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The Influence of Frequency of Cutting on the Yield, Chemical Composition, Digestibility and Nutritive Value of some Grass Species.*

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I. INTRODUCTION.

The steadily increasing volume of literature on pasture research bears mute testimony to the interest taken by agricultural workers all over the civilised world in problems relating to the pastoral resources of their respective countries. This is not surprising in view of the fact that pasture represents the raw material for the manufacture of the most important animal products, such as milk, meat, wool, and hides.

Problems associated with pasture research become imperative in a country such as the Union of South Africa where " more than 85 per cent of the land is unfit for cultivation, being too dry, mountainous, or otherwise unsuitable, and can be utilised only for pasturage " (Leppan, 1928, 1936). In this connection it may be pointed out that the rainfall of South Africa varies from about 50 inches on the Natal coast to less than 2 inches at Luderitzbucht on the west coast, whereas fully half of the Union receives less than 20 inches per annum, and only about a quarter receives more than 25 inches. The problems confronting the pasture investigator are consequently many and varied.

An important preliminary to intensive pasture investigations is exact knowledge with regard to the plant population of a country. The inception of a Botanical Survey of the Union in 1918, under the supervision of the Chief of the Division of Plant Industry was, therefore, a step in the right direction. As a result of this work, in conjunction with that of earlier botanists, it became possible soon afterwards to divide the country into some nineteen main botanical regions (Pole-Evans, 1920). This work is still proceeding and aims at recording and mapping the chief types of plants in each of the different botanical regions. At the same time the necessity was felt for establishing permanent stations for veld research in these regions and several such stations have been founded, but it is not intended to follow their development in detail. Suffice it to state that these experiment stations are studying problems of pasture research directly associated with the areas in which they are situated.

A great stimulus was furthermore given to pasture research by the decision of the Union Government in 1933 to combat soil erosion along national lines, for it is well known and appreciated that soil erosion and veld deterioration are closely related. A national scheme for pasture improvement and management thus came into being. The Devision of Plant Industry is mainly responsible for this work, and a review of their activities has been published by Pole-Evans (1936).

Problems pertaining to the pastoral resources of a country can best be solved with the full co-operation of the botanist, the chemist, and the animal nutritionist. Whilst, however, the botanist will be primarily interested in " the botanical composition of the vegetative covering, the habitat-range and limiting factors of the major pasture species, the factors which govern the destiny of the grassland associations, and the procedure necessary to avoid undesirable successions ", the biochemist, on the other hand, will be interested primarily in the chemical composition of the pasture and the effects thereupon of external factors such as rainfall and stage of growth. In conjunction with the nutritionist the biochemist is interested in the effects of the pasture upon the animal. He studies the chemical composition of the herbage to determine to what extent this can be correlated with its feeding value. To what extent, for instance, is the low value of certain types of grazing due to deficiency of one or more of the nutrients now known to be essential constituents of the diet. Developments in the science of nutrition have resulted in the recognition of the fact that animals are more likely to suffer from a lack of some inorganic salts, proteins under certain conditions, or of certain vitamins which are required in comparatively small amounts, than from an insufficiency of the energy-yielding and fat-forming carbohydrates.

The value of chemical composition as a means of assessing the feeding value of pastures has been realised for a long time. As early as 1873 Müller suggested the chemical analysis of German pastures as a means of determining their feeding value. In their investigations into the cause and prevention of Lamziekte in Bechuanaland Theiler and his associates (1920) were able to demonstrate the deficiency of phosphate in some South African pastures and the necessity for supplementing the natural grazing with phosphate in one form or another. As a direct outcome of this classical work Henrici (1928, 1930) undertook a more detailed study of the phosphorus content of grasses in the Vryburg district and parts of the Eastern Transvaal. Somewhat later, in 1930, the Director of Veterinary Services inaugurated a series of monthly surveys of the pastures of the Union of South Africa with the object of ascertaining the extent of phosphorus deficiency in the pastures of the country as a whole. At the same time these surveys aimed at finding out whether deficiencies other than phosphorus also occur in the natural pastures, and at collecting data on the feeding value of natural pastures growing in different areas under different environmental conditions. In this way a mass of data on the chemical composition of samples of natural pasturage has accumulated at the Veterinary Research Laboratory at Onderstepoort. Some of this information has been published by du Toit and his associates (1932, 1935), and a paper on the results of analysis of a further four thousand samples is being prepared for publication.

These samples were obtained in the field in different areas by following the grazing animals and collecting the samples as selectively as the grazing animal followed selected its food. It soon became apparent, however, that pasture samples at all stages of growth were being received during any one month of collection with the doubtful exception of the winter collections from the greater part of the area covered when mainly mature, dry grass was received. The analyses therefore varied as the stages of growth did for different samples and it was soon realised that more definite knowledge on the influence of stage of growth on the chemical composition of grasses was needed.

With this object in view species of indigenous grasses were established in pure stands on small plots and subjected to various systems of defoliation ranging from monthly cuts to one cut in every twelve months. Preliminary results of these investigations were published by du Toit et al (1934, 1935), and indicated inter alia that grasses which were allowed to grow undisturbed through the whole of the growing season and then left to dessicate on the veld became so low in their phosphorus and protein contents that animals which have to subsist entirely on such material would not ingest sufficient of these nutrients for maintenance requirements. Even aftermath growth, i.e. growth following upon a defoliation in February or March was relatively poor in phosphorus and protein if allowed to become dry on the veld. These results forced the conclusion that more and better use must be made of the produce of the growing season.

Chemical composition in itself cannot, however, be of much assistance unless it can be correlated with nutritive value. Unfortunately the determination of the latter entails much more work than the former in that actual feeding experiments involving costly equipment need to be carried out with animals. As a first step digestibility data are of great importance, and, as pointed out recently by Ross (1936), " it is surprising how little has been done in this direction ". While it is realised that work done in other countries on the chemical composition of pastures in relation to their nutritive value may be of great assistance to us in estimating the value of our pastures from data on chemical composition, the differences in soil type and fertility, flora, and climatic conditions, resulting in differences in the chemical composition of the vegetation, necessitate undertaking of similar work in the Union.

The chief shortcomings of South African pastures are to be found mainly in the long periods of dormancy. In the summer-rainfall areas of the Union the dry, cold winter months cause almost complete cessation of growth. The growing season commences with the first spring rains, usually in September, and continues with varying intensity to about the end of April. The continued provision of nutritious grazing during this period could be accomplished by introducing a system of rotational grazing. The adoption of a system which would produce optimum results presupposes, however, an understanding of the factors influencing yield, chemical composition, and nutritive value of the pasture.

On the other hand, if the deterioration of the herbage in regard to its nutritive qualities during the dormant season is borne in mind, and if it is admitted that farming in many parts of the country can be stabilised only when droughts are considered normal occurrences, supplementary feed in one form or another will have to be provided; during the dry season if continued production is aimed at, and during times of drought if heavy losses of stock are to be prevented.

The provision of supplementary feed could be accomplished in several ways. The utilisation of part of the annual maize crop for this purpose has been repeatedly advocated. The feasibility of combining rotational grazing with cutting for hay, thereby conserving any excess growth in a nutritious condition for the time of scarcity could with advantage be explored. In this connection reference may be made to a series of experiments conducted at the Grootfontein School of Agriculture, Middelburg (Maré, 1937), and which aimed at ascertaining data on the influence of different systems of grazing by sheep on the permanency and productivity of an established lucerne pasture. By combining a system of rotational grazing with cutting for hay a uniform carrying capacity of 24 sheep per morgen during summer and winter was obtained for a period of three successive years.

The problem of improving and supplementing the poor and inadequate grazing of summer and autumn in the areas of winter-rainfall and summer drought is receiving much attention at the Stellenbosch-Elsenburg College of Agriculture (Marais and Sim, 1937). Lucerne, which was formerly considered suitable only for cultivation on irrigable soil, has been successfully established under dryland conditions at Elsenburg. Such a lucerne pasture was found to provide excellent grazing during May, June and July, the time of the year when other forage crops and the natural veld are as yet too immature to be grazed or cut for silage. Furthermore the first spring growth may be cut and conserved as silage or hay, after which the lucerne may be grazed until January. The possibilities of lucerne in the drier parts of the winter rainfall area are also being investigated at that Institute.

In many of the better favoured areas of the Union the production of forage crops under irrigation will certainly be of importance in providing supplementary feed, but unfortunately the possibilities for irrigation schemes are limited. On the other hand, certain regions of the summer rainfall area are blessed with a rich grass flora which grows rapidly during the rainy season and, if not grazed down regularly, soon reaches a stage of maturity where it is unpalatable and of low nutritive value. By applying scientific methods of management some of this growth can be made to contribute towards the provision of supplementary feed during the times of scarcity. A possible system is considered to be the reservation of certain level areas on the farm solely for the purpose of cutting for hay at suitable intervals during the growing season.

The investigation to be reported on in the following pages is an attempt to obtain information on certain phases of the possibility mentioned above and aims at finding an answer to the question: How often should grasses be cut for hay during the growing season with the highest possible benefit to animals which have to be fed for maintenance or production of the material so obtained, and, at the same time, with the least possible injury to the vitality of the plants which have to continue yielding nutritious herbage during succeeding growing seasons.

II. REVIEW OF THE LITERATURE.

A review of the literature bearing upon the subject of pasture research would form an important investigation in itself, and would be out of place in an article of this nature. Only a limited number of references have been collected from available sources, and it is hoped that these will prove adequate for the purpose of illustrating some of the earlier work and the present state of our knowledge.

The idea that the nutritive value of pasture is dependent upon its chemical composition is not new. The suggestion of Müller (1873) that the chemical analysis of German pastures should be undertaken as a means of determining their feeding value has previously been referred to. Towards the end of the last century the available data on the chemical constituents of plant ash were compiled by Wolff (1880). In more recent times Prof. E. Mangold of Berlin inaugurated a series of investigations into the mineral composition of the most commonly used German fodders. The inaugural dissertation of Theel (1933) on the mineral content of meadow hays may be quoted as an example of this work. This investigator was unable to find a correlation between the mineral and organic constituents of hay, a protein-rich hay being often deficient in mineral matter.

According to Orr (1929) the first systematic work on the chemical composition of plants was undertaken by Lawes and Gilbert (1856-1900). Detailed analyses of the ash were made and the results showed that the chemical composition of the mixed herbage was closely dependent upon its botanical composition and the stage of development of the plants. Orr states that "it is interesting to note that work on these grass plots laid out at Rothamsted in 1856 is still being continued". An account of the more recent work at that station is given in a monograph by Brenchley (1924).

Some of the earliest investigations into the chemical composition of South African feeding stuffs were made by Juritz (1890) when he published the results of a few analyses of some of the principal fodder plants of the Karroo. Similar work was continued by him (Juritz 1914) and others [Vipond (1914) and Marchand and Smit (1919)]. However, no systematic investigation of South African pastures was undertaken until after the results of the work of Theiler and associates (1920) on Lamziekte in relation to phosphorus deficiency became known. In fact, it may be stated in general that interest in the mineral composition of pastures has been largely influenced by development in our knowledge of the food requirements of animals. Since certain pastures had been proved to be so poor in one or other constituent that this deficiency may cause disease in the grazing animal, it became a matter of economic necessity to study the composition of natural pastures, and the factors having an influence on that composition. The problem was considered to be of such importance that as a result of the answers received from the various Governments within the British Commonwealth of Nations to a questionnaire issued by a sub-committee of the Civil Research Committee of the British Cabinet, the whole question of the mineral content of the pastures was reviewed by Orr (1929) in a monograph containing all the available information bearing on the subject in an easily accessible form.

At the suggestion of Major Elliot (1926) a systematic investigation of the chemical composition of pastures was begun at the Rowett Institute, Aberdeen, in 1923. Samples of pasture were collected from many grazing areas in Britain and from some overseas parts of the Empire. From data so accumulated Godden (1926) was able to show wide differences in the mineral content of pastures of different origin. The following table given by Godden may be quoted as an illustration of the dry matter composition of poor and rich pastures:—

	% CaO	% P_2O_5	% Na_2O	% K_2O	% Cl	% N
Island of Lewis—						
Eaten	·286	·243	·377	·678	·115	1·340
Not eaten	·295	·177	·379	·540	·102	1·029
Falkland Islands	·225	·488	·290	1·980	·580	1·650
Taplow Pastures highly treated.	2·473	·997	·698	2·398	·498	3·562
Average for cultivated pastures	1·004	·735	·246	3·177	·950	2·830

The herbage of untreated natural pastures was found to be markedly poorer than that of cultivated pastures in respect of minerals and nitrogen, while the percentage of mineral constituents in the ash of " not eaten " grass from the hill pastures were only about 50 per cent. of those in the ash of " eaten " grass. Sheep thus appeared to eat, by preference, the herbage which contained the higher percentage of mineral ingredients. It was further shown that in spite of marked differences in the mineral content of the different types of pasture there was little difference in their caloric value as calculated.

In South Africa Taylor (1922) collected samples of grass species occurring most commonly on the veld of the Cedara experimental farm at approximately the same period of each year. These samples were taken when the grasses were in the early flowering stage, and the phosphate (P_2O_5) content of the average veld grass was found to be very constant at about 0·2 per cent. of the dry matter. Henrici (1928) observed that the phosphate content of grasses fluctuated to a marked degree in the course of the year, and that the Armoedsvlakte grasses had a phosphate content only one-half to one-sixth of that of European grasses. A similar state of affairs existed at Ermelo (Henrici, 1930), although the rainfall in this district was higher than at Armoedsvlakte. The same investigator (1932, 1934, 1935) continued her work on the mineral composition of natural pastures in various other parts of the country. Everywhere she found grasses to be poor in phosphate content when compared with values for European cultivated pastures. Sodium and nitrogen were also found to be distinctly low in some cases. On the other hand, the bushes of the Eastern Cape Province were higher in protein content than the grasses and most of them were rich in phosphorus and calcium.

Du Toit and co-workers (1932, 1935) analysed many thousands of samples of natural pasturage from different areas in the Union in addition to studying the mineral and protein content of individual grass species at different stages of growth. They concluded that practically all South-African pastures were low in phosphorus for the greater part of the year. Different species of grasses grown on the same soil showed remarkable variations in composition at the same stage of growth, while the percentage of certain constituents, phosphorus, potassium, nitrogen, and chlorine, decreased to a remarkable extent in all species as the period of growth advanced beyond one month. Crude protein varied more or less directly with the phosphorus content and is extraordinarily low during certain seasons of the year. Generally the sodium content was so low that it suggested an insufficiency of this constituent for producing animals on pasture.

A considerable amount of attention has been devoted to the factors affecting the yield, mineral, and protein content of pasture species as such studies were regarded as fundamental to any extensive work in the field. In this connection the work done by Australian investigators deserves to be mentioned. Richardson, et al (1931) found that pure species grown under similar soil conditions in controlled pot cultures and harvested at a definite stage of growth showed wide differences in mineral and nitrogen content and in relative yielding capacity. Growth stage was found to exercise a determining influence on the nitrogen and mineral content of pasture species. Nitrogen assimilation and the absorption of essential nutrients were most active at the tillering stage, while photosynthesis rose to a maximum shortly after the flowering stage. The percentage of nitrogen, phosphoric acid, potash, and to a lesser extent, calcium and magnesium in these plants thus fell rapidly from the early tillering stage to maturity. The application of soluble phosphate did not materially affect the phosphorus content of plants grown on fertile soil. On the other hand, dressings of superphosphate on phosphorus deficient soil increased the phosphorus content and the yield of the herbage. Davies and Sim (1931) obtained the highest yield of dry matter from a natural pasture by allowing the herbage to reach maturity, more frequent cutting tending to reduce the yield. However, three cuts during the growing season yielded approximately 94 per cent. of the dry matter obtained from one cut, and produced herbage of higher nutritive value than that of mature herbage.

Through these investigations it has been shown that while the environment expressed in terms of climate, soil composition, and pasture management exerted an important influence on the mineral content of the individual plant, there was a limit to the ability of plants to make use of available plant nutrients, which was imposed by the nature of the species itself. The necessity for further work on pure species in regard to their suitability for specific environmental conditions with a view to introducing such species into the permanent pastures was obvious. Applying varying systems of defoliation to a perennial grass, *Phalaris tuberosa* which was found to be persistent and of high yielding capacity in the Australian zone of winter rainfall and summer drought (Trumble and Davies, 1931) Richardson, et al (1932) concluded that a system of three cuts during the growing season would probably give optimum results, if the yield of dry matter, the yield of nutrients, and the permanence of the plant in an arid environment were taken into consideration.

Cashmore (1934) made a comparative study of *Lolium perenne* and *Phalaris tuberosa*, and found that the latter was the more persistent and more productive species when once established. Preliminary work involving trials of species, strains, and mixtures of herbage plants suitable for an irrigated reclaimed swamp has been started by Trumble and Davies (1934). They indicated that the yield of mixtures containing perennial rye-grass, cocksfoot, white and red clover was approximately double that of the best perennial rye-grass pure swards.

A clear picture of the various projects in grassland research being studied in Australia at the present time is obtained by a perusal of a bulletin recently published by the Imperial Bureau of Plant Genetics, Aberystwyth, Wales (1934).

According to McConkey (1931) grassland products form 94 per cent. of the total exports of New Zealand. In view of this fact and considering that the country is blessed with a well distributed annual rainfall it is not surprising to learn that " nowhere in the world is the standard of pasture management higher than in New Zealand ". (Grassland Research Committee, Pretoria University—African Explosives and Ind. Ltd. 1932). However, while the favourable climatic conditions were no doubt a contributory factor, the investigations by Cockayne, Bruce Levy, Hudson, and others (1933) on the testing of species and strains which would prove most suitable for the environment, and the influence of fertiliser and management on the productivity of the pastures, have been and will be the main factor in deciding on the most efficient methods of utilising the herbage.

Through their researches into the chemical composition and yield of individual species of grasses Fagan and Jones (1923) did much to clarify thought on some aspects of pasture management. Attention was focussed on the differences in yielding capacity and chemical composition of individual species. It was shown that the total protein produced by hay and aftermath was less than that given by a smaller yield of several pasture cuts. The contradictory results in regard to the yield of dry matter obtained by Stapledon et al (1925-26), who found that the yield of Italian Rye-grass was increased with increasing number of cuts was attributed by them partly to the fact that this species recovered very quickly after cutting or grazing.

Taylor (1929, 1932) also studied the influence of season and fertilizer on the yield and chemical composition of pasture under different intensities of grazing. His conclusions were in the main the same as those arrived at by other investigators. A few points of special interest may, however, be referred to. It was found that the protein content of *Themeda triandra var. Burchellii*, the predominant species of the Rooigras veld of Natal, was considerably lower than that of European grasses after a similar period of growth, the figures for fort-nightly and monthly cuts being on an average 12·25 per cent. and 10·0 per cent. of the dry matter, respectively. As pointed out by Paterson (1933, 1935) the more rapid growth of plants in tropical regions as opposed to growth in the temperate zones of the world may produce a much quicker drop in the percentage of protein. Further, cutting the herbage at fort-nightly intervals killed so many plants that it was not possible to continue the experiment on the same quadrats during the following season. Du Toit et al (1935) found that cutting at monthly intervals may also prove at times too drastic for the vitality of the plants.

Prior to the now well known work of Woodman and his co-workers (1926, 1927, 1928, 1929, 1931, 1932) of the Animal Nutrition Institute, Cambridge, little was known in regard to the digestibility of grass at the pasture stage of growth. This work is fundamental to a knowledge of intelligent pasture management and the feeding of stock on pasture. The yield, chemical composition and digestibility of pasture after periods of growth ranging from one week to five weeks were studied. It was found that pasture cut at weekly intervals had a protein content around 25 per cent. throughout the whole season, and a digestibility of over 80 per cent. In fact, the digestibility and nutritive value of such closely grazed pasture compared very favourably with that of a concentrate such as linseed cake, and if supplementary food was needed on pasture of this nature it should be given in the form of a carbohydrate-rich food which would balance the ration. Monthly rotational grazing was found to provide the optimum conditions for the maximum yield of starch equivalent from pastures. Close-grazing at monthly intervals had the further advantage over more drastic systems of conferring on the herbage a " balance " which rendered it more suited to form the sole diet of farm animals. Lengthening of the interval of unchecked growth from a month to five weeks showed a slight falling off in nutritive value, though the actual yield of starch equivalent and digestible protein may suffer no depression. The following table shows that in Woodman's 1925-26 experiments, though the dry matter produced under hay management was about double that produced by pasture, yet in terms of starch equivalent the yield was approximately the same, while the pasture crop produced considerably more protein per acre:—

	lb. per acre.	
	Pasture.	Meadow.
Dry matter	3667·0	7990·0
Starch equivalent	2532.0	2880.0
Digestible protein	754·0	465·0

Ross et al (1927, 1931) tested the digestibility of Teff and Lucerne hay for sheep and cattle. Whilst the values for these mature materials were very much lower than those for the pasture cuts in Woodman's work, they did not differ markedly from data for material of similar composition elsewhere.

That the intensive rotational system of grassland management holds out definite possibilities in certain regions of the Union has been indicated by some recent experiments. Taylor (1931) kept two Friesland cows from October to May on two-thirds of a morgen of fertilised Kikuyu pasture. The plot was divided into three camps and the grazing rotated on these for the period mentioned. No supplementary feed was given and the production of milk was more than 2,000 gallons per morgen. Analysis of the herbage at intervals during the trial showed the following composition for the dry matter:

Crude protein	19·0	—	28·0	per cent.
CaO	0·33	—	0·53	per cent.
P_2O_5	0·83	—	1·07	per cent.

Moses (1934) presented data which indicated that under normal conditions in the tropical coastal belt of Natal the carrying capacity of a fertilised Kikuyu pasture was in the neighbourhood of 1½ head of mature cattle per acre. Cutting the herbage within enclosed quadrats at the grazing stage produced from 12,000 to 14,000 lb. of dry matter per acre in the course of 12 months. The average crude protein and phosphate (P_2O_5) contents of the dry matter were 14·0 per cent. and 0·80 per cent, respectively.

It is evident then that the main factors influencing the chemical composition of pastures are species of plants, stage of growth of the plants, climatic conditions, and the nature of the soil. Of these factors stage of growth appears to be the most important, in that the percentage of nitrogen, phosphorus, potassium and to a lesser extent calcium and magnesium in the dry matter of the plants falls rapidly from the early tillering stage to maturity. Furthermore, the yield of dry matter is generally highest when the herbage is allowed to reach the mature stage of growth before being harvested, and, finally, increasing maturity depresses the digestibility of the herbage.

Section A.—The Influence of Frequency of Cutting on the Yield and Chemical Composition of Grasses.

III. PLAN OF THE INVESTIGATION.

In February, 1934, an area of natural veld on flat open country about a mile from the Onderstepoort Laboratories was ploughed, the existing vegetation removed and the soil cultivated to a depth of about 9 inches.

The soil profile has been described as follows:

Horizon A_1—About 9 inches deep, consisting of loose crumb structure, reddish brown, light sandy loam of fine texture on the surface and gradually becoming firmer lower down.

Horizon A_2—About 8 inches deep, more compact than A_1, but also of fine sandy appearance, brown in colour.

Horizon B—About 8 inches deep, yellowish-grey in colour, firm and sticky (with moisture) but containing still a high percentage of sand.

Horizon C—Partially weathered and decomposed gravel derived probably from Norite.

The loss on ignition was found to be 4·8 per cent. for horizon A_1, while chemical analysis showed it to contain 0·00025 per cent. available phosphate (P_2O_5), 0·111 per cent. available lime (CaO) and 0·073 per cent total nitrogen.

For the estimation of the available lime and phosphate an extract was prepared by shaking the air-dry soil with one per cent. citric acid in the ratio of 1 : 10 in a suitable container for one hour, allowing the mixture to stand overnight, and shaking it for a further one hour before filtering. Calcium and phosphorus were determined on this extract by the usual methods.

A total of 25 plots, each (24 × 17) square feet was laid out on an area of approximately (60 × 40) square yards in such a manner that each plot was bounded by a path, 3 feet wide, running between plots as indicated on the accompanying chart.

Five species of indigenous grasses, each replicated five times, were planted on the plots in a Latin Square arrangement. The species selected were *Chloris gayana* (Rhodes grass), *Panicum maximum* (hairy Buffelsgras), *Cenchrus ciliaris* (Buffelsgras), *Digitaria Pentzii*, *Pretoria small*, and *Setaria Lindenbergiana*.

The *Chloris* and *Cenchrus species* were obtained from the Prinshof Pasture Experiment Station, Pretoria, and from Pienaar's River in the Pretoria district, respectively. The *Setaria* species came from Pretoria North while the remaining two grasses were collected locally.

The grasses were propagated from roots and the method of planting was briefly as follows: The aerial portions of the plants which were dug up in such a manner that most of the roots remained intact, were cut off leaving about 4 inches of the basal internodes of the tillers to the roots. The stools were then split up into smaller units of a few tillers with roots each and these planted in rows 12 inches apart, so that only the root portions were underground and in intimate contact with the soil. Each plot was watered after being planted.

Owing to the advanced stage in the season when the grasses were planted and in spite of frequent watering during March and April very little growth took place before winter set in. At the commencement of the following growing season it was observed that with the exception of Rhodes grass and the *Digitaria species* the majority of plants failed to grow. It was consequently decided to utilise the whole of the 1934-35 season for the purpose of establishing uniform stands on all the plots. Due to the growth habit of the *Chloris* and *Digitaria species*, both grasses being of the stoloniferous type sending out runners which root at the nodes and so form new plants, this ideal was realised by the end of the season in the case of the two species mentioned without further attention except occasional watering and weeding. On the other hand much attention had to be devoted to the establishment of the three bunch grasses, especially the *Setaria* and *Panicum species*, in the way of replanting. Where plants failed to grow new plants were introduced during October. Several of these plants again failed to take root and had to be replanted in December and January. Through these efforts fairly uniform stands of growing stools were obtained, but owing to the difference in time of planting a number of stools were inferior in development to the majority which commenced growing during the previous season and early in the 1934-35 season.

Plan of experimental area showing layout of plots.

[A, B, C, D, and E represent grass species
1, 2, 3, 4, and 6 represent cutting treatments]

Nevertheless, in April, 1935, the grasses on all plots were cut short. A certain amount of growth took place following this cut. The investigation commenced when on the 25th October, 1935, the remaining dry matter from growth of the previous season was removed by cutting to about 2—4 inches from the ground. Each of the 25 main plots was pegged to a size of (22×15) square feet leaving a border of 12 inches wide all round. Main plots were again sub-divided into five equal sub-plots measuring (22×3) square feet. A different treatment was allocated at random to each sub-plot within a main plot so that there were five replications for each treatment. A restriction was, however, applied to the randomisation of treatments within plots. Reference to the chart reveals this restriction to be that with regard to rows a treatment occurs once only in the same position within a main plot.

The experiment covered two successive 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 severally on the yield, chemical composition and digestibility of the grasses. Nitrogen, phosphorus, and calcium balances were, however, also determined.

IV. METEOROLOGICAL DATA.

The main features in the weather conditions for the period of the experiment are given in table I. For the purpose of comparison the average monthly rainfall from January to Dcember for the last 25 years is included in the table. It will be seen later that for the two seasons covering the experiment the plots were harvested in each case for the last time early in April. Consequently, the rainfall which could have influenced the composition and yield of the herbage obtained was that recorded for the period September to the end of March. Comparing the rainfall during the period mentioned for the two seasons of the experiment with the average, it is found that the total for both seasons is above the normal. The figures are 27·45 inches and 29·58 inches for the 1935-36 and the 1936-37 seasons, respectively, while the average total for the last 25 years is only 24·95 inches. On the other hand, a glance at figure 1 giving the distribution of the rainfall as monthly totals for the seasons of the experiment reveals several deviations from the normal. Up to January the 1935-36 season was abnormally dry, while the 1936-37 season approximated more closely to normal conditions except for a dry spell in December. During both seasons more rain fell after January than the amount normally registered. However, the

TABLE I

Rainfall (inches) and average maximum and minimum temperature

Day of Month.	September. 1935.	October.	November.	December.	January. 1936.
1	0·12	—	—	0·11	0·31
2	—	—	—	0·33	—
3	—	—	—	0·02	—
4	—	0·14	—	0·67	—
5	—	—	0·34	0·20	—
6	—	—	—	0·25	—
7	—	—	—	0·10	—
8	—	—	—	0·25	—
9	—	—	—	—	—
10	0·08	0·16	—	0·31	—
11	—	—	—	—	1·16
12	0·11	—	—	—	0·20
13	—	—	—	—	1·18
14	—	—	—	—	—
15	—	—	—	0·04	—
16	0·05	—	—	—	—
17	—	—	—	—	0·48
18	—	—	—	—	0·37
19	—	—	—	—	—
20	—	—	—	—	—
21	—	—	—	—	—
22	—	—	—	—	—
23	—	—	—	—	—
24	—	0·18	1·61	—	—
25	—	0·15	—	—	—
26	—	0·02	—	—	—
27	—	—	—	0·06	0·67
28	—	—	—	0·50	—
29	—	—	0·14	0·23	—
30	—	—	—	—	—
31	—	0·32	—	0·10	0·32
TOTAL	0·36	0·97	2·09	3·17	4·69
Average monthly total for last 25 years	0·61	2·12	5·33	4·79	4·87
Average Maximum temperature °F.	81·8	91·1	88·2	87·6	87·6
Average minimum temperature °F.	43·9	52·2	55·5	56·8	58·1

177-178b →

TABLE 1 *(cont.)*

minimum temperatures for the period September, 1935, to April 1937. Average monthly to

February.	March.	April.	May.	June.	July.	August.	September.
—	0·46	—	—	—	—	—	—
0·01	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	0·30	—	—	—	—	—
0·66	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
0·35	—	—	0·33	—	—	—	—
0·12	—	—	0·01	—	—	—	—
—	0·16	—	—	—	—	—	—
—	—	—	—	—	—	—	0·46
3·10	—	—	0·06	—	—	—	—
0·18	0·23	0·11	—	—	—	—	—
—	1·15	—	—	—	—	—	—
—	0·10	—	—	—	—	—	—
—	—	—	—	—	—	—	—
0·07	0·10	—	0·12	—	—	—	—
1·64	—	—	0·14	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	0·02	—	—	—	—
—	0·07	—	1·08	—	—	—	—
1·05	—	—	2·50	—	—	—	—
0·49	0·92	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	0·10	—	—	—	—	—
—	—	—	—	—	—	—	—
—	0·09	—	—	—	—	—	—
—	3·27	—	—	—	—	—	—
—	1·85	—	—	—	—	—	—
—	0·10	—	—	—	—	—	—
7·67	8·50	0·51	4·26	nil.	nil.	nil.	0·46
3·84	3·39	0·97	0·69	0·08	0·36	0·56	0·61
85·2	80·0	79·8	71·4	72·1	70·7	76·0	77·6
58·3	56·1	49·0	40·6	33·4	33·6	36·2	40·6

7. *Average monthly total rainfall for the last 25 years included.*

October.	November.	December.	January. 1937.	February.	March.	April.
—	—	—	—	—	—	—
—	—	—	0·32	—	—	—
—	—	—	0·75	0·05	—	—
—	—	—	0·22	0·15	—	—
—	0·08	—	—	0·42	0·04	—
—	—	—	1·14	—	—	0·80
—	—	—	—	0·21	0·03	0·14
—	1·45	—	0·35	0·09	—	—
—	0·26	0·10	—	4·26	—	—
—	0·85	0·04	—	3·89	—	—
—	0·64	0·11	—	0·02	—	—
—	0·26	0·18	—	0·66	—	0·44
0·73	—	0·10	—	—	—	0·01
—	—	—	0·03	0·72	—	—
—	0·22	0·33	0·04	0·03	—	—
—	—	0·32	—	0·06	0·03	—
0·10	0·18	—	—	0·06	0·04	—
—	0·71	—	—	—	—	—
—	0·03	—	—	—	—	—
—	0·27	—	0·03	0·02	—	0·03
0·38	0·03	—	—	—	0·56	—
0·03	0·34	—	—	—	—	—
—	0·33	—	—	—	—	—
—	0·83	—	0·17	—	—	—
—	—	0·05	0·05	—	0·18	—
—	—	—	0·15	—	—	0·77
0·23	—	—	0·81	—	—	—
0·83	—	—	0·30	—	0·16	—
0·38	0·06	1·46	0·15	—	0·34	—
—	—	0·68	—	—	—	—
—	—	—	—	—	—	—
2·69	6·54	3·37	4·51	10·64	1·38	2·20
2·12	5·33	4·79	4·87	3·84	3·39	0·97
83·2	82·2	88·0	85·0	84·2	85·8	82·2
51·4	54·5	55·5	59·5	59·4	53·9	45·8

distribution of the rainfall for the latter half of the 1936-37 season was such that plant growth did not receive the maximum benefit from it. Early in February heavy downpours were experienced and this was followed by dry and hot weather intermittently relieved by light ineffective showers. Dry spells during both seasons were accompanied by high maximum temperatures (see fig. 1). The variations in the average monthly minimum temperatures did not show marked differences during the two seasons.

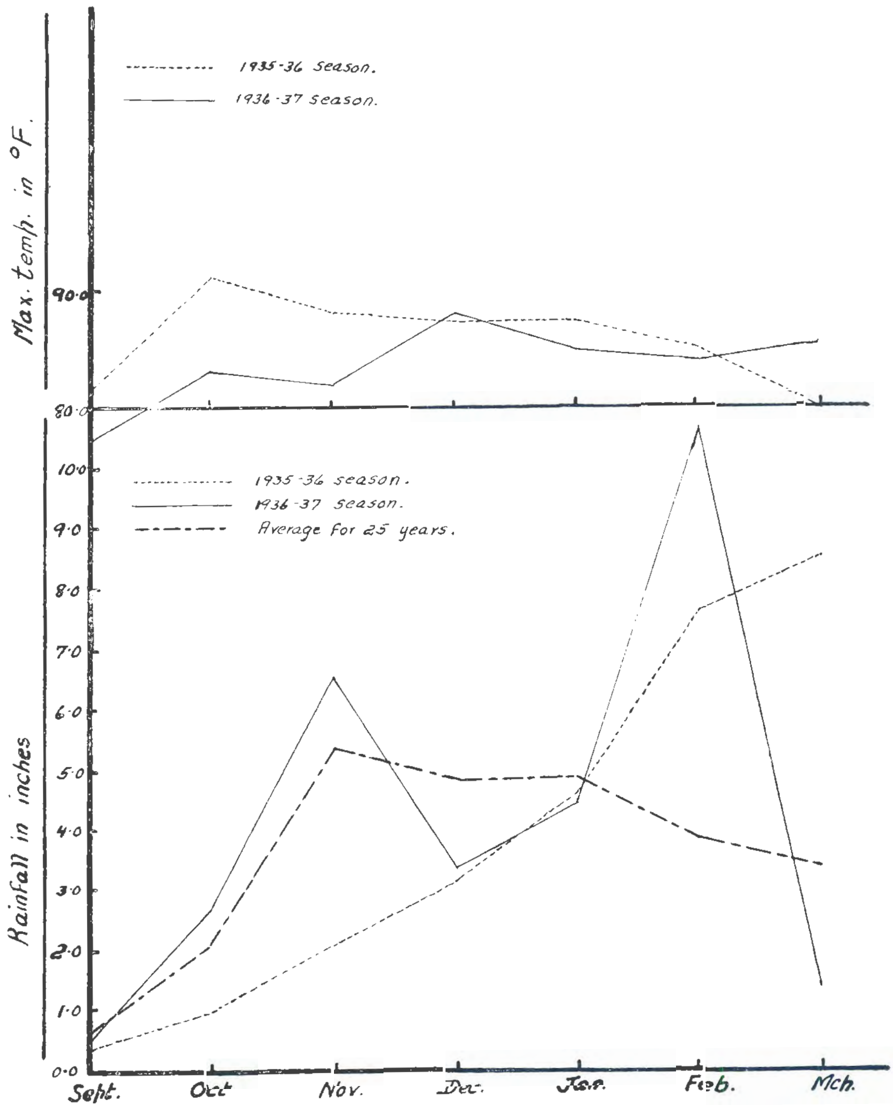

Fig. 1.—Showing monthly rainfall and average maximum temperatures for the seasons 1935-36 and 1936-37.

V. TECHNIQUE.

(1) Cutting and Drying of Herbage.

While it was intended to cut the herbage according to the scheme given under " plan of the investigation ", weather conditions did not permit of this plan being strictly adhered to. Thus, growth was so poor during the first half of the 1935-36 season that the first monthly cuts could not be made before the beginning of January. Until early in April, the concluding date for cutting operations for the season, four monthly cuts and two 2-monthly cuts were obtained. There was one 4-monthly cut, while those portions of the plots which should have been cut after 6 months were harvested at the same time as all other portions early in April, and considered as 4-monthly cuts. The herbage obtained under the 3-monthly system of cutting for the season was made up of a 3-monthly cut on the 3rd March, and another cut only a month afterwards on the 6th April. This was unfortunate since the 3-monthly treatment was, no doubt detrimentally affected by this monthly cut when compared with other more lenient systems.

Reporting on the trend of organic food reserves in Alfalfa roots as affected by cutting practices, Granfield (1935) found that frequent cutting as in pre-flowering stage appeared to result in lower carbohydrate and nitrogen contents of the roots when winter arrived, and conversely with infrequent cutting. Also, the amount of growth which took place after the last regular cutting had a material bearing on the reserves stored in the roots before winter. Permitting the aftermath to remain during the winter, instead of removing it, appeared to result in more vigorous growth during the following spring.

In view of these observations by Granfield the present experiment was designed to have the last cuts as early as possible in April and to allow the small amount of growth taking place before winter set in to remain on the plots. At the same time, the deviations from the general plan of the investigation, exemplified, for instance, by the application of monthly cuts to portions of the plots to which a 3-monthly cutting treatment has been allocated, were made necessary by the circumstance that the investigation aimed at comparing the yield of dry matter under five different treatments and the period of growth for all systems had consequently to be of the same duration: the final cuts for each treatment had to be on the same date.

During the 1936-37 season cutting was commenced with somewhat earlier, the monthly and 2-monthly portions of all plots being cut for the first time on the 15th December. After this date cuts were made according to plan except that no monthly cuts were made in March owing to poor growth.

Cutting was done by hand with a sickle to about 2-4 inches from the ground, depending upon the growth habit of the species. Thus the stoloniferous species, *Chloris* and *Digitaria,* were cut shorter than the three bunch grasses. The material was sampled for dry matter determination immediately after being cut and then spread open on grain bags on the ground to dry in the sun until about 4 p.m. in the afternoon. Small samples were usually found to be almost dry by this time if cut by 10 a.m. However, all samples were collected in hessian bags in the afternoon and removed to a corrugated iron building near the laboratory, where they were hung up to dry in the bags. When air-dry the material was weighed and the figures so obtained were used to compare the yield from the different species and treatments.

It is realised that these figures do not represent the true yield of dry matter as cut, since it has been reported (Kirsch, 1933) that loss of dry matter, presumably through respiration, occurs with even the best known methods of hay-making. Whereas dry matter has been determined on the herbage as cut the best procedure would have been to weigh the fresh herbage and then calculate the weight of dry matter. No facilities were, however, available on the site of the experimental plots so that the only alternative was to weigh the air-dry material. Whilst the method employed does not give absolute values for yield of dry matter it does serve to show up the relative yielding capacities of species and treatments.

It may be added that the material inside the bags was turned over occasionally so that no " heating " of the grass occurred.

(2) Chemical Methods.

For the determination of dry matter about 250-300 gm. of freshly cut herbage was introduced into an ordinary canned-fruit flask and the lid tightly screwed on. The flask with its contents was then taken directly to the laboratory about a mile away and weighed. The herbage was transferred to a small canvas bag and dried to constant weight at 100° C.

For the purpose of determining chemical composition the material from the five replications of any one species and treatment was treated as a single sample. Thus, the air-dry material obtained from the five replications of the monthly cuts of Rhodes grass in January, for instance, was mixed after weighing and a representative sample of about 100 grams taken. This was finely ground, bottled, and put away for chemical analysis.

Crude protein, crude fibre, and ether-soluble extract were determined by the usual methods employed by agricultural workers. Total ash, silica-free ash and the extract for the determination of calcium, magnesium, potassium and sodium were obtained by a method described by Louw (1934). A seperate extract was prepared for the determination of phosphorus and chlorine according to the directions given by Malan and van der Lingen (1931). The essential difference between the methods for preparing the two extracts was the addition of calcium acetate solution to the material before incineration in the case of the phosphorus-chlorine extract. All inorganic constituents, excepting chlorine, were determined by micro-methods. The following are brief deails of the principles on which the methods employed are based:—

(i) *Phosphorus.*—Methods of Bell and Doisy (1920) and Deniges (1920), adapted for the determination of phosphorus in grasses by Malan and van der Lingen (1931).—Principle—Molybdate added to test solution. Phosphomolybdate is formed. This is reduced by hydroquinone and sodium sulphite or by stannous chloride to form a blue compound which is estimated colorimetrically.

(ii) *Calcium.*—Method of Clark and Collip (1935). Principle—Oxalate added to test solution. Calcium oxalate is formed and this is titrated with a 0·01 N potassium permanganate solution.

(iii) *Magnesium.*—Method of Briggs (1924) modified by Malan and Van der Lingen (1931) and Holzapfel (1934). Principle—The calcium present is precipitated as oxalate and subsequently the magnesium as magnesium ammonium phosphate after which the phosphorus is dtermined colorimetrically.

(iv) *Potassium.*—Method of Kramer and Tisdall (1921) adapted to grass analysis by Malan and van der Lingen (1931) and modified by Hubbard (1933). Principle— Potassium is precipitated under standarised conditions as potassium sodium cobalti nitrite which is titrated with 0·01 N potassium permanganate solution.

(v) *Sodium.*—Method of Barrenscheen (1927) modified by Louw (1933). Principle—Sodium is precipitated as the triple acetate, Uranyl-zinc-sodium acetate. Potassium ferro cyanide is added to the triple acetate in solution. A brown colour is formed, the intensity of which is proportional to the amount of uranium present.

(vi) *Chlorine.*—Volhard's method for the detection of halides was adapted by Malan and van der Lingen for the determination of chlorine in grasses. Principle—Chloride is precipitated as silver chloride by the addition of silver nitrate to the test solution and the excess silver nitrate titrated with potassium sulpho-cyanide.

VI. RESULTS.

(1)The Influence of Frequency of Cutting on the Yield of dry Matter.

The aggregate seasonal yields of air-dry herbage for individual cutting treatments, species, and replications for the two seasons of the experiment are given in tables 2 and 4. The arrangement of the data within the tables is similar to the lay-out of the plots (see chart), except that the figures giving the yields of air-dry herbage for treatments have been re-arranged within rows in order to facilitate the drawing up of the tables. Row totals and column totals are included in the tables as these figures are made use of in the method employed for the statistical analysis of the data. Two additional tables are given for the purpose of applying this analysis. These are tables 3 and 5 giving the grand seasonal totals for air-dry material for species and cutting treatments.

The following is a statistical analysis of the yield data made under the direction of Dr. A. Laurence of the Division of Economics and Markets, Union Department of Agriculture.

(*a*) 1935-36 *Season*.

Crude Calculations from Tables 2 and 3.

Total sum of squares of deviations for all sub-plots	= (Sum of squares for sub-plots)	— $\frac{(\text{Grand total})^2}{125}$
	= 350,192,293	— $\frac{(198,301)^2}{125}$
	= 350,192,293	— 314,586,293
	= *35,606,000*	
Total sum of squares of deviations for plots	= $^1/_5$ (Sum of squares for plots)	— 314,586,293
	= $^1/_5$ (1,710,795,019)	— ,,
	= 342,159,004	— ,,
	= *27,572,711.*	
Sum of squares for rows	= $^1/_{25}$ (Sum of squares for row totals)	— 314,586,293
	= $^1/_{25}$ (7,889,521,591)	— ,,
	= 315,580,864	— ,,
	994,571.	
Sum of squares for columns	= $^1/_{25}$ (Sum of squares for column totals)	314,586,293
	= $^1/_{25}$ (7, 994,996,067)	— ,,
	= 317,799,843	— ,,
	= *3,213,550.*	
Sum of squares for varieties	= $^1/_{25}$ (Sum of squares for variety totals)	— 314,586,293
	= $^1/_{25}$ (8, 334,076,755	— ,,
	= 333,363,070	— ,,
	= *18,776,777.*	
Total sum of squares	= $^1/_5$ (Sum of squares of 25 totals in table 3)	— 314,586,293
	= $^1/_5$ (1,689,171,211)	,,
	= 337,834,242	— ,,
	23,247,949.	
Sum of squares for cuts	= $^1/_{25}$ (Sum of squares for cut totals)	314,586,293
	$^1/_{25}$ (7,933,707,285)	,,
	= 317,348,291	— ,,
	= *2,761,998.*	
Sum of squares for inter-action (cuts X varieties)	= (Total sum of squares) — (sum of squares for varieties + sum of squares for cuts)	
	= 23,247,949 — (18,776,777 + 2,761,998)	
	= *1,709,174.*	

TABLE 2.

Yields of Air-dry grass in grams per 66·0 square feet.

1935-36 *Season.*

Cutting Intervals.	C.	E.	D.	B.	A.	Total.	Row Totals.
1 month	1,037	1,382	953	1,162	1,418	6,452	
2 months	1,523	1,661	761	1,963	1,205	7,113	
3 months	1,444	1,979	951	2,055	1,426	7,855	37,875
4 months	1,676	1,765	1,070	2,097	1,745	8,353	
6 months	1,470	1,658	869	2,723	1,382	8,102	
TOTAL	7,150	8,445	4,604	10,500	7,176	37,875	
	D.	C.	A.	E.	B.		
1 month	1,043	1,011	851	2,256	2,240	7,401	
2 months	1,043	1,190	1,194	2,808	2,273	8,508	
3 months	1,231	1,499	931	2,434	2,314	8,409	42,764
4 months	1,243	1,230	1,265	2,940	2,285	8,963	
6 months	1,185	1,743	1,117	2,728	2,710	9,483	
TOTAL	5,745	6,673	5,358	13,166	11,822	42,764	
	B.	D.	E.	A.	C.		
1 month	2,138	882	1,328	853	1,195	6,395	
2 months	2,046	1,029	1,276	2,198	1,254	7,803	
3 months	2,079	935	1,431	1,422	1,632	7,499	38,015
4 months	2,265	1,365	1,375	1,420	1,552	7,977	
6 months	2,235	990	1,547	1,170	2,398	8,340	
TOTAL	10,763	5,201	6,957	7,063	8,031	38,015	
	E.	A.	B.	C.	D.		
1 month	1,757	1,420	1,637	938	887	6,639	
2 months	1,896	1,282	1,379	1,210	1,127	6,894	
3 months	1,916	1,567	1,911	1,229	964	7,587	37,669
4 months	2,200	1,655	1,496	1,157	1,734	8,242	
6 months	2,078	1,712	1,922	1,322	1,273	8,307	
TOTAL	9,847	7,636	8,345	5,856	5,985	37,669	
	A.	B.	C.	D.	E.		
1 month	1,254	1,848	918	933	1,388	6,341	
2 months	2,212	2,655	1,029	1,012	2,137	9,045	
3 months	1,371	2,044	1,205	1,095	1,950	7,665	41,978
4 months	1,495	2,686	1,379	1,152	3,104	9,816	
6 months	1,715	1,964	2,380	970	2,082	9,111	
TOTAL	8,047	11,197	6,911	5,162	10,661	41,978	
COLUMN TOTALS	41,552	39,152	32,175	41,747	43,675	—	198,301

TABLE 3.

Yields of Air-dry grass in grams per 330 square feet, showing varietal, cutting, and interaction effects.

1935-36 *Season.*

(Means in brackets).

Cutting Intervals.	A.	B.	C.	D.	E.	Total.
1 month..........	5,796 (1,159·2)	9,525 (1,905·0)	5,099 (1,019·8)	4,698 (939·6)	8,111 (1,622·2)	33,229
2 months.........	8,091 (1,618·2)	10,316 (2,063·2)	6,206 (1,241·2)	4,972 (954·4)	9,778 (1,955·6)	39,363
3 months.........	6,717 (1,343·4)	10,403 (2,080·6)	7,009 (1,401·8)	5,176 (1,035·2)	9,710 (1,942·0)	39,015
4 months.........	7,580 (1,516·0)	10,829 (2,165·8)	6,994 (1,398·8)	6,564 (1,312·8)	11,384 (2,276·8)	43,351
6 months.........	7,096 (1,419·2)	11,554 (2,310·8)	9,313 (1,862·6)	5,287 (1,057·4)	10,093 (2,018·6)	43,343
TOTAL......	35,280	52,627	34,621	26,697	49,076	198,301

Analysis of Variance.

	Degrees of freedom.	Sum of squares.	Mean Square.	Standard deviation.	Log_e S.D.	z.
Rows.............	4	994,571	—	—	—	—
Columns..........	4	3,213,550	—	—	—	—
Varieties..........	4	18,776,777	4,694,194	2,166·6	7·68094	1·25395
Error (*a*).........	12	4,587,813	382,318	618·3	6·42699	—
Total plots........	24	27,572,711	—	—	—	—
Cuts..............	4	2,761,998	690,499·5	831·0	6·72264	1·37077
Interaction........	16	1,709,174	106,823	326·8	5·78937	0·43750
Error (*b*)..........	*80*	*3,562,117*	44,526·5	211·0	5·35187	—
Total sub-plots....	124	35,606,000	—	—	—	—

From Fisher's (1932) tables giving the z values for different degrees of significance we have that for $n_1 = 4$ and $n_2 = 12$, $z = 0{\cdot}5907$ at $P = {\cdot}05$, and $z = 0{\cdot}8443$ at $P = {\cdot}01$; for $n_1 = 4$ and $n_2 = 60(80)$, $z = 0{\cdot}4632$ at $P = {\cdot}05$, and $z = 0{\cdot}6472$ at $P = {\cdot}01$, and for $n_1 = 16$ and $n_2 = 80$, $z = 0{\cdot}2855$ at $P = {\cdot}05$, and $z = 0{\cdot}3975$ at $P = {\cdot}01$. Hence from a comparison of the observed and the theoretical values for z it is concluded that varieties are significantly different, cuts are significantly different, and interaction (variety × cuts) is significantly different, all at $P = {\cdot}01$. It is therefore permissible to proceed to the t-test to discover where this significance lies.

(i) *Significant differences between varieties.*

Variety.	Totals.	Means.
Chloris gayana............(A)	35,280	1,411·2
Setaria Lindenbergiana............(B)	52,627	2,105·1
Cenchrus ciliaris............(C)	34,621	1,384·8
Digitaria Pentzii Pretoria Small............(D)	26,697	1,067·9
Panicum maximum............(E)	49,076	1,963·0

The standard error of a single plot is 618·3, and of the mean of 25 plots is $\frac{618 \cdot 3.}{\sqrt{25}}$ The standard error of the difference between two means $= \frac{618 \cdot 3 \times \sqrt{2}}{\sqrt{25}}$

$= 174 \cdot 9.$

For $n = 12$, the degrees of freedom on which the estimate of error is based, $t = 2 \cdot 179$ at $P = \cdot 05$, and $t = 3 \cdot 055$ at $P = \cdot 01$ (Fisher's tables). Hence for significance at $P = \cdot 05$, the difference must be $= (2 \cdot 179 \times 174 \cdot 9) = 381 \cdot 1$, and at $P = \cdot 01$, the difference must be $(3 \cdot 055 \times 174 \cdot 9) = 534 \cdot 3$. Whence it may be concluded that while there is no significant difference between the *Setaria* and *Panicum* species, both these species yielded significantly more dry matter than the *Chloris*, *Digitaria*, and *Cenchrus* varieties, the odds being over 100 : 1 in favour of this significant variety effect. The three last-mentioned varieties are insignificantly different.

(ii) *Significance of differences between cuts.*

Cutting intervals.	Totals.	Means.
4 months............	43,351	1,734·0
6 months............	43,343	1,733·7
2 months............	39,363	1,574·5
3 months............	39,015	1,560·6
1 month............	33,229	1,329·2

The standard error of a single sub-plot $= 211 \cdot 0$, and the standard error of the difference between means of 25 sub-plots

$= \frac{211 \cdot 0 \times \sqrt{2}}{\sqrt{25}}$

$= 59 \cdot 7.$

For $n = 80$ (30), $t = 2 \cdot 042$ at $P = \cdot 05$, and
$t = 2 \cdot 750$ at $P = \cdot 01$.

For significance at $P = \cdot 05$, difference must, therefore be
$= (2 \cdot 042 \times 59 \cdot 7)$
$= 121 \cdot 9$, and

for significance at $P = \cdot 01$, difference must be
$= 2 \cdot 750 \times 59 \cdot 7$
$= 164 \cdot 2.$

Whence the statistically significant elements in the results may be summarised as follows: Cutting at 2, 3, 4, and 6 monthly intervals yielded significantly more dry matter than cutting at monthly intervals, the odds being over 100:1 in favour of this cutting effect. Also the 4 and 6 monthly cutting systems are better than the 3-monthly system at P = ·01, and the 2-monthly system at P = ·05. Other differences are not significant.

(iii) *The significance of interaction.*

This significance means that we are premitted to seek the significant differences within the body of table 3, where the means are given in brackets. These variety means are tabulated below in decreasing order of magnitude. The figures preceding the means refer to the cutting interval.

Variety A.		Variety B.		Variety C.		Variety D.		Variety E.	
2,	1,618·2	6,	2,310·8	6,	1,862·6	4,	1,312·8	4,	4,276·8
4,	1,516·0	4,	2,165·8	3,	1,401·8	6,	1,057·4	6,	2,018·6
6,	1,419·2	3,	2,080·6	4,	1,398·8	3,	1,035·2	2,	1,955·6
3,	1,343·4	2,	2,063·2	2,	1,241·2	2,	954·4	3,	1,942·0
1,	1,159·2	1,	1,905·0	1,	1,019·8	1,	939·6	1,	1,622·2

The standard error of a single sub-plot = 211·0, and hence the standard error of the difference between means of 5

$$= \frac{211{\cdot}0 \times \sqrt{2}}{\sqrt{5}}$$

$= 133{\cdot}4.$

For $n = 80$ (30), $t = 2{\cdot}042$ at P = ·05, and
$t = 2{\cdot}750$ at P = ·01.

For significance at P = ·05, difference must, therefore, be
$= (2{\cdot}042 \times 133{\cdot}4)$
$= 272{\cdot}4$, and

for significance at P = ·01, difference must be
$= (2{\cdot}750 \times 133{\cdot}4)$
$= 366{\cdot}9.$

Whence for *Chloris gayana*, a 2-monthly cutting rotation yields significantly more dry matter than a 3-monthly cutting at P = ·05, and yields significantly more dry matter than a monthly cutting system at P = ·01; also, a 4-monthly system is significantly better than a monthly system at P = ·05.

For *Setaria Lindenbergiana*, significantly more dry matter will be obtained by cutting after an interval of 6 months than by cutting the herbage every month, the odds being over 100 to 1 in favour of this cutting effect.

For *Cenchrus ciliaris*, cutting after an interval of 6 months is significantly better than cutting after intervals of either 1, 2, 3, or 4 months at $P = \cdot 01$. The 3- and 4-monthly cutting systems are similarly significantly superior to the monthly system of cutting.

For the *Digitaria species*, and the *Panicum* variety a rest period of 4 months is significantly better than a rest period of only one month at $P = \cdot 01$, and significantly better than rest periods of 2 and 3 months at $P = \cdot 05$. Also, in the case of the *Panicum* variety, significantly more dry matter is obtained by allowing the herbage to grow undisturbed for six months before it is harvested than by cutting it at monthly intervals, the odds being more than 100 : 1 in favour of the six-monthly cutting rotation.

All other differences not mentioned in the summary of conclusions are not significant.

(*b*) *The* 1936-37 *Season*.

The results for the above mentioned season are given in tables 4 and 5. The statistical analysis of these results was executed in a manner similar to what has been done with the data for the 1935-36 season. From the analysis of variance it was found that varieties are significantly different at $P = \cdot 05$, and cuts are significantly different at $P = \cdot 05$. The z value appropriate to interaction and error was, however, observed to be smaller than the theoretical z value from Fisher's tables for $n_1 = 16$ and $n_2 = 80$ at both the one per cent. and the five per cent. points of distribution. The t-test was, therefore, applied only to cuts and varieties. The following is a summary of the conclusions drawn :

(i) *Varieties.*

Both *Panicum maximum* and *Setaria Lindenbergiana* produce significantly more dry matter than either *Cenchrus ciliaris* or the *Digitaria species* at $P = \cdot 05$. *Chloris gayana*, *Panicum maximum*, and *Setaria Lindenbergiana* are insignificantly different in regard to their respective yielding capacities. The same insignificant difference is found between *Cenchrus ciliaris*, *Chloris gayana* and the *Digitaria species*.

(ii) *Cuts.*

Significantly more dry matter is produced by cutting at 6- and 4-monthly intervals than by cutting at 3- and 1-monthly intervals, and a 2-monthly system is decidedly superior to a monthly system for the production of dry herbage, the odds being more than 100 : 1 in favour of the said significant cutting effects. The yields of dry matter under a 2-monthly and a 3-monthly cutting system are significantly different in favour of the former system. On the other hand, the yield of dry matter from cutting at 2-, 4-, and 6-monthly intervals is insignificantly different.

TABLE 4.

Yields of Air-dry grass in grams per 66·0 square feet.
1936-37 *Season.*

Cutting Intervals.	C.	E.	D.	B.	A.	Total.	Row Totals.
1 month	719	1,149	1,034	1,288	1,648	5,838	
2 months	1,028	1,410	1,014	1,872	1,399	6,723	
3 months	817	1,650	825	1,297	1,445	6,034	34,099
4 months	1,350	1,477	973	2,177	1,772	7,749	
6 months	1,107	1,213	1,210	2,643	1,582	7,755	
TOTAL	5,021	6,899	5,056	9,277	7,846	34,099	
	D.	C.	A.	E.	B.		
1 month	896	591	717	2,449	1,930	6,583	
2 months	1,172	1,049	1,023	3,040	2,262	8,546	
3 months	1,415	890	877	3,150	1,560	7,892	42,722
4 months	1,203	1,214	1,201	3,164	2,670	9,452	
6 months	1,403	1,562	1,207	3,582	2,495	10,249	
TOTAL	6,089	5,306	5,025	15,385	10,917	42,722	
	B.	D.	E.	A.	C.		
1 month	1,868	800	1,058	658	907	5,291	
2 months	1,860	930	1,210	2,118	996	7,114	
3 months	1,632	945	1,425	1,328	1,105	6,435	32,583
4 months	1,465	900	1,145	1,290	1,381	6,181	
6 months	1,872	928	1,310	897	2,555	7,562	
TOTAL	8,697	4,503	6,148	6,291	6,944	32,583	
	E.	A.	B.	C.	D.		
1 month	1,291	1,373	1,032	709	630	5,035	
2 months	1,438	1,069	1,184	1,064	1,032	5,787	
3 months	1,280	1,315	1,120	771	780	5,266	30,247
4 months	2,215	1,563	1,257	950	1,453	7,438	
6 months	1,593	1,430	1,663	1,062	973	6,721	
TOTAL	7,817	6,750	6,256	4,556	4,868	30,247	
	A.	B.	C.	D.	E.		
1 month	937	1,722	872	562	914	5,007	
2 months	2,297	2,238	940	382	1,656	7,513	
3 months	1,315	1,653	924	675	1,580	6,147	34,970
4 months	1,527	2,064	1,495	675	2,847	8,608	
6 months	1,245	1,682	2,352	573	1,843	7,695	
TOTAL	7,321	9,359	6,583	2,867	8,840	34,970	
COLUMN TOTALS	34,945	32,817	29,068	38,376	39,415	—	174,621

Summarising the main features in the results of the two seasons of the experiment with reference to the statistically significant elements it is found that of the grass species studied *Setaria Lindenbergiana* and *Panicum maximum* rank first as producers of dry matter. In regard to cutting treatment the most outstanding feature is the depressing effect on the yield of dry matter of a system whereby grasses are cut at monthly intervals during the growing season when compared with more lenient systems of cutting. This effect has been observed for all the species combined as well as for species individually. 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. The inferior position taken in by the 3-monthly system during the 1936-37 season cannot be accepted as normal without further proof, in view of the fact that a monthly cutting treatment, mentioned earlier in this report, had to be applied at the end of the previous season to suit the requirements of the experiment. Furthermore, the evidence from the results of species combined in the 1936-37 season and from the results of individual species for the previous season suggests that the amount of dry matter obtainable under a 2-monthly system of cutting may not differ materially from that 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.

TABLE 5.

Yields of Air-dry grass in grams per 330·0 square feet, showing varietal, cutting, and interaction effects.

1936-37 *Season.*

Cutting Intervals.	A.	B.	C.	D.	E.	Total.
1 month..........	5,333	7,840	3,798	3,922	6,861	27,754
2 months.........	7,906	9,416	5,077	4,530	8,754	35,683
3 months.........	6,280	7,262	4,507	4,640	9,085	31,774
4 months.........	7,353	9,633	6,390	5,204	10,848	39,428
6 months.........	6,361	10,355	8,638	5,087	9,541	39,982
TOTAL......	33,233	44,506	28,410	23,383	45,089	174,621

To conclude these remarks it should be pointed out that the results obtained are probably valid only for the conditions of soil and climate under which the grasses were grown.

(2) THE INFLUENCE OF CLIMATE ON THE YIELD OF DRY MATTER.

Among the many factors which influence crop production rainfall is the major determinant of yield, especially in regions where the reliability of effective rains is not high. It is, in addition, a common experience that the amount of annual rainfall is not as important as the quantities falling at definite periods during the growing season. Unfortunately, it appears that little or nothing has been done in the summer rainfall area of the Union to ascertain during which period or periods of the growing season rain has the greatest influence on the production of grass species. Work done by du Toit, et al (1935) and by Taylor (1929, 1932) seems to indicate that different species of grasses have different periods of optimum growth under normal conditions of rainfall. In a region of summer-rainfall the atmospheric factors of temperature, humidity, and wind velocity may have a profound influence on the effectiveness of rainfall by governing the rate of evaporation and transpiration.

The seasonal production of the five species studied is given in Tables 6 and 7 for the seasons 1935-36 and 1936-37, respectively. The figures represent the total amount of air-dry herbage obtained from five replications by cutting at monthly intervals in the course of the growing season. Since the general trend in regard to seasonal production is the same for all species the means for all species have been used to illustrate the effect of rainfall on the seasonal production in graphical form. Furthermore, the totals given for January, 1936, and for December, 1936, and again for April, 1937, do not represent growth during one month only and cannot therefore represent a single point in a graph describing true monthly totals. To overcome this difficulty the total for January, 1936, has been split up into three equal portions to represent monthly cuts for November, December and January. Although very little, nevertheless, growth did commence during the 1935-36 season in October and continued intermittently to the date on which the herbage was cut for the first time in January. The splitting up of the cumulative growth in January into three portions as indicated is thus justfied under the circumstances and will give a truer picture of the effect of rainfall on growth. For similar reasons the totals for December, 1936, and April, 1937, have been split up to represent two points on the graph.

TABLE 6.

Showing seasonal production of dry matter in grams.
1935-36 *Season.*

Species.	January.	February.	March.	April.
Chloris gayana	1,507	1,315	1,713	1,261
Setaria Lindenbergiana	2,797	1,787	3,376	1,565
Cenchrus ciliaris	1,384	1,230	1,638	847
Digitaria Pentzii Pta. Sm.	1,254	1,154	1,478	812
Panicum maximum	1,823	2,308	2,841	1,139
TOTAL	8,765	7,794	11,046	5,624
Mean	1,753	1,559	2,209	1,125