figures for production starch equivalent (P.S.E.) in table 19. From the method of computation it is evident that the figures represent net energy values, one pound of starch equivalent, according to Kellner, having a net energy value of 1,071 calories.

The results in table 19 again bring out the influence of the stage of growth of the herbage on its feeding value. The dry matter of the 4-monthly cuts fed in period 1 contains only 44·00 per cent. digestible organic matter including 2·27 per cent. digestible crude protein as against 57·22 per cent. digestible organic matter including 6·61 per cent. digestible crude protein in the herbage of period 4, cut at monthly intervals during the 1935-36 season. In the hay samples of the following season the digestible organic matter increases in a similarly progressive manner from 42·80 per cent., including only 1·42 per cent. digestible crude protein in the 6-monthly cuts to 58·20 per cent. of which 5·07 per cent. is digestible crude protein, in the herbage from the highest frequency of cutting fed in the final period of the series of trials. The nutritive ratio is extremely wide in most cases, but is profoundly influenced by the stage of growth of the grass samples. For the 1935-36 samples it decreases from 18·6 to the medium value of 7·8 in the monthly cuts, while for the 1936-37 samples it remains wide for all systems of cutting, but, nevertheless decreases from 29·6 in the oldest to 10·6 in the youngest herbage.

As may be expected, considering the method of computation, the starch equivalents vary similarly to the digestible organic matter in the hay samples studied, the values increasing from 21·92 to 38·18 and from 22·11 to 38·92 with increasing frequency of cutting in the herbage samples of the 1935-36 and 1936-37 seasons, respectively.

Following a procedure employed by Woodman (1930) the amounts of starch equivalent which the sheep were consuming during the periods of seemingly increasing liveweight were calculated. For this purpose digestion periods 3 and 4 and digestion periods 8 and 9 were chosen(cf table 16). These two sets of periods were each of about four weeks duration, namely, from the 14th March to the 11th April and from the 25th June to the 23rd July, to be henceforth known as period A and period B, respectively. The average daily consumption of dry matter per head was 1·41 lb. for period A and the same amount, viz. 1·41 lb., for period B (cf. table J). The mean starch equivalent content of the herbage fed during the two periods was 35·03 and 37·45 for periods A and B, respectively, so that the mean daily starch equivalent consumption of the sheep amounted to 0·49 lb. in period A and 0·53 lb. in period B, and on this they were able fully to maintain live weight. The mean weights of the sheep (average for three animals) were 72·3 lb. in period A and 74·4 lb. in period B. Employing Rubner's formula, viz. $E_1 = E_0\left(\frac{V_1}{V_0}\right)^{\frac{2}{3}}$, where E_1 and E_0 relate to energy consumption and V_1 and V_0 to the corresponding live-weights, the figures above for starch equivalent consumption become 0·61 lb. and 0·65 lb. for a sheep of 100 lb. live-weight in periods A and B respectively.

Wood and Capstick (1926) gave a figure of 1·26 lb. of starch equivalent as the maintenance allowance for a sheep weighing 100 lb., while Woodman (1930) indicated that 0·86 lb. of starch equivalent enabled a sheep to fully maintain 100 lb. live-weight. The mean for the figures computed from the data of the present investigation, namely, 0·63 lb. for a sheep weighing 100 lb. is exactly 50 per cent. of Wood and Capstick's figure and considerably lower than the value calculated by Woodman. On the other hand, Møllgaard (1931) in his book "Grundzüge der Ernährungsphysiologie der Haustiere" gave a figure of 708 NK_F as the maintenance requirement of a sheep weighing 50 Kg. This, converted by the expressions 2365 NK_F = 1 Kg. starch equivalent and $E_1 = E_0\left(\frac{V_1}{V_0}\right)^{\frac{2}{3}}$ becomes 0·62 lb. of starch equivalent per 100 lb. live-weight, a figure which is practically the same as that obtained above. However, Møllgaard's figure has been taken from the older German investigations and the figure of 0·63 above has been computed from the data of a short term trial under experimental conditions, and may for that reason be an under-estimation of the net energy requirements for maintenance, if the other figures quoted in the above discussion are to be considered as standard values. In this connection it should be pointed out that the figure here obtained has been calculated from the data from the herbage samples of the lowest degree of maturity, and it will consequently be still lower if computed from the data obtained in periods 1, 2, 5, 6, and 7. If, therefore, 0·63 lb. starch equivalent is an under-estimation of the maintenance requirement, the animals must have been on a sub-maintenance ration for the whole of the series of trials, and such a conclusion is unacceptable in view of the fact that the animals may be considered to have at least maintained body-weights for the period January 19 to July 23, a period of fully 6 months during which they subsisted entirely on the experimental rations, except for the 8 days between periods 4 and 5 when they were fed on the Teff-lucerne hay mixture, the composition of which did not differ materially from that of the grass hay consumed during period 4.

Nevertheless, whilst the results of the present investigation seem to indicate that the animals employed are able to maintain live-weight on much smaller amounts of starch equivalent than are demanded by European standards, they do ,on the other hand, focus attention on the necessity for long-term trials with the object of establishing whether samples of grass hay obtained according to the systems of cutting applied during the two seasons of the experiment will at the same level of dry matter intake provide sufficient net energy to maintain live-weight, irrespective of the stage of growth of the grasses, and disregarding for the moment other deficiencies which may be present in herbage of an advanced stage of maturity, such as protein and phosphorus. The present series of trials aimed primarily at determining digestibility and were not planned for the purpose of establishing the relative energy value of herbage of varying degree of maturity for the maintenance of sheep, but they do indicate the necessity for utilising grasses at the younger stages of growth.

To conclude this discussion it will be interesting to compile a new table from table 13, giving the production of dry matter and crude protein under the different frequencies of cutting applied to the grasses, in the light of the data relating to digestion coefficients in table 17. Table 20 shows the production of digestible crude protein and starch equivalent from each of the series of cutting treatments to which the grasses were subjected.

In view of the influence of cutting frequency on the digestibility and gross production of pasture species discussed earlier it may be expected to affect the yield of digestible nutrients in a similar manner, only to a more marked degree. A glance at table 20 reveals the fact that while there may be no difference between the monthly and the 2-monthly systems, the production of digestible nutrients from any one of these treatments is superior to that from the more lenient systems of cutting. The effect of repeated defoliations at monthly intervals on the vitality and yielding capacity of the grasses is not reflected in the yield of digestible nutrients for the first season of the experiment but becomes distinctly noticable during the second season, when there was a difference of about 20 per cent. in the production of starch equivalent in favour of the 2-monthly system of cutting. In view of this circumstance there again seems to be justifiable grounds for the conclusion reached earlier in this report, namely that, under the climatic conditions of the experiment, a system of cutting natural veld grasses at intervals of 2 months during the growing season will result in the optimum utilisation of such pasture.

TABLE 20.

Seasonal production of digestible crude protein and starch equivalent in pounds per acre.

	Season.	Cutting treatment.				
		1 month.	2 months.	3 months.	4 months.	6 months.
Digestible crude protein.......	1935–36	128	122	87	57	57
	1936–37	82	82	58	49	33
Starch equivalent............	1935–36	738	729	632	552	552
	1936–37	627	746	601	596	514

(*c*) THE INFLUENCE OF FREQUENCY OF CUTTING ON THE NITROGEN, PHOSPHORUS AND CALCIUM BALANCES.

The nitrogen, phosphorus, and calcium balances for each of the series of nine digestion trials appear in tables L, M and N of the appendix, the period numbers corresponding with those in Table 14.

Considering the average of the mean daily balances for the three sheep it is seen that, except for period 5 when a negative balance was obtained, the amount of hay consumed provided sufficient nitrogen to maintain the sheep in nitrogen equilibrium and to permit of the storage of nitrogen in the animal organism during some of the periods of the series.

From the data given in Table 21 it is possible to arrive at an approximate figure for the nitrogen maintenance requirement of a fullgrown Merino wether weighing about 70 lb. (cf. Table 16). From an inspection of Table 21 it may be concluded that during digestion periods 1 and 6 the sheep were on an average in nitrogen equilibrium, the amounts of nitrogen digested being 2·29 grams and 2·03 grams respectively. The mean value for the two periods, viz. 2·16 grams digestible nitrogen is assumed to be adequate for the maintenance of nitrogen equilibrium. Since, however, the wool of the sheep always grows allowance for the nitrogen thus stored should be made in the maintenance requirement.

Møllgaard (1931) gives an average amount of 14·0 grams digestible protein to be the additional requirement for wool growth of a sheep weighing 100 kg., or proportionally, 0·72 grams digestible nitrogen for a sheep of 70 lb. live weight. The total requirement for maintenance and wool growth would then be 2·88 grams digestible nitrogen or 18·0 grams digestible crude protein per day for a sheep weighing 70 lb. According to Wood and Woodman's " Rations for Live Stock " (1932) a sheep of similar weight would require 0·28 lb. per week or 18·2 grams digestible protein per day. It should, however, be mentioned that the figures in their table for protein are given in terms of " protein equivalent ".

TABLE 21.

Digestion Period.	Hay sample fed.	Percentage Crude Protein in dry matter.	Actual mean daily dry matter intake (gms.).	Mean daily N. intake (gms.).	Coefficient of apparent digestibility.	Mean daily N. digested (gms.).	Mean daily N. balance (gms.).	Calculated daily dry matter intake required for N. maintenance (gms.).
1	4-monthly cuts, 1935–36 season	5·50	631	5·54	41·3	2·29	+ 0·16	794
2	3-monthly cuts, 1935–36 season	6·90	656	7·12	51·4	3·66	+ 0·77	516
3	2-monthly cuts, 1935–36 season	8·84	647	9·15	60·4	5·52	+ 2·41	338
4	1-monthly cuts, 1935–36 season	10·42	638	10·63	63·5	6·75	+ 1·80	272
5	6-monthly cuts, 1936–37 season	4·37	638	4·45	32·4	1·44	− 0·30	1,276
6	4-monthly cuts, 1936–37 season	5·00	641	5·12	39·6	2·03	+ 0·13	908
7	3-monthly cuts, 1936–37 season	6·28	642	6·45	50·4	3·25	+ 1·10	569
8	2-monthly cuts, 1936–37 season	7·18	648	7·45	55·1	4·11	+ 1·52	454
9	1-monthly cuts, 1936–37 season	8·40	635	8·53	60·3	5·14	+ 1·51	356

TABLE 22.

Digestion Period.	Mean body weight of sheep (Kg.).	Mean daily dry matter intake (gms.).	Mean daily nitrogen intake (gms.).	Mean daily total faecal nitrogen (gms.).	Mean daily metabolic faecal nitrogen (gms.).	Coefficient of apparent digestibility.	Coefficient of true digestibility.	Mean daily nitrogen absorbed (gms.).	Mean daily urinary nitrogen (gms.).	Mean daily endogenous urinary nitrogen (gms.).	Mean daily nitrogen utilised (gms.).	Percentage utilization.
1	32·3	631	5·54	3·25	1·77	41·3	73·2	4·06	2·13	1·03	2·96	72·9
2	32·3	656	7·12	3·48	1·84	51·4	78·4	5·58	2·89	1·03	3·72	66·7
3	32·7	647	9·15	3·63	1·81	60·4	80·2	7·33	3·12	1·04	5·25	71·6
4	33·2	638	10·63	3·88	1·79	63·5	80·4	8·54	4·94	1·06	4·66	54·6
5	33·6	638	4·45	3·01	1·79	32·4	72·6	3·23	1·75	1·08	2·56	79·3
6	32·7	641	5·12	3·09	1·79	39·6	74·6	3·82	1·91	1·05	2·96	77·5
7	32·3	642	6·45	3·19	1·80	50·4	78·5	5·06	2·16	1·04	3·94	77·8
8	33·2	648	7·45	3·35	1·81	55·1	79·3	5·91	2·59	1·07	4·39	74·3
9	34·5	635	8·53	3·39	1·78	60·3	81·2	6·92	3·63	1·10	4·39	63·4

The figure calculated above would be lower if given in similar terms, depending on the pure protein content of the rations of grass hay consumed, but would nevertheless be in close agreement with that given in "Rations for Live Stock". The amount of material available did not permit of duplication of individual trials to establish whether the nitrogen balances observed would persist indefinitely. At the same time, there seems to be ground for the point of view that in the case of protein the growth obtained in a few weeks of feeding or the rate of nitrogen retention in even shorter periods under properly controlled conditions, will be representative of the adequacy of the protein supply [Mitchell and Hamilton (1929)].

In any case, even if it is only approximate, the figure calculated may serve the purpose of determining the relative values of the hay samples fed during digestion periods 1-9, as sources of nitrogen for the maintenance requirements of the Merino sheep. These values appear in the last column of Table 21 and represent the weight of dry matter which a 70 lb. sheep must consume daily of any one of the different hay samples to ensure the ingestion of 18·0 grams digestible crude protein, i.e. the requirement for maintenance and wool growth. The figures afford yet another demonstration of the profound influence of frequency of cutting on the nutritive value of grasses. For instance, in the case of the samples of the 1936-37 season, a sheep has to consume no less than about 1300 grams of the dry matter of the 6-monthly cuts for its nitrogen requirements, whereas the nitrogen in only 356 grams of the dry matter of monthly cuts is adequate for the same needs.

However, the dry matter intake remained practically the same for all the periods in the series of experiments and the plane of nitrogen intake consequently varied from period to period. Under these conditions it will be interesting if the percentage utilization or biological value of the nitrogen at the different planes of intake corresponding with herbage obtained under different frequencies of cutting were known.

In the nitrogen balance method described by Mitchell (1923) the biological value of a protein is defined as the percentage of the absorbed nitrogen which is retained by the body for repair or the construction of nitogenous tissue. Due to the fact that a certain fraction of the faecal nitrogen is derived from the intestinal tract and its secretions during digestion the ordinary coefficient of digestibility discussed earlier in this paper is not a true measure of the amount of nitrogen absorbed; the undigested food nitrogen only, and not the total nitrogen in the faeces, should be deducted from the nitrogen intake to obtain the amount actually absorbed. Furthermore, the urinary excretions contain nitrogen resulting from tissue catabolism as well as nitrogen resulting from incomplete utilization of dietary nitrogen. It is obvious, therefore, that the body's contribution of nitrogen to the urinary and faecal excretions must be assessed to permit of the measurement of the percentage utilization of the nitrogen absorbed.

Various direct methods have been devised for separating the two forms of faecal nitrogen by digestion of the faeces with enzymes or special solvents, [Pfeiffer and Lemmermann (1901); Wöhlbier

(1930)] but these are considered to be based on unacceptable assumptions and do not give the information desired [Woodman (1924), Mitchell and Hamilton (1929), Watson and Horton (1936)]. Several workers in the field of nutrition are now making use of indirect methods for the estimation of the endogenous urinary faecal nitrogen. [Mitchell (1923), Sotola (1930), Martin and Robinson (1922), Boas Fixsen (1930), Hutchinson and Morris (1936)]. Briefly the principle of this method resolves itself into the measurement of the faecal and urinary excretion of nitrogen when the animal consumes a nitrogen-free ration complete in all respects except for the absence of nitrogen. The body's contribution of nitrogen to the urinary and faecal excretions during periods of protein feeding is then measured by the nitrogen content of the urine and faeces of the experimental animal when receiving a nitrogen free ration, the feed intake being such as to provide liberally for the energy maintenance requirement. It has also been shown that the excretion of nitrogen in the faeces of animals on nitrogen-free diets varies directly with the amount of feed consumed.

The present series of trials were not planned for the purpose of measuring biological values, but, since both the endogenous urinary nitrogen and the metabolic faecal nitrogen of the same three sheep (employed in these trials) were determined by Smuts (1938) in experiments following directly on the digestion trials, the values obtained by him are assumed to be a fair indication of the endogenous nitrogen metabolism of the animals during the digestion experiments reported in this paper. Smuts fed a nitrogen-free ration containing about 25 per cent. crude fibre and found the average endogenous urinary and faecal nitrogen of the three animals to be 0·032 grams nitrogen per kilogram body weight and 0·28 grams per 100 grams food intake, respectively. Using these figures the percentage utilization of the nitrogen estimated to have been absorbed from the rations fed in digestion periods 1 to 9 has been calculated in Table 22 from the experimental data shown in Table 16 and Tables J and L of the appendix. Average values for the three sheep have been used throughout.

A glance at Table 22 shows that the figures for the "true" digestibility greatly exceeds those for the "apparent" digestibility, the differences between the two series of values becoming less as the nitrogen content of the feed consumed increases. The accuracy of the figures for the digestibility is, of course, dependent upon the accuracy of the figure for the metabolic faecal nitrogen, and since the determination of the latter is based upon an indirect method of uncertain exactness, the values for the true digestibility must be looked upon as only approximate. At the same time a slight under or overestimation of the metabolic faecal nitrogen will not seriously affect the value calculated for the percentage of nitrogen utilised by the animal body, as both the numerator and the denominator of the fraction determining the biological value are influenced by the figure for the metabolic faecal nitrogen.

The accepted influence of the level of nitrogen intake on its utilisation by the animal organism [Mitchell (1923)] is clearly demonstrated by the variations in the figures for the percentage utilisation in Table 22 with variations in the nitrogen concentration of the rations. With increasing intake in periods 1 to 4, and again in periods 5 to 9 the percentage utilisation tends to decrease, the highest and lowest values being indicated for periods 5 and 4 when the nitrogen intake was at its lowest and highest, respectively.

Whilst, therefore, the actual amount of nitrogen utilised for maintenance and tissue growth was highest during those periods when grasses at the younger stages of growth were fed, (see column 12, Table 22), the wastage of nitrogen in the metabolic processes of the animal was least when the rations consisted of more mature herbage. If the level of nitrogen intake had been the same for each of the nine hay samples of varying degree of maturity tested, the percentage utilisation of the nitrogen absorbed may be expected to have been of a somewhat similar magnitude throughout. On the other hand, from what has been stated earlier in this paper under "general scheme of the trials" with reference to the amount of grass hay which the type of sheep employed in the experiments will consume continuously, it is doubtful whether the animal will consume the weight of 6 monthly cut grass hay which is needed for its nitrogen maintenance requirements (see Table 21). At the same time the relatively small amount of hay obtained by cutting at monthly intervals, which will suffice for its nitrogen needs, will probably not be adequate to provide for its energy requirements. Consequently, if grass hay has to be made use of, without the addition of other energy-yielding or nitrogenous supplements, it is concluded that it may be utilised most advantageously, as a maintenance ration for adult sheep, when cut at the intermediate stages of growth, viz. at 2- or 3- monthly intervals.

Owing to the shortness of the feeding experiments and since the inadequacy of nutrients that may be stored in considerable amounts relative to current expenditure in the animal body may be deferred for longer periods of time than in the case of protein, there is little justification for embarking upon a discussion of the results obtained in the measurements of the calcium and phosphorus balances. These balances have been included with the other results of the investigation merely to indicate probable influences of the different rations on the mineral metabolism of the animals within the short interval of time allotted to each digestion trial.

The data for the calcium balances have been decidedly disappointing in that consistently negative balances were obtained, in spite of variations in the mineral content of the rations consumed. In considering these results it should be borne in mind that mature sheep were employed in the experiments. The maintenance requirements for such animals does not appear to be definitely known [Franklin (1935)], but is undoubtedly small relative to that for growing animals. Factors which may have influenced the calcium balances are the digestibility or availability of the calcium in, the unfavourable calcium-phosphorus ratio of, actual deficiency of phosphorus during some periods, and, the probable absence of unknown factors in the experimental rations.

Apparently the grass samples obtained by cutting at monthly and 2-monthly intervals and fed during periods 4 and 9, and periods 3 and 8, respectively, tended to bring about a condition of phosphorus equilibrium in the animals, whereas negative balances were registered for all other periods. In view of the advantages attaching to a system of cutting herbage at 2-monthly intervals during the growing season, as indicated previously, the mineral metabolism of animals subsisting entirely on such herbage could with advantage be investigated with special reference to the requirements for maintenance and growth in respect of calcium and phosphorus.

IX. GENERAL SUMMARY AND CONCLUSIONS.

Five species of indigenous grasses, namely *Chloris gayana*, *Setaria Lindenbergiana*, *Cenchrus Ciliaris*, *Digitaria Pentzii Pretoria small*, and *Panicum maximum*, were established each in five replications on 25 plots, each measuring (24 × 17) square feet, in a Latin Square arrangement. Each plot was again subdivided into five equal portions and a different treatment allocated at random to each subplot within a main plot. The effective cutting area of a subplot measured (22 × 3) square feet. The experiment covered two growing seasons and the treatments applied were:—

(1) Cutting the herbage at monthly intervals;

(2) Cutting the herbage at 2-monthly intervals;

(3) Cutting the herbage at 3-monthly intervals;

(4) Cutting the herbage after 4 months growth, followed by an aftermath cut of 2 months growth; and

(5) Cutting the herbage once only towards the end of the growing season, usually a 6-monthly cut.

The objects of the investigation were to study the effect of the treatments on the yield, chemical composition, digestibility and nutritive value of the grasses under natural conditions of soil and climate. To test the digestibility the produce obtained under any one cutting treatment for all the species combined was treated as a single sample. Three adult Merino wethers were employed and the hay samples were tested in nine successive digestion periods.

The following is a summary of the results obtained:—

(1) Grasses of the stoloniferous type were readily propagated from roots, whereas the establishment of bunch grasses by this method demanded much care and attention.

(2) The intrusion of weeds and other grass species indigenous to the locality on the established pure stands occurred most on those sub-plots cut at monthly intervals.

(3) Of the grass species studied *Setaria Lindenbergiana* and *Panicum maximum* gave the highest yields of dry matter.

(4) The yield of dry matter was lowest when cutting the grasses at monthly intervals during the growing season.

(5) Of the more lenient cutting treatments the 6- and 4-monthly systems produced on the whole more dry matter than the 2- and 3-monthly systems.

(6) Evidence which suggests that the amount of dry matter obtainable under a 2-monthly system of cutting may not differ materially from that resulting from one cut at the end of the season or two cuts as represented by a 4-monthly cut in February followed by an aftermath cut two months afterwards, has been obtained.

(7) Rainfall is the most important factor governing the yield of grass under natural conditions. It would appear that there is a period of optimum growth which is independent of the rainfall during seasons when the latter is normal in amount and distribution.

(8) The content of phosphorus, potassium, chlorine, and crude protein of the dry matter of herbage samples is markedly influenced by cutting treatments, the values decreasing with decreasing frequency of cutting. Calcium and magnesium values do not show appreciable variation with stage of growth, while the general tendency for sodium is to decrease with age in the plant. The crude fibre content varies more or less inversely with the protein content and the percentage ether-soluble extract shows irregular fluctuations with variations in the stage of growth. The nitrogen-free extract shows little variation in the dry matter of herbage from different cutting treatments.

(9) On the whole the dry matter content of grasses increases with age in the plant. It is, however, considerably influenced by climatic conditions. Drought is associated with high values while suitable moisture and temperature conditions causing active growth are favourable to low values for dry matter content.

(10) While there may be no difference in the production of crude protein and phosphorus under a monthly and a 2-monthly system of cutting, a steady decrease in the production of these nutrients is indicated as the intervals between cuts become longer.

(11) Except for the ether-soluble extract which occasionally shows irregular fluctuations, the coefficients of apparent digestibility for all the constituents of the organic matter of the hay samples decrease steadily with advancing stage of growth. The crude fibre was found to be more digestible than the nitrogen-free extract.

(12) Lengthening the interval between cuts greatly influenced the nutritive value. The dry matter of 6-monthly cut herbage contained only 22·11 per cent. starch equivalent including 1·42 per cent. digestible crude protein as against 38·92 per cent. starch equivalent including 5·07 per cent. digestible crude protein in the dry matter of monthly cuts.

(13) The nutritive ratio remained wide, but improved from 1:29·6 to 1:10·6 in the dry matter of 6-monthly and monthly cut herbage, respectively.

(14) The data of the digestion trials seem to suggest that the animals employed were able to maintain live-weight on much smaller amounts of starch equivalent than are demanded by European standards. The figure calculated is 0·63 lb. of starch equivalent per day for a sheep weighing 100 lb., and confined to a metabolism crate.

(15) The production of digestible nutrients obtainable by cutting grasses at monthly and 2-monthly intervals is considerably higher than that resulting from the more lenient systems of cutting. The unfavourable effect of repeated defoliations at monthly intervals on the vitality of the plants is reflected in a higher yield of starch equivalent under the 2-monthly system during the second season of the experiment.

(16) With practically the same dry matter intake for all the samples of hay tested the concentration of nitrogen in the rations consumed varied according to the stage of growth from digestion period to period. Under these conditions the most economic utilisation of the nitrogen absorbed occurred during those periods when the animals were consuming herbage of the highest degree of maturity containing the lowest percentage of nitrogen. However, a sheep will probably not consume sufficient of such poor and comparatively unpalatable hay to provide for its nitrogen maintenance requiremnts.

(17) The consistently negative calcium balances obtained were probably not due to an absolute deficiency of this mineral in the grass samples. No explanation is given for the phenomenon.

(18) The animals appeared to have been in a state of phosphorus equilibrium when feeding on herbage cut at monthly and 2-monthly intervals.

Since the results obtained with the grass species studied on the particular type of soil and under the climatic conditions obtaining during the two seasons of the investigation may not be taken to apply generally, it is not possible to lay down clear directions for the practical man. Nevertheless, from a consideration of the evidence of the data obtained in this experiment as a whole it seems to be a warrantable conclusion that a system of cutting grasses at approximately 2-monthly intervals during the growing season for the purpose of providing feed during times of scarcity will result in the most economical utilisation of indigenous grass species under natural conditions.

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XI. REFERENCES.

BARRENSCHEEN, H. K., UND MESSINER, L. (1927). "Eine Kolorimetrische Mikrobestimmung des Natriums." *B.Z.*, Band 189, S. 308.

BELL, R. D., AND DOISY, E. A. (1920). "Rapid colorimetric methods for the determination of phosphorus in urine and blood." *J.B.C.*, Vol. 45, p. 55.

BOAS FIXSEN, M. A. (1930). "The biological values of proteins." *Biochem. Journ.*, Vol. 24, p. 1794.

BRENCHLEY, W. E. (1924). "Manuring of Grass-land for Hay." Cited by Orr (1929).

BRIGGS, A. P. (1924). "Some applications of the colorimetric phosphate method." *J.B.C.*, Vol. 59, p. 255.

CASHMORE, A. B. (1934). "A comparative study of *Lolium perenne* and *Phalaris tuberosa* at varying stages of growth." *Coun. for Sci. and Ind. Res., Australia, Bull. No.* 81.

CHRISTENSEN, F. W., AND HOPPER, T. H. (1932). "Effect of weathering and stage of maturity on the palatability and nutritive value of Prairie hay." *Agric. Expt. Stn., North Dakota, Bull. No.* 260.

CLARK, E .P., AND COLLIP, J. B. (1935). *J.B.C.*, Vol. 63, p. 461. Cited by Godden, W. (1937). "Methods for the chemical analysis of biological material in nutrition investigations." *Tech. Comm. No.* 9, *Imp. Bur. of Anim. Nut.*

COCKAYNE, A. H., et al (1933). "Technique employed in Grassland Research in New Zealand." *Herbage Publication Series Bull. No.* 11.

DAVIES, J. G., AND SIM, A. H. (1931). "The influence of frequency of cutting on the productivity, botanical and chemical composition, and the nutritive value of 'natural' pastures in Southern Australia." *Coun. for Sci. and Ind. Res., Australia, Bull. No.* 18.

DENIGES (1920). *Compt. rend, Soc. Biol.* 84, 875. Cited by Green, H. H. 1928). "Studies in mineral metabolism. IV. Determination of phosphorus compounds in blood by dry combustion." *Jour. Agric. Sci.*, Vol. 18, p. 372.

DU TOIT, P. J., et al (1932). "A study of the mineral content and feeding value of natural pastures in the Union of South Africa (First report)." *18th Rept. Dir. of Vet. Ser. and An. Ind.*, pp. 525-577.

DU TOIT, P. J., et al (1934). "A study of the mineral content and feeding value of natural pastures in the Union of South Africa (Second report)." *Onderstepoort Jour. of Vet. Sci. and An. Ind.*, Vol. 2, No. 2, p. 607.

DU TOIT, P. J., et al (1935). "A study of the mineral content and feeding value of natural pastures in the Union of South Africa (Third report)." *Onderstepoort Jour. of Vet. Sci. and An. Ind.*, Vol. 5, No. 1, p. 201.

DU TOIT, P. J., et al (1935). "A study of the mineral content and feeding value of natural pastures in the Union of South Africa. IV. The influence of frequency of cutting on the yield, persistency, and chemical composition of grass species." *Onderstepoort Jour. of Vet. Sci. and An. Ind.*, Vol. 5, No. 1, p. 215.

ELLIOT, W. (1926). "Investigation on the mineral content of pasture grass and its effect on herbivora. I. General Report." *Jour. Agric. Sci.*, Vol. 16, p. 59.

FAGAN, T. W., AND JONES, H. T. (1924). "The nutritive value of grasses as shown by their chemical composition." *Welsh Plant Breeding Station, Aberystwyth. Series H. No.* 3.

FISCHER, R. A. (1932). "Statistical methods for research workers." *Oliver and Boyd, Edinburgh.*

FRANKLIN, M. C. (1935). "The lime requirements of sheep." *New Zealand Jour. Agric.*, Vol. 51, p. 257.

FRAPS, G. S. (1930). "Digestibility by sheep of the constituents of the nitrogen-free extract of feeds." *Texas Agric. Expt. Stn. Bull. No.* 418.

GODDEN, W. (1926). "Investigation on the mineral content of pasture grass and its effect on herbivora. III. Report on the chemical analyses of samples of pasture from various areas in the British Isles." *Jour. Agric. Sci.*, Vol. 16, p. 78.

GRANFIELD, C. O. (1935). "The trend of organic food reserves in Alfalfa roots as affected by cutting practices." *Jour. Agric. Res.*, Vol. 50, p. 697.

GRASSLAND RESEARCH COMMITTEE. Pretoria University--African Explosives and Industries, Ltd. (1932). "The grasslands of South Africa. Problems and possibilities." Series 1, No. 23.

HALL, T. D. (1932). "Intensive grazing of veld." *S. Afr. Jour. Sci.*, Vol. 29, p. 389.

HENRICI, M. (1928). "The phosphorus content of the grasses of Bechuanaland in the course of their development." *13th and 14th Repts. Dir. Vet. Ed. and Res.*, p. 1077.

HENRICI, M. (1930). "The phosphorus content of grasses in the Eastern Transvaal." *16th Rept. of the Dir. of Vet. Ser. and An. Ind.*, p. 435.

HENRICI, M. (1932). "An investigation of the content of phosphorus, calcium and protein of grasses in the coastal region of Natal and Southern Zululand." *Sci. Bull No.* 115, *Dept. Agric., Union of S. Africa.*

HENRICI, M. (1934). "An investigation of pastures in the Eastern Province and in the Albany District." *Sci. Bull. No.* 134, *Dept. Agric., Union of S. Africa.*

HENRICI, M. (1935). "Fodder plants of the Broken Veld (Fauresmith district). Their chemical composition, palatability and carrying capacity.' *Sci. Bull. No.* 142, *Dept. Agric., Union of S. Africa.*

HOLZAPFEL, C. R. (1934). "Modifications of the methods used at Onderstepoort for the determination of (A) magnesium and calcium, (B) potassium, in grass-extracts." *Onderstepoort Jour. Vet. Sci. and An. Ind.*, Vol. 2, No. 1, p. 115.

HUBBARD, R. S. (1933). "Note on the precipitation of small amounts of potassium as potassium sodium cobalti-nitrite." *J.B.C.*, Vol. 100, p. 557.

HUTCHINSON, J. C. D., AND MORRIS, S. (1936). "The digestibility of dietary protein in the ruminant I. Endogenous nitrogen excretion on a low nitrogen diet and in starvation." *Biochem. Jour.*, Vol. 30, p. 1682.

IMPERIAL BUREAU OF PLANT GENETICS, ABERYSTWYTH (1934). "Grassland research in Australia." *Herbage Publication Series, Bull. No.* 14.

IYER, A. V. (1935). "The influence of progressive ripening of fodders on the mineral nutrition of cattle." *Ind. Jour. Vet. Sci. and An. Husb.*, Vol. 5, p. 129.

JURITZ, C. F. (1890). "Chemical constitution of Colonial fodder plants." Cited by Juritz (1914).

JURITZ, C. F. (1914). "Notes on some indigenous and other fodder plants." *Sci. Bull. No.* 6, *Dept. Agric., Union of South Africa.*

KELLNER, O. (1915). "The scientific feeding of animals." Duckworth and Co., London.

KIRSCH, W. (1933). "Recent research on forage crop cultivation, fodder conservation and utilization, at the Animal Breeding Institute of the University, Königsberg." *Imperial Bureau of Animal Nutrition. Technical Communication No.* 3.

KRAMER, B., AND TISDALL, F. F. (1921). "A clinical method for the quantitative determination of potassium in small amounts of serum." *J.B.C.*, Vol. 46, p. 339.

LAWES, J. B., AND GILBERT, J. H. (1900). *Philo. Trans. Ser. B,* 139-210. Cited by Orr (1929).

LENKEIT, W. (1932). "Die Durchgangszeiten des Futters durch den Verdauungskanal der Haustiere, der quantitative Verlauf der Ausscheidung und die motorische Darmfunktion." *Berliner Tierärzt. Wochensch.*, Jg. 48, S. 17.

LEPPAN, H. D. (1928). "The Agricultural Development of arid and semi-arid regions with special reference to South Africa." *Central News Agency, Ltd., South Africa.*

LEPPAN, H. D. (1936). "The interdependence of animals, crops and pasture." *Univ. Pretoria, Series* 1, *No.* 37.

LOUW, J. G. (1933). "The colorimetric determination of sodium in vegetation." *Onderstepoort Jour. Vet. Sci. and An. Ind.*, Vol. 1, No. 2, p. 425.

LOUW, J. G. (1934). "A routine method for the determination of soluble ash in plant material." *Onderstepoort Jour. Vet. Sci. and An. Ind.*, Vol. 3, No. 1, p. 191.

MALAN, A. I., AND VAN DER LINGEN, G. (1931). "The Micro-determination of some inorganic elements in blood and vegetation." 17*th Rept. of the Dir. Vet. Ser. and An. Ind.*, p. 443.

MARAIS, J. S., EN SIM, J. T. R. (1937). "Weidings in die winterreën-gebied." *Hulpboek vir Boere in Suid-Afrika,* bls. 409. *Dept. van Landb. en Bosbou, Unie van S.A.*

MARÉ, G. S. (1937). "Lusern as Weiding vir skape." *Huplboek vir Boere in Suid-Afrika,* bls. 423. *Depart. van Landb. en Bosbou, Unie van S.A.*

MARCHAND, B., AND SMIT, B. J. (1919). "The composition of some feeding stuffs." *Bull. No. 5, Dept. of Agric., Union of S. Africa.*

MARTIN, C. J., AND ROBISON, R. (1922). "The minimum nitrogen expenditure of man and the biological value of various proteins for human nutrition." *Biochem. Jour.*, Vol. 16, p. 407.

McCONKEY, O. (1931). "Recent advances in pasture management." *E.M.B.* 43. *His Majesty's Stationery Office, London.*

MITCHELL, H. H., AND HAMILTON, T. S. (1929). "The biochemistry of the amino acids." *American Chem. Soc. Monograph Series.*

MITCHELL, H. H. (1923). "A method of determining the biological value of protein." *J.B.C.*, Vol. 58, p. 873.

MITCHELL, H. H. (1923). "The biological values of proteins at different levels of intake." *J.B.C.*, Vol. 58, p. 905.

MØLLGAARD, H. (1931). "Grundzüge der Ernährungsphysiologie der Haustiere." Verlagsbuchhandlung Paul Parey, Berlin.

MOSES, D. (1934). "Experiments with improved Pastures in the Coastal Belt. Part II. Production under intensive management." *S.A. Jour. Sci.*, Vol. 31, p. 299.

MÜLLER, H. (1873). *Landw. Jahrb.* 2, 1-107. Cited by Orr (1929).

NORMAN, A. G. (1936). "The composition of forage crops. I. Rye grass." *Biochem. Jour.*, Vol. 30, p. 1354.

ORR, J. B. (1929). "Minerals in pastures." *H. K. Lewis & Co., Ltd., London.*

PATERSON, D. D. (1933). "The influence of time of cutting on the growth yield and composition of tropical fodder grasses." *Jour. Agric. Sci.*, Vol. 23, p. 615.

PATERSON, D. D. (1935). "The growth, yield and composition of certain tropical fodders." *Jour. Agric. Sci.*, Vol. 25, p. 369.

PETRIE, A. H. K. (1934). "The drift of the content of potassium and calcium with age in plants." *Australian Journ. Exp. Biol. and Med. Sci.*, Vol. 12, p. 99.

PFEIFFER AND LEMMERMANN (1901). *Landw. Versuchsstat.* 55, 129. Cited by Woodman (1924).

POLE EVANS, I. B. (1920). "The veld: Its resources and dangers." *S. Afric. Jour. Sci.*, Vol. 17, p. 1.

POLE EVANS, I. B., et al (1936). "Pastures and Forage crops in South Africa." *Herb. Pub. Series, Bull. No.* 18.

RICHARDSON, A. E. V., et al (1931). "Factors affecting the mineral content of pastures." *Bull. No.* 49, *Coun. Sci. and Ind. Res., Australia.*

RICHARDSON, A. E. V., et al (1932). "The influence of growth stage and frequency of cutting on the yield and composition of a perennial grass – *Phalaris tuberosa*." *Bull. No.* 66, *Coun. Sci. and Ind. Res., Australia.*

RIGG, T., et al (1932). "The effect of season and fertilizers on the dry-matter content of a Nelson Dairying Pasture." *New Zealand Jour. Sci. and Techn.*, Vol. 13, p. 295.

ROSS, J. C., et al (1927). "Die Verteerbaarheid van teffhooi vir skape." *Wetensk. Bull. No.* 57, *Landboudepartement, Pretoria.*

ROSS, J. C., et al (1931). "Digestibility of teff hay, maize oil cake and lucerne hay for cattle." *Bull. No.* 20, *University of Pretoria.*

ROSS, J. C. (1936). "The agricultural chemist and animal nutrition." *Jour. S. African Chem. Inst.*, Vol. 19, p. 45.

SMUTS, D. B. (1938). Unpublished data.

SOTOLA, J. (1930). "Biological values and supplementary relations of the proteins in alfalfa hay and in corn and sunflower silage." *Jour. Agric. Res.*, Vol. 40, p. 79.

STAPLEDON, R. G., et al (1925-26). "Italian rye-grass for winter and early spring keep: The effect of methods of grazing on productivity and palatability and on the chemical and botanical composition of the herbage." *Welsh Plant Breeding Station, Aberystwyth. Series H, No.* 5.

STAPLES, R. R., AND TAYLOR, A. J. (1929). "Studies in pasture management. A preliminary report on the seasonal composition of certain South African pasture grasses in relation to their manuring and intensity of grazing." *S. Afric. Jour. Sci.*, Vol. 26, p. 139.

TAYLOR, A. J. (1922). "The composition of some indigenous grasses." *S. Afric. Jour. Sci.*, Vol. 19, p. 218.

TAYLOR, A. J. (1931). "Duisend gellings melk per ½ morg." *Boerdery in S.A.*, Deel 5, bls. 545.

TAYLOR, A. J. (1932). "Studies in pasture management. A further report on the seasonal composition of certain South African pasture grasses in relation to their manuring and intensity of grazing." *Sci. Bull. No.* 109, *Union Dept. Agric.*

THEEL, E. (1933). "Über den Mineralstoffgehalt deutscher Futtermittel. Ergebnisse an Wiesenheu." *Inaug. Diss. Landw. Hochschule, Berlin.*

THEILER, A., et al (1920). "The cause and prevention of Lamziekte." *Jour. Dept. of Agric. (Union of S.A.)*, Vol. 1, p. 221.

TRUMBLE, H. C., AND DAVIES, J. G. (1931). "The rôle of pasture species in regions of winter rainfall and summer drought." *Jour. Coun. Sci. and Ind. Res., Australia*, Vol. 4, p. 140.

TRUMBLE, H. C., AND DAVIES, J. G. (1934). "The establishment, persistency, and productivity of selected pasture species on an irrigated reclaimed swamp." *Bull. No.* 80, *Coun. Sci. and Ind. Res., Australia.*

TRUMBLE, H. C., AND CORNISH, E. A. (1936). "The influence of rainfall on the yield of a natural pasture." *Jour. Coun. Sci. and Ind. Res.*, Vol. 9, p. 19.

VIPOND, H. J. (1914). "De samenstelling van produkten en voedingstoffen." *Bull. No.* 1, *Unie Dept. van Landb.*

WATSON, S. J. AND HORTON, E. A. (1936). "Technique of digestibility trials with sheep and its application to rabbits." *Empire Jour. Exp. Agric.*, Vol. 4, p. 25.

WÖHLBIER, W. (1930). "Die Bestimmung der Verdaulichkeit des Rohproteins mittels Tierversuch und auf künstlichem Wege. II. Die Bestimmung der Stoffwechselprodukte auf analytischem Wege." *Die Tierernährung*, Band 1, S. 467.

WOLFF, E. (1880). "Aschen-Analysen." Cited by Orr (1929).

WOOD, T. B., AND CAPSTICK, J. W. (1926). "The maintenance requirement of the adult sheep." *Jour. Agric, Sci.*, Vol. 16, p. 325.

WOOD, T. B., AND WOODMAN, H. E. (1932). "Rations for live stock." *Ministry of Agric. and Fisheries.* Bull. No. 48.

WOODMAN, H. E. (1924). "Critical note on the method of correcting protein digestion coefficients." *Jour. Agric. Sci.*, Vol. 14, p. 428.

WOODMAN, H. E., et al (1926). "Nutritive value of pasture. I. Seasonal variations in the productivity, botanical and chemical composition, and nutritive value of medium pasturage on a light sandy soil." *Jour. Agric. Sci.*, Vol. 16, p. 205.

WOODMAN, H. E., et al (1927). "Nutritive value of pasture. II. Seasonal variations in the productivity, botanical and chemical composition, and nutritive value of pasturage on a heavy clay soil." *Jour. Agric. Sci.*, Vol. 17, p. 209.

WOODMAN, H. E., et al (1928). "Nutritive value of pasture. III. Influence of the intensity of grazing on the composition and nutritive value of pasture herbage." *Jour. Agric. Sci.*, Vol. 18, p. 266.

WOODMAN, H. E., et al (1929). "Nutritive value of pasture. IV. Influence of intensity of grazing on the yield, composition and nutritive value of pasture herbage." *Jour. Agric. Sci.*, Vol. 19, p. 236.

WOODMAN, H. E., AND EVANS, R. E. (1930). "Nutritive value of pasture. VI. The utilization by sheep of mineral deficient herbage." *Jour. Agric. Sci.*, Vol. 20, p. 587.

WOODMAN, H. E., et al (1931). "Nutritive value of pasture. VII. The influence of the intensity of grazing on the yield, composition and nutritive value of pasture herbage." *Jour. Agric. Sci.*, Vol. 21, p. 265.

WOODMAN, H. E., et al (1932). "Nutritive value of pasture. The influence of intensity of grazing on the yield, composition and nutritive value of pasture herbage." *Jour. Agric. Sci.*, Vol. 22, p. 852.