UNIVERSITY of EDINBURGH.

I. A REVIEW of the DEVELOPMENT of GRASSLAND SCIENCE.

II. AN INVESTIGATION into TEMPORARY GRASS on CERTAIN SOIL TYPES in respect of ESTABLISHMENT and YIELD.

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THESIS for Degree of Doctor of Philosophy
(Science - Agriculture).

MAY, 1931.

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P A R T I.

REVIEW of the HISTORY and DEVELOPMENT of GRASSLAND SCIENCE.

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2. From an Extensive to a more Intensive System.
3. Condition of Grassland Management in the Eighteenth Century.
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ORIGIN. The origin of grassland husbandry is lost in antiquity and it is impossible to say definitely at what time, or by what method, grassland areas were first treated as a means of increasing the quantity and quality of stock products. Before early man began to pay attention to the wild animals of the earth, the natural grassland, existing under good conditions of soil and climate, would have been grazed in an indiscriminate manner except in so far as selective grazing on any particular area was carried out by association of wild animals.

It is recorded that the first farms to be established, primitive enough, yet with distinct signs of farm organisation, were situated on the drier uplands and here conditions of good pasture were found. From 4000-6000 years B.C. the climate of this country was much more humid than it is at present and the lower elevations consisted of dense forest and great marsh areas.

As man accumulated flocks and herds by domestication of the wild animals and by breeding, he was gradually forced to give up the nomadic life and settle down under conditions which would suit both stock and human being alike. He selected the uplands therefore where the pasture was good and he set about increasing the grassland area by clearing large tracts of woodland. With the increase of grassland would come the improvement of stock.

SETTLING DOWN OF EARLY MAN.

It was not, however, until the Bronze Age that agriculture generally /

generally began to assume a real importance. Primitive bronze implements increased in number. The earliest form of organised cultivation is known as the "extensive" or the "wild-field-grass system of agriculture (9). Fresh grassland was ploughed up as required and used for one or two years and then allowed to run out to grass when more of the old grass was taken in. The system therefore would be made up of a cereal break, a break of young grass produced by the invasion of the stubble by natural grasses and a wide area of permanent "wild-field-grass". There is no doubt that the early farmer would thus be able to control the density and texture of his grazing by thus providing a break of young nutritious grass and at the same time he would thus prevent depletion of plant food in the soil by growing a restorative crop in the form of grass. Later still, when the Celtic farm was developed during the Iron Age, the area of grassland and tilled land was still further extended by burning of woods and heath to provide fresh pasture to the ever increasing flocks and herds. The system, becoming a little more specialised now, included three distinct grassland types - (1) the young grass consequent on the development of cereal cultivation, (2) meadow grass which was cut annually for hay, and (3) permanent grassland for grazing. Such a system as this continued right down to the coming of the Romans and indeed the essence of the system continued far into modern times before any thought of the extensive use of new crops dawned. The Romans did bring with /

WILD-FIELD-GRASS SYSTEM.

CELTIC FARM.

GRASSLAND TYPES.

with them new crops and new practices, but the basal principles of the early rotation which was just grain followed by bare fallow allowed to run out to grass remained until new crops such as the turnip and clover were introduced in the eighteenth century. The most important crop was, in early times, therefore grass since it supplied food for stock during the spring, summer and autumn and provided winter keep in the form of hay during the winter.

ROMANS. The Romans very soon recognised the fact that good farming must depend, inter alia, upon drainage, and accordingly

DRAINAGE. they set about draining marshes; clearing forest, and bringing in large stretches of fertile soil. Pasturing land, since it cost little, was reckoned to be the most profitable method of management (4) and very particular directions were laid down as to the exact methods for improving existing meadows and for the forming of new ones. These ancient and shrewd farmers also appreciated the necessity of as rich a pasture as possible and this they attempted to obtain by burning of

HERBAGE BURNING. the herbage during the month of August (5). The dry, dead, fibrous stems of the grasses which had seeded were thus burnt and it was claimed that fresh richer herbage followed upon the hard unnutritious growth which stock refused to eat.

The Roman system of haymaking seems, too, to demonstrate the same principles as the system of the present day.

HAYMAKING. The meadows were commonly cut twice, in May and in August or September/

September (6). The second cut is recorded to have provided softer, sweeter hay than the material which reaches its full growth. The Romans were most careful to leave the herbage in an evenly cut condition and free from any roughnesses. To permit the pasture to run to seed was undesirable. Instructions are laid down as to when hay should be cut. Practically all the Roman writers on Agriculture are agreed that lateness in cutting gives bad quality hay and it is therefore better to cut before withering sets in or seeding takes place.

NORMANS. Such was the condition of affairs in this country when the dark and ruthless Normans overwhelmed the country with the Feudal System. It was perhaps about this period that the hay meadows were fenced off from February or March to Midsummer and allotted in half acre areas to the villagers. The common

COMMON PASTURES. pastures became the most important part of all the land because it was on such land that the sheep and cattle of the village were fed. The practice of more or less concentrated farming, stock rearing, grain production and pasture, led to an increasing exhaustion of the soil. As has been stated by Ernle "the absolute scarcity of winter always succeeded the relative

DECAY of MANOR. plenty of autumn"(10). Such soil exhaustion led to the breakdown of the Manorial System (51). Crops fell in yield and a great number of small occupiers gave up their holdings. The more fortunate farmers were able to increase their farms.

Sheep /

Sheep now became of much greater importance and consequently with them grassland. There was always a good market for English wool and specialisation was in this direction. Fresh impulse was again given to an old movement which continued in activity for a long time to come. The movement is described as enclosure. During the second half of the sixteenth century wool rose in price, and large estates were enclosed for sheep farming. With the growth of enclosure, there no doubt came the better management of grassland, but records at this time do not show any considerable advance, in this respect, on previous periods. Pasture land increased in area and the system held a distinct advantage in the sense that necessary rest and manuring were given to the land, fertility accumulated and the risk of further exhaustion was obviated. The movement which finally enclosed practically all the remaining common fields, meadows, pastures and waste lands began in the seventeenth century and ceased in the nineteenth. Because of the great diversity of the soil, the enclosed land was put to different uses, pasture and tillage in varying proportions. Little or nothing is recorded, during this long period of evolution of the modern farming system, of the treatment of grassland or of the condition or quality of the pastures in relation to the products exported. The fact that British wool held the markets may throw some light on the relative position of British pastures among those of other competing /

ENCLOSURE.

WOOL.

competing countries. Towards the completion of enclosure, facilities were developing for more thorough grassland management. Enclosure at once implies a better control of grassland, rotational grazing, liming, manuring, cultural treatment.

IMPROVED GRASSLAND MANAGEMENT.

With the seventeenth century came new ideas for the furtherance of agriculture and rumours of root crops and artificial grasses to augment the hay crop. Such developments were not, however, to materialise until the eighteenth century. Jethro Tull had introduced the drill machine and Viscount Townshend had demonstrated the usefulness of the turnip and clover (26) before the big development came in the establishment of the Norfolk four course rotation (27). All these improvements have had a very distinct and important bearing on grassland science. The introduction of the root crop insured cleaning of the land, thorough manuring and thorough tillage; the inclusion of clover, a leguminous crop, meant a return to the soil of a large amount of nitrogenous material. The new rotation, the new crops meant greater fertility and therefore a big stride in the direction of grass improvement. Grass and clover seeds were sown down under more ideal conditions, crops were heavier, more stock was kept, winter feeding was less of a risk.

JETHRO TULL.

TOWNSHEND.

NORFOLK ROTATION.

With the introduction of the Norfolk rotation there ended the first phase of the development of grassland science and then began the second. The first phase had been an extensive one, the new phase was to reveal a character less extensive /

GRASSLAND SCHEME.

extensive and more intensive. The grassland within the former scheme now consisted of four groups -

(1) Young grass consisting of a one year's temporary grass and clover seed mixture.

(2) Meadow land for hay and grazing.

(3) Permanent grass.

(4) Hill grazings.

The cultivation of sown grasses was however not worth while until the land was drained and properly freed from weeds. The earliest experiments with temporary pastures and hay were made with red clover, lucerne and Sainfoin. By the end of the eighteenth century, in Scotland, the following mixture was common(76) :-

Perennial Rye Grass	...	2 bushels
Red Clover	...	10 lb.
White Clover	...	4 "
Trefoil	...	3 "
Rib Grass	...	4 "

It was not until well on in the nineteenth century, however, that a wider range of constituents became apparent. During this period the perennial ley was seldom the object of cultivation, this being confined to temporary leys. The practice was to eat off the young seeds in the autumn, the young leys being mown in the first and sometimes in the second year. For the rest ofthe life of the herbage, it was grazed.

EIGHTEENTH CENTURY MANAGEMENT. ENGLAND.

An excellent account of the practice of grassland management in the Midlands of England near the end of the eighteenth century is given by William Marshall (46). Grassland consisted /

consisted of lowland grass or "meadow" and middleland grass or "turf". The basis of general management was to keep the middleland grass constantly in a state of pasturage. Spring management reveals the fact that stock were encouraged to drop their excrement in a particular part of the field. The dung was then collected into heaps and ultimately spread over the parts of the field making the greatest demands. Winter application of this material was also practised. There is as yet no mention of the application of artificial manures. Winter management reveals an outstanding characteristic, namely, that of putting up the pasture in autumn for a supply of spring feed. Areas were put up as early as September, the herbage having first been eaten down evenly and bare. The first stock to go on in the spring were ewes and lambs which were held to receive a wholesome supply of food. Cattle were combined with sheep up to a number sufficient to be carried by the herbage. In some parts of the country, an efficient system of shifting stock was carried out, i.e. the practice of grazing by head stock and followers. The stock were turned out at first of May and remained on the pasture, until sold, without any attention.

EIGHTEENTH-NINETEENTH CENTURY MANAGEMENT-SCOTLAND.

During the infancy of Scottish Agriculture, any winter food, with the exception of straw, was seldom provided for horses or cattle; they were left out all winter. At the beginning of the nineteenth century only an inconsiderable quantity /

quantity of hay, chiefly from natural meadows, was prepared in the Hebrides and on the opposite coasts. Soon there followed the practice of enclosing good yielding areas with no summer pasturing. These areas were "hained" or saved. Then came the development of converting meadow land herbage into hay and meadows of this type soon abounded in all parts of Scotland. So important was the meadow that the rent of the farm was often fixed on the basis of the amount of meadow land it contained.

When improvements in agriculture commenced in Scotland and sown grasses were introduced, bog meadows became of less value. In time the meadows were drained and limed or marled with the result of an increased oat crop, better clover and rye grass and pasture of improved quality. Such practices thus prepared the way for the conversion of bog meadow to arable land.

In several reports, it is stated that the land would require considerable improvement before the putting down of grass and clover seeds. Liming and marling, cleaning of the land, draining and sufficient manure were considered to be essentials before land would produce clover.(31) A typical seed mixture consisted of red clover 8-14 lib., white clover 3 lib., rib grass 3 lib., and 1-2 bushels "ray" grass. Rye grass and red clover constituted the first and second year's produce and white clover and rib grass were added to the mixture for the third harvest year's produce. Red clover bore /

bore little or no part in the third year's herbage. Often the rib grass was omitted. It was observed that clover was choked out where too much rye grass was used; and also that if rye grass perfects its seed, it exhausts the soil (30).

With regard to the usefulness of the various crops grown at this time, the growing of red clover alone or in mixture for soiling is emphasised. Cocksfoot is spoken of as answering all the purposes of rye grass. It was observed too that hay made from clover and rye grass was better than meadow hay because of the control of the composition through cutting before the mixture reaches the hard, wiry, fibrous stage. Perennial Rye grass is stated to be peculiarly valuable because it was the earliest and latest grass grown(52). Sir John Sinclair, Bart., discusses at some length in his General Report of the Agricultural State etc. of Scotland such important points as natural meadows and the sequence of operations in the improvement of these, hay making, the occasional cultivation of pastures and the management of land kept in grass and of natural upland pastures (53). All of the foregoing points emphasise the fact that grassland management was becoming a science and that important observations were made and valuable practices established. During the very early part of the nineteenth century a botanical analysis of meadow land in Stirlingshire was made showing Carex sp. in greatest amount and following in turn Ranunculus, Plantago, Holcus,etc.(25)

From this point there gradually appeared developments in the /

1850-1910 DEVELOP-MENTS.

the directions of manuring of grassland and the compounding of grass and clover seed mixtures. The classification of grassland types was still more or less the same as the original grouping. The outstanding difference was that now very particular interest was taken in and attention paid to the individual types, from the preparation of land for the sowing down of mixtures right on through the complete life history of the pasture. Such problems as the following stood out as important in the development of grassland management during the latter half of the nineteenth century and the first decade of the twentieth:-

(1) A desire to acquire greater knowledge concerning the more important grass and clover species, particularly with regard to longevity, palatability, yield and behaviour when grown in company with other species. Little or no work was done in trying definitely to relate species to other conditions of environment until much later.

(2) The response on the part of permanent pasture to manuring, particularly phosphatic manuring. Basic Slag and ground mineral phosphate were found to be valuable sources of phosphoric acid because they were basic in reaction and relatively cheaper per unit than superphosphate which was acid in reaction.

(3) Was it possible to stimulate herbage growth by judicious cultivations and what form of implement or implements could be devised to produce the greatest beneficial response ?

(4) /

(4) Was it possible to increase the carrying capacity of existing pastures by some well thought out system of grazing?

Such problems as these led up to the most recent phase in the development of grassland science, a phase which, since its inception, has produced a vast number of workers in all parts of the world and in due course an overwhelming mass of data which has now characterised grassland management as one of the most important and most vital of all agricultural problems.

MOST RECENT DEVELOPMENT.

In essence the most recent work has consisted of a concentration on and an extension of those very problems which puzzled graziers for many years and which have been enumerated above. By degrees, the list was supplemented, and today an attempt to review thoroughly, from a national and international standpoint, the scope of research work on grassland, involves one in an extremely formidable task. Each country has approached the subject according to the main problems which have made themselves apparent. In Britain, in Sweden and in Denmark the subject of grassland management has received wide attention.

The trend of the development of grassland science, at the present time, may be briefly outlined in the following manner:-

1. WORK ON GRASS AND CLOVER SEED MIXTURES.

Specialisation in this direction has been carried out at the North of Scotland College of Agriculture, Aberdeen, by Mr W. M. Findlay. He has conducted trials with individual grasses /

grasses, such as Perennial Rye Grass, Italian Rye Grass, Cocksfoot and Timothy, Meadow Fescue, Tall Oatgrass and Rough Stalked Meadow Grass in respect of the relation between the weight of hay produced and the quantity of the individual grasses sown (14). Furthermore a considerable amount of work has been done in connection with Red Clover in respect of nationalities, soil, time and method of sowing and general points relating to culture of the crop (15). At the same centre Profeit and Findlay (16) have worked on the subject of the restoration of land to pasture.

At the Welsh Plant Breeding Station, Aberystwyth, Professor R. G. Stapledon has published voluminous reports on trials conducted. Work has been done in assessing the value of the different species of grasses and clovers for different conditions and in connection with the whole question of the putting of land down to grass in relation to those different conditions (73).

At the same centre considerable attention has been given to the problem of plant establishment with particular reference to the effects of environmental and agronomic factors (74). Conclusions have been drawn with regard to the best month in which to sow herbage seeds in West Wales, with regard to the question of basing of seed proportions in a mixture on the potential number of plants that may be expected from 1 lb. of seed of the different species, and with regard to the necessity of increasing the seed rates on poor soils and at high elevations.

In/

In another direction this station has studied the factors which influence sward establishment on the one hand and progressive changes in the sward on the other and has treated the problem from the point of view of individual species. The investigations were started by working with pure species and ascertaining the factors influencing soil establishment; subsequently the species were sown in mixtures and the factor of competition made the chief object of study(75).

Considerable investigations were carried out at the Cockle Park Experimental Station, Northumberland, by the late Professor Gilchrist. Seeds for hay and pasture received attention (17) (18), but by far the most outstanding work was carried out in connection with Wild White Clover (19) (20) (21). A valuable contribution was also made in connection with the history and value of Late Flowering Red Clover (22).

On the Continent Lindhard in Denmark carried out trials dealing firstly with the different nationalities of grasses (1879-1907) (32).

Similar work was carried out with clovers, the earlier work dealing with nationalities and the later with pedigreed strains. Lindhard (33) shows a range of productivity for over twenty nationalities of Red Clover and Witte in Sweden (80) (81) conducted trials on a similar basis as Lindhard and demonstrated the outstanding difference between late flowering red clover and early flowering red clover (82).

The significance of the above work is the general superiority /

superiority of home grown seed and that it is good policy for every country to select for its own use seed adapted to its particular needs. Witte (83) has pointed out, for example, that plant improvement should be essentially a local undertaking.

Furthermore, Lindhard (34) deduced from results of botanical analyses made on seed mixture trials started by Nielson that certain variable factors react on the species such as environment and particularly climate. Soil germination, early establishment, overwintering capacity and the effect of date of sowing on establishment and development are the points investigated.

Again, Lindhard (36) proved that the excessive rates originally suggested by Stebler (71) are now practically unnecessary. Rhodin in Sweden (49) has worked on the subject of increasing and decreasing the rates of seeding. Rhodin (50) also conducted trials on clay soil in dry situations and found that the seeds mixture plots sown without a nurse crop and under corn cut early or green fodder gave about equal crops in the first harvest year while similar mixtures sown under corn allowed to ripen fully gave heavier crops.

In connection with the compounding of seeds mixtures, Lindhard (37) (38) reports on the importance of clovers in the mixtures as regards proportion, on simple and very complex mixtures and on the behaviour of various grasses. Rhodin (49) deals with the relative yielding capacity of grass mixtures and /

and clover mixtures in special investigations. Witte and Nystrom (85) also conducted trials with mixtures. Mixtures for special conditions received attention by Basse and Mentz (1) who showed that in certain circumstances considerable additions of Italian Rye Grass have been without effect on the yield. They also showed that it is beneficial to add sand to peaty soil.

2. WORK CONDUCTED MORE FROM A PURELY BOTANCIAL AND PARTICULARLY ECOLOGICAL STANDPOINT.

This has been more specially the line of investigation taken up by Professor Stapledon at the Welsh Plant Breeding Station and Lindhard in Denmark. Reference has already been made to the work of Lindhard in respect of mixtures and the influence of environment. Lindhard (39) also reported on trials conducted on sand, clay and bog, comparing the yielding capacities under the various conditions. He also studied the manner of growth of the various constituents of the herbage (40) (39) (41) (42) as also did Osvald (48).

At Aberystwyth the attention has been paid by Davies and Thomas (3) to the behaviour of grasses in the seeding year when sown in pure plots with regard to establishment, rate of growth and palatability.

Stapledon (68) has worked out the seasonal productivity of herbage grasses; (Williams (77) the productivity of different strains and nationalities of Red Clover and in great detail the most outstanding botanical characteristics of different varieties /

varieties and nationalities of red clover (78) and also (79) has studied some of the factors influencing yield and quality of red clover seeds. Stapledon and Davies (69) have investigated the yield and other properties of various species and strains of herbage plants under different methods of management. Smith R. (62) (63) and Smith W. G. have contributed valuable articles concerning botanical surveys in Scotland (54) (55) (56) (57) (58) (59) (60).

3. WORK ON HERBAGE STRAINS.

Considerable work has been carried out on the Continent in this connection by Lindhard in Denmark (43) (44) (45) whose trials conducted from 1909-1917 dealt with the superiority of strains of herbage plants developed by careful methods of selection. The particular grasses dealt with were Perennial and Italian Rye Grass, Cocksfoot and Timothy. Witte in Sweden (84) (83) reported results similar to Lindhard, e.g. that pedigreed Timothy out-yielded ordinary commercial Timothy and similarly with Perennial Rye Grass. Witte and Nystrom (85) showed that a special variety of rye grass - "Jaedersk" does best in damp, cold years and shows to advantage on peaty and boggy soils, out-yielding ordinary commercial strains.

At the Station of the Scottish Society for Research in Plant Breeding, Corstorphine, Edinburgh, critical examination of the grass species revealed the presence of distinct growth forms within species and attention has been directed towards the /

the study of competition between the growth forms within a species as distinct from interspecific competition. Progress has also been made with the genetical analysis of species-populations collected in the wild. Species crossing has been limited to Phleum pratense x P. alpinum.

At Aberystwyth the breeding of herbage plants has advanced along the lines of fixing an extra-leafy hay type of cocksfoot and three distinct pasture types. Meadow Foxtail has also afforded a line of investigation in respect of results given by a comparatively pure breeding leafy strain in the matter of early keep under the influence of nitrogenous manures. Work is also carried out with rye grasses, timothy, red fescue, clovers and other legumes.

4. THE CHEMICAL ASPECT.

This has resolved itself into a study of the nutritive value of pastures from various points of view.

i. The nutritive value of pastures from the point of view of the mineral content. This has been the work of the Rowett Research Institute, Bucksburn, Aberdeen, (Dr. J. B. Orr). Results of recent research in nutrition have shown the importance of the mineral content of the diet. At this Institute and in conjunction with other Institutes the whole subject of mineral content of pastures has been examined. The work has resolved itself into (a) the analysis of samples of pasture from different areas to determine /

determine the mineral content and the seasonal variation in the percentage composition; (b) feeding experiments with sheep. (47) Elliot has reported generally on the work carried out (7). Elliot and Crichton have investigated the effect of the addition of mineral salts to the ration of sheep (8). Godden has reported on the chemical analyses of samples of pasture from various areas in the British Isles (23). Cruickshank has investigated the seasonal variations in the mineral content of pastures (2), and Godden has reported on the effect of fertilisers on the mineral content of pastures (24). Woodman and Evans have also contributed reasons for the failure of grazing animals to thrive in regions of mineral-deficient pasturage, basing their reasons on the digestibility of the organic constituents, unpalatability of the herbage, and the physiological utilization of the digested nutrients (86). At Aberystwyth Fagan and Provan have shown the influence of the application of fertilisers on the average percentage of nitrogen and phosphoric acid content of upland and lowland pasture; also on the percentage of lime in the herbage (13).

ii. The nutritive value of pastures from the point of view of energy and protein. This has been the work of the School of Agriculture, Cambridge, (Dr. H. E. Woodman). The investigations have been concerned with a great number of problems connected with grassland, but the main part of the research has dealt with the seasonal production of starch equivalent and /

and digestible protein from the pasture and its connection with soil, weather and botancial conditions. Woodman and others have shown the seasonal changes which take place in the botanical composition of the herbage and particularly the influence of frequent and close cutting on the wild white clover constituent. They have demonstrated, too, seasonal variations in yield and chemical composition, in nutritive value and in mineral content on a light soil (87) and similarly on a heavy clay soil (88). Woodman then introduced the element of grazing into the problem and the influence of the intensity on the composition and nutritive value of pasture herbage has been demonstrated (89). This work led to the subject of pasture grass conservation and the effect of artificial drying on the digestibility of pasture herbage (90).

The Agricultural Research Staff of Imperial Chemical Industries Limited have also contributed to this subject, Greenhill having researched into the chemical composition of intensively treated pasture (28).

From the general chemical standpoint, Fagan and Jones at Aberystwyth have investigated the nutritive value of grasses, as pasture, hay and aftermath, as shown by their chemical composition (11).

5. THE MANURING OF GRASSLAND.

A great amount of work has been done in this connection by Farm Institutes and County Staffs in England and by County Extension /

Extension Staffs of the Agricultural Colleges in Scotland. Special mention may be made of the work of Somerville who has investigated the influence of manures on the botanical composition of the herbage of permanent grassland (64), and the influence of manures generally on fertility and meat and milk (65) (66) (67). The effect of nitrate of soda on the yield and chemical composition of a simple seeds mixture in the first harvest year under different systems of management has been worked out at Aberystwyth by Fagan and others (12). Quite recently, a method for increasing the productivity of grassland has been introduced. The method consists of repeated dressings of nitrogenous manures and originated in Germany during the war. The system is now known as the System of Intensive Grassland Management (72). In 1918 The Border Counties Committee for the Development of Pastoral Lands recommended to the Board of Agriculture for Scotland that there was need of experiments on the utility of rock phosphates as compared with basic slag for the improvement of land used entirely for grazing. The late Dr. W. G. Smith, Advisory Officer in Soil Botany, Edinburgh and East of Scotland College of Agriculture, started observations on a series of plots dressed with the above manures. This opened up more detailed work in connection mainly with the manuring of permanent pasture. Comparisons of treated and untreated plots were made in respect of botanical composition, grazing and duration /

duration of the dressings (61).

6. THE IMPROVEMENT OF GRASSLAND BY CULTIVATIONS.

In connection with the improvement of the physical condition of the soil in respect of aeration, water content and such like, and of the textural condition of the sward, much demonstration has been done. The relation between soil and sward condition and the ultimate influence of manures has also been well demonstrated.

The same observation is characteristic of the practice of renovating worn out pasture by special grass and clover seeds mixtures. The functions, in all these respects, of ordinary harrows, chain harrows, disc cultivators, ordinary cultivators, rollers and ploughs have been clearly brought out mainly by County Extension Staffs in this country and by firms particularly interested in the various implements. It has been proved that in the improvement of old pasture some cultivation operation or series of operations may be desirable and necessary.

7. THE GRAZING OF GRASSLAND.

Reference has already been made to the work carried out by Dr. Woodman and his colleagues at Cambridge (67,68,69,70) in connection with the nutritive value of pasture grass from the point of view of energy and protein. Woodman has demonstrated the exceedingly high content of protein and relatively low content of crude fibre of closely grazed pasturage. This discovery /

discovery is of paramount importance. The high value of such pasture can only be maintained by close grazing. Reference has also been made to the application of the Hohenheim system of grassland management to pasturage in this country (72). This system clearly emphasises the necessity of preventing the herbage becoming too long or course and the arrangement of a scheme whereby the grazing will be rotational, the intensity of grazing suitable and the periods of time of grazing on the pasture sections sufficiently long to ensure the desired closeness. Efficient management of grazing will ensure the maximum nutritive value of the pasture.

The importance of the biotic factor in relation to grassland has been emphasised by Stapledon and Jones (70) and a technique has been described for ascertaining the selective grazing of sheep on a quantitative basis and the amount of time sheep devote to performing various functions such as grazing, chewing the cud, and resting.

The effect of varying the periods of rest in rotational grazing has been investigated by Jones and Jones at Aberystwyth (29).

The fundamental principle in the philosophy of grassland management amounts to the co-operation of all workers with a view to establishing certain facts concerning the yield of our grassland areas, their seasonal behaviour and the particular point at which the herbage becomes a productive food; and on the other side a system of management, manuring, cultivating, grazing, which will maintain high yield and good quality.

LITERATURE CITED.

1. BASSE, N. and MENTZ, A. Hedeselskabets Tiddskr. 1922, p.123.
2. CRUICKSHANK, E. M. Jour. Agric. Sci. (1926) 16. 89.
3. DAVIES, W. and THOMAS, M.T. Welsh Jour. Agric. (1928) 4. 206.
4. DICKSON, A. The Husbandry of the Ancients (1788) Vol.II. 285.
5. ---------- Ibid. 314.
6. ---------- Ibid. 317.
7. ELLIOT, W. E. Jour. Agric. Sci. (1926) 16. 59.
8. ---------- and CRICHTON A. Ibid. 65.
9. ERNLE, LORD. English Farming Past and Present (1927) 2.
10. ---------- Ibid. 34.
11. FAGAN, T. W. and JONES, H.T. Univ. Coll. of Wales, Aberystwyth, Series H No.3. 1920-1923.
12. ---------- and OTHERS Ibid. Series H No.9. 1926-1927.
13. ---------- and PROVAN, A.L. Ibid. Series H.No.11.1921-1929.
14. FINDLAY, Wm. M. North of Scot. Coll. of Agric. Bulletin No.30 (1926).
15. ---------- Ibid. No.24 (1919).
16. ---------- and PROFEIT, W. J. Trans. High. & Agric. Soc. of Scot. (1919).
17. GILCHRIST, D. A. Jour. B. of Agric. Vol. 7 No.4 Mar. 1901.
18. ---------- Address to Bath and West and Southern Counties Soc. 1922.
19. ---------- Jour. of B. of Agric. Vol. 16 No.9 Dec. 1909 and Vol. 22 No.11 Feb1916.
20. ---------- Farmer and Stockbreeder Year Book 1917.
21. ---------- Address to Gloucester Chamber of Agric. 1918.
22. ---------- Jour. of B. of Agric. Vol. 26 No.1. April 1919.

23. /

23. GODDEN, W. Jour. Agric. Sci. (1926) 16. 78.

24. ---------- Ibid. 16. 98.

25. GRAHAM, P. General View of the Agriculture of Stirlingshire (1812).

26. GRAS, N. S. B. A History of Agriculture 212.

27. ---------- Ibid. 183.

28. GREENHILL, A. W. Jour. Agric. Sci. (1930) 20. 573.

29. JONES, M. G. and JONES, Ll. Univ. Coll. Wales, Aberystwyth, Series H No. 11. 1921-1929.

30. KEITH, G. S. Agriculture of Aberdeenshire (1811).

31. LESLIE, W. General View of the Agriculture in Counties of Moray and Nairn (1811).

32. LINDHARD, E. 1910 Statens Forsøgsvirksomhed i Plantekultur. 48 Ber.

33. ---------- 1911 Ibid. 54 Ber.

34. ---------- 1908 Ibid. 31 Ber.

35. ---------- 1917 Ibid. 122 Ber.

36. ---------- 1907. Ibid. 27 Ber.

37. ---------- 1910 Ibid. 51 Ber.

38. ---------- 1915 Ibid. 100 Ber.

39. ---------- 1909 Ibid. 42 Ber.

40. ---------- 1908 Ibid. 36 Ber.

41. ---------- 1912 Ibid. 69 Ber.

42. ---------- 1919 Lantbruksveckans Handlingar.

43. ---------- 1913 Statens Forsøgsvirksomhed i Plantekultur 70 Ber.

44. ---------- 1915 Ibid. 95 Ber.

45. ---------- 1918 Ibid. 126 Ber.

46. MARSHALL, W. The Rural Economy of the Midland Counties (1790).

47. /

47. ORR, J. B. and OTHERS Scot. Jour. Agric. Vol. 8 No. 4.

48. OSVALD, H. Svenska Mosskulturföreningens Tidskrift 1919.

49. RHODIN, S. Centralanstalten förförsöksväsendet på jordbruksområdet. Jordbruksavdelningen. N: r 204.

50. ---------- Ibid. Meddelande N: r 204.

51. SEEBOHM. The Evolution of the English Farm (1927) 186.

52. SINCLAIR, SIR J. Husbandry of Scotland (1813).

53. ---------- General Report of the Agricultural State of Scotland (1814).

54. SMITH, W. G. Scot. Geog. Mag. Vol. 20 No.12 Dec. 1904.

55. ---------- Ibid. Vol. 21 Nos. 1,2,3. 1905.

56. ----------(& RANKIN) Geog. Jour. Aug. 1903.

57. ----------(& MOSS) Ibid. Apr. 1903.

58. ---------- Jour. Ecol. Vol. 6 No. 1. March 1918.

59. ---------- Scot. Jour. Agric. Vol. 1. No. 3 July 1918.

60. ---------- Jour. Agric. Sci. Vol. 6. Part 1. Jan. 1914.

61. ---------- Scot. Jour. Agric. Vol. 6. No. 3 July 1923.

62. SMITH, R. Scot. Geog. Mag. Vol. 16. No. 7 July 1900.

63. --------- Ibid. Vol. 16. No. 8 Aug. 1900.

64. SOMERVILLE, W. Jour. B. of Agric. Vol. 7. No. 2 Sept. 1900.

65. ---------- Ibid. Supplement No. 5. Jan. 1911.

66. ---------- Ibid. Vol. 21. No. 6 Sept 1914 and Vol. 22. No.12 March 1916.

67. ---------- Min. Agric. Misc. Publics. No. 30. 1921.

68. STAPLEDON, R. G. Univ. Col. Wales, Aberystwyth, Series H. No.3. 1920-1923.

69. ---------- (and DAVIES) Ibid. Series H.No.10. 1923-1928.

70. ---------- (and JONES) Ibid. Series H.No. 5. 1925-1926.

71. /

71. STEBLER, F. G. Grass Seed Mixtures. (2nd edition, Bern 1883).

72. STEWART, J. G. Min. of Agric. & Fish. Misc. Publics. No. 60. p. 41.

73. UNIVERSITY COLLEGE OF WALES, ABERYSTWYTH, Advisory Bulletin No. 1. (1925).

74. ---------- Series H. No.6, 1923-1926. (1927)

75. ---------- Series H. No.8, 1921-1928. (1928)

76. WATSON, J. A. S. Trans. High. & Agric. Soc. Scot. Vol. 41. 13 (1929)

77. WILLIAMS, R. D. Univ. Coll. of Wales, Aberystwyth, Series H. No. 3. 1920-1923.

78. ---------- Ibid. Series H. No.7. 1919-1926.

79. ---------- Ibid. Series H. No.11.1921-1929.

80. WITTE, H. Sveriges Utsädesförenings Tidskrift Vol.23 1913 p.51.

81. --------- Ibid. p.378.

82. --------- Ibid. Vol.33 1923 p.169.

83. --------- Ibid. Vol.26 1916 p.185.

84. --------- Ibid. Vol.26 1916 p.195.

85. --------- (& NYSTROM) Svenska Mosskulturföreningens Tidskrift 1922 p.27.

86. WOODMAN, H. E. & OTHERS Jour. Agric. Sc. 20 (1930) 587.

87. ---------- Ibid. 16 (1926) 205.

88. ---------- Ibid. 17 (1927) 209.

89. ---------- Ibid. 18 (1928) 266 and 19 (1929) 236.

90. ---------- Ibid. 20 (1930) 53.

P A R T II.

AN INVESTIGATION into TEMPORARY GRASS on CERTAIN SOIL TYPES in respect of ESTABLISHMENT and YIELD.

1. Objects in View.
2. Material and Methods.
3. Study of the Factors.
4. Results and Discussion.
5. Summary and Conclusions.
6. Acknowledgments.
7. Literature Cited.
8. Appendix:- Tables, Graphs, Photographs.

1. OBJECTS in VIEW.

From the foregoing review of the development of grassland science it will have been gathered that very little attention has been given to the relation between the herbage and soil and climatic conditions. Recently there has been considerable world development in the study of soils with regard to such characteristics as reaction, lime requirement, exchangeable bases, and the determination of the influence these characteristics have on crop development. The full value of work on grassland cannot be realised without contributions of definite data being made in respect of certain soil characteristics. The late Dr. W. G. Smith of Edinburgh and Dr. Ogg, now Director of the Macaulay Soil Institute, Aberdeen, drew attention to this fact.

Dr. Smith had for a long time worked along the lines of ecology of hill pasture and tended pastures. He felt however that a considerable amount of attention should be given to the correlation of conditions, soil and climatic, which exist at the time of sowing down grass and clover seed mixtures and the behaviour of the herbage throughout its whole life. The work of laying out plots under different conditions was delegated to me and the working out of a technique and the collection of figures have formed subjects of study for the past three years.

The soil determinations were carried out under the supervision of Dr. Ogg.

The principal objects in view have been :-

1. /

1. To determine the botanical composition of the herbage produced by a given grass and clover seed mixture sown down on various soil types, certain definite characteristics of which are known. The determinations which have been made are reaction (pH) lime requirement, exchangeable calcium, loss on ignition, moisture content and mechanical analysis; and to record, over a definite period, the changes which take place among the species of the herbage in respect of mortality, degree of tillering, competition and the like, assuming normal procedure in management.

2. To determine, using the same seeds mixture on the same soil types, the total annual amount of dry matter produced per unit area and the total seasonal amount on each soil type; and to determine to what extent the constituents of the seeds mixture contribute to the yield of dry matter. This part of the investigation involves three phases :-

(a) Estimation of the dry matter of the Hay - first harvest year.
Estimation of the dry matter of the Aftermath - first harvest year.

(b) Estimation of the dry matter of the Hay - second harvest year.
Estimation of the dry matter of the Aftermath - second harvest year.

(c) Estimation of the dry matter in each of the pasture cuts - end of first harvest year onwards.

3. To determine the influence of lime on the herbage in respect of botanical composition, tillering capacity of the ingredients and /

and dry matter yield.

4. To ascertain to what extent weather conditions are responsible for such conditions as the percentage of the various ingredients in the herbage, tillering of grasses, rate of development of clovers and yield of dry matter, both total and seasonal.

It might be added that no definitely accurate determinations have been possible for various reasons, among which the most outstanding may be mentioned :-

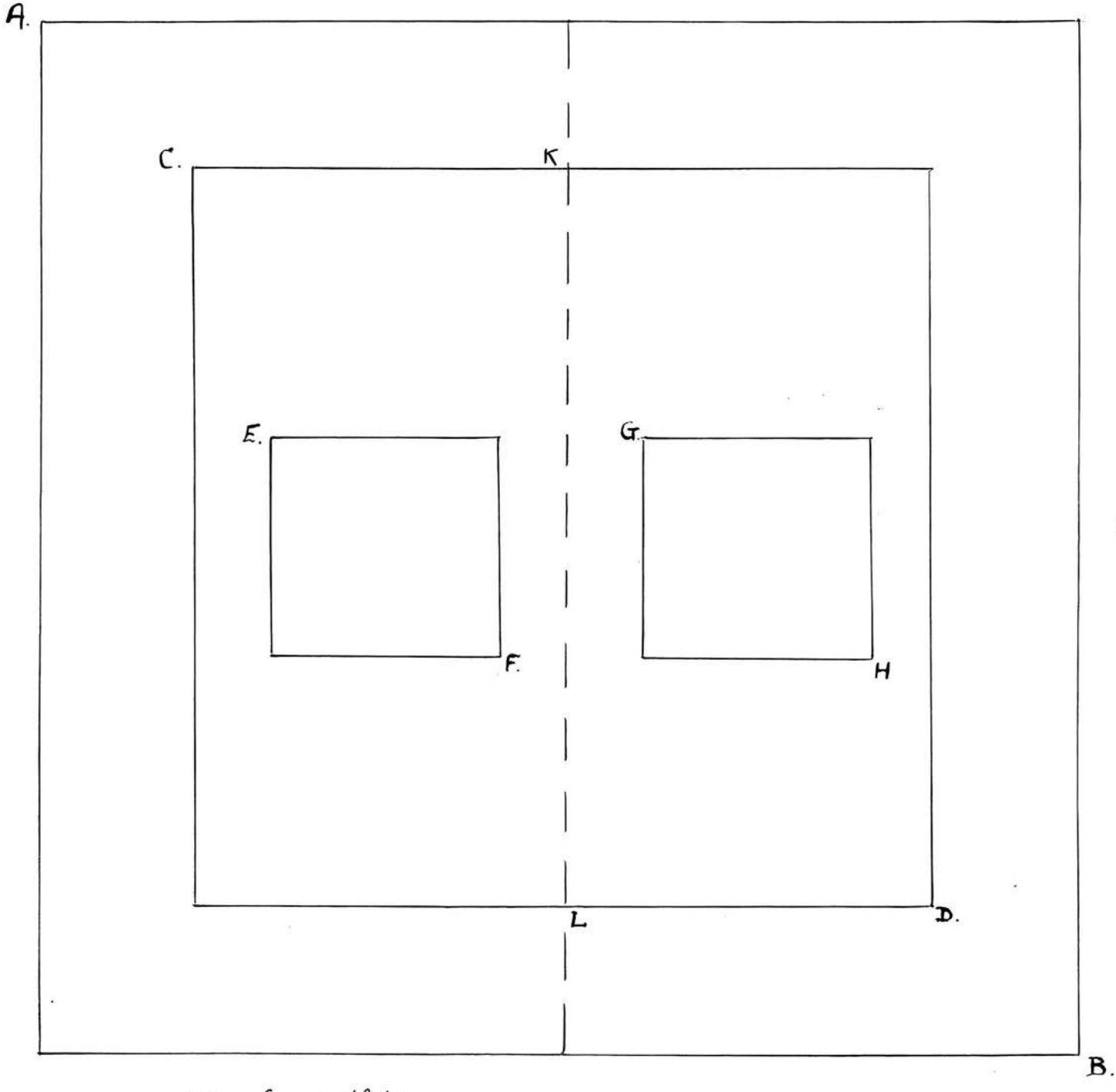
(a) The seeds were sown under practical conditions and therefore absolutely even sowing was impossible because of a number of uncontrollable factors, such as variations in the different sowing machines, sowing by hand, speed of the machine, difference in weight of the mixture constituents. Unevenness in sowing would therefore influence competition.

(b) The difficulty in selecting a plot truly representative of the herbage. Even after numerous precautions had been taken in selecting a fair sample, there still remained the sampling difficulty within the plot itself.

The methods used in the various analyses will reveal the fact that a detailed study has been made of a very small area taken as representative of the herbage.

The problem has resolved itself, therefore, into a searching after tendencies of the species within the small area studied.

PLAN of PLOT laid out on FOUR SOIL TYPES.



AB. = fenced plot.

CD = plot treated and on which observations were made.

CL = limed section; EF = plot for hay, aftermath and pasture clips.

KD = unlimed section; GH = " " " " " " " .

Scale :- 1 inch. = 2 feet.

To face page 33.

2. MATERIAL and METHODS.

1. METHOD of PLOT SELECTION.

PLOTS.

The plots selected for this investigation were, as far as could be judged, representative of the particular field in which they were fenced in from grazing. Care was taken to select plots so as to avoid 'openings' and 'closings', stock sites, mole heaps, sheltered areas, and anything which would tend to increase the number of influencing factors or introduce a source of error. The dimensions of each plot were 14 feet square, a strong fence of wire and small-meshed wire netting being erected. The wire netting was sunk below the soil level to a depth of 8 inches. The fence was erected a few feet wider than the actual experimental plot to prevent interference by stock and drips from the wire. The plot was then divided into two equal parts, one half having carbonate of lime applied to the extent of the lime requirement of the particular plot, the other half being unlimed. Within each half plot there was pegged off a one yard square plot typical of the surrounding herbage and this provided the hay, aftermath and pasture cuts for separation and dry matter estimation. From around the small plots, turves were taken periodically in order to ascertain the behaviour of the constituents of the herbage mixture. (See Plan opposite and photograph in Appendix, page 178).

2. SEEDS MIXTURE.

IXTURE.

The following seeds mixture was selected for the investigation because the constituents are comparatively easy to identify /

identify, because since considerable acreages were sown down the mixture is cheap, and because it affords a sound basis upon which more elaborate mixtures may be built :-

Perennial Rye Grass	12 lb.	Rough Stalked Meadow Grass	1 lb.
Italian Rye Grass	8 "	Broad Leaved Red Clover	1 "
Cocksfoot	8 "	Late Flowering Red Clover	2 "
Timothy	3 "	Alsike	1 "

Wild White Clover 1 lb.

A total of 37 lb. per acre.

PURITY. (a) Purity was determined by taking a representative sample of each species and separating the foreign material from the true seed and weighing. The purity percentage was calculated.

GERMINATION PERCENTAGE. (b) Germination percentage was determined by selecting 100 seeds of each species true to type and germinating those over a given time. The test was carried out in duplicate.

REAL VALUE. (c) The real value of the separate species was calculated by using the formula $\frac{P \times G}{100}$ where P= Purity % and G = Germination %.

No. SEEDS Per Lb. (d) The number of seeds per lb. of each species was found by weighing 1000 seeds and calculating the number per lb. Weighings were repeated a considerable number of times for all species and the figures tabulated alongside the numbers determined by other workers. (2, 12, 36, 31).
The figure used in the investigation is the average of all findings.

(e) /

VIABLE SEEDS. (e) From the above figures it was possible to calculate the total number of seeds of each species and the number of viable seeds sown per unit area.

3. SOIL DETERMINATIONS.

SAMPLING. (a) Soil Sampling. Fifty borings each of soil and subsoil were taken by means of a soil auger immediately after the plot was fenced. The soil and subsoil samples were separately mixed and after being thoroughly air-dry these afforded the representative samples for the various analyses, all of which were carried out in duplicate.

REACTION. (b) The pH both of soil and subsoil was determined by the electrometric method, using Biilmann's quinhydrone electrode. Ten grams of air-dry soil passing the 3 mm. sieve, 20 c.c. CO_2-free distilled water and a few decigrams of quinhydrone were shaken for one minute and the determination completed according to Biilmann. (4). As all the pH results were below 7, it was unnecessary to use the colorimetric method of pH determination as described by Gillespie. (14)

LIME REQUIREMENT. (c) Lime Requirement was determined by the Hutchinson and MacLennan method. (24) Twenty grams air-dry soil passing the 3 mm. sieve and 300 c.c. N/50 calcium bicarbonate were shaken for three hours and titrated with 0.2 N HCl using methyl orange as indicator. The results have been stated as gm. $CaCO_3$ per 100 gm. air-dry soil.

(d) /

EXCHANGEABLE CALCIUM. (d) Exchangeable calcium. This was determined by treating 25 gm. of air-dry soil passing the 3 mm. sieve with normal sodium chloride solution. The soil sample was shaken up with 200 c.c. of the warm solution and allowed to stand overnight. The supernatant liquid was decanted through a filter and the soil stirred up with a further 100 c.c. of the cold solution. This was allowed to settle and then decanted in the same manner. The process was repeated until one litre of filtrate had accumulated. A second litre was collected in the same manner and the determination continued according to Ogg and Dow. (32)
The results have been stated as percentages of CaO present in the air-dry soil.

LOSS ON IGNITION. (e) Loss on ignition. About 10 gm. air-dry soil passing the 3 mm. sieve were placed in an electric muffle and ignited. The soil was then cooled and weighed and the loss in weight determined. The igniting process was repeated until constant weight was reached. The results are expressed as percentages of air-dry soil.

MOISTURE. (f) Moisture in Air-dry soils and subsoils. About 10 gm. of air-dry soil passing the 3 mm. sieve were placed in a water oven and brought to constant weight. The loss in weight equivalent to moisture is expressed as a percentage of air-dry soil and subsoil in each case.

MECHANICAL ANALYSIS. (g) Mechanical Analysis. The mechanical analyses of the soils and subsoils were made according to the method of the /

Agricultural Education Association.(1)

CALCIUM ESTIMATION. (h) Volumetric estimation of calcium of the lime applied to the grass plots was made according to Cumming and Kay.(9) The calcium was precipitated as calcium oxalate. The washed precipitate was dissolved in sulphuric acid and the solution titrated with standard permanganate.

4. BOTANICAL DETERMINATIONS.

The work in this connection has proceeded by means of a large number of systematic botanical analyses in order to ascertain the composition of the plant community and the development and yield of each species throughout the year in the plots selected. The grass and clover seed mixture was sown down according to local practice and the plots selected subdivided and partially limed as already described.

The botanical determinations resolve themselves into three stages :-

TURF ANALYSIS. (a) Analyses of turves from plots :-

i. Immediately after harvesting of nurse crop to determine the percentage of each species in the stand.

ii. During the spring of the first harvest year to determine the influence of overwintering.

iii. During the spring of the second harvest year to determine the mortality of the various species during the second winter.

iv. During the autumn of the second harvest year to determine the influence of periodic cutting on the species of the herbage.

v. /

v. During the spring of the third harvest year to determine the percentage contribution made by the individual species to the herbage.

The method of analysis used was that employed by Nielsen and Lindhard. (28) From the limed and unlimed sections of each plot six turves were cut at each of the periods above indicated. Each turf had superficial dimensions of 6 ins. x 6 ins. and they were selected at regular intervals so that the six turves might be fully representative of the small treated or untreated area. The turves were then separately analysed, the plant species being separated and counted. The tillers of each grass species were also counted and the clover cover ascertained by estimating the total number of square inches of turf covered by clover foliage. (3). By using the turf method, one works with complete plants and is never in any doubt as to species; the analysis can be done relatively quickly and gives a true picture of the small area. The chief difficulty is to determine how far the plant cover from such a small area corresponds to the average composition of the plot. By taking six turves, therefore, at equal intervals from a subplot of approximately 14 feet x 7 feet, a fairly reliable conclusion regarding proportion of species can be reached.

This method was used in all the turf separations.

(b) /

(b) Analyses of Hay and Aftermath.

HAY SEPARATIONS.

The plan followed was to cut the herbage for hay in the first harvest year and cut the aftermath also. In order to arrive at the percentage contribution by weight of each species to the hay and to the aftermath cuts, a plot, one yard square in area, was pegged off on each of the limed and unlimed sub-sections. The square yard plot in each case was cut for hay and aftermath hay alike. The material was separated into species, the latter being dried to constant weight in a hot oven where a temperature of 100°C was reached. The dried separations were cooled and weighed and the percentage contribution to the dry matter calculated. At the time of cutting the small plot for hay and aftermath hay, the rest of the complete fenced plot was cut over so that, at all times, the complete herbage received the same treatment.

Cutting, in this connection and in the case of the pasture, was carried out by means of shears at ground level. The aim of cutting the herbage of the plots at ground level ensured that uniformity in this operation would exist on all plots.

(c) Pasture Analysis.

PASTURE ANALYSIS.

The plots were brought to their zero point (pasture) at the close of the first harvest year by cutting over the square yard sections, separating the material into grasses, clovers /

clovers and weeds, drying and weighing each group and calculating the percentage contribution of the groups to what was noted as the first pasture cut. The pasture cuts were looked upon as more or less equivalent to the influence of the grazing animal with these important differences that cutting by means of shears was more drastic than even hard grazing and no return of fertilising material was made to the soil through the excrement of the animal. Cutting by means of the shears, however, ensured a certain definite standard where cutting was at ground level.

Throughout the investigation pasture cuts were taken from the limed and unlimed plots at regular intervals and separated into grasses, clovers and weeds.

5. DRY MATTER DETERMINATIONS.

As stated under pasture analysis, the cut material was separated into three groups - grasses, clovers, and weeds. These separations were then placed in shallow zinc trays and dried to constant weight in an oven capable of giving a temperature of 100°C. The material was finally weighed and the percentage contribution of each group, to the total dry matter, calculated.

From the above determinations it has been possible to compile a statement of total dry matter yielded by the various plots, limed and unlimed, for a complete year and to state to what extent the grasses and clovers each contributed to the dry matter over the complete year or at particular seasons.

6. METEOROLOGICAL DETERMINATIONS.

In order that the yield data might be interpreted to the the full extent, a record of meteorological conditions was kept throughout the investigation. The following records were obtained :-

Monthly rainfall, Maximum and Minimum temperatures, Humidity, Sunshine in hours, Soil Temperature at four of the seven plots and Monthly rainfall and Maximum and Minimum temperatures at the other three.

7. DESCRIPTION OF THE GENERAL CONDITIONS UNDER WHICH THE TESTS WERE CARRIED OUT.

The centres were primarily selected on the basis of soil type, four plots being located on the Experimental Farm of the Edinburgh and East of Scotland College of Agriculture at Boghall, Miltonbridge, Midlothian. The remaining three plots were selected on the basis of soil type coupled with the susceptibility, varying in degree, of the areas chosen to invasion by Agrostis species. These three plots are located at - (1) Bangour, West Lothian, the Home Farm of the Mental Hospital, Board of Control, Edinburgh; (2) at Wedderlie; and (3) at Cammerlaws, both of which lie on the southern slopes of the Lammermuir Hills. A detailed mechanical analysis of all the soils along with their other characteristics will be found in the appendix. The following is a brief report on the general conditions under which the grass and clover seed mixtures were sown down :-

A./

A. Kimming Hill)
B. Anchordales) Boghall, Milton Bridge, Midlothian.
C. Crofts Garden)
D. Crofts.)

Boghall Farm lies astride the Biggar road about 6 miles from Edinburgh. The arable portion of the farm lies at an elevation varying from 550 feet to 800 feet, the hill extending from 800 to 1600 feet above sea level.

The soil shows considerable differences in different parts of the farm, depending upon the origin and mode of formation. Plots were therefore selected as far as practicable upon all soil types, namely,- Kimming Hill - light; Anchordales - medium; Crofts Garden - heavy; Crofts - peaty. The exposure of all plots is neutral and the elevation 650 feet above sea level. The rotation practised on the farm is a five course one, namely :- Oats, Roots and Potatoes, Barley and Wheat, Seeds, Pasture.

CULTURAL DATA.

CULTURAL DATA.

(a) Nurse Crop.

Kimming Hill - Oats. Anchordales - Plumage Archer Barley.
Crofts Garden - Oats. Crofts - Setter Wheat.

(b) Seeding of Nurse Crop.

Oats were sown at the rate of 5 bushels; barley at the rate of 4 bushels, and Wheat at the rate of 4 bushels per acre.

Kimming /

Kimming Hill was sown on 3rd April 1928 by hand.
Anchordales " " 6th April 1928 by drill machine.
Crofts Garden " " 10th April 1928 by hand.
Crofts " " 28th Novr. 1927 by drill machine.

(c) Sowing of Seeds Mixture.

Kimming Hill was sown on 26th April 1928 by hand.
Anchordales " " 25th April 1928 by broadcast machine.
Crofts Garden " " 26th April 1928 by hand.
Crofts " " 26th April 1928 by hand.

(d) Manuring of Nurse Crop.

Kimming Hill lea oats received 3 cwts per acre of a mixture made up of 1½ cwt. Sulphate of Ammonia, 1½ cwt. Superphosphate, ½ cwt. Ground Mineral Phosphate, 1 cwt. Potash Salt (30%). This was applied on 29th March 1928.

(e) General Observations.

The conditions of the tilth at the time of sowing was, in all cases, normal. The cultural sequence at the time of sowing of the grass seeds was harrowing, sowing, harrowing, rolling.

Details of purity, germination and real value of the constituents of the mixture will be found in the appendix page 131.

GEOLOGY. GEOLOGY.

The geology of the farm of Boghall is discussed at considerable length by Hart (19). During the Glacial Period boulder /

boulder clay, sands and gravels were laid down in this region and a considerable part of the farm is characterised by these drift deposits. The boulder clay is the most extensive, although it is covered in certain parts by later deposits. Overlying the boulder clay occur two large spreads of sands and gravels. The spread on the part of the arable land is variable in character.

The Kimming Hill Plot (A.) is a characteristic glacial sand and is probably located on the lightest part of the field. This field is variable and may be characterised as a fine, sandy, brown loam, the geology of which is glacial sand and gravel overlying basalt.

The Anchordales Plot (B.) may be classed as an alluvium over basalt and described as a brown or chocolate-coloured loam, medium in texture. This soil is the outcome of a spread of alluvium from the Boghall Burn, extending north east from which the deposit becomes siltier in character.

The Crofts Garden Plot (C.) lies nearer the Boghall Burn than the Anchordales one and is distinctly heavier in character, being classed as a reddish loam fairly heavy in texture.

Patches of peaty soil occur in the hollows on the arable land of the farm and the Crofts Plot (D.) occurs in one of these hollows. There has, however, been a deposition of silty material transported by water from the Boghall Burn.

E. Bangour Home Farm is situated on the Edinburgh-Bathgate road about three miles from Bathgate. The elevation varies from

500 /

500 to 900 feet above sea level. The soil generally is heavy in nature.

The soil type on which the seeds mixture was sown is heavy, the exposure neutral and the elevation 700 feet. The rotation practised is Oats, Mashlum for ensilage, Roots and Potatoes, Oats, Seeds, Pasture, Pasture.

CULTURAL DATA.

The seeds mixture was sown down with Record Oats which was sown on 17th April 1928 by broadcast machine at the rate of 6 bushels per acre. The condition of the tilth at the time of sowing was normal.

The grass and clover seeds were sown by broadcast machine on the 24th April 1928 under normal conditions.

The nurse crop received no artificial manure, the previous root crop having been dressed with a mixture consisting of ½ cwt. Nitrate of Soda, 3 cwt. Basic Slag, 2 cwt. Kainit, 1 cwt. Fermented Bone Meal.

Here, as in many other cases, agrostis is troublesome, and on making investigations of young grass and pasture it was found that bent was present in the second harvest year in fair abundance but not in the grass being made into hay in the first harvest year.

The young grass is not grazed in the seeding year but is put up for hay immediately after the harvesting of the nurse crop.

The cultural treatment carried out at sowing of the seeds was Cambridge roller, sowing, harrowing, Cambridge roller.

Details /

Details of purity, germination and real value of the constituents of the mixture will be found in the appendix, page 132.

GEOLOGY. The area in which this farm is located is characterised by Lower Silurian rocks interspersed with basalt and dolerite. A considerable area of the farm in question is covered by a moderately heavy grey loam overlying a heavy clay with basalt material consisting of boulder clay.

F. Wedderlie is situated on the south side of the Lammermuir Hills, in Berwickshire, about 8 miles north east of the town of Lauder. The elevation of the field, Crooked Acres, in which the mixture was sown, is 800 feet above sea level and the exposure is easterly. The soil is a heavy loam overlying a heavy clay. This field was included in the policy fields of Wedderlie in former years and had been in grass for a considerable time before it was ploughed up during the war and put through a rotation. The following is the history of cropping :-

CULTURAL DATA.

1919	Lea Oats	1923, 1924, 1925	Pasture
1920	Roots	1926	Oats
1921	Roots	1927	Roots
1922	Oats & Rape sown down.	1928	Oats sown down.

In 1922 the part of the field sown down with rape as the nurse crop was invaded by agrostis in the first harvest year and this developed to such an extent that bent, in a short time, was the only constituent.

The /

The seeds mixture in 1928 was sown down with Victory Oats which were sown by broadcast machine on 7th May at 6 bushels per acre. The seeds mixture was sown by broadcast machine on 25th May. The nurse crop received no manurial treatment. The previous crop however, which was roots, received 10 cwt. Ground Lime per acre and 7 cwt. Turnip Manure per acre, the analysis of which is unknown.

The condition of the tilth at the time of sowing was normal. The field was drained in 1925.

In this district, the tendency is for Agrostis to appear in the herbage in the second harvest year but in a number of cases it has been evident in the first harvest year.

The local practice is to graze the young grass in the seeding year with sheep and reserve only a small section for hay.

The cultural treatment at time of sowing the seeds mixture was rolling, sowing of seeds mixture, harrowing, rolling.

The details concerning purity of seeds, etc. will be found in the appendix, page 133.

GEOLOGY. Since the Wedderlie and the Cammerlaws plots adjoin each other, it will be convenient to discuss at this point the geology of both plots.

The locality in which these two plots occur is partly on the Upper Old Red Sandstone and partly on the Lower Silurian formations. The greater part of the Old Red Sandstone /

Sandstone area is covered with glacial drift, mostly boulder clay with fairly large areas of sand and gravel. There are numerous hollows characterised by layers of peat varying in thickness.

The soil of the Wedderlie plot may be described as a stiff, red loam with boulder clay as basal material and overlying grits of the Silurian age.

The Cammerlaws plot may be described as consisting of a very black loam, distinctly peaty in appearance, with a subsoil of gravel and boulder clay as basal material, all overlying sandstones and marls of the Upper Old Red Sandstone age.

G. Cammerlaws, Westruther, Berwickshire, is situated about a mile south east of Wedderlie and is close to the Westruther-Duns road. The elevation of the field sown down is 750 feet above sea level and is exposed both to the north and south. The soil is very variable in this field, but particular attention has been paid to a part of it characterised by a shallow peaty soil overlying a gravelly material.

The plot at this centre was sown down with rape, the latter being sown at the rate of 10 lb. per acre during June 1928.

The rotation practised on the above farm is the same as that on Wedderlie.

The geology of the Cammerlaws plot has already been discussed under Wedderlie.

3. STUDY of the FACTORS.

The four groups of factors concerned are :-

I. The grass and clover seed mixture.

II. Soil data.

III. Meteorological data.

IV. Management, i.e. the laying down of the mixture and after-treatment.

The method of dealing with the above will be to summarise the outstanding conclusions made, consequent on the more important work done, in these connections, during very recent years and to attempt to use the data, collected in connection with this particular problem, as a means of accounting for the more outstanding results gathered under what will prove to be a somewhat intricate environment.

I. THE SEEDS MIXTURE.

The mixture itself is a factor of fundamental importance. Such characteristics as the purity, germination capacity and source of the various species; the proportion of each species in the mixture and the proportion of soil each species is intended to cover are all of very great value. Out of the extensive researches that have been carried out, there have emerged two discoveries which, in the future, will have a far-reaching effect. These discoveries are firstly that strains, within the species of grasses and clovers, characterised by special properties which result in successful growth and development are of greater value than the ordinary species themselves; with this matter of strain may be coupled that of source /

STRAIN.

NATIONALITY. source or nationality of the seed; and secondly that there are varying degrees of differences between the laboratory

GERMINATION. germination of seeds and the field germination, in many cases very great differences. This points to the necessity of a certain degree of knowledge of the conditions which influence field germination and the adjustment of the species proportions in the mixture so that as near as possible the correct density of herbage may be produced and maintained.

At Aberystwyth (42), Professor Stapledon and his colleagues have demonstrated that the fundamental principles of pasture establishment must be deduced from a knowledge of the properties and behaviour of the various species of grasses and clovers. This has led to nationality and strain investigation which in turn gave rise to the improvement of pasture plants by breeding. The most outstanding result has been the recognition of the superiority of indigenous types over cultivated types of the species of grasses. Through the study of forms present in different populations from grazed habitats a number of factors have been discovered, which, under certain conditions, favour the survival of certain types and the elimination of others. Consequently, it is important to correlate the various types of herbage plants and the particular environment to which they are adapted. Work of this nature has been done with Rye Grass, Cocksfoot, Red and White Clover at Aberystwyth and with Timothy at the Plant Breeding Station, Edinburgh.

With /

With regard to nationality, the trials which have been conducted at Aberdeen (13), Aberystwyth (47) and various other centres (7, 46) have conclusively shown that varieties of imported Red Clover are not so well suited to conditions in this country as home raised varieties. Because of being better adapted to soil and climatic conditions, the native clovers give better yields and last longer.

With regard to the problem of germination, it has been shown by Stapledon (44) that laboratory germination does not necessarily indicate to what extent the various seeds will establish themselves. Different species seem to possess different powers of establishment. The mortality in seedlings or the non-germination of the seeds may be considerably great. It is admitted that there are many factors other than viability which may tend to influence the establishment of the young herbage, but such emphasise the necessity of using improved methods of prescribing the quantities of the various species of the mixture in relation to the environment.

With regard to the particular seeds mixture used in this problem, the following points were kept in mind:-

1. The herbage to be cut for hay in the first harvest year.
2. A certain intensity of grazing to be carried out during the autumn of the seeding year and early spring of the first harvest year.
3. Grazing in the second, third and fourth harvest years.
4. The mixture to be sown down with a spring nurse crop (cereal) according to local cultural practices.

5. /

5. The mixture to receive no direct manuring.

As the investigation proceeded several additional determinations were made, e.g. the aftermath in the first harvest year was cut for hay, hay was taken in the second harvest year and the aftermath in the second harvest year also cut for hay.

The mixture, as has been stated elsewhere, is taken as the basis and as one of the constant factors of the present investigation.

SEED PROPORTIONS.

In Table I. will be found the relationship between the ingredients of the mixture worked out on the basis of the number of seeds in the mixture and expressed as a percentage. Other characteristics of the constituents will be found in the appendix.

TABLE I.

TABLE I. showing proportions of species in the Mixture.

Constituent.	Rate of Seeding per acre.	No. of Seeds per lb.	Total No. of Seeds per acre.	Per cent of Mixture.
Perennial Rye Grass.	12 lb.	218,000	2,616,000	16.5
Italian Rye Grass.	8	240,000	1,920,000	12.2
Cocksfoot.	8	460,000	3,680,000	23.4
Timothy.	3	1,068,000	3,204,000	20.4
Rough Stalked Meadow Grass.	1	2,234,000	2,234,000	14.2
Broad-leaved Red Clover.	1	232,250	232,250	1.5
Late-Flowering Red Clover.	2	232,250	464,500	2.8
Alsike.	1	667,000	667,000	4.3
Wild White Clover.	1	750,000	750,000	4.7

The /

The following brief characterisation of the various ingredients of the mixture may be given and refers mainly to soil, climate, longevity, importance, and the like :-

PECIES. PERENNIAL RYE GRASS is considered to be best suited to a cool climate and well drained, moist soils in good condition. It does not do well on poor dry soils. The young shoots are easily frosted back in the late spring. The herbage in early winter is usually thick, relative to the amount included in the seeds mixture. During the mid summer months, it tends to become bare and brown unless there has been sufficient rainfall. In the second and third harvest years, it provides good pasture for a considerably long period but only under the best conditions of soil, climate and treatment.

ITALIAN RYE GRASS is characterised by quickness of growth and earliness. It is particularly suited to good soils. It fails on dry sandy soils or peaty soils in poor condition. If made into hay the majority of the plants die out during the winter of the second harvest year. By cutting relatively early, it is possible to ensure a good aftermath and a considerable proportion in the pasture of the next year. The amount in the mixture has a considerable influence upon the weediness of the land. It may have an adverse effect upon slow developing grasses and upon clovers to the extent of reducing the ability of these constituents to colonise the blank spaces when it dies out.

COCKSFOOT /

COCKSFOOT has the outstanding properties of earliness, quick recovery after grazing or cutting and resistance to drought. It is primarily a pasture grass and is of small importance in the hay crop of the first harvest year. Under conditions favourable to its growth, it is, in the majority of cases, the most predominant constituent in the pasture and where it is in relatively large proportion classes the pasture as early. It is of less value for winter grazing since it dies down and becomes withered. Cocksfoot is very useful on thin, dry soil and on average soils in droughty seasons.

TIMOTHY develops well on soils which are deep and moist and is specially suitable for clay and peaty soils. On light soils and particularly in dry seasons, it does badly. It is later than most of the other grasses. It appears to a fair extent in the aftermath if the cutting of the hay is not delayed. Timothy forms a useful ingredient in the subsequent pasture years.

ROUGH STALKED MEADOW GRASS is characteristic of damp conditions. This grass, under proper conditions, is one of the best for filling up blank spaces caused by the dying out of more temporary kinds and also by the mortality amongst those species not so well adapted for the particular conditions. It fails badly on light soils unless the rainfall is high. During a dry summer, the proportion of this constituent may be considerably reduced or the quality adversely influenced.

RED /

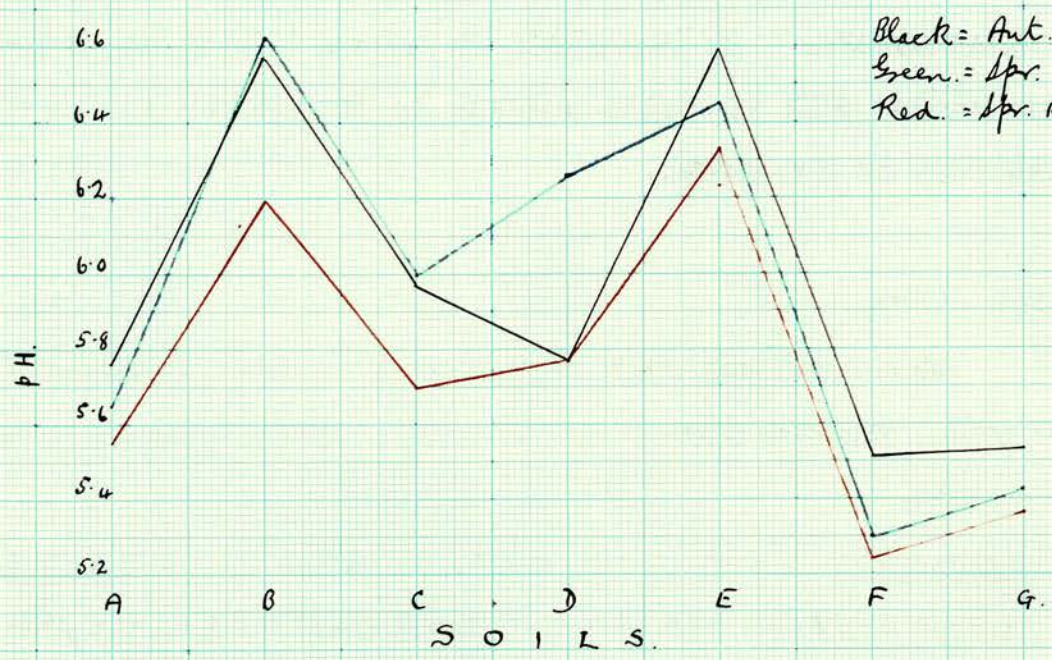
RED CLOVER may be very adversely affected by unsuitable conditions and although it may give successful growth on practically all soil types, it may become deficient on very light and very heavy soils and on peaty soils. The longevity will depend upon a number of conditions, but the greatest bulk will appear in the first harvest year and will gradually decrease until the third harvest year when the proportion in the pasture may be very small or it may have disappeared altogether.

ALSIKE has for its chief function that of a reserve plant in that it takes the place of Red Clover if that constituent fails. It lasts longer than Red Clover. It is best adapted for wettish soils in good condition and will grow under varying degrees of soil acidity.

WILD WHITE CLOVER is primarily a pasture plant and is outstandingly useful for filling up blank spaces in the herbage and so preventing loss of water by evaporation and the colonisation of such spaces by weeds. It can withstand drought to a considerable extent. The main factors which limit the growth of this clover are probably excessive water content of the soil, deficiency of lime, phosphates and potash. The method of management during the first harvest year will determine the rate of development of this constituent. If hay is taken in the first harvest year, the clover will probably not be in very great evidence until the third harvest year. If the hay crop has been light and cut early, it may appear evident in the second /

To face page 56.

GRAPH I. Reaction of soils - Aut. 1928 (untreated) and Spring 1930 (limed and unlimed.)



GRAPH II. Reaction of subsoils - Aut. 1928 (untreated) and Spring 1930 (limed and unlimed)

second season. If the field is grazed during the first year, the clover will be quite evident in the second season and possibly in the first.

II. SOIL DATA.

These are reaction, "lime requirement", exchangeable calcium, organic matter and moisture content, and mechanical analysis.

(a) Reaction. All of the areas in which the centres occur, except Bangour, have been investigated by Ogg (33,36) in connection with acidity surveys and work on reaction, "lime requirement" and exchangeable calcium. The difference between the procedures is that in this particular case the area investigated was confined to one 14 feet by 14 feet and the number of borings of soil and subsoil was fifty, whereas in the case of Ogg's work, borings were carried out over two parishes in one case, a somewhat smaller area in another, and over the farm of Boghall. The original analysis was carried out during October 1928 and the second analysis during April 1930 a considerable time after the lime had been applied.

All of the soils under review have passed through a normal rotation and are now carrying grazing stock. They can therefore be classed as cultivated soils. Graphs I. and II. opposite, indicate the range of pH values for the seven soils and subsoils. Graph I. represents the pH range in the /

GRAPHS I. & II.

the soils (untreated) in October 1928, and in the soils (limed and unlimed) in April 1930. Graph II. represents the subsoil pH values at the same periods.

Range of pH values in cultivated soils.

The soils and subsoils show a comparatively small range, namely, 5.51 to 6.59 (soils) and 5.51 to 6.57 (subsoils) or from acid to slightly acid. In the case of the slightly acid soils no lime would probably be required for most crops, but in the lower pH soils, lime would be necessary in a considerable number of cases. The range of pH values here found compares favourably with those found by other workers in other countries. In Table II. these values are given and show a range from 5 to 7 for cultivated soils.

TABLE II.

TABLE II. The soil reaction of different countries.

Cultivated Soils.

Country.	Range of pH.	
Russia (Leningrad)	5.5 to 6.2	
Denmark.	6.0 " 7.0	
Sweden.	6.0 " 7.0	
Finland.	5.0 " 6.5	(80% of Samples)
Bavaria.	5.5 " 6.0	(42% " ")
	below 6.2	(50% " ")

Acidity at varying soil depths.

It will be noted that even for shallow depths, there is a tendency to less acidity in the sub-layers of soil. It has been found by several researchers that the surface soil has the greatest acidity and that acidity decreases with increased depth. Available figures are summarised as follows and these include pH values, "lime requirement" and exchangeable calcium.

CGG. (34)

No. of layer in profile.	Cultivated Soil Exchangeable Calcium. (as % CaO)	pH	Heath Soil. Exchangeable Calcium. (as % CaO)	pH.
1	0.275	6.37	0.047	4.84
2	0.383	6.87	0.059	5.44
3	0.415	6.78	0.052	5.48

CROWTHER. (8) Vertical Distribution of Reaction (pH values).

Depth in Inches.	Manured. Limed.	Unlimed.	Unmanured.	Manured. Limed.	Unlimed.	Unmanured.
0 - 4.5	4.07	3.74	5.70	6.09	4.38	5.42
4.5 - 9	4.33	3.98	5.99	6.27	4.56	5.58
18 - 22.5	5.79	5.06	6.31	6.77	6.06	6.61
31.5 - 36	6.55	-	6.78	6.73	6.28	6.63

The work of Salisbury (40) also confirms this.

(b) "Lime requirement". The problems of "lime requirement" and the acidity of selected fertile soils have been investigated by Hendrick and Ogg (20, 21). Although the published figures of "lime requirement" are few, those that are available show common requirements up to 0.4 per cent.

RANGE. The figures here tabulated indicate a range from 0.068 per cent to 0.376 per cent in the soils and from 0.047 to 0.501 per cent in the corresponding subsoils. The lowest percentage occurs on the Anchordales plot which has been classed as a medium loam and was limed within the rotation. The highest percentage occurs on the Crofts plot which consists of a peaty soil and accounts for the relatively high requirement. It should be noted that these figures are laboratory /

laboratory figures and do not strictly indicate the needs of the soil with regard to lime. Such demands will depend, to a considerable extent, upon such factors as climate, the geology of the soil type and the type of crop to be grown.

(c) Exchangeable calcium. The soils show a range from 0.038 per cent CaO to 0.310 per cent CaO. The majority of these figures seem low in comparison with the results of other workers. Smith's (41) figures for cultivated soils range from 0.12 per cent to 0.55 per cent CaO. The figures of Robinson and Williams (37), on the other hand, have a range from 0.05 per cent to 0.43 per cent CaO.

RANGE.

(d) Loss on Ignition. The organic matter content as indicated by loss on ignition varies in the seven soils from 5.655 per cent in one of the heaviest types to 23.456 per cent in the peaty type and in the subsoils from 6.040 per cent in a heavy type to 34.407 per cent in the peaty soil.

(e) Moisture in Air-dry Soils and Subsoils. The percentages range from 1.901 to 5.650 in the soils and from 1.539 to 6.931 in the subsoils. The high organic content is characterised by high moisture content but in all the figures the soil type (silt and clay) is also involved.

(f) Mechanical Analysis. A summary of the figures is given in Table III.

TABLE /

TABLE III.

TABLE III. Summary of Mechanical Analysis of Soils and Subsoils (fractions expressed as percentages).

Fractions.	A.	B.	C.	D.	E.	F.	G.
SOILS.							
Coarse Sand.	55.42	28.50	20.78	14.43	24.59	15.78	17.90
Fine Sand) Silt.)	19.91	38.09	41.33	19.40	29.19	37.44	45.67
Fine Silt.) Clay.)	15.06	24.42	29.32	36.88	31.64	36.50	22.72
SUBSOILS.							
Coarse Sand.	48.50	31.16	15.38	7.59	22.05	15.98	14.98
Fine Sand.) Silt.)	25.52	35.89	39.05	14.98	33.54	37.47	53.24
Fine Silt.) Clay.)	15.56	25.36	36.64	35.94	32.68	38.80	22.80

Soil A. is an outstanding free, open, very porous type consisting of over 50 per cent of coarse sand. This type dries out very easily and suffers from very considerable leaching. The sub-layer is very similar in composition, so that the extreme conditions would be reached in a very dry season.

Soil B. has already been classed as a medium loam and both in soil and subsoil reveals a relatively high percentage of fine sand plus silt. Water absorption and retention would be expected to be normal.

Soil C. has a very high proportion of fine sand plus silt and a slightly higher fine silt plus clay percentage than the previous type. The coarse sand, responsible for the efficiency of the natural drainage, is relatively low. The same observations /

observations apply to the subsoil except that the fine silt plus clay is in higher proportion. This type has been classed as a red stiffish loam, is difficult to manage, particularly in wet seasons, and is not characterised by excessive leaching.

Soil D. has the outstanding character of high organic content, with the result of high water absorbing and retentive properties. This fact, coupled with a high fine silt plus clay percentage classes this type as badly aerated, acid and wet. The subsoil even possesses these characteristics in a greater degree because of the higher percentage of organic matter and the lower percentage of coarse sand.

Soil E. is a heavy type with slightly heavier subsoil. The tendency is towards difficulty in natural drainage.

Soil F. is the heaviest of all the soils possessing very high percentages of both fine sand plus silt and fine silt plus clay. The coarse sand fraction is low. The same remarks apply to the subsoil. This type, in fact, is difficult to manage, the extreme difficulty being reached in very wet seasons. It is a cold, exposed,late soil.

Soil G. has a moderate amount of organic matter but relatively very high fine sand plus silt fraction with next to lowest fine silt plus clay and a low percentage of coarse sand. The subsoil is very similar in mechanical composition with the exception of a much lower organic content. This type is therefore absorptive of water, is retentive, and yet quite

free /

free draining. There may be a tendency to over-leaching.

Correlation of Soil Factors.

It has been shown, but not quite conclusively, that there exist fairly close relationships between :-

i. pH and "lime requirement".

ii. pH and exchangeable calcium.

Hissink (22) has shown that there does exist some relationship between the lime content and the pH and that also a change in structure of the clay humus substances of the soil and the acidity (pH) go hand in hand with the bringing of calcium oxide in contant with such substances. This in turn may have an effect upon crop yield and general development and in grassland problems may influence such conditions as yield of hay and aftermath, length of grazing season and quality of herbage and such like.

Ogg and Dow (35) have also shown similar relationships.

In regard to this investigation, the various soil data collected, except mechanical analysis, are recorded in Table IV.

TABLE IV. /

TABLE IV.

TABLE IV. Comparisons:- pH, "lime requirement", exchangeable calcium, organic matter, moisture.

Plot.	pH.	Lime Requirement.	Exchangeable Calcium.	Organic Matter.	Moisture.
SOILS.					
A.	5.76	0.188	0.053	7.226	1.984
B.	6.57	0.068	0.112	6.195	1.901
C.	5.97	0.110	0.080	5.655	2.244
D.	5.77	0.376	0.310	23.456	5.650
E.	6.59	0.094	0.141	10.895	3.082
F.	5.51	0.251	0.038	7.662	2.559
G.	5.53	0.313	0.080	11.483	2.254
SUBSOILS.					
A.	5.79	0.157	-	7.358	2.313
B.	6.57	0.047	-	5.229	1.752
C.	6.12	0.078	-	6.477	2.185
D.	5.85	0.501	-	34.407	6.931
E.	6.15	0.125	-	9.205	2.541
F.	5.53	0.172	-	6.040	1.765
G.	5.51	0.250	-	7.356	1.539

It will be seen from the Table that generally :-

1. The lower the pH, the higher the "lime requirement".
2. The lower the pH, the lower the exchangeable calcium.
3. The lowest pH soils have a relatively high organic content.

III. METEOROLOGICAL DATA.

In the study of the climate of a country or district, it is necessary, before drawing reliable conclusions, to have at one's disposal data collected over a long period.

The /

The figures here quoted are therefore only meant to indicate the type of weather obtaining at the various centres during the seasonal periods of the three years of the investigation and do not indicate the climate of the districts.

The important periods of the year, as far as the relation of weather to crop is concerned,are :-

1. December, January, February, during which months preparation for the sowing of crops is done. Rainfall and frost are of importance during this period.
2. March, April, May - the sowing months. During this period the two important operations are tilth production and the actual sowing. Rainfall and temperature are again of outstanding importance.
3. June, July, August - the growing season, during which increment is put on rapidly or slowly.
4. September, October, November - the months of gradual slowing down of metabolism on the part of permanent crops and harvesting in others. As far as pasture is concerned, the problem is to discover some means of extending the grazing season as far into the year as possible. Such will be most difficult where the altitude is great and the exposure and weather of the severest.

The year has been divided into periods, in the above manner, in a somewhat arbitrary way, but these periods do roughly correspond to the more important physiological processes of crops and also to seasonal work on the farm.

Summary /

Summary of the more important data. Figures with reference to seasonal rainfall in inches, rain days during the four seasons, mean maximum and minimum temperatures in degrees Fahrenheit for the seasons and the mean number of sun hours per day for each period will be found in Table V.

TABLE V.

RAINFALL. From the point of view of seasonal precipitation, the general conclusion, for all plots, is that the driest period existed from March to May and the wettest from June to August. The exception is in the year 1930 when at all centres the wettest period was from September to November. Actually, the driest and wettest months varied from year to year as will be observed if the detailed figures in the appendix are examined. The number of rain days varied according to the season but generally the fewest occurred during the spring period and the most during the autumn period, although the difference between spring and summer in this respect is not very great.

The total annual rainfall did not vary to any great extent at the various centres, in one and the same year, with the exception of Boghall in 1930, this centre being slightly wetter than Bangour and somewhat wetter than Marchmont. Another significant fact is that, at all centres, 1929 was much drier than either 1928 or 1930, the season at each centre accounting to the greatest extent for this being autumn.

TEMPERATURE. The observation of greatest importance, in this connection, is the high maximum temperatures during the spring and summer seasons at Boghall in the years 1929 and 1930, and during autumn in all years at Bangour and Marchmont.

SUNSHINE /

TABLE V. showing SEASONAL RAINFALL in inches, RAIN DAYS, TEMPERATURE (Fahr.) and TOTAL SUN HOURS - BOGHALL (Plots A.B.C.D.)

	Seasonal Rainfall.			Rain Days.			Max. Temp. (mean)			Min. Temp. (mean)			Sun Hours per day (mean)		
	1928.	1929.	1930.	1928.	1929.	1930.	1928.	1929.	1930.	1928.	1929.	1930.	1928.	1929.	1930.
Dec. to Feb.	-	4.28	9.01	-	45	60	44.3	39.1	44.9	34.2	30.0	32.3	-	1.9	2.4
Mar. to May	4.41	5.93	7.05	53	32	48	48.6	51.3	61.8	37.8	36.7	36.8	3.1	5.4	4.4
June to Aug.	12.70	9.86	10.41	57	51	55	59.2	61.1	62.6	47.3	48.9	48.9	5.3	5.6	5.8
Sept to Nov.	8.94	7.99	13.91	55	49	64	53.9	53.0	51.4	40.8	42.0	41.4	3.4	3.6	2.7
Total	26.05+	28.06	40.38												

RANGOUR (Plot E.)

	Seasonal Rainfall.			Rain Days.			Max. Temp. (mean)			Min. Temp. (mean)		
	1928.	1929.	1930.	1928.	1929.	1930.	1928.	1929.	1930.	1928.	1929.	1930.
Dec. to Feb.	8.56	4.72	9.15	65	49	65	41.0	38.7	41.2	31.9	28.8	31.3
Mar. to May	4.89	4.34	4.75	50	37	49	48.7	31.3	48.7	36.8	35.7	36.3
June to Aug.	12.13	10.16	11.32	62	60	62	60.5	61.9	62.9	46.5	46.4	47.5
Sept to Nov.	10.10	8.99	12.06	64	63	61	52.6	52.5	51.1	39.7	40.0	40.1
Total	35.68	28.21	37.28									

MARCHMONT (Plots F. G.)

	Seasonal Rainfall.			Rain Days.			Max. Temp. (mean)			Min. Temp. (mean)		
	1928.	1929.	1930.	1928.	1929.	1930.	1928.	1929.	1930.	1928.	1929.	1930.
Dec. to Feb.	9.92	6.00	7.03	71	55	66	42.2	39.0	42.2	31.8	28.9	31.4
Mar. to May	6.70	3.42	5.48	59	36	50	49.9	53.3	49.9	37.5	36.2	36.7
June to Aug.	11.37	10.64	9.93	52	51	53	62.0	63.3	65.1	47.2	47.6	48.5
Sept to Nov.	8.79	6.72	12.72	61	57	63	53.5	54.5	52.3	40.6	40.9	40.9
Total	36.78	26.78	35.18									

SUNSHINE. Sunshine readings were recorded only at one centre, namely, Boghall. The year 1929 was relatively outstanding in that the spring period showed a larger mean number of sun hours per day than either 1928 or 1930. Otherwise, no very great variation is evident.

IV. MANAGEMENT.

There are a considerable number of conditions, under this head, which will tend, singly and collectively, to influence the herbage at different periods of its life history. Such factors are sufficiently well known to warrant the omission of a lengthy discussion at this juncture. It will suffice to enumerate, in sequence, the more important of these and to state that it is always necessary to give careful consideration to all of them if a good stand is to be established and maintained.

MANAGEMENT FACTORS.

These management factors are :-

(a) Condition of weather and soil during autumn before sowing of seeds.

(b) Condition of weather and soil at time of sowing.

(c) Cultivations to produce desired tilth.

(d) Time of sowing.

(e) Nature of the nurse crop and rate of seeding.

(f) Manuring of the crop previous to the nurse crop and seeds. Manuring of the nurse crop and seeds.

(g) Time of harvesting the nurse crop.

(h) Treatment of the young herbage in the autumn of the seeding year /

year, such as application of phosphates and potash (if such have not already been applied) grazing or putting up for hay direct.

(k) Treatment during spring of first harvest year such as limiting grazing period in relation to enclosing for hay, nitrogenous manuring, cultivations, e.g. rolling.

(l) Treatment of the aftermath and in the pasture years, judicious stocking, cultivating (harrowing and rolling), and manuring.

As has already been stated, the particular methods used in the laying down of the seeds mixture in question were those used by the farmers on whose land this investigation was conducted. From the discussion of the centres, it will have been gathered that there was no great variation in the methods generally. In certain specific details, there was considerable variation, e.g. at Cammerlaws, the seeds were sown down with rape, at Bangour the young herbage was put up for hay immediately after the harvesting of the nurse crop and not grazed in the seeding year as in the other cases.

V. OTHER FACTORS.

There are many other factors of importance which it would be necessary to consider in a general discussion of grassland and which therefore are not enumerated or discussed in this paper. It is necessary to mention one, however, which seems to be of paramount importance. This is the biological factor and more particularly that of nitrification.

NITRIFICATION.

An important piece of work carried out by Russell (38,39) in /

in connection with the nitrate contents of arable soils has suggested "when a period unfavourable to nitrification comes to an end and more favourable conditions set in, the rate of nitrate accumulation tends to be more rapid in the early part of this new period than later on." Out of this statement there arise two further observations, namely;-

(a) that nitrates accumulate rapidly during late spring and early summer.

(b) that the activity of bacteria can be increased by exposing the soil to conditions unsuitable for active life and then removing the unfavourable conditions, e.g. sterilisation of soil.

The application is that bacteria are freer than usual in the late spring and early summer consequent on winter conditions being unfavourable to active life in the soil. In due course, however, the factor inimical to the nitrifying bacteria may again become evident and nitrate production decreases. Russell has shown that during summer a slower rate must be expected.

It might be reasonably argued on the above basis that there might be increased nitrate production after any unsuitable period, for instance during early autumn after a very dry summer with the consequent influence upon growth generally and second crop hay and early autumn grazing in particular.

It has been further shown by Löhnis (29) that there are two maximum periods of nitrification per annum and that approximately the process shows a rapid rise from January to March /

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Fig. 2. Salpeterbildung in Lösung geimpft mit Sand - - - - - - - - - - - - - -
von Februar 1928 bis Januar 1929 (% von Ammon-N-nitrifiziert) {ZIMBACH (27)}

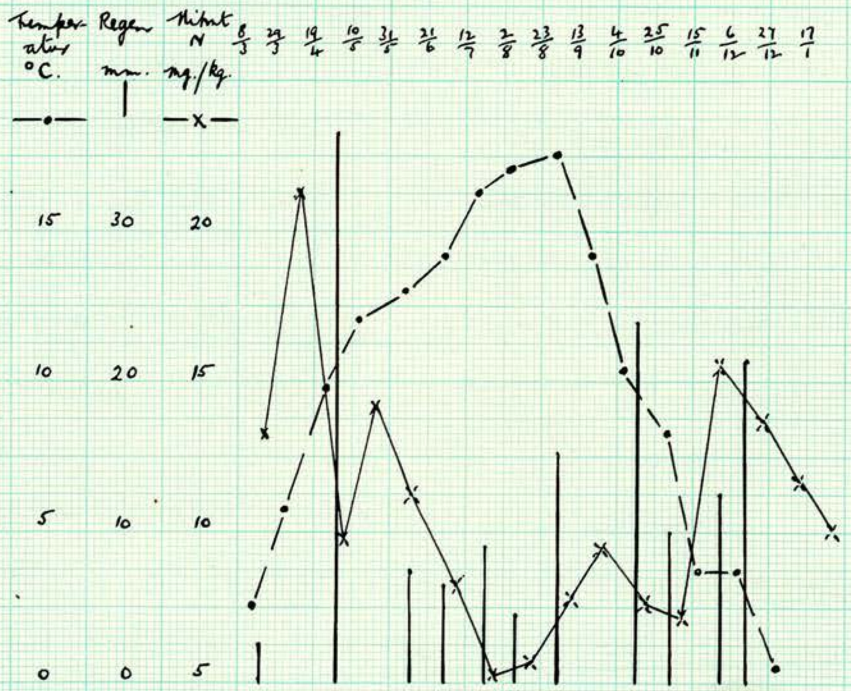


Fig. 3. Einfluß von Erdtemperatur und Niederschlägen auf den Verlauf der Nitratkurve in einem unbebauten Teilstück vom März 1928 bis Januar 1929.
{ZIMBACH (27)}

March, when the first or spring maximum is reached, followed by a gradual decline to July-August when a minimum is reached. Immediately following this, there is again a rapid acceleration in the rate of nitrification and the second or autumn maximum is reached during August-September, followed in turn by a steady decline to the January minimum. Löhnis (30) goes into the whole question of nitrification very thoroughly and has compiled an extraordinarily detailed and extensive bibliography on the subject.

Limbach (27) arrived at the same conclusion and the graphs opposite are extracted from his work to show the seasonal fluctuation of the nitrification process. Only one graph in Fig. 2 is shown, namely, that for sand, but the others, for loam and moor soil, show the same tendency. In an attempt to correlate this tendency of two annual nitrification maxima with weather conditions, Limbach, in the same work, concluded that there is no relation or in other words the second or autumn peak is reached irrespective of temperature or rainfall (Fig. 3).

Green (15) also has shown seasonal variation with the difference that he seeks to demonstrate a marked rise in December. In certain soils, under forest conditions, Clarke (6) states that the curve for nitrate tends to go down until the general minimum is reached during the latter part of August. After this period there is a steady increase, and on less acid soils, a minimum is reached during November.

Further work by King and Whitson (25, 26), Hall, A.D.[16] and

Hall /

Hall, T. D. (17,18), Clark (5), and others serve to demonstrate the same principle.

The evidence concerning the fluctuations of nitrates in the soil is clear, but that for a definite correlation of fluctuation with weather conditions (rainfall and temperature) is conflicting. Several authorities aver that the fluctuations occur independent of weather, others hold that there is an intimate relation between the two.

The particular grass problem now being investigated raises, very emphatically, the importance of the nitrate fluctuations. Having introduced the factor of nitrate production in soils, the problem is further complicated and opens up a vast field of research in which practically no work has been carried out, namely, the influence of the plant community on the soil micro flora.

In the "Results and Discussion" section of this paper, certain facts in connection with the seasonal behaviour of pasture will be brought out along with suggestive observations concerning weather and the application of the above general findings with regard to the seasonal fluctuations in nitrate production.

SUMMARY /

SUMMARY of the foregoing STUDY of FACTORS.

I. The Seeds Mixture.

(a) Strain, nationality and germination are of importance.

(b) The mortality of seedlings may be very great in overwintering.

(c) The mixture was compounded on the basis of percentage area of plot to be covered by each species and pure seedings of the various species, allowing for the disappearance of the temporary constituents and general mortality.

(d) The proportions of the species in the mixture have been expressed as percentages.

II. Soil Data.

(a) All of the soils under review are cultivated soils and show a range of pH values from 5.51 to 6.59; subsoils range from 5.51 to 6.57. The greater the depth of sampling, the higher is the pH value, with exceptions.

(b) "Lime Requirement" varies from 0.068 to 0.376 per cent for soils and from 0.047 to 0.501 per cent for corresponding subsoils.

(c) Exchangeable calcium ranges, for soils, from 0.038 to 0.310 per cent CaO.

(d) Organic Matter (loss on ignition) varies, in soils, from 5.655 per cent to 23.456 per cent and in the corresponding subsoils from 6.040 to 34.407 per cent.

(e) Moisture in air-dry soils shows a range from 1.901 to 5.650 per cent and in the subsoils from 1.539 to 6.931.

(f) /

(f) Mechanical analysis. The soils are seven in number and have been characterised on the basis of coarse sand, fine sand plus silt, fine silt plus clay. An examination of the figures in Table III, along with organic matter percentages, led to the following classification :-

Soil A. - free, open, very porous.

Soil B. - medium loam.

Soil C. - red, stiff loam.

Soil D. - high organic content, high fine silt plus clay percentage.

Soil E. - grey, stiff loam.

Soil F. - cold, exposed, stiff wet loam; heaviest of all the types.

Soil G. - black, friable loam.

(g) Correlation of soil factors. From a general review of the data, it may be assumed that low pH, high "lime requirement" low exchangeable calcium and high organic content are fairly closely related.

III. Meteorological Data.

The years have been divided up into seasonal periods to correspond roughly with physiological processes of the plant and farm operations generally.

The more important data considered are rainfall on a seasonal basis and rain days per seasonal period; temperature, (maximum and minimum) the mean readings in degrees Fahrenheit for the four seasons being given for each centre; and sunshine (at one centre only), consisting of the mean number of sun hours /

hours per day for each seasonal period.

IV. Management.

No detailed consideration of management factors has been made but a sequence list of the more important conditions influencing pasture establishment has been compiled and the necessary attention to these emphasised.

V. Other Factors. The number of conditions influencing pasture establishment and management are very numerous and at once characterise any such problem as extremely complex. A supplementary factor of great importance isthe production of nitrates and the conditions influencing such. The general conclusion is that nitrification is at its maximum in the early part of a period following conditions which have been unfavourable to general active life in the soil. It is thought that this might account, for example, to a certain extent, for the alternate luxuriance and depression of certain herbage. The fact is established that there are two periods of maximum nitrate production per annum and two minima, the former occurring in early spring (March) and early autumn (September), the latter at the end of the summer period (August) and at the end of the winter period (February). Certain workers hold that the nitrate fluctuations are consequent upon weather fluctuations, others produce figures to show there is no necessary relationship. These observations are of outstanding importance in view of the seasonal fluctuations of herbage yields.

4. RESULTS and DISCUSSION.

The subject matter of this section is arranged under the following heads :-

I. Botanical Composition.

Behaviour of ingredients of the mixture throughout the period November 1928 to April 1931 and the relation between results and factors already studied.

II. Dry Matter Estimations.

A. Hay - June-July 1929.

B. Aftermath - September 1929.

C. Hay - July 1930.

D. Aftermath - September 1930.

E. Pasture Separations - December 1929 to October-November 1930.

I. BOTANICAL COMPOSITION.

The Behaviour of the Individual Constituents throughout the Period Autumn 1928 to April 1931.

Seedling Establishment. Results obtained on the percentage establishment of the common herbage plants have been reported on by Davies (10). "Under normal conditions only a proportion of the viable seed sown is successful in the production of seedlings as found in the autumn of the year of sowing." The casualties between the seeding and the first harvest year, i.e. in overwintering during the first winter, have also been shown to be great; and experiments have also been conducted to indicate the loss in seedlings during the period immediately after sowing (11).

The /

The results, as will be shen from the following Tables, are not conclusive, in this respect, but this may be due to a number of causes such as the error in sowing which is difficult to reduce under practical conditions, the mixing of the seeds, the velocity of the wind at time of sowing, the state of the soil in relation to tilth. A considerable proportion of the figures indicate however the tendency to mortality between the actual seeding date and the autumn of the first year. Accordingly, the autumn of 1928 has been taken as the zero point from which counts have been carried out and comparisons made.

Perennial Rye Grass.

Table VI. has been compiled to indicate the behaviour of Perennial Rye Grass throughout the course of the investigation on the limed and unlimed sections.

The percentage contribution of this grass to the herbage in the autumn of the seeding year, before any lime had been applied, varied from 28.7 per cent in Plot D. to 47.9 per cent in Plot F. This range is roughly one quarter to one half of the herbage in the respective plots. At the outset, this means, particularly in Plot F, that competition must play a very big part in subsequent periods or that the mortality in seedlings will level up things.

TABLE VI /

TABLE VI.

TABLE VI. Percentage contribution of Perennial Rye Grass to the herbage on all plots.

	Oct-Nov. 1928.	April-May 1929.		April 1930.	
Plot.	Untreated.	Limed.	Unlimed.	Limed.	Unlimed.
A.	43.29	42.22	32.50	39.60	44.40
B.	30.97	19.18	47.86	31.34	33.62
C.	29.80	14.00	30.30	25.50	36.30
D.	28.70	30.50	28.60	32.10	22.00
E.	33.60	20.60	17.00	23.50	34.00
F.	47.90	38.90	31.80	41.00	47.00
G.	34.50	23.00	31.00	35.50	28.50
Average	35.53	26.91	31.29	32.65	35.11

After a winter period of approximately four months, there was indicated considerable mortality in several of the plots. On the limed section of Plot B. the proportion was 19.18 per cent, whereas on the unlimed section the percentage was 47.86. The same observation may be made with regard to Plots C. and G. On the average, however, there was a slight loss of seedlings between the autumn of seedling establishment and the first spring and there was little difference between the limed and unlimed sections. In the spring of the second harvest year, the percentage contribution on the limed section had improved. On the average, the limed and unlimed sections were the same.

From an examination of the plots in the autumn of 1930, it was found that on Plot A. the percentages were 58 (limed) and 60 (unlimed), on Plot D. 54.5 (limed) and 30 (unlimed),

Plot /

Plot G. 38 (limed) and 21 (unlimed). On the other plots the percentages on both limed and unlimed sections were approximately 30.

The two Plots D. and G. were interesting because these showed a relatively low pH, high "lime requirement" and high loss on ignition. Plot D. was classed as a peaty soil and G. as a black loam, peaty in appearance. In both cases, the percentage of Perennial Rye Grass was considerably greater on the limed than on the unlimed plot. By the spring of 1931, however, Perennial Rye Grass had become much reduced on Plot D. and slightly reduced on Plot G. the percentages respectively being 15 (limed), 10 (unlimed) and 20 (limed, 15 (unlimed).

On Plot F. Perennial Rye Grass, in the spring of 1931, had become reduced to 20% (limed) and 15% (unlimed). On the other plots, this grass had remained more or less constant.

In an adverse environment, this constituent tends to decrease and where constituents are present which are adapted to the unfavourable conditions, competition will add to the rate of decrease.

Italian Rye Grass.

Table VIII indicates the history of Italian Rye Grass. The percentage contribution in the autumn of the seeding year varies from 12.26 per cent on Plot B. to 23.8 per cent on Plot E.

TABLE /

TABLE VII. TABLE VII. Percentage contribution of Italian Rye Grass to the herbage on all plots.

	Oct-Nov. 1928.	April-May 1929.		April 1930.	
Plot.	Untreated.	Limed.	Unlimed.	Limed.	Unlimed.
A.	15.29	6.70	13.75	0.76	-
B.	12.26	15.75	11.56	3.74	4.42
C.	17.70	28.60	11.30	2.20	1.30
D.	18.60	7.90	12.00	-	-
E.	23.80	12.90	20.50	1.7	3.3
F.	11.30	14.00	19.60	2.8	1.5
G.	12.70	12.30	10.40	1.6	0.7
Average	15.95	14.00	14.16	1.83	1.60

During the first winter there was a considerable mortality amongst seedlings in Plots A. (limed) D. (limed and unlimed) and E. (limed). The figures for limed and unlimed sections are inconclusive and if averaged indicate no difference between the sections. It is interesting, however, to note that the contribution of Italian Rye Grass in the spring of 1930 was directly proportional to soil type and fertility. Plots B. C. E. and F. may be taken as normally fertile soils with Plot B. the most fertile of the group (medium loam) with a high pH (6.57) and a low "lime requirement" (0.068). The other Plots A. D. and G. possessed certain outstanding characters, such as low pH, high loss on ignition and difference in mechanical analysis, and on these Italian Rye Grass had disappeared by the spring of 1930. Evidently, when the acidity and lime characteristics along with physical characteristics become /

become cumulative in their effects, the life history of this grass is considerably shortened. Considerable traces were found during the autumn of 1930 in Plots B. C. E. and F. but none was found in Plots A. D. and G. No definite superiority on the part of the limed section was observed.

Cocksfoot.

Table VIII. details the percentage contribution of Cocksfoot to the herbage on limed and unlimed sections of the various plots.

TABLE VIII.

TABLE VIII. Percentage contribution of Cocksfoot to the herbage on all plots.

	Oct-Nov. 1928.	April-May 1929.		April 1930.	
Plot.	Untreated.	Limed.	Unlimed.	Limed.	Unlimed.
A.	11.76	12.88	13.75	32.82	19.50
B.	29.31	16.44	15.60	29.10	25.66
C.	16.30	7.30	5.00	7.10	11.10
D.	11.90	11.00	10.60	7.68	15.30
E.	1.50	6.50	6.80	4.30	6.60
F.	12.20	17.00	15.90	14.10	6.10
G.	17.80	13.20	18.60	9.70	21.80
Average	14.4	12.0	12.3	14.9	15.2

The most outstanding result was the contribution of Cocksfcot on plots A. and B.- the former an outstandingly light, dry soil type and the latter a medium fertile type. In the case of Plot A. the limed section was very superior to/

to the unlimed, whereas on Plot B. there was little difference. In these plots it will be observed that this constituent reached its best contribution in the second harvest year. On examination in April 1931, it was found that Cocksfoot had held its place on these plots. The behaviour of this constituent varied on the other plots. On Plot C, a heavy soil type, the contribution was relatively low, considerable mortality occurring between November 1928 and the spring of 1929. From the latter period onwards there was a fluctuation on the unlimed plot but on the limed plot the quantity was fairly constant. On Plot D, a peaty type, there was a gradual decrease in the quantity and an analysis during April 1931 revealed only a trace. On Plot E. the contribution was low and the 1931 analysis showed that Cocksfoot had done poorly up to this date. On Plot F. the quantity was fairly constant throughout the period and the spring 1931 analysis gave 10% on the limed section and 5% on the unlimed. Analysis of Plot G. in April 1931 showed a contribution of 20% on the limed section and 15% on the unlimed.

Timothy.

This species (Table IX) gave good results on two of the heavy soil types, namely Plots E. and F, and particularly on the limed sections. On these plots there was a gradual improvement onwards from the seeding year and on analysis during April 1931 revealed the fact that Timothy held its position (Plot E. 15% (limed) 12% (unlimed), Plot F. 10% (limed) 5% unlimed.) On Plot D. Timothy failed probably on account of the excessive /

excessive competition of the quicker growing species. On Plot C, which is heavy, the result was inconclusive, but in this case also there have been many seemingly negative results. An analysis of Plot C. in spring 1931 revealed 10% Timothy on the limed section and about the same percentage on the unlimed part. Timothy has shown a constancy on Plot G. but an analysis in April 1931 showed a considerable diminution in both sections. On Plot A. Timothy revealed more or less normal development but in the spring of 1931 no trace of the species was found. Plot B. demonstrated a moderately even distribution and in April 1931 there was practically no difference between the two sections, there existing 15% on the limed and 13% on the unlimed sections.

TABLE IX.

TABLE IX. Percentage contribution of Timothy to the herbage on all plots.

	Oct-Nov. 1928.	April-May 1929.		April 1930.	
Plot.	Untreated.	Limed.	Unlimed.	Limed.	Unlimed.
A.	7.30	10.82	7.50	6.89	7.00
B.	4.02	12.33	1.10	11.93	13.27
C.	5.30	6.60	6.30	1.10	5.00
D.	0.30	0.60	5.30	-	1.90
E.	3.90	4.50	5.70	16.60	7.70
F.	6.20	4.80	4.70	10.60	5.30
G.	13.50	11.30	11.40	8.90	14.30
Average	5.8	7.3	6.0	8.0	7.7

Rough /

Rough Stalked Meadow Grass.

This constituent (Table X.) has proved to be characteristically dominant on the heavy and peaty soil types. On Plots C. and E. the grass started off very slowly but had established itself by spring 1929 and still further improved its position by spring 1930. During April 1931, it was still very aggressive on these heavy soils. The limed section shows a superiority over the unlimed section. The same remarks apply to Plot D. (peaty type) with the exception of the superiority of the limed section. Plots B. and G. have shown a much lower contribution to the herbage due to the greater competition on the part of the other members. There has been steady improvement on Plot G. (peaty) with retrogression on Plot B. (medium loam). Plot F. (heavy) has hot revealed the same results as Plots C. and E.

TABLE X.

TABLE X. Percentage contribution of Rough Stalked Meadow Grass to the herbage on all Plots.

	Oct-Nov. 1928.	April-May 1929.		April 1930.	
Plot.	Untreated.	Limed.	Unlimed.	Limed.	Unlimed.
A.	4.23	11.85	20.62	2.29	13.0
B.	9.00	24.00	18.48	10.44	11.5
C.	4.90	25.70	35.3	38.0	23.7
D.	2.2	14.6	9.8	37.5	57.0
E.	1.9	27.0	22.8	34.7	26.4
F.	1.2	6.1	7.9	11.2	4.6
G.	0.6	3.5	1.6	12.1	10.6
Average	3.4	16.1	16.6	20.9	20.9

Clovers /

Clovers.

Table XI. suggests the following conclusions:-

(1) Percentage establishment, as represented by Clovers present in the young grass during October-November 1928, varied considerably, the lowest establishment occurring on the light soil type. The high establishment on Plot D. can only be accounted for by bad sowing. The average establishment worked out at 18.7 per cent.

(2) Mortality over the first winter, as indicated by the Clovers present in the stand during April-May 1929, was greatest on the heavy soils (Plots E. and F.) and on all plots there was a greater proportion of clover plants in the limed than in the unlimed sections. On Plot A. the difference between the limed and unlimed sections was great, on Plot B. it was about the same, on Plots D.E.F. there was little difference, on Plots C. and G. it was medium.

(3) Change in the Clover contribution, as indicated by the percentage in the herbage during April 1930, was quite conclusive. On the plots with lowest pH values and highest "lime requirement" (Plots A. C. D. F. and G.) there has been a considerable decrease and a very marked difference between the limed and unlimed sections. Of the two kinds of Red Clover, it was Late Flowering Red that remained in the herbage until well into the second harvest year. Alsike disappeared rapidly from Plot A, was dominated in Plot B. by the Red Clovers, was well represented in Plots C. and F. and was present in largest quantity in Plots D. and G. By the spring /

spring of 1930, it had practically disappeared from Plot E.

As regards Wild White Clover, an indication as to its contribution to the herbage can best be given by considering the percentage in the final analysis in April 1931. On the limed sections of Plots A. E. F. and G. it contributed approximately one third to the herbage; on the unlimed section of Plot A. about one fifth, on Plot E. it was not well developed, on Plot F. about two thirds and on Plot G. about one half. On both sections of Plot B. the percentage was approximately 20. The unlimed section of Plot C. revealed a 20% contribution and the limed section 10%. On both sections of Plot D. there was only a trace.

(4) With regard to clover cover as indicating the extent of development of the plants and density in all cases the limed sections were superior to the unlimed sections, particularly on Plots A. D. E. and F.

TABLE XI. /

TABLE XI.

TABLE XI. Percentage contribution of Clovers to herbage on all plots; and percentage Clover Cover.

Plot.	Oct-Nov.1928. Untreated.	April-May 1929. Limed.	April-May 1929. Unlimed.	April 1930. Limed.	April 1930. Unlimed.	Autumn 1930. Limed.	Autumn 1930. Unlimed.
A.	9.17	10.81	3.74	5.33	0	-	-
Cover.	4.6	3.7	0.9	14.8	0	26	3.7
B.	13.7	11.66	4.61	10.44	7.08	-	-
Cover.	23	27.7	7.4	33	9.3	28.5	11.1
C.	18.7	15.0	11.8	12.5	5.2	-	-
Cover.	17.6	17.6	11.1	22.3	12.5	8.6	4.6
D.	36.5	32.3	32.2	14.2	3.8	-	-
Cover.	69	58	36	12.5	4.2	2.8	0.9
E.	20.1	15.6	13.6	14.0	6.6	-	-
Cover.	9.7	50.3	28.5	18.5	3.7	15.7	4.6
F.	20.6	14.9	13.6	9.1	6.0	-	-
Cover.	9.7	42.5	22.2	26.8	12.0	4.8	1.6
G.	12.3	18.1	13.5	17.7	11.3	-	-
Cover.	4.1	25	7.4	32.3	18.5	20	15.2
Average Contribution.	18.7	17.0	13.3	12.0	5.7	-	-
Average Cover.	19.6	32.1	16.2	23.0	8.6	15.2	5.9

Weeds.

The figures for weed contribution are given in Table XII. As the investigation proceeded, the weed percentage generally increased and particularly was this the case on the unlimed sections /

sections. The greatest percentages of weeds occurred in Plot C. where the chief was Couch Grass, in Plots F. and G. where Bent and Yorkshire Fog were rampant and in Plot A. characterised by Rumex sp.

TABLE XII.

TABLE XII. Percentage contribution of Weeds to the herbage on all Plots.

	Oct.-Nov, 1928.	April-May 1929.		April 1930.	
Plot.	Untreated.	Limed.	Unlimed.	Limed.	Unlimed.
A.	8.9	4.6	8.1	12.2	15.2
B.	0.7	0.7	1.1	2.9	4.4
C.	7.3	2.8	-	13.6	17.4
D.	1.8	3.1	1.5	8.5	-
E.	15.2	12.9	13.6	5.2	15.4
F.	0.6	4.3	6.5	11.2	29.5
G.	8.6	18.6	13.5	14.5	12.8
Average	6.1	6.7	6.3	9.7	13.5

Summary of Conclusions based on analysis of April 1931.

The following summary (Table XIII.) is given as indicating the contribution of the various ingredients at the spring period of 1931 and after growth and development under varying conditions over a period of three complete years. The grasses are listed in order of greatest contribution and the plus signs indicate superiority of the particular plot section in the matter of Wild White Clover cover and weeds.

TABLE /

TABLE XIII. TABLE XIII. Summary of Botanical Analysis made during April 1931.

Plot.	Grasses.	Clover Cover. Limed.	Clover Cover. Unlimed.	Weeds. Limed.	Weeds. Unlimed.
A.	Perennial Rye Grass Cocksfoot.	+ +	+	Moss + Rumex +	+ + + + +
B.	Perennial Rye Grass Cocksfoot Timothy Rough Stalked Meadow Grass	+ + + = + + + even		—	—
C.	Perennial Rye Grass Rough Stalked Meadow Grass Cocksfoot Timothy.		+	Couch	+
D.	Rough Stalked Meadow Grass Perennial Rye Grass Cocksfoot.	Trace		Annual Meadow Grass.	
E.	Perennial Rye Grass Cocksfoot Timothy.	+ + even	+	Buttercup.	
F.	Perennial Rye Grass. Rough Stalked Meadow Grass Cocksfoot Timothy.	+	+ +	Agrostis + Holcus +	+ + + +
G.	Perennial Rye Grass Cocksfoot Rough Stalked Meadow Grass Timothy (trace)	+		Agrostis + Holcus +	+ + + +

Tillering./

Tillering.

In discussing the figures given in Table XIV. three points are kept in mind :-

(1) The degree of tillering may be taken as a guide to the density of the various species in the herbage.

(2) Tillering may indicate to what extent the species will contribute to the dry matter estimations.

(3) The degree of stooling out on the part of the grasses will determine the extent of competition set up by each grass type.

When the botanical analyses were made on the various dates, the number of tillers was also counted. In Table XIV. the average number of tillers is given for each grass during autumn 1928 (seeding year), Spring 1929 (first harvest year), Spring and Autumn 1930 (second harvest year) on limed and unlimed sections. The object in view was to ascertain if the particular factors influenced the tillering capacity of the grasses to any significant extent. In view of the statements already made with regard to the relation between the soil factors and competition, the aggressiveness of the species, judged by tillering, may be taken as an index of the response made in the various environments.

TABLE XIV /

TABLE XIV. Tillering capacity of the Grasses (average per plant) of the mixture at four different dates - November 1928 (1), April 1929 (2), April and November 1930 (3 and 4).

Constituent.		A. L.	A. UL.	B. L.	B. UL.	C. L.	C. UL.	D. L.	D. UL.	E. L.	E. UL.	F. L.	F. UL.	G. L.	G. UL.
Perennial Rye Grass.	1.	-	1.7	-	2.2	-	1.7	-	1.6	-	2.7	-	1.5	-	5.0
	2.	3.1	3.6	4.8	2.1	4.5	4.0	2.8	4.3	3.6	5.2	1.8	1.3	5.4	4.3
	3.	2.4	2.7	3.0	3.5	3.4	4.5	6.2	5.5	2.8	3.6	3.2	1.5	3.8	3.0
	4.	2.2	2.7	2.7	2.8	3.9	5.3	8.2	6.0	3.0	4.0	4.2	4.3	2.6	3.0
Italian Rye Grass.	1.	-	2.2	-	3.6	-	3.8	-	3.7	-	3.8	-	2.2	-	5.0
	2.	2.3	2.8	3.0	2.0	3.2	3.8	4.0	4.7	2.8	5.1	2.0	2.9	5.4	6.3
	3.	1.0	-	1.8	3.4	2.7	4.0	-	-	2.5	2.3	3.5	2.0	2.0	2.0
	4.	-	-	-	-	2.0	-	-	-	-	2.0	1.0	-	-	-
Cocksfoot.	1.	-	1.0	-	1.1	-	1.1	-	1.0	-	1.0	-	1.0	-	1.1
	2.	1.1	1.7	2.0	1.1	1.0	1.7	1.5	2.0	1.0	1.0	1.0	1.0	1.3	1.1
	3.	1.8	2.3	3.0	3.6	3.1	3.4	8.7	7.8	5.2	3.0	1.8	1.1	2.2	5.2
	4.	2.5	2.0	3.1	3.1	3.3	3.2	6.8	4.0	3.0	5.0	1.7	2.1	2.1	3.0
Timothy.	1.	-	1.9	-	1.7	-	2.0	-	1.0	-	2.0	-	1.2	-	1.3
	2.	1.7	2.2	2.1	1.5	2.0	2.1	1.0	1.0	1.4	1.0	1.3	1.3	1.4	1.4
	3.	2.3	2.3	2 .2	2.6	2.0	2.5	-	1.8	2.6	4.1	2.6	2.5	2.3	2.5
	4.	2.0	2.1	2.4	2.3	2.6	2.6	4.0	-	3.1	3.3	2.7	2.5	2.3	2.2
Rough Stalked Meadow Grass.	1.	-	2.0	-	2.4	-	1.1	-	2.1	-	1.1	-	1.2	-	1.5
	2.	2.0	1.9	2.9	2.1	2.6	3.8	3.4	4.5	2.7	2.5	1.5	1.6	3.3	2.0
	3.	2.0	1.4	2.7	2.3	4.6	3.6	3.2	5.3	Numerous		1.4	3.1	2.6	2.2
	4.	2.5	3.2	2.6	2.8	2.9	Numerous	Numerous		Numerous		3.8	3.5	3.7	2.0

L. = limed and UL. = unlimed section.

Perennial Rye Grass.

During the autumn of the seeding year this grass tillered best on Plots B. E. and G. It reached its maximum tillering during the spring of the first harvest year when monthly cutting commenced and during the period up to November 1930, tillering generally decreased, except on Plot D, where there was a decided increase in the average number of tillers per plant. This was probably due to the decrease in the percentage of other constituents and therefore a decrease in competition. No conclusive difference could be observed between the limed and unlimed sections.

Italian Rye Grass.

This constituent showed a greater tillering capacity, under the conditions, during the first year. It reached its maximum tillering during the spring of the first year and remained on Plots C. E. and F. until November 1930.

Cocksfoot.

Cocksfoot was slow in establishing itself and tillering increased up to the spring of the second harvest year after which, as monthly cutting proceeded, there was generally a slight depression in stooling out. There was no significant difference between the limed and unlimed sections and tillering on the various plots was fairly even.

Timothy.

This ingredient was also slow in developing tillers and the /

the principle of increase and influence of the monthly cuts seemed to be the same as those in the case of Cocksfoot.

Rough Stalked Meadow Grass.

Tillering in this case was consistently the same throughout the plots, with the exception of Plots C. E. and F. (heavy soil types) and Plots D. and G. (Peaty soil types) in which cases, in November 1930, tillering may be described as profuse.

In a full interpretation of tillering, it is necessary to study Table XIII. along with Table XIV. Whether a sole of grass and clover is good or bad in relation to the species sown must be judged by the percentage contribution of each species to the herbage and the degree of tillering of the individual species. For example, in Plot D. (Table XIII.) the herbage consisted almost entirely of Rough Stalked Meadow Grass, tillering profusely (Table XIV.) along with a much smaller quantity of Perennial Rye Grass and Cocksfoot, both of which also tillered well. Again, on Plot B. Perennial Rye Grass, Cocksfoot, Timothy and Rough Stalked Meadow Grass all contributed evenly to the herbage (Table XIII.) and tillered consistently (Table XIV.) producing along with Wild White Clover an ideal, close herbage type with no undue competition, no blanks and consequently a minimum of weeds. The other swards can be characterised in the same way.

II. DRY MATTER ESTIMATIONS.

A. HAY. June-July 1929. (First harvest year - App. p.148).

(1) Total dyy matter on limed and unlimed sections.

On Plots B. and E. there was a difference in total dry matter yield in favour of the limed section. It will be observed that these plots have the highest pH and lowest "lime requirement" figures in the plot series. Plot G. also showed a difference in favour of the limed section. The other plots gave a negative result. The yields varied from 178.2 gms. on the limed section of Plot A. to 531.0 gms, on the limed section of Plot D.

(2) Contribution of the species, on a percentage basis.

In Table XV. the percentage contribution, of the separate grass constituents, the clovers and weeds to the hay cut, is given for limed and unlimed sections of each plot.

Perennial Rye Grass made its greatest contribution to the first year's hay on Plot A. to the extent of 67.8% on the limed section and 61.6% on the unlimed section, this grass forming approximately two thirds of the hay yield. Plot G. also demonstrated a high contribution. On these plots it will be found that the clovers contributed least to the hay. Observations made with regard to the other plots lead to the conclusion that the contribution of Perennial Rye Grass was inversely proportional to the clover contribution. The differences between the limed and unlimed /

TABLE XV. Percentage contribution of the Ingredients to the Hay (first year) on all plots.

L = limed and UL = unlimed sections: Hay cut during June-July 1929.

	A.		B.		C.		D.		E.		F.		G.	
	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.
Perennial Rye Grass.	67.8	61.6	32.2	42.9	21.6	35.0	37.7	41.3	32.4	36.1	34.4	32.3	58.1	44.5
Italian Rye Grass.	11.90	14.6	17.0	18.9	36.9	41.0	14.2	14.9	13.9	15.3	12.5	11.5	18.7	20.5
Cocksfoot.	4.20	1.6	3.1	3.9	0.2	0.2	1.2	1.1	0.5	0.3	1.1	0.7	1.5	1.8
Timothy.	1.6	1.1	2.4	1.7	7.0	2.6	0.8	0.6	6.0	5.3	0.9	0.8	3.5	2.9
Rough Stalked Meadow Grass.	2.4	1.8	5.3	5.9	5.9	9.4	1.8	1.6	2.7	4.9	0.2	0.1	1.2	1.1
Clovers.	1.3	0.5	37.1	25.8	26.0	11.2	43.8	38.8	44.2	37.3	50.1	53.4	9.5	10.4
Weeds.	10.8	18.8	2.9	0.9	2.4	0.6	0.5	1.6	0.3	0.8	0.8	1.2	7.5	18.8

unlimed sections were not significant or consistent.

Italian Rye Grass showed a considerable variation in contribution, reaching its highest percentage on Plot C. (36.9 and 41.0) and its lowest on Plot A. (11.9 and 14.6). On the limed section of Plot C, however, the contributions of Perennial Rye Grass and Clovers were relatively low and moderate, respectively. Consequent on a general study of this constituent on the various plots, the following conclusion may be drawn, namely, that where the clovers have negatively influenced the development of Perennial Rye Grass, Italian Rye Grass has to a certain extent compensated,and where the Perennial Rye Grass bulked largely in the hay, Italian Rye Grass was somewhat depressed. There was no significant difference between the limed and unlimed sections.

Cocksfoot contributed little to the hay in the first year, but it is interesting to note that the greatest amounts were found in the limed section of Plot A. and the unlimed section of Plot B.

Although Timothy also contributed little to the hay, the greatest quantities were found in the hay from the limed sections of Plots C. and E.

Rough Stalked Meadow Grass made its greatest contributions on Plots C. B. and E.

The Clovers have already been discussed in relation to Perennial and Italian Rye Grass. They contributed least to the hay on Plot A. and most on Plot D. In all cases,except Plots /

Plots F. and G. the limed section was better than the unlimed

As far as Weeds are concerned, these appeared to the greatest extent in the hay of the sections of Plot A. and consisted of Bromus, Holcus, Agrostis and Polygonum species, and on Plot G. consisting of the same species along with a little Sweet Vernal and Tall Oat Grasses. Clovers were low in these plots. Small amounts of weeds were identified in Plots D. (Bromus, Holcus, Equisetum) E. (Holcus, Ranunculus) and F. (Holcus, Agrostis, Bromus). The weeds on Plot B. consisted mainly of Brome grass, Yorkshire Fog, Chickweed and Thistles. The weed contribution was indirectly proportional to the amount of clover in the various hay lots. The superiority of weeds on the limed and unlimed sections generally varied according to the amount of clover and Perennial Rye Grass contributed.

B. AFTERMATH. September 1929 (First harvest Year - App. p.149).

Table XVI. has been compiled in a similar way to the previous one and indicates the aftermath hay contributions. A number of outstanding observations may be made :-

(1) Perennial Rye Grass did not recover to the same remarkable extent as Italian Rye Grass. The lowest contributions of each were found on Plot B. and Plot F. in which plots the clovers contributed considerable amounts to the second crop hay.

(2) Cocksfoot showed distinct signs of recovery but did not contribute to the aftermath to any considerable extent.

(3) /

TABLE XVI. Percentage contribution of the Ingredients to the Aftermath (first year) on all plots.

L = limed and UL = unlimed sections: Aftermath cut for Hay during September 1929.

	A.		B.		C.		D.		E.		F.		G.	
	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.
Perennial Rye Grass.	95.9	97.9	0.8	2.0	5.8	9.0	11.3	11.6	39.7	13.7	0.7	0.7	1.0	1.7
Italian Rye Grass.			3.6	5.8	18.2	24.6	39.0	27.1			4.5	5.5	12.1	11.7
Cocksfoot.			3.9	6.4	1.2	1.9	6.6	8.3		2.7	0.9	1.0	5.2	4.0
Timothy.			0	0	0.5	0.8	0.6	0	0	0	0	0	1.2	0.4
Rough Stalked Meadow Grass.			0	0	0	0	0	0	0	0	0	0	0	0
Clovers.	3.8	1.8	91.5	85.8	72.0	61.0	42.5	53.0	60.3	80.5	93.9	92.7	79.2	77.0
Weeds.	0.3	0.3	0.2	0	2.3	2.7	0	0	0	0.2	0	0.1	1.3	5.2

(3) Timothy and Rough Stalked Meadow Grass did not appear in the hay; Timothy, at least to the extent of only a trace.

(4) Clovers generally were rampant and contributed in an exceptional degree to Plots B. E. F. G. C. On Plots A. B. and C. the limed section was superior to the unlimed, on Plots F. and G. there was no difference and on Plot E. there was a negative result.

(5) Weeds were dominated and had suffered from the first cutting and clover competition.

(6) Grasses which established themselves slowly like Timothy and Rough Stalked Meadow Grass have been dominated in the second hay crop by the quickly growing Red Clovers, particularly Broad-Leaved Red Clover. The clovers have also had an influence on Perennial Rye Grass and less effect upon the quickly growing Italian Rye Grass.

(7) Liming showed its greatest influence upon the clover constituents.

(8) Clovers contributed a much greater amount of dry matter to the second hay crop than they did to the first hay crop.

(9) The reason for the above results seems to turn upon the influence of lime upon the soilreaction and "lime requirement" and this influence was more marked upon certain plots of a specific soil type.

(10) In this connection, the influence of soil microorganisms on herbage growth may be significant. The problem of the inter /

inter-relation of weather conditions and dry matter yield or dry matter yield and the action of bacteria is dealt with, in greater detail, in another section of this paper.

(11) On examining the appropriate Table in the appendix (p.149) it will be observed that on all plots, except D. and E, the total dry matter was greater on the limed section.

(12) The weeds consisted mainly of grass weeds, the other types being much less evident and having suffered from cutting and competition.

C. H A Y. July 1930. (Second harvest year - App. p. 150).

(1) Total dry matter on limed and unlimed sections.

On Plots A. D. and E. the limed sections produced a bigger hay crop than the unlimed, on Plot B. the sections were equal and on Plots C. F. and G. the unlimed sections produced more dry matter than the limed, but on Plots F. and G. not to any significant extent. On Plots A. B. C. and D. (both sections) the total dry matter yield was greater in the second than in the first harvest year, whereas on the other plots it was less, except on the unlimed section of Plot G. (second harvest year).

(2) Contribution of the species on a percentage basis.

In Table XVII. the percentage contribution, of the separate grass constituents, the clovers and weeds, to the second year's hay, is given for limed and unlimed sections of all plots.

The hay in the second year is mainly composed of Perennial Rye /

TABLE XVII. Percentage contribution of the Ingredients to the Hay (second year) on all plots.

L = limed and UL = unlimed sections: Hay cut during July 1930.

	A.		B.		C.		D.		E.		F.		G.	
	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.
Perennial Rye Grass.	50.2	56.7	19.6	26.3	42.3	41.2	45.0	48.5	46.7	53.5	36.5	32.5	21.5	19.2
Italian Rye Grass.	0	0	2.3	1.8	0	0	0	0	1.5	0.5	0	0	1.5	0.4
Cocksfoot.	17.2	14.6	14.4	18.4	12.6	11.8	29.0	32.5	4.8	2.9	4.6	1.7	7.7	5.8
Timothy.	1.8	0.5	4.4	4.6	11.3	11.1	4.3	4.9	16.8	12.8	8.8	3.4	10.1	3.9
Rough Stalked Meadow Grass.	1.1	0.2	3.3	2.0	11.2	4.9	16.7	8.8	3.6	3.2	4.4	0.1	4.0	1.8
Clovers.	22.0	18.3	55.8	46.9	22.6	30.3	4.4	5.3	24.3	25.2	41.5	52.1	40.4	60.5
Weeds.	7.7	9.7	0.2	0	0	0.7	0.6	0	2.3	1.9	4.2	10.2	14.8	8.4

Rye Grass, Cocksfoot, a little Timothy and Rough Stalked Meadow Grass and Red Clover. In this case, as in the first year's hay, the contribution of Perennial Rye Grass was in inverse proportion to the clover. In Plot D. the clovers were in very small quantity and Perennial Rye Grass made up approximately one half of the hay. On Plot B. the clovers contributed approximately one half to the hay, and Perennial Rye Grass one fifth (limed section) and one quarter (unlimed section).

Italian Rye Grass had practically disappeared.

Cocksfoot contributed most on Plots A. B. and D.

Timothy did best on the heavier soil types, i.e. on Plots C. E. and F. and on the peaty loam Plot G. (limed).

Rough Stalked Meadow Grass produced best on Plot D. (peaty) and Plot C. (heavy).

In some of the plots the clovers produced better on the limed section, in some they were equal on limed and unlimed sections and on others the unlimed section produced a greater weight.

Weeds have been considerably suppressed and consisted mainly of grass weeds (Bromus, Holcus and Agrostis) with Rumex evident, particularly on Plot A.

D. AFTERMATH. September 1930. (Second harvest year - App. p.151).

Table XVIII. summarises the percentage contribution of grasses and clovers to the second hay crop of the second harvest year/

year. The clovers generally contributed a greater proportion to the dry matter than in the case of the first 1930 hay cut.

ABLE XVIII. TABLE XVIII. Percentage contribution of Grasses, Clovers and Weeds to the Aftermath (2nd year) on all Plots.

L. = limed and UL. = unlimed sections.

Aftermath cut for hay during September 1930.

	A.		B.		C.		D.		E.		F.		G.	
	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.	L.	UL.
rasses.	64.1	62.8	36.5	70.3	78.0	71.0	90.0	82.0	41.3	33.5	43.3	32.2	29.3	40.7
lovers.	35.0	36.0	63.5	29.7	22.0	29.0	10.0	18.0	58.7	66.5	56.7	67.8	70.7	59.3
eeds.	0.9	1.2	0	0	0	0	0	0	0	0	0	0	0	0

Weeds had disappeared. Again, the grasses are inversely proportional to the clovers.

E. PASTURE SEPARATIONS.

The results are summarised and discussed under the following heads :-

(a) Total Yield of Dry Matter on limed and unlimed at all centres.

(b) Analysis of the Dry Matter Yields.

i. Total dry matter yield of grass, clover and weed groups on all plots.

ii. Seasonal fluctuations in yield of dry matter of grass, clover and weed groups.

iii. Contribution of each group, on a percentage basis, to the dry matter at each separation, on all plots.

(c) /

(c) Relation between the Factors and Results.

(a) Total Dry Matter Yields.

In Table XIX. the total dry matter yields, on limed and unlimed plots, at all centres from December 1929 to November 1930, are indicated. Differences in yield, in favour of the limed plot existed at five centres and showed a range from 23.4 gms. to 69.5 gms. On Plot B. (Anchordales) and Plot C. (Crofts Garden) there were differences of 25.8 gms. and 156.5 gms. respectively, in favour of the unlimed plot.

(b) Analysis of the Dry Matter Yields.

i. Total dry matter yield of grass, clover and weed groups on all plots.

Table XIX. indicates the total yield of dry matter for the period November 1929 to December 1930 in respect of grasses, clovers and weeds on limed and unlimed plots. The total yield of grasses was greater on the limed plots in all cases, except Plot C. where there was a difference of 52.3 gms. in favour of the unlimed plot, and Plot B. where the yields were equal. On the other plots the differences in favour of the limed section ranged from 24.1 gms. to 63.4 gms.

As regards Clovers, differences in favour of the limed section existed on Plots A. D. E. and G. varying from 2.4 gms. to 15.9 gms. whereas on Plots B. C. and F. the differences in favour of the unlimed section ranged from 22.9 gms. to 106.7 gms.

Weeds on the limed section of Plots A. B. C. F. were greater in yield than those of the unlimed section, on Plots D. and /

and G. the yields were equal and on Plot E. weeds on the unlimed section were double those on the limed part.

ABLE XIX.

TABLE XIX. Dry Matter Yields in gms. of Grasses, Clovers and Weeds for period November 1929 to December 1930. (second harvest year).

	GRASSES.		CLOVERS.		WEEDS.		TOTAL.	
Plot.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.	Limed.	Unlimed.
A.	202.1	138.7	14.3	11.9	10.8	7.1	227.2	157.7
B.	281.8	281.1	119.6	148.4	2.3	-	403.7	429.5
C.	260.6	312.9	54.5	161.2	2.9	0.4	318.0	474.5
D.	418.6	364.5	24.3	13.6	0.1	1.2	443.0	379.3
E.	142.8	115.6	29.0	26.4	5.6	12.0	177.4	154.0
F.	324.9	266.9	59.5	82.4	1.9	0.7	386.3	350.0
G.	103.9	79.8	66.5	50.6	12.2	13.0	182.6	143.4

ii. Seasonal fluctuations in yield of dry matter of grass, clover and weed groups.

A summary of the seasonal changes in respect of total yield of dry matter on both limed and unlimed sections of all plots is recorded in Table XX. In discussing these figures, the following points must be noted:-

The first or zero clip (December 1929) was made approximately three months after the whole plot had been cut over, i.e. at the time of making the aftermath determination in the first harvest year, so that the December pasture clip was probably higher than it would have been if the pasture plot had been cut during October and November 1929.

The /

TABLE XX. Seasonal fluctuation of Total Dry Matter in gms. from December 1929 to November 1930.

DRY MATTER IN GMS.

	A.	B.	C.	D.	E.	F.	G.	Period.
Limed Section.								
1st Minimum.	8.0	15.0	10.7	27.9	6.3	20.1	6.1	Between December and April.
1st Maximum.	57.3	80.5	66.8	121.7	61.2	90.7	50.5	June.
2nd Minimum.	25.0	53.6	42.3	41.1	19.8	56.5	27.5	August.
2nd Maximum.	34.1	65.8	46.7	53.9	26.6	60.1	29.8	September.
Unlimed Section.								
1st Minimum.	15.0	19.8	8.7	27.2	6.1	17.9	8.6	Between December and April.
1st Maximum.	26.4	94.2	98.4	110.2	51.5	85.6	42.8	June.
2nd Minimum.	17.1	60.2	72.2	30.1	19.6	39.6	21.2	August.
2nd Maximum.	32.0	68.7	75.2	47.7	24.9	57.2	24.4	September.

The second pasture clip (April 1930) was made approximately four months after the December 1929 cut, so that the April dry matter was probably higher than it would have been had the pasture plot been cut during January, February and March 1930.

From the figures recorded in the Table it will be seen that there was a minimum yield, probably sometime between December and April, a maximum yield during June, a second minimum during August and a second maximum during September. These minima and maxima, occurring alternately, were true for all plots and for both limed and unlimed sections. A perusal of the detailed pasture separation tables in the appendix will substantiate this statement. Furthermore, the minima and maxima yields were greater on the limed than on the unlimed sections for all plots, except Plots B. and C.

As regards the constituent groups of the dry matter, it will be concluded from a consideration of the periodical clips that the observations made above also hold good for these groups. A graphical record has been made of the grass and clover groups for the limed and unlimed sections on all plots along with the data referring to reaction, "lime requirement", exchangeable calcium, loss on ignition, mechanical analysis, rainfall and temperature. Those graphs will be found from page 170 to page 176 in the appendix.

iii. Contribution of grasses, clovers and weeds, on a percentage basis, to the dry matter at each periodical cut.

In /

In addition to considering the dry matter from a purely annual standpoint, interesting observations may be made by examining the relation between grasses, clovers and weeds within each separate periodical cut. For purposes of comparison, it is necessary to use some standard system, namely, comparison on a percentage basis. Consequent on an examination of percentage contribution of the grass and clover groups to the periodical dry matter, the observations in Table XXI. are given, these having been arrived at by expressing all dry matter weights as percentages of the total periodical yield :-

ABLE XXI. TABLE XXI. Months of greatest and least contribution of Grasses and Clovers to each periodical cut.

	GRASSES.		CLOVERS.	
	PERIOD of		PERIOD of	
PLOTS.	Greatest Contribution.	Least Contribution	Greatest Contribution.	Least Contribution.
Limed.	May & Oct.	August	September	May & Oct.
Unlimed.	" "	July	July	" "
Limed.	April & Nov.	July	July	April & Nov.
Unlimed	" "	"	"	" "
Limed.	" "	"	"	April & Oct.
Unlimed.	" "	"	"	" "
Limed.	" "	"	"	" "
Unlimed.	" "	"	"	" "
Limed.	April & Oct.	"	"	" "
Unlimed.	" "	"	"	" "
Limed.	" "	"	"	" "
Unlimed.	" "	"	"	" "
Limed.	" "	Augt.	Augt.	" "
Unlimed.	" "	"	"	" "

The /

The two periods of the year during which grasses contributed most to the dry matter were April-May and October-November; the least contribution was made during July-August. The reverse was the case with the clovers, the greatest proportion appearing in July-August-September and the least during April-May and October-November. In both grasses and clovers this occurred irrespective of liming.

As regards weeds, the greatest contribution to the dry matter was made during July and the least during the winter months. The density of grasses and clovers, as indicated by the percentage contribution of each, had a considerable influence upon the weed percentage.

(c) Relation between the Factors and the above Results.

The factors, as have already been noted, group themselves into three main groups, namely, soil, meteorological and bacteriological. Certain relationships have been suggested in the soil data, the soil types have been characterised and the weather conditions discussed. In Table XXII. the main figures have been summarised.

The following notes have been compiled, consequent on a study of Tables XIX. XX. and XXII. and the appropriate data in the appendix:-

Plot A. The total dry matter of the limed section of this plot was considerably greater than that of the unlimed section showing a tendency towards a relationship between acidity and yield. If a closer examination of the plot figures is made,

it /

TABLE XXII. Total Dry Matter in gms. and Factors (soil etc.).
Period December 1929 to October - November 1930.

Plot.	pH	L.R.	Exch. Ca.	Loss on Ignition	Mechanical Analysis. Fr.$_1$	Fr.$_2$	Fr.$_3$	Total Rainfall	Mean Temperature. Max.	Min.	Total Dry Matter. Limed	Unlimed.
A.	5.76	0.188	0.053	7.226	55.42	19.91	15.06	40.38	55.2	39.8	227.2	157.7
B.	6.57	0.068	0.112	6.195	28.50	38.09	24.42	40.38	55.2	39.8	403.7	429.5
C.	5.97	0.110	0.080	5.655	20.78	41.33	29.32	40.38	55.2	39.8	318.0	474.5
D.	5.77	0.376	0.310	23.456	14.43	19.40	36.88	40.38	55.2	39.8	443.0	379.3
E.	6.59	0.094	0.141	10.895	24.59	29.19	31.64	37.28	50.9	38.8	177.4	154.0
F.	5.51	0.251	0.038	7.662	15.78	37.44	36.50	35.18	52.3	39.3	386.3	350.0
G.	5.53	0.313	0.080	11.483	17.90	45.67	22.72	35.18	52.3	39.3	182.6	143.4

Fr.$_1$ = coarse sand. Fr.$_2$ = fine sand + silt. Fr.$_3$ = Fine silt + clay.

it will be seen that the greatest contribution was made by the grasses and that there was a considerable difference in yield, in favour of the limed section. In Table XXII. the factors of the problem are summarised. The grasses which contributed outstandingly to the herbage were Perennial Rye Grass and Cocksfoot. Timothy and Rough Stalked Meadow Grass were dominated. The tendency seems to be that, in a soil type such as this where leaching is excessive and where quickly germinating seeds and rapidly establishing seedlings exist, many factors act together producing an accumulated influence, with the result that the slow germinating seeds and seedling establishment are abnormally influenced to the extent of practically disappearing, in due course, from the herbage. An examination of the plot during April 1931 showed that Perennial Rye Grass, Cocksfoot and Wild White Clover had contributed equally, the two grasses being present to the same extent on both limed and unlimed sections, Wild White Clover being present to a greater degree on the limed plot. The unlimed section was considerably weedier than the limed section and was less luxuriant in growth.

Furthermore, from Table XX. it will be observed that there was a considerably greater difference between the first minimum and maximum on the limed section than on the unlimed section and that there was a much greater quantity of material at the second minimum (August) on the limed than on the unlimed plot. There was little difference in the second maximum, which was probably due to the development of the foreign members of the herbage on the unlimed section.

The /

The tendencies seem therefore to be that the application of ground limestone altered the pH value and lowered the "lime requirement", influenced favourably the mechanical structure of the soil type with a secondary influence on water-holding capacity. The factor complex indicated, in turn produced an altered environment in which competition played an important part. The three dominant constituents already mentioned are all rapidly developing species once they are established and the conditions present in the limed section greatly accelerated their growth, giving the results already detailed.

Plot B. The difference in total dry matter yield of limed and unlimed sections was not significant. This particular plot, more or less all through the investigation, gave equal results on limed and unlimed parts. The yield of grasses was the same on both sections. There was a difference in clovers in favour of the unlimed plot, but this may be partly due to the experimental error in which there are numerous phases in a problem such as this.

The plot was practically neutral in reaction, had a "lime requirement" of only 0.68 ton calcium carbonate per acre, had a relatively good exchangeable calcium value (0.112), had an average mechanical analysis and produced the second highest yield of all the plots.

If the minima and maxima figures are examined in Table XX. it will be seen that there was no very significant difference between the corresponding quantities on limed and unlimed sections.

On /

On examining this plot in April 1931, it was found that all the permanent constituents were well represented and fairly equally distributed,namely, Perennial Rye Grass, Cocksfoot, Timothy, Rough Stalked Meadow Grass and Wild White Clover.

In brief, this plot revealed a more or less optimum environment with a corresponding response on the part of the species of the mixture on both sections.

Plot C. There was a considerable superiority exhibited by the unlimed section all through the pasture period, particularly in the clover group both as regards total yield of dry matter and seasonal fluctuations. In view of the fact that the pH value and exchangeable calcium were relatively low and the "lime requirement" amounted to 1.1 ton calcium carbonate per acre, it is difficult to suggest reliable reasons for the reversal ofthe differences, except that the plot had been badly sown or that the selection of the square yard plots was bad or that the ground limestone applied to a heavy, almost unmanageable soil type had aggravated the already difficult conditions. The yields, however, were high on both limed and unlimed sections compared with the other plots. An examination during April 1931 revealed that all the permanent constituents were present, that Perennial Rye Grass and Rough Stalked Meadow Grass contributed approximately two thirds to the herbage and that Cocksfoot, Timothy and Wild White Clover made up equally the rest of the stand.

Plot /

Plot D. This plot was characterised by a pH value of 5.77, a "lime requirement" of 3.76 tons calcium carbonate per acre, a loss on ignition of 23.456 per cent, and a high fine silt plus clay fraction, all of which are factors of a fairly extreme nature when comparison is made with the other plots. There was a considerable difference, all through the problem, between limed and unlimed sections, the balance being in favour of the limed section. Outstanding characteristics were the lowness of the yield of clovers on both sections, and the fact that the yield of clovers on the limed section was approximately double that on the unlimed section.

The maxima yields on both sections were high as also was the difference between the first minimum and first maximum. The grass that contributed best to the pasture cuts was Rough Stalked Meadow Grass and in fact in April 1931, the herbage of both limed and unlimed sections consisted mainly of this grass, there being only a trace of the other species. In this instance it has proved, pre-eminently, to be a grass suitable for the conditions already detailed. The clovers have practically disappeared from the herbage.

Plot E. This plot was very similar to Plot B. in respect of certain soil factors and behaviour of the constituents. Table XXII. indicates a pH value of 6.59, the highest of the series, a "lime requirement" of approximately a ton of calcium carbonate per acre and exchangeable calcium of 0.141 per cent. The soil type, however, differed from that of Plot B. The difference between /

between the total dry matter yields on limed and unlimed sections was hardly great enough to yield a definite conclusion. as to the influence of lime. The field in which the plot was located was treated with basic slag and also limed during the rotation and this probably accounted for the similarity in behaviour of the two sections right through the investigation. The clovers, which are the most sensitive reactors to the effect of lime, showed the least difference. It may be taken, therefore, that, as in the case of Plot B, Plot E. was very near to the lime adsorption point suitable for optimum herbage development.

More or less the same remarks apply to the problem of minima and maxima seasonal yields as indicated in Table XX, with this qualification that there existed a considerable difference, in favour of the limed plot, between the first maximum in the limed section and the first maximum in the unlimed section.

The two outstanding grasses were Perennial Rye Grass and Rough Stalked Meadow Grass with Timothy moderately represented. Cocksfoot did not do well. Wild White Clover was present in fair quantity. From a botanical analysis of the plot during April 1931 the following figures are given :-

	Limed Section.	Unlimed Section.
Perennial Rye Grass	30%	30
Cocksfoot	5	5
Timothy	10	10
Rough Stalked Meadow Grass.	20	20
Wild White Clover	30	20
Weeds.	5	15

Plot /

Plot F. This plot showed a superiority on the part of the limed section to the extent of 36.3 gms. (Table XIX), a difference of 58 gms. between the grass dry matter yields in favour of the limed plot but a reversal in the clovers of 22.9 gms in favour of the unlimed plot.

The last-mentioned may be due to the experimental error or to the fact of lower density of grasses on the unlimed section having allowed of better clover development.

The pH of this plot was 5.51, the lowest of the series, the "lime requirement" equivalent to 2.5 tons calcium carbonate per acre and exchangeable calcium of 0.038 per cent, all relatively extreme characteristics. The soil type was distinctly heavy.

The grasses which established themselves to the greatest extent were Perennial Rye Grass, Timothy and Rough Stalked Meadow Grass with Cocksfoot in the fourth place. Wild White Clover established itself well on both plots.

As regards seasonal fluctuations, the same principle was demonstrated as in previous plots with regard to minima and maxima seasonal yields of dry matter.

This plot was botanically analysed during April 1931 and revealed the following characteristics :-

	Limed.	Unlimed.
Perennial Rye Grass.	20%	15%
Cocksfoot.	10	5
Timothy.	10	5
Rough Stalked Meadow Grass.	20	15
Wild White Clover.	10	Trace
Weeds.	30	60

In /

In comparison with previous observations, Perennial Rye Grass and Rough Stalked Meadow Grass held their places, but Timothy took a place equal to Cocksfoot. The Wild White Clover revealed only a trace on the unlimed section. The weeds consisted mainly of Bent and Yorkshire Fog. In appearance the limed plot was dark green and healthy in colour whereas the unlimed plot was made up of much dead material and lacked the healthy green colour. Furthermore the limed section carried a better bite than the unlimed.

There existed, too, a striking difference between the sward inside and outside the plot. In the main field, the herbage had more or less completely reverted to the characteristic Bent-Yorkshire Fog condition. The appearance was that of dense dead flower stalks and little green showing except in very local parts where much selective grazing had been done. In such areas the bite was fresh and fairly plentiful.

Again, there existed the cumulative difficulty, low pH and high "lime requirement" along with stocking with sheep only, the result being that the environment in the first place was against the sown species and in favour of the Bent and Yorkshire Fog and in the second place selective grazing encouraged local roughnesses consisting of a Bent-Yorkshire Fog association. These roughnesses spread and the field reverted to the troublesome condition. The carefully treated plot has conclusively demonstrated that such soils require outstanding attention along ~~with~~ the lines of correction of acidity and judicious /

judicious grazing of proper density with mixed stock. Mowing and burning are usually carried out but not until the herbage has reverted.

Plot G. The soil determinations, as in certain other plots, were outstanding, namely, a pH value of 5.53, a "lime requirement" of 3.13 tons calcium carbonate per acre and a very low exchangeable calcium value along with a relatively high loss on ignition.

Generally, the herbage responded well to the application of lime. The total yields of dry matter were low but the plot was located in a field of very low fertility.

The summer maximum was higher on the limed section as also was the autumn minimum and maximum.

On examining the plot during April 1931, the following conclusions were reached :-

	Limed.	Unlimed.	
Perennial Rye Grass.	20%	15%	
Cocksfoot.	20	15	
Timothy	Trace	Trace	
Rough Stalked Meadow Grass	20	15	
Wild White Clover.	10	5	
Weeds.	30	50	Agrostis, Holcus, Prunella, Chickweed, Daisy.

This plot suffered invasion to a considerable extent by both Bent grass and Yorkshire Fog, and what has been noted in connection with Plot F. applies also in this case.

Seasonal /

Seasonal Fluctuations and Environment.

From a study of Table XX. and the Pasture Separation Tables in the Appendix, the following observations are presented :-

(1) Where the pH values and exchangeable calcium were low and the "lime requirement" high, growth in spring started earlier on the limed sections both as regards grasses and clovers and lasted further into the year than the unlimed herbage.

(2) The first maximum yields (June) were generally greater on the limed than on the unlimed sections with the exceptions already noted and there was greater increment between the first minimum and first maximum yields on the limed sections, i.e. between February and June, a period of vital importance to the grazier and flockmaster.

(3) The second minimum yield (August) was generally greater on the limed sections than on the unlimed or in other words the effect of lime at this particular period has been to prevent too great a depression of the yield curve. There was less fluctuation on the limed than on the unlimed section between June and September, i.e. there was a more constant and less diminishing bite on the limed section and the grazing period was pushed further into the autumn-winter period.

(4) There was no significant difference between the second maxima.

To /

To what extent the seasonal fluctuations were caused by the various conditions of the environment is difficult to say, but two factors seem significant. These are -
(a) Weather; and (b) Seasonal fluctuations in nitrification.

As regards weather, Table XXIII. gives rainfall, maximum, minimum and soil (4 ins. 3 p.m.) temperatures immediately preceding and during the minima and maxima dry matter periods. During January and February it is possible that the low temperature may have caused the first minimum. Gradual improvement in water supply along with increased temperatures coincided with gradual herbage increment until the first maximum was reached in June. June was a relatively dry month, July was better, but during this period there was a decrease in herbage yield, the second minimum being reached in August. The greatly increased rainfall during August may have accounted for the second peak in the dry matter during September, increased rainfall in any one month showing its maximum influence during the following month. In order to substantiate the principle, if it exists, the problem would require to be investigated over a considerably long period of years under a replication scheme. Particular attention has been given to this question of seasonal fluctuations, particularly in connection with species and strains by Stapledon and Davies (43), and it has also been suggested that "the seasonal productivity of pastures is affected as much or more by the plants' functional periodicity as by meteorological conditions" (45).

As /

TABLE XXIII.

TABLE XXIII. Seasonal Fluctuations in Dry Matter Yield in relation to weather on Plots A.B.C. and D. from December 1929 to November 1930.

Month.	Rainfall in ins.	TEMPERATURES in °F. Max.	Min.	Soil (4 ins. 3 p.m.)	Dry Matter.
Jany.	3.80	42.4	33.0	36.1	1st minimum
Feby.	0.51	38.6	28.6	-	
May.	3.40	54.7	39.9	56.3	
June.	1.71	63.8	46.9	64.4	1st maximum
July.	3.53	61.5	50.0	62.7	
Augt.	5.17	62.7	50.0	60.8	2nd minimum
Sept.	5.32	58.0	47.5	55.7	2nd maximum

As regards the relation between seasonal fluctuations in nitrate production and dry matter, anything that may be said is highly speculative. The various points, however, may be reviewed. Two points have been established, namely, that two dry matter minima yields occurred during February and August and two maxima yields during June and September; that two maxima periods of nitrate production occur early in April and about the middle of September and two minimum periods during February and August. The June maximum in dry matter seemed somewhat far removed from the April (early) maximum in nitrate production, but it would require to be established at what period the first nitrate maximum occurs for Plots A. B. C. and D. Again, if Limbach /

Limbach is correct in stating that there is no definite relationship between nitrate production and meteorological conditions and if there is a connection between seasonal productivity of herbage and seasonal fluctuations in nitrates, then the whole problem is suggestive and work is required to throw light on the three items of the questions.

A result, in this particular investigation, which tends to favour the nitrate-dry matter interpretation was the general superiority of the limed sections of the plots over the unlimed sections, presumably the lime having favourably influenced nitrate production with a particular effect upon the grasses. No explanation can be found for the fluctuation in nitrate production. As has already been stated, a vast field is opened up, namely, that of the soil microflora and the correlation of soil environment to their activities, seasonal and otherwise. Suggestive results have been recorded by Humfeld and Erdman (23) on the significance of the hydrogen-ion concentration in soil nitrification studies. The addition of calcium carbonate to the plots in their experiments greatly caused an increase in nitrification.

5. SUMMARY and CONCLUSIONS.

A review of the development of grassland science has been made in Part I. of this paper and the following points established :-

The evolution of grassland science may be divided into four distinct phases, namely, the earliest development, grassland practices during the Middle Ages, Modern development and most recent work. It has been indicated that grassland management had its origin under very primitive conditions, that development was extremely slow and that it has always been influenced by external conditions chiefly by practices abroad. The tendency during the Middle Ages was from an extensive towards an intensive system. The establishment of the Norfolk four course rotation and the introduction of clover and turnips marked the beginning of more rapid development. Reference has been made to pastoral practices and manuring and also to cultural operations.

The development in most recent years has been more rapid and vast. It has been convenient to classify the developments according to the nature of the work carried out at the numerous research stations abroad and in this country.

The all important and elaborate investigations carried out at Aberystwyth by Professor Stapledon and his colleagues, at Aberdeen by Dr. Orr and colleagues, and at Cambridge by Dr. Woodman have been referred to, and also the work of numerous other research workers. Foreign investigators, particularly European /

European, have also added a wealth of knowledge to the subject of grassland science. The problem, as a whole, has been approached from the chemical or nutritional point of view and from the ecological or purely botanical standpoint.

It has been suggested that one phase in the ecological study of grassland which has not been worked out is the relationship between establishment and yield and a number of soil factors.

PART II. The various problems investigated and discussed in Part II. of this paper constitute an attempt (1) to work out a suitable technique for use in future work, and (2) to discover if any significant change is produced on temporary grass by altering soil environmental conditions.

GENERAL SCHEME. The objects in view involved determination of soil reaction (pH), "lime requirement", exchangeable calcium, loss on ignition, moisture content and mechanical analysis of soils and their sub-soils on seven plots located in different parts of the Lothians of Scotland. A suitable grass and clover seed mixture was compounded and sown down under varying conditions of climate and practice.

The investigation was spread over a period of three years, from the spring of 1928, when the seeds were sown, until the spring of 1931. The plots were classified into light, medium, heavy and peaty soil/ types and each plot was fenced against vermin, divided into two equal parts, one half being limed up to its "lime requirement", the other half being left untreated. The /

The botanical composition of limed and unlimed sections of all plots was carried out at specified periods, the total annual and seasonal dry matter yields of a selected area on both sections of the plots were recorded on a pasture, and hay and aftermath basis. The hay and aftermath estimations were carried out during the first (1929) and second (1930) harvest years, the pasture determinations being made, monthly, over a complete year (1930). A detailed analysis of each dry matter cut was made and the contribution of groups of plants or individual species discussed in relation to the factors studied.

SUMMARY of RESULTS.

A study of the factors revealed the following :-

The superiority of indigenous types over cultivated types of grass species is now recognised. Nationality in clovers is of great importance and field germination is a truer index of establishment than laboratory germination. The grass and clover seed mixture was taken as the basis of the investigation, forming the constant factor. The ecological characters of the grasses and clovers have been briefly discussed.

SOIL DATA.

As regards soil characteristics it was found that the pH values ranged from 5.51 to 6.59. All the soils were cultivated soils and revealed the characteristic of lower acidity in the sub-layers than in the surface layer.

"Lime requirement" varied from 0.068 per cent or 0.68 ton of calcium carbonate per acre to 0.376 per cent or 3.76 tons of calcium carbonate per acre and from 0.047 to 0.501 per cent in the sub-soils.

Exchangeable calcium varied from 0.038 to 0.310 per cent calcium /

calcium oxide.

Loss on ignition as indicating organic matter ranged from 5.655 to 23.456 per cent in the soils and from 6.040 to 34.407 per cent in the subsoils.

Moisture varied from 1.901 to 5.650 per cent in soils and from 1.539 to 6.931 in the subsoils (air-dry).

A detailed mechanical analysis of soils and subsoils led to a characterisation of the various plots.

A fairly close relationship between pH, "lime requirement", exchangeable calcium and organic matter was shown to exist and this group of factors constituted what might be called the acidity complex.

WEATHER DATA. In compiling the meteorological tables, the years were divided into seasonal periods to correspond as nearly as possible with the physiological processes of the plant.

Rainfall, temperature and sunshine have been discussed.

MANAGEMENT. The chief management factors have been enumerated in sequence and the importance of these emphasised. In the laying down of the seeds mixture at the various centres, there was some variation in the methods.

OTHER FACTORS. The biological factor was of greatest importance amongst many other conditions which might have been investigated.

It has been shown by certain workers that there exist two maxima periods of nitrate production per annum and that approximately the process shows a rapid rise from January to March when the first maximum is reached, followed by a minimum in July-August. A second maximum is reached in August-September. The view /

view is held by Limbach that these fluctuations occur independently of weather.

An examination of the results, along with a knowledge of the factors studied, revealed the following tendencies :-

BOTANICAL ANALYSIS. There existed a considerable mortality in seedlings between the actual date of sowing and the autumn of the first harvest year. Autumn 1928 was taken as the zero point from which botanical counts and comparisons were made.

Botanical analyses of the herbage were carried out at four different dates and on analysing the results of the behaviour of the individual species it was found that Perennial Rye Grass tended, in an adverse environment, to decrease in quantity. The suitability of other species to the conditions and therefore competition added to the decrease. On plots of low pH and high "lime requirement" this grass responded to liming.

Italian Rye Grass showed a tendency to considerable mortality during the first winter; the figures for limed and unlimed sections were inconclusive. This grass developed and yielded best on the medium loam and heavier soils, all relatively fertile types. It diminished rapidly on the light and peaty types. Adverse conditions tended to shorten the life of this biennial.

Cocksfoot was outstanding on the light and medium soil types and responded well to liming on the light soil. It reached its best contribution in the second harvest year. On the /

the heavier and peatier types, Cocksfoot decreased on the unlimed sections.

Timothy gave good results on the heavy soil types and particularly on the limed sections.

The reason for failure on the peaty soil was probably excessive competition on the part of other constituents. It gradually died out on the light soil. The medium loam was a normal soil and Timothy succeeded equally well on both sections.

Rough Stalked Meadow Grass was dominant on the heavy and peaty soils, the response to liming being evident.

A number of tendencies revealed by the clovers have been discussed, chiefly percentage establishment which was lowest on the light soil, mortality during the first winter which was greatest on the heavy soils, change in the contribution consequent on liming when there was a considerable difference between the limed and unlimed sections in favour of liming.

Weeds tended to increase on the unlimed sections. The tillering of the grass constituents has been discussed in detail.

DRY MATTER ESTIMATIONS. HAY.

Total dry matter yields of hay and aftermath during 1929 and 1930 have been studied and the contribution of the species recorded on a percentage basis. From the discussion it may be concluded that the contribution of Perennial Rye Grass to the hay and aftermath in both years was inversely proportional to the clover contribution. The clovers responded very markedly to liming, particularly where the pH value was low and the "lime requirement" high.

Italian /

Italian Rye Grass reached its highest contribution on the heavier and medium types and compensated for the decrease in Perennial Rye Grass consequent on the clover influence.

Cocksfoot, Timothy, and Rough Stalked Meadow Grass made their greatest contribution to the second year's hay. Cocksfoot responded to liming on the light acid soil, and Timothy responded to lime on the heavy types.

Clovers dominated the slow-growing grasses like Timothy and Rough Stalked Meadow Grass in the aftermath.

The influence of soil microorganisms on the plant community may be great and requires investigation.

The hay in the second year consisted of Perennial Rye Grass, Cocksfoot, a small proportion of Timothy and Rough Stalked Meadow Grass, and Red Clover.

PASTURE. Pasture cuts were made on limed and unlimed sections of all soil types from December 1929 to November 1930. A study of the analyses revealed a number of tendencies.

Generally, liming had a marked effect upon the total annual dry matter yielded. Grasses and clovers developed better on the limed sections than on the unlimed.

There existed throughout the year two minima (February and August) and two maxima (June and September) yield periods in dry matter and in this connection the limed sections were superior to the unlimed.

Grasses contributed most to the herbage during April-May and October-November, the least contribution having been made during /

during July-August. The reverse was the case with the clovers.

In a discussion of the relation between the factors and the results, a tendency to a relation between acidity and yield has been shown. There was the result of a complex accumulated influence on the soils of lower pH and higher "lime requirement". Liming generally improved matters. In the case of the soils approaching neutrality, the effect of the application of lime was least marked. An important question, in this connection, arises, namely, the adsorption capacity of the various soils as regards lime. The clay-humus substances varied in quantity in the various soils. The question is - Was the lime applied equivalent to the total amount capable of being adsorbed by the various soils and if not, would it have been reasonable to expect that there would have been a greater response on the part of the herbage to a greater application of lime? Questions such as these can only be answered by further experiment.

Furthermore, it is suggested that there is probably some connection between the seasonal fluctuation in the dry matter and the seasonal fluctuation in nitrate production, and that the fluctuations are not entirely a result of meteorological conditions.

The whole work just reported on suggests the following further schemes of investigation :-

(1) An enquiry into the relation between the soil factors already emmerated and single species of grasses and clovers over a longer period, with a much wider range of pH values, at higher altitudes and on soils of greater "lime requirement".

(2) /

(2) An enquiry into the seasonal fluctuations in pasture and nitrate production on different soil types.

(3) An enquiry into the influence of the herbage on the soil microflora on different soil types and seasonally.

6. ACKNOWLEDGMENTS.

In the carrying out of this investigation, many sources of valuable and much appreciated assistance and advice have been tapped. Reference cannot be made to all of these sources. It is desired, however, to express sincere thanks to the following :-

Professor Shearer, Edinburgh University, for supervising the work.

Dr. W. G. Ogg, Director of the Macaulay Institute for Soil Research, Aberdeen, and Dr. A. Lauder, Edinburgh and East of Scotland College of Agriculture, for facilities to carry out the soil investigations and for general guidance.

The various farmers for providing facilities to conduct the field part of the experiments.

It is desired also to pay tribute to the work carried out by the late Dr. W. G. Smith, Advisory Officer in Agricultural Botany at the Edinburgh centre, in connection with the ecological study of Scottish grassland. Many of the ideas embodied in this problem were due to discussion and experimental work carried out in co-operation with him; and it was ultimately intended, as has already been stated, to extend both his own and this side of grassland research in Scotland.

7. LITERATURE CITED.

1. AGRICULTURAL PROGRESS (1928) 3, 137.
2. ARMSTRONG, S. F. (Cambridge 1921) British Grasses.
3. ---------- (1907-8) Jour. Agric. Sci. 2, 283.
4. BIILMAN, E. (1924) Jour. Agric. Sci. 14, 232.
5. CLARK, E. and OTHERS, Agric. Jour. India 17, 463.
6. CLARKE, G. R. (1924) Oxford Forestry Memoirs No. 2.
7. COX, J. F. and MEGEE, C. R. (1924) Mich. Agric. Coll. Spec. Bull. No. 130.
8. CROWTHER, E. M. (1925) Jour. Agric. Sci. 15, 232.
9. CUMMING, A. C. and KAY, S. A. (Edinburgh 1922) Quantitative Chemical Analysis p. 81.
10. DAVIES, W. Univ. Coll. Wales, Aberystwyth, Series H. No. 6. 1923-1926.
11. ---------- and THOMAS, M. T. (1928) Welsh Jour. Agric. 4, 206.
12. FINDLAY, W. M. (London 1925) Grassland in Scotland (Farm Crops - Paterson) Vol. 3.
13. ---------- (1919) North Scot. Coll. Agric. Bull. No. 24.
14. GILLESPIE, L. J. (1920) Soil Sci. 9, 115.
15. GREEN, H. H. (1914) Centralbt f. Bakt. II Abt. Bd. 41, S. 577.
16. HALL, A. D. (London 1917) The Book of Rothamsted Experiments, p. 230.
17. HALL, T. D. (1921) Soil Sci. 12, 301.
18. ---------- (1924) Ibid. 18, 219.
19. HART, R. (1929) Jour. Agric. Sci. 19, 90.
20. HENDRICK, J. and OGG, W. G. (1916) Jour. Agric. Sci. 7, 458.
21. ---------- (1920) Agric. Educ. Abstracts, Cambridge, 8.
22. HISSINK, D. J. (1926) Trans. Sec. Comm. Inter. Soc. Soil Sci. Groningen (Holland) 1926, p.174.

23. /

23. HUMFELD, H. and ERDMAN, L. W. (1927) (Iowa Acad. Sci. Proc. 34 pp.63-67) U.S.A. Expt. Stn. Rec. Vol. 64, No. 3, p. 208.

24. HUTCHINSON, H. B. and MACLENNAN, K. (1915) Soil Sci. 7, 73.

25. KING, F. H. and WHITSON, A. R. (1900) (Wisconsin Stn. Rep. 1900) U.S.A. Expt. Stn. Rec. Vol. 13, p. 24.

26. ---------- (1901) (Ibid 1901) Ibid p.930.

27. LIMBACH, S. (1929) Centralbt f. Bakt. II Abt. Bd. 78. S 354.

28. LINDHARD, E. (1917) Statens Forsøgsvirksomhed i Plantekultur 122 Ber. (Investigation on Grass Fields in Jutland 1905-1910).

29. LÖHNIS, F. (1905) Mitteilungen landw. Inst. d. Univ. Leipzig Heft 7. S 1-105.

30. ---------- (Berlin 1910) Hand. landw. Bakt. S 619.

31. McCONNELL, P. (London 1919) Note-book of Agricultural Facts and Figures.

32. OGG, W. G. and DOW, W. T. (1928) Jour. Agric. Sci. 18, 132.

33. ---------- Ibid. 131.

34. ---------- Ibid. 142.

35. ---------- Ibid. 139, 140.

36. ---------- Scot. Jour. Agric. 11, 273.

36a. PERCIVAL, J. (London 1926) Agricultural Botany.

37. ROBINSON, G. W. and WILLIAMS, R. (1925) Trans. Farad. Soc. 20,586.

38. RUSSELL, E. J. (1914) Jour. Agric. Sci. 6, 46.

39. ---------- (London 1927) Soil Conditions and Plant Growth, p. 180.

40. SALISBURY, E. J. (1922) Jour. Ecol. 9, 220.

41. SMITH, A. M. (1925) Jour. Agric. Sci. 15, 466.

42. STAPLEDON, R. G. and DAVIES, W. Univ. Coll. Wales, Aberystwyth, Series H. No.10. 1923-28.

43. /

43. STAPLEDON, R. G. and DAVIES, W. Univ. Coll. Wales, Aberystwyth, Series H. No.10. 1923-28, p.16.

44. ---------- and OTHERS Ibid. No. 6. 1923-26.

45. ---------- Ibid. No. 3. 1920-23, p.27.

46. WIGGANS, R. G. (1928) Cornell Univ. Ithaca, N.Y. Bull. No.463.

47. WILLIAMS, R. D. Univ. Coll. Wales, Aberystwyth, Series H. No.7 1919-1926.

A P P E N D I X.

SEED DATA.

SOIL DETERMINATIONS.

BOTANICAL DETERMINATIONS.

DRY MATTER DETERMINATIONS.

METEOROLOGICAL DATA.

S E E D D A T A.

SPECIES - Percentage of Mixture.

Purity Percentage.

Germination percentage.

Real Value.

Source.

SEED DATA.

A. Kimming Hill. B. Anchordales.

C. Crofts Garden. D. Crofts.

Constituent	Per cent of Mixture.	Purity %.	Germination %.	Real Value.	Source.
erennial Rye Grass(12)	16.5	99.4	94	93.4	Ayrshire.
talian Rye Grass (8)	12.2	99.8	98	97.8	France.
ocksfoot (8)	23.4	95.6	94	89.8	Germany or Poland.
imothy (3)	20.4	99.3	98	97.3	America.
ough Stalked Meadow Grass (1)	14.2	90.7	93	84.4	Denmark.
road-leaved Red Clover (1)	1.5	99.2	94	93.2	Mixed.
ate-flowering Red Clover (2)	2.8	98.4	92	90.5	Sweden.
lsike (1)	4.3	98.2	98	96.2	Canada.
ild White Clover (1)	4.7	95.7	78	74.6	Kent.

Figures in brackets = No. of lb. of species in the mixture.

SEED DATA.

E. Bangour.

Constituent	Percent of Mixture.	Purity %.	Germination %.	Real Value.
Perennial Rye Grass (12)	16.5	99.	90	89.
Italian Rye Grass (8)	12.2	99.	95	94.
Cocksfoot (8)	23.4	93.	90	84.
Timothy (3)	20.4	98.5	97.75	96.
Rough Stalked Meadow Grass (1)	14.2	93.	93	86.5
Broad-leaved Red Clover(1)	1.5	99.5	91 + 2% hard seeds	90.5
Late-flowering Red Clover (2)	2.8	98.5	88 + 4% "	86.7
Alsike (1)	4.3	98.5	93 + 6% "	91.6
Wild White Clover (1)	4.7	98.	80 + 16% "	78.4

Figures in brackets = No. of lb. of species in the mixture.

SEED DATA.

F. Wedderlie. G. Cammerlaws.

Constituent.	Per cent of Mixture.	Purity %.	Germination %.	Real Value.	Source.
rennial Rye Grass (12)	16.5	99	88	87	Ireland.
alian Rye Grass (8)	12.2	99	86	85	Ireland.
cksfoot (8)	23.4	90	94	84.6	Denmark.
mothy (3)	20.4	99	97	96	America.
ugh Stalked Meadow Grass (1)	14.2	-	-	-	-
oad-leaved Red Clover (1)	1.5	99	93 + 3% Hard Seeds	92	Chile.
te-flowering Red Clover (2)	2.8	98	86 + 8% "	84.3	England.
sike (1)	4.3	98.5	93 + 3% "	91.6	Canada.
ld White Clover (1)	4.7	96.6	83 + 5% "	80.2	Kent.

Figures in brackets = No. of lb. of species in the mixture.

S O I L D E T E R M I N A T I O N S.

REACTION - pH.

LIME REQUIREMENT.

EXCHANGEABLE CALCIUM.

LOSS on IGNITION.

MOISTURE.

MECHANICAL ANALYSIS.

REACTION; pH of Soils and Subsoils.

	AUTUMN 1928. (Oct.)		SPRING 1930. (Apr.)			
	Before Treatment.		Limed.		Unlimed.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
A. Kimming Hill.	5.76	5.79	5.65	-	5.55	-
B. Anchordales.	6.57	6.57	6.62	6.59	6.19	6.25
C. Crofts Garden.	5.97	6.12	6.00	6.08	5.70	6.07
D. Crofts.	5.77	5.85	6.26	5.83	5.77	5.72
E. Bangour.	6.59	6.15	6.45	6.16	6.33	6.20
F. Wedderlie.	5.51	5.53	5.30	5.46	5.24	5.22
G. Cammerlaws.	5.53	5.51	5.41	5.27	5.36	5.30

LIME REQUIREMENT of Soils and Subsoils (1928).

(expressed as gm. calcium carbonate per 100 gm. air-dry soil)

		SOIL.	SUBSOIL.
A.	Kimming Hill.	0.188	0.157
B.	Anchordales.	0.068	0.047
C.	Crofts Garden.	0.110	0.078
D.	Crofts.	0.376	0.501
E.	Bangour.	0.094	0.125
F.	Wedderlie.	0.251	0.172
G.	Cammerlaws.	0.313	0.250

EXCHANGEABLE CALCIUM - Soils.

(expressed as percentages of CaO present in air-dry soil)

		SOIL. (Oct. 1928).
A.	Kimming Hill.	0.053
B.	Anchordales.	0.112
C.	Crofts Garden.	0.080
D.	Crofts.	0.310
E.	Bangour.	0.141
F.	Wedderlie.	0.038
G.	Cammerlaws.	0.080

LOSS ON IGNITION - Soils and Subsoils.

(expressed as a percentage)

		SOIL.	SUBSOIL.
A.	Kimming Hill.	7.226	7.358
B.	Anchordales.	6.195	5.229
C.	Crofts Garden.	5.655	6.477
D.	Crofts.	23.456	34.407
E.	Bangour.	10.895	9.205
F.	Wedderlie.	7.662	6.040
G.	Cammerlaws.	11.483	7.356

MOISTURE in Air-Dry Soils and Subsoils.

(expressed as a percentage)

		SOIL.	SUBSOIL.
A.	Kimming Hill.	1.984	2.313
B.	Anchordales.	1.901	1.752
C.	Crofts Garden.	2.244	2.185
D.	Crofts.	5.650	6.931
E.	Bangour.	3.082	2.541
F.	Wedderlie.	2.559	1.765
G.	Cammerlaws.	2.254	1.539

MECHANICAL ANALYSIS of SOILS and SUBSOILS.

(Fractions expressed as percentages).

S O I L S.

	A.	B.	C.	D.	E.	F.	G.
oarse Sand	55.42	28.50	20.78	14.43	24.59	15.78	17.90
ine Sand	14.34	24.72	23.07	10.76	18.33	20.47	30.11
ilt	5.57	13.37	18.26	8.64	10.86	16.97	15.56
ine Silt	7.97	13.29	16.42	18.00	17.34	21.21	16.36
lay	7.09	11.13	12.90	18.88	14.30	15.29	6.36
oisture	1.98	1.91	2.24	5.65	3.08	2.56	2.25
gnition Loss	7.22	6.20	5.66	23.46	10.90	7.66	11.48
Total	99.59	99.12	99.23	99.82	99.40	99.94	100.02

S U B S O I L S.

oarse Sand	48.50	31.16	15.38	7.59	22.05	15.98	14.98
ine Sand	20.18	23.33	23.17	8.93	23.48	21.99	35.63
ilt	5.34	12.56	15.88	6.05	10.06	15.48	17.56
ine Silt	8.62	13.84	20.84	16.85	19.18	23.16	15.80
lay	6.94	11.52	15.80	19.09	13.50	15.64	7.00
oisture	2.31	1.75	2.19	6.93	2.54	1.77	1.54
gnition Loss	7.36	5.23	6.48	34.41	9.21	6.04	7.36
Total	99.25	99.39	99.74	99.85	100.02	100.06	99.92

BOTANICAL DETERMINATIONS.

1. Proportion of the species (seed) in the mixture at seeding.

2. Number of plants of each species at end of seeding year, in the spring of the first harvest year, in the spring of the second harvest year and in the autumn of the second harvest year, on limed and unlimed plots.

3. Total number of tillers of each species of grass at the periods detailed in paragraph 2, on limed and unlimed plots.

BOTANICAL ANALYSIS. PLOT A. (KIMMING HILL)

Date at head of sections is date of turf separations.
Area analysed = 1.5 sq. ft. (6 turves each 6 ins. square.)

		14th Novr. 1928.		28th April 1929.		7th April 1930.					
		UNLIMED.		LIMED.		UNLIMED.		LIMED.		UNLIMED.	
CONSTITUENT.	% of Seed Mixture.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No.of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers
Perennial Rye Grass.	16.5	184	322	164	512	104	378	236	572	172	476
Italian Rye Grass.	12.2	65	147	26	60	44	126	5	9	0	0
Cocksfoot.	23.4	50	52	50	56	44	76	195	354	77	177
Timothy.	20.4	31	59	42	72	24	54	37	86	27	63
Rough Stalked Meadow Grass.	14.2	18	37	46	94	66	126	14	27	50	72
Red Clover.	4.3	29	.	24	.	6	.	9+	.	0	.
Alsike.	4.3		.	8	.	0	.	0	.	0	.
Wild White Clover.	4.7	10	.	10	.	6	.	23	.	0	.
Weeds.	.	38	.	18	.	26	.	73	.	59	.
Slugs.	.	.	.	10	.	4	.	eggs 45	.	.	.
Tipula Larvae.	.	.	.	.	.	4	.	.	.	.	.
Wire Worms.	.	.	.	.	.	2	.	.	.	.	.
Clover Cover.	.	4.6%	.	3.7%	.	0.9%	.	14.8%	.	0	.

+ Late Flowering Red Clover.

BOTANICAL ANALYSIS. PLOT B. (ANCHORDALES)

Date at head of sections is date of turf separations.
Area analysed = 1.5 sq. ft. (6 turves each 6 ins. square.)

		14th Novr. 1928.		28th April 1929.			7th April 1930.			
		UNLIMED.		LIMED.		UNLIMED.		LIMED.		UNLIMED.	
CONSTITUENT.	% of Seed Mixture.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers
Perennial Rye Grass.	16.5	131	290	56	272	164	354	84	256	76	272
Italian Rye Grass.	12.2	52	188	46	140	40	84	10	18	10	34
Cocksfoot.	23.4	124	142	48	90	54	62	78	230	58	208
Timothy.	20.4	17	30	36	76	4	6	32	70	30	78
Rough Stalked Meadow Grass.	14.2	38	92	70	208	64	138	28	76	26	62
Red Clover.	4.3	24	.	16	.	14	.	10	.	0	.
Alsike.	4.3		.		.		.	2	.	8	.
Wild White Clover.	4.7	34	.	18	.	2	.	16	.	8	.
Weeds.	.	3	.	2	.	4	.	8	.	10	.
Slugs.	.	.	.	.	.	6	.	.	.	.	.
Tipula Larvae.	.	.	.	.	.	.	.	4	.	8	.
Wire Worms.	.	.	.	.	.	.	.	.	.	.	.
Clover Cover.	.	23%	.	27.7%	.	7.4%	.	33%	.	9.3%	.

BOTANICAL ANALYSIS. PLOT C. (CROFTS GARDEN).

Date at head of sections is date of turf separations.
Area analysed = 1.5 sq. ft. (6 turves each 6 ins. square.)

	20th Novr. 1928.			24th April 1929.				7th April, 1930.			
		UNLIMED.		LIMED.		UNLIMED.		LIMED.		UNLIMED.	
CONSTITUENT.	% of Seed Mixture.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants	No. of Tillers.	No. of Plants	No. of Tillers.	No. of Plants.	No. of Tillers.
Perennial Rye Grass.	16.5	123	218	50	226	134	540	94	324	87	390
Italian Rye Grass.	12.2	73	280	102	330	50	194	8	22	3	12
Cocksfoot.	23.4	67	76	26	26	22	36	26	82	27	93
Timothy.	20.4	22	42	24	46	28	60	4	8	12	30
Rough Stalked Meadow Grass.	14.2	20	23	92	244	156	594	140	652	57	207
Red Clover	4.3	43	.	38	.	22	.	34+	.	9+	.
Alsike.	4.3			10	.	18	.	10	.	0	.
Wild White Clover.	4.7	34	.	4	.	12	.	2	.	3	.
Weeds.	.	30	.	10	.	0	.	50	.	42	.
Slugs.	.	10 + eggs	.	.	.	.	.	.	.	.	.
Tiplua Larvae.	.	1	.	8	.	22	.	1	.	.	.
Wire Worms.	.	.	.	.	.	.	.	.	.	.	.
Clover Cover.	.	17.6%	.	17.6%	.	11.1%	.	22.3%	.	12.5%	.

+ Late-flowering Red Clover.

BOTANICAL ANALYSIS. PLOT D. (CROFTS)

Date at head of sections is date of turf separations.
Area analysed = 1.5 sq. ft. (6 turves each 6 ins. square.)

		20th Novr. 1928.		3rd May 1929.				7th April 1930.			
		UNLIMED.		LIMED.		UNLIMED.		LIMED.		UNLIMED.	
CONSTITUENT.	% of Seed Mixture.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.	No. of Plants.	No. of Tillers.
Perennial Rye Grass.	16.5	91	145	100	284	76	326	113	708	59	327
Italian Rye Grass.	12.2	59	220	26	106	32	150	0	0	0	0
Cocksfoot.	23.4	38	41	36	56	28	54	27	236	41	322
Timothy.	20.4	1	1	2	2	14	14	0	0	5	9
Rough Stalked Meadow Grass.	14.2	7	15	48	166	26	118	132	422	154	817
Red Clover.	4.3	84	.	78	.	54	.	18+	.	5+	.
Alsike.	4.3		.	14	.	24	.	27	.	5	.
Wild White Clover.	4.7	31	.	14	.	8	.	5	.	0	.
Weeds.	.	6	.	10	.	4	.	30	.	0	.
Slugs.	.	18 + eggs	.	4	.	2	.	.	.	.	.
Tipula Larvae.	.	.	.	6	.	8	.	.	.	.	.
Wire Worms.	.	.	.	.	.	.	.	.	.	.	.
Clover Cover.	.	69%	.	58%	.	36%	.	12.5%	.	4.2%	.

+ Late-flowering Red Clover.

BOTANICAL ANALYSIS. PLOT E. (BANGOUR)

Date at head of Sections is date of turf separations.
Area analysed = 1.5 sq. ft. (6 turves each 6 ins. square)

CONSTITUENT.	% of Seed Mixture.	16th Octr. 1928. UNLIMED+ No. of Plants.	No. of Tillers.	9th May 1929. LIMED. No. of Plants.	No. of Tillers.	UNLIMED. No. of Plants.	No. of Tillers.	15th April, 1930. LIMED. No. of Plants.	No. of Tillers.	UNLIMED. No. of Plants.	No. of Tillers.
Perennial Rye Grass.	16.5	69	187	64	234	30	158	54	150	62	
Italian Rye Grass.	12.2	49	187	40	114	36	186	4	10	6	
Cocksfoot.	23.4	3	3	20	20	12	12	10	52	12	
Timothy.	20.4	8	15	14	20	10	10	38	100	14	
Rough Stalked Meadow Grass.	14.2	4	5	84	228	40	100	80	254	48	
Red Clover.	4.3	30	.	26	.	14	.	20+	.	6+	
Alsike.	4.3		.	10	.	6	.	2	.	0	
Wild White Clover.	4.7	11	.	12	.	4	.	10	.	6	
Weeds.	.	31	.	40	.	24	.	12	.	28	
Slugs.	.	.	.	.	.	.	.	.	.	.	
Tipula Larvae.	.	.	.	.	.	.	.	.	.	.	
Wire Worms.	.	.	.	.	.	.	.	.	.	.	
Clover Cover.	.	9.7%	.	50.3%	.	28.5%	.	18.5%	.	3.7%	

+ Late-flowering Red Clover.

BOTANICAL ANALYSIS. PLOT F. (WEDDERLIE)

Date at head of sections is date of turf separations.
Area analysed = 1.5 sq. ft. (6 turves each 6 ins. square)

CONSTITUENT.	% of Seed Mixture.	31st Octr.1928. UNLIMED. No. of Plants.	31st Octr.1928. UNLIMED. No. of Tillers.	17th May 1929. LIMED. No. of Plants.	17th May 1929. LIMED. No. of Tillers.	17th May 1929. UNLIMED. No. of Plants.	17th May 1929. UNLIMED. No. of Tillers.	17th April 1930. LIMED. No. of Plants.	17th April 1930. LIMED. No. of Tillers.	17th April 1930. UNLIMED. No. of Plants.	17th April 1930. UNLIMED. No. of Tillers.
Perennial Rye Grass.	16.5	160	250	178	320	136	184	116	376	124	186
Italian Rye Grass.	12.2	38	86	64	120	84	246	8	28	4	8
Cocksfoot.	23.4	41	41	78	82	68	70	40	72	16	18
Timothy.	20.4	21	25	22	30	20	26	30	62	14	36
Rough Stalked Meadow Grass.	14.2	4	5	28	44	34	56	32	88	12	38
Red Clover.	4.3	48	.	48	.	40	.	16+	.	14+	.
Alsike.	4.3		.	12	.	8	.	8	.	0	.
Wild White Clover.	4.7	21	.	8	.	10	.	2	.	2	.
Weeds.	.	2	.	20	.	28	.	32	.	78	.
Slugs.	.	.	.	.	.	.	.	.	.	.	.
Tipula Larvae.	.	.	.	4	.	.	.	.	.	.	.
Wire Worms.	.	.	.	.	.	.	.	.	.	.	.
Clover Cover.	.	9.7%	.	42.5%	.	22.2%	.	26.8%	.	12.0%	.

+ Late-flowering Red Clover.

BOTANICAL ANALYSIS. PLOT G. (CAMMERLAWS)

Date at head of sections is date of turf separations.
Area analysed = 1.5 sq. ft. (6 turves each 6 ins. square)

CONSTITUENT.	% of Seed Mixture.	31st Octr.1928. UNLIMED. No. of Plants.	31st Octr.1928. UNLIMED. No. of Tillers.	17th May 1929. LIMED. No. of Plants.	17th May 1929. LIMED. No. of Tillers.	17th May 1929. UNLIMED. No. of Plants.	17th May 1929. UNLIMED. No. of Tillers.	17th April 1930. LIMED. No. of Plants.	17th April 1930. LIMED. No. of Tillers.	17th April 1930. UNLIMED. No. of Plants.	17th April 1930. UNLIMED. No. of Tillers.
Perennial Rye Grass.	16.5	120	600	94	516	120	484	88	342	76	228
Italian Rye Grass.	12.2	44	226	50	272	40	254	4	8	2	4
Cocksfoot.	23.4	62	69	54	70	72	82	24	96	58	128
Timothy.	20.4	47	62	46	68	44	64	22	52	38	96
Rough Stalked Meadow Grass.	14.2	2	3	14	46	6	12	30	80	28	62
Red Clover.	4.3	16	.	36	.	24	.	24+	.	10+	.
Alsike.	4.3		.	24	.	20	.	10	.	8	.
Wild White Clover.	4.7	27	.	14	.	8	.	10	.	12	.
Weeds.	.	30	.	76	.	52	.	36	.	34	.
Slugs.	.	.	.	.	.	.	.	.	.	.	.
Tipula Larvae.	.	.	.	.	.	.	.	2	.	2	.
Wire Worms.	.	.	.	.	.	.	.	2	.	.	.
Clover Cover.	.	4.1%	.	25.0%	.	7.4%	.	32.3%	.	18.5%	.

+ Late-flowering Red Clover.

DRY MATTER DETERMINATIONS

on Limed and Unlimed Plots.

1. Hay Separations in the first and second harvest years and the contribution of species in each case.

2. Aftermath Separations as in Para. 1.

3. Pasture Separations:- Monthly Cuts over the second harvest year; contribution of grasses, clovers and weeds to the Dry Matter.

HAY SEPARATIONS. First harvest year - 1929; Dry Matter in gms. and separations expressed as percentages of total Dry Matter. Area analysed = 1 sq. yd.

ENTRE.	P.R.G.	I.R.G.	Cocks.	Tim.	R.S.M.G.	Clovers.	Weeds.	Total.
Limed.	121.0	21.3	7.5	2.9	4.2	2.0	19.3	178.2
%.	67.8	11.9	4.2	1.6	2.4	1.3	10.8	
Unlimed.	133.3	31.6	3.6	2.5	3.8	0.8	40.76	216.36
%.	61.6	14.6	1.6	1.1	1.8	0.5	18.8	
Limed.	125.5	66.5	12.0	9.0	20.9	144.7	11.6	390.2
%.	32.2	17.0	3.1	2.4	5.3	37.1	2.9	
Unlimed.	156.5	68.8	14.3	6.0	21.8	93.7	3.2	364.3
%.	42.9	18.9	3.9	1.7	5.9	25. 8	0.9	
Limed.	82.7	141.2	0.65	26.9	22.2	99. 5	9.5	382.65
%.	21.6	36.9	0.2	7.0	5.9	26. 0	2.4	
Unlimed.	138.7	162.5	0.65	10.4	37.5	43.8	2.4	395.95
%.	35.0	41.0	0.2	2.6	9.4	11.2		
Limed.	200.0	75.0	6.5	4.0	10.0	232.5	3.0	531.0
%.	37.7	14.2	1.2	0.8	1.8	43.8	0.5	
Unlimed.	219.0	79.0	6.0	3.2	8.6	206.0	9.0	530.8
%.	41.3	14.9	1.1	0.6	1.6	38.8	1.6	
Limed.	116.4	49.9	1.9	21.5	9.7	159.2	1.1	359.7
%.	32.4	13.9	0.5	6.0	2.7	44.2	0.3	
Unlimed.	119.0	50.3	1.1	17.6	16.0	123.2	2.5	329.7
%.	36.1	15.3	0.3	5.3	4.9	37.3	0.8	
Limed.	151.0	55.0	4.5	4.0	1.0	220.0	3.5	439.0
%.	34.4	12.5	1.1	0.9	0.2	50.1	0.8	
Unlimed.	145.3	51.7	3.0	3.3	0.5	239.5	5.6	448.9
%.	32.3	11.5	0.7	0.8	0.1	53.4	1.2	
Limed.	185.7	60.5	4.7	11.1	3.6	30.0	23.9	319.5
%.	58.1	18.7	1.5	3.5	1.2	9.5	7.5	
Unlimed.	118.0	54.5	4.7	7.7	3.0	27.7	49.8	265.4
%.	44.5	20.5	1.8	2.9	1.1	10.4	18.8	

Dates of Cutting:- A. 1.7.29; B. 28.6.29; C. 27.6.29; D. 3.7.29; E. 8.7.29; F. 9.7.29; G. 9.7.29.

AFTERMATH SEPARATIONS. First harvest year - 1929; Dry Matter in gms. and separations expressed as percentages of total Dry Matter. Area analysed = 1 sq. yd.

CENTRE.	P.R.G.	I.R.G.	Cocks.	Tim.	R.S.M.G.	Clovers.	Weeds.	Total.
Limed	----------	----------	63.0	----------	----------	2.6	0.2	65.8
%			95.9			3.8	0.3	
Unlimed	----------	----------	51.7	----------	----------	1.0	0.2	52.9
%			97.9			1.8	0.3	
Limed	2.0	9.7	10.5	trace	trace	245.0	0.5	267.7
%	0.8	3.6	3.9	0	0	91.5	0.2	
Unlimed	4.0	11.4	12.7	trace	trace	169.0	-	197.1
%	2.0	5.8	6.4	0	0	85.8	-	
Limed	18.5	57.5	3.8	1.7	trace	225.9	7.6	315.0
%	5.8	18.2	1.2	0.5	0	72.0	2.3	
Unlimed	17.5	47.5	3.8	1.6	trace	118.0	5.3	193.7
%	9.0	24.6	1.9	0.8	0	61.0	2.7	
Limed	23.4	81.0	13.5	1.2	trace	88.0	trace	207.1
%	11.3	39.0	6.6	0.6	0	42.5	0	
Unlimed	26.7	62.7	19.0	trace	trace	122.5	trace	230.9
%	11.6	27.1	8.3	0	0	53.0	0	
Limed	-------	38.5	-------	-	-	58.7	-	97.2
%		39.7		-	-	60.3	-	
Unlimed	3.7	17.8	3.5	-	-	105.0	0.3	130.3
%	2.9	13.7	2.7	-	-	80.5	0.2	
Limed	2.0	11.9	2.5	-	-	246.7	-	263.1
%	0.7	4.5	0.9	-	-	93.9	-	
Unlimed	1.2	10.7	2.0	-	-	182.0	0.3	196.2
%	0.7	5.5	1.0	-	-	92.7	0.1	
Limed	1.0	11.7	5.0	1.2	-	76.7	1.3	96.9
%	1.0	12.1	5.2	1.2	-	79.2	1.3	
Unlimed	1.3	8.7	3.0	0.3	-	57.2	3.9	74.4
%	1.7	11.7	4.0	0.4	-	77.0	5.2	

Dates of cutting:- A. 9.9.29; B. 10.9.29; C. 10.9.29; D. 9.9.29; E. 11.9.29; F. 16.9.29; G. 16.9.29.

HAY SEPARATIONS. Second harvest year - 1930; Dry Matter in gms. and separations expressed as percentages of total Dry Matter. Area analysed = 1 sq. yd.

CENTRE.	P.R.G.	I.R.G.	Cocks.	Tim.	R.S.M.G.	Clovers.	Weeds.	Total.
Limed	149.0	-	51.0	5.5	3.2	65.0	22.8	296.5
%	50.2	-	17.2	1.8	1.1	22.0	7.7	
Unlimed	152.2	-	39.5	1.5	0.7	49.2	26.2	269.3
%	56.7	-	14.6	0.5	0.2	18.3	9.7	
Limed	94.5	11.0	69.6	21.3	16.0	266.0	1.3	479.7
%	19.6	2.3	14.4	4.4	3.3	55.8	0.2	
Unlimed	125.5	8.0	87.5	21.5	9.3	223.5	-	475.3
%	26.3	1.8	18.4	4.6	2.0	46.9	-	
Limed	193.2	trace	57.8	51.7	51.2	102.5	trace	456.4
%	42.3	o	12.6	11.3	11.2	22.6	o	
Unlimed	234.7	trace	67.0	63.0	28.0	170.3	4.0	567.0
%	41.2	o	11.8	11.1	4.9	30.3	0.7	
Limed	339.0	--	219.5	32.7	126.0	32.4	4.5	754.1
%	45.0	o	29.0	4.3	16.7	4.4	0.6	
Unlimed	293.0	-	195.7	29.9	54.0	32.2	-	604.8
%	48.5	o	32.5	4.9	8.8	5.3	-	
Limed	143.0	4.7	14.8	51.4	11.0	74.0	7.2	306.1
%	46.7	1.5	4.8	16.8	3.6	24.3	2.3	
Unlimed	147.5	1.5	7.7	35.2	8.7	69.5	5.2	275.3
%	53.5	0.5	2.9	12.8	3.2	25.2	1.9	
Limed	116.5	-	14.7	28.0	14.0	133.2	13.4	319.8
%	36.5	o	4.6	8.8	4.4	41.5	4.2	
Unlimed	110.0	-	5.3	11.3	0.5	176.7	34.2	338.0
%	32.5	o	1.7	3.4	0.1	52.1	10.2	
Limed	64.5	4.5	23.5	30.5	12.2	121.5	44.7	301.4
%	21.5	1.5	7.7	10.1	4.0	40.4	14.8	
Unlimed	59.4	1.2	17.9	12.0	5.7	188.0	26.2	310.4
%	19.2	0.4	5.8	3.9	1.8	60.5	8.4	

Dates of cutting:- A. 7.7.30; B. 7.7.30; C. 7.7.30; D. 7.7.30; E. 9.7.30; F. 8.7.30; G. 8.7.30.

AFTERMATH SEPARATIONS. Second harvest year - 1930;

Dry Matter in gms. and separations expressed as percentages of total Dry Matter. Area analysed = 1 sq. yd.

CENTRE.		Grasses.	Clovers.	Weeds.	Total.
A.	Limed	71.7	39.0	1.0	111.7
	%	64.1	35.0	0.9	
	Unlimed	53.0	30.5	1.0	84.5
	%	62.8	36.0	1.2	
B.	Limed	79.0	137.5	--	216.5
	%	36.5	63.5	--	
	Unlimed	127.5	53.7	--	181.2
	%	70.3	29.7	--	
C.	Limed	127.7	36.0	--	163.7
	%	78.0	22.0	--	
	Unlimed	107.5	44.0	--	151.5
	%	71.0	29.0	--	
D.	Limed	191.0	22.4	trace	213.4
	%	90.0	10.0	o	
	Unlimed	141.0	31.0	trace	172.0
	%	82.0	18.0	o	
E.	Limed	56.5	80.2	trace	136.7
	%	41.3	58.7	o	
	Unlimed	36.5	72.0	trace	108.5
	%	33.5	66.5	o	
F.	Limed	95.7	125.0	--	220.7
	%	43.3	56.7	o	
	Unlimed	61.0	128.7	--	189.7
	%	32.2	67.8	o	
G.	Limed	25.6	62.0	trace	87.6
	%	29.3	70.7	o	
	Unlimed	39.4	57.5	trace	96.9
	%	40.7	59.3	o	

Dates of cutting:- A. 11.9.30; B. 11.9.30; C. 11.9.30; D. 11.9.30; E. 17.9.30; F. 15.9.30; G. 15.9.30.

PASTURE SEPARATIONS. PLOT A. (KIMMING HILL); second harvest year;

Dec. 1929 to Nov. 1930. Dry Matter in gms.
Area analysed = 1 sq. yd.

Date of Cutting.	Interval in Days.	LIMED. Grasses.	Clovers.	Weeds.	Total.	UNLIMED. Grasses.	Clovers.	Weeds.	Total.
16.12.29.	-	10.1	-	-	10.1	16.0	-.	-	16.0
7. 4.30.	112	8.0	-	-	8.0	15.0	-	-	15.0
9. 5.30.	32	33.5	2.7	0.3	36.5	25.0	1.3	0.1	26.4
6. 6.30.	28	50.3	3.5	3.5	57.3	22.0	1.9	1.7	25.6
7. 7.30.	31	38.3	2.5	4.1	44.9	16.5	3.5	2.0	22.0
11. 8.30.	35	21.2	2.2	1.6	25.0	14.2	1.9	1.0	17.1
11. 9.30.	31	29.7	3.1	1.3	34.1	26.5	3.2	2.3	32.0
9.10.30.	28	11.0	0.3	trace	11.3	3.5	0.1	trace	3.6
10.11.30.	32	Herbage very short; impossible to collect clippings.							

PASTURE SEPARATIONS. PLOT B. (ANCHORDALES); second harvest year;
Dear. 1929 to Novr. 1930; Dry Matter in gms.
Area analysed = 1 sq. yd.

Date of Cutting.	Interval in days.	LIMED. Grasses.	Clovers.	Weeds.	Total.	UNLIMED. Grasses.	Clovers.	Weeds.	Total.
16.12.29.	-	15.3	7.1	-	22.4	15.4	5.2	-	20.6
7. 4.30.	112	14.0	1.0	-	15.0	19.1	0.7	-	19.8
9. 5.30.	32	45.7	11.3	-	57.0	41.7	11.4	-	53.1
6. 6.30.	28	64.0	16.0	0.5	80.5	63.5	30.7	-	94.2
7. 7.30.	31	34.9	28.5	0.7	64.1	34.2	36.9	-	71.1
11. 8.30.	35	31.2	21.9	0.5	53.6	33.0	27.2	-	60.2
11. 9.30.	31	41.7	23.5	0.6	65.8	40.0	28.7	-	68.7
9.10.30.	28	24.0	7.3	trace	31.3	23.7	5.1	-	28.8
10.11.30.	32	11.0	3.0	-	14.0	10.5	2.5	-	13.0

PASTURE SEPARATIONS. PLOT C. (CROFTS GARDEN); second harvest year;
Dec. 1929 to Nov. 1930; Dry Matter in gms.
Area analysed = 1 sq. yd.

Date of Cutting.	Interval in Days.	LIMED. Grasses.	Clovers.	Weeds.	Total.	UNLIMED. Grasses.	Clovers.	Weeds.	Total.
16.12.29.	-	25.0	1.2	-	26.2	22.1	2.1	-	24.2
7. 4.30.	112	10.4	0.3	-	10.7	8.4	0.3	-	8.7
9. 5.30.	32	37.5	9.5	-	47.0	46.7	22.8	-	69.5
6. 6.30.	28	52.3	14.5	-	66.8	63.6	34.8	-	98.4
7. 7.30.	31	30.6	15.0	1.5	47.1	38.7	42.0	0.2	80.9
11. 8.30.	35	32.3	8.7	1.3	42.3	41.8	30.2	0.2	72.2
11. 9.30.	31	42.0	4.6	0.1	46.7	49.2	26.0	-	75.2
9.10.30.	28	21.0	0.7	trace	21.7	32.7	3.0	-	35.7
10.11.30	32	9.5	trace	-	9.5	9.7	trace	-	9.7

PASTURE SEPARATIONS. PLOT D. (CROFTS); second harvest year;

Dec. 1929 to Nov. 1930; Dry Matter in gms.

Area analysed = 1 sq. yd.

Date of Cutting.	Interval in Days.	LIMED. Grasses.	Clovers.	Weeds.	Total.	UNLIMED. Grasses.	Clovers.	Weeds.	Total.
16.12.29.	-	49.5	0.6	-	50.1	36.8	0.3	-	37.1
7. 4.30.	112	27.8	0.1	-	27.9	27.1	0.1	-	27.2
9. 5.30.	32	51.0	3.5	-	54.5	54.3	2.0	-	56.3
6. 6.30.	28	111.9	9.8	-	121.7	106.2	3.8	0.2	110.2
7. 7.30.	31	33.8	7.2	0.1	41.1	27.1	2.5	0.5	30.1
11. 8.30.	35	48.3	2.2	-	50.5	44.0	3.2	0.5	47.7
11. 9.30.	31	53.1	0.8	-	53.9	43.3	1.5	-	44.8
9.10.30.	28	32.5	0.1	-	32.6	22.7	0.2	-	22.9
10.11.30.	32	10.7	-	-	10.7	3.0	-	-	3.0

PASTURE SEPARATIONS. PLOT E. (BANGOUR); second harvest year;
Dec. 1929 to Oct. 1930; Dry Matter in gms.
Area analysed = 1 sq. yd.

Date of Cutting.	Interval in Days.	LIMED. Grasses.	Clovers.	Weeds.	Total.	UNLIMED. Grasses.	Clovers.	Weeds.	Total.
17.12.29.	-	9.7	0.2	-	9.9	11.0	0.2	-	11.2
15. 4.30.	119	6.2	0.1	-	6.3	6.0	0.1	-	6.1
12. 5.30.	27	16.9	1.7	-	18.6	12.7	0.8	-	13.5
12. 6.30.	31	55.1	5.5	0.6	61.2	43.7	5.7	2.1	51.5
9. 7.30.	27	13.1	5.4	1.3	19.8	11.7	6.1	1.8	19.6
13. 8.30.	35	16.2	8.9	1.5	26.6	13.8	7.6	3.5	24.9
17. 9.30.	35	17.0	6.4	1.7	25.1	13.6	5.7	4.1	23.4
12.10.30.	33	8.6	0.8	0.5	9.9	3.1	0.2	0.5	3.8

PASTURE SEPARATIONS. PLOT F. (WEDDERLIE); second harvest year;
Dec. 1929 to Oct. 1930; Dry Matter in gms.
Area analysed = 1 sq. yd.

Date of Cutting.	Interval in Days.	LIMED. Grasses.	Clovers.	Weeds.	Total.	UNLIMED. Grasses.	Clovers.	Weeds.	Total.
18.12.29.	-	34.2	2.2	-	36.4	25.2	1.8	-	27.0
17. 4.30.	120	19.9	0.2	-	20.1	17.2	0.7	-	17.9
19. 5.30.	32	40.8	11.7	-	52.5	36.0	12.3	-	48.3
16. 6.30.	28	76.0	14.5	0.2	90.7	61.2	24.2	0.2	85.6
8. 7.30.	22	27.1	10.5	0.5	38.1	25.7	13.9	-	39.6
12. 8.30.	35	42.7	13.1	0.7	56.5	37.4	19.8	-	57.2
15. 9.30.	34	53.2	6.6	0.3	60.1	45.1	8.3	0.5	53.9
15.10.30.	30	31.0	0.7	0.2	31.9	19.1	1.4	trace	20.5

PASTURE SEPARATIONS. PLOT G. (CAMMERLAWS); second harvest year;
Dec. 1929 to Oct. 1930; Dry Matter in gms.
Area analysed = 1 sq. yd.

Date of Cutting.	Interval in Days.	LIMED.				UNLIMED.			
		Grasses.	Clovers.	Weeds.	Total.	Grasses.	Clovers.	Weeds.	Total.
18.12.29.	-	14.8	2.1	-	16.9	9.1	1.1	-	10.2
17. 4.30.	120	5.9	0.2	-	6.1	8.5	0.1	-	8.6
19. 5.30.	32	12.9	6.8	0.4	20.1	6.7	3.2	0.2	10.1
16. 6.30.	28	31.9	16.5	2.1	50.5	24.9	14.9	3.0	42.8
8. 7.30.	22	10.5	14.7	2.3	27.5	9.2	12.5	2.4	24.1
12. 8.30.	35	9.8	16.1	3.9	29.8	6.5	11.3	3.4	21.2
15. 9.30.	34	14.5	9.0	2.8	26.3	13.2	7.2	4.0	24.4
15.10.30.	30	3.6	1.1	0.7	5.4	1.7	0.3	trace	2.0

METEOROLOGICAL DATA.

Monthly Rainfall at all centres.

Maximum and Minimum Temperatures at all centres.

Relative Humidity at one centre (Plots A.B.C.D.).

Sunshine at one centre (Plots A.B.C.D.).

Soil Temperatures at one centre (Plots A.B.C.D.).

TABLE showing RAINFALL per month (in inches) December 1927 to November 1930 at BOGHALL (Plots A, B, C, and D.)

	Rainfall 1928.	Rain Days 1928.	Rainfall 1929.	Rain Days 1929.	Rainfall 1930.	Rain Days 1930.
December (1927)			2.29 (1928)	18	4.70 (1929)	24
January	6.17	26	1.06	13	3.80	26
February	2.81	16	0.93	14	0.51	10
March	1.93	24	2.44	7	2.60	18
April	0.91	16	1.88	13	1.05	20
May	1.57	13	1.61	12	3.40	10
June	5.46	20	2.47	16	1.71	14
July	2.48	14	2.97	13	3.53	19
August	4.76	23	4.42	22	5.17	22
September	2.24	15	0.38	5	5.32	20
October	3.20	19	3.17	20	3.32	25
November	3.50	21	4.44	24	5.27	19

TABLE showing MEAN TEMPERATURES (Max. and Min.) per month
December 1927 to November 1930 (in degrees Fahrenheit)
at BOGHALL (Plots A. B. C. and D.)

	1928.		1929.		1930.	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
December (1927)	-	-	41.9	32.4	43.6	35.5
January	44.	34.3	39.0	29.5	42.4	33.0
February	44.6	34.1	36.4	28.3	38.6	28.6
March	42.5	35.1	51.4	34.1	42.1	32.1
April	49.2	37.6	46.6	35.1	48.7	38.5
May	54.0	40.8	55.9	40.9	54.7	39. 9
June	56.8	43.4	59.5	45.2	63.8	46.9
July	61.1	49.3	63.1	52.4	61.5	50.0
August	59.6	49.2	60.6	49.3	62.7	50.0
September	58.1	45.2	61.5	48.2	58.0	47.5
October	55.3	39.4	51.0	41.0	52.0	42.2
November	48.3	37.8	46.6	37.0	44.4	34.6

TABLE showing the MONTHLY MEAN of RELATIVE HUMIDITY (%)
from December 1927 to November 1930 at BOGHALL
(Plots A. B. C. and D.)

	1928.			1929.			1930.		
	9 a.m.	3 p.m.	9 p.m.	9 a.m.	3 p.m.	9 p.m.	9 a.m.	3 p.m.	9 p.m.
December (1927)	-	-	-	88.1	87.3	88.7	89.8	85.5	87.1
January	90.8	86.	89.	88.3	85.9	86.4	90.5	86.3	88.1
February	89.9	86.	91.8	84.3	79.7	85.4	90.2	80.2	86.7
March	89.0	85.4	89.4	80.8	70.7	83.0	87.9	78.4	88.9
April	81.	69.4	82.8	80.8	67.8	84.5	83.1	80.1	87.2
May	79.3	73.5	86.2	82.9	69.1	79.7	80.5	70.1	90.9
June	77.5	70.7	81.7	76.5	66.2	85.2	74.8	65.8	81.3
July	79.8	77.7	86.2	81.0	74.6	86.3	81.2	73.9	87.8
August	88.5	79.3	89.7	-	-	-	83.7	75.1	88. 2
September	81.1	70.2	85.4	-	-	-	85.0	82.9	89.7
October	86.6	81.0	90.6	90.0	84.	92.	83.7	79.9	86.4
November	88.9	84.	86.6	92.7	86.6	90.8	86.7	83.1	86.0

TABLE showing MEAN DAILY SUNSHINE (hours) per month from December 1927 to November 1930 at BOGHALL (Plots A. B. C. and D.)

	1928.		1929.		1930.	
	Mean.	Range.	Mean.	Range.	Mean.	Range.
December (1927)	-	-	1.6	0-6.1	1.9	0-4.5
January	1.5	0-6.8	1.4	0-5.8	2.1	0-6.1
February	2.9	0-8.9	2.9	0-8.7	3.1	0-7.6
March	1.6	0-8.6	5.8	0-11.1	3.6	0-10.4
April	3.4	0-9.2	4.5	0-11.9	3.8	0-9.2
May	4.3	0-12.5	5.9	0-14.5	5.7	0-13.0
June	6.3	0-15.1	6.8	2-15.5	8.1	0-14.9
July	5.6	0-14.0	5.5	0-14.5	4.1	0-15.1
August	4.0	0-10.6	4.4	0-11.3	5.1	0-13.5
September	5.1	0-10.2	5.07	0-10.9	2.9	0-10.0
October	3.1	0-9.1	4.0	0-8.8	3.1	0-8.0
November	2.0	0-6.0	1.9	0-5.8	2.26	0-8.0

TABLE showing MEAN SOIL TEMPERATURES per month
from December 1927 to November 1930 at
BOGHALL (Plots A.B.C.D.)

	1928.				1929.			
	4".	8".	1'.	4'.	4".	8".	1'.	4'.
December (1927)	-	-	-	-	35.1 34.8 34.0	35.5 35.9 35.1	36.8 - -	40.7 - -
January	35.3 36.6 36.0	30.2 30.8 30.6	36.9 - -	38.8 - -	32.8 33.2 33.2	33.6 33.8 33.8	33.9 - -	37.2 - -
February	36.1 38.2 37.0	34.5 31.9 31.5	37.2 - -	38.6 - -	33.3 34.1 33.6	34.1 34.3 34.1	34.6 - -	37.2 - -
March	37.6 39.4 38.4	- - -	38.3 - -	38.2 - -	33.9 42.0 40.2	37.9 39.3 40.3	38.2 - -	38.1 - -
April	41.6 46.1 44.8	42.2 43.7 44.9	42.4 - -	42.1 - -	40.4 44.9 43.1	41.7 43.1 43.7	41.7 - -	42.6 - -
May	48.6 55.4 54.0	49.0 51.0 52.5	49.4 - -	46.8 - -	48.8 53.5 52.0	47.7 49.7 51.1	48.0 - -	45.6 - -
June	51.3 56.6 55.7	52.3 54.0 55.2	52.3 - -	50.8 - -	53.5 60.3 57.4	53.8 56.3 57.2	54.1 - -	51.7 - -
July	54.8 60.1 59.1	55.2 57.0 58.1	55.3 - -	53.2 - -	57.2 62.5 59.9	57.4 59.6 60.1	58.1 - -	55.0 - -
August	54.9 59.9 58.0	55.6 57.1 58.0	55.7 - -	54.7 - -	54.2 58.0 56.4	54.7 56.7 57.1	55.1 - -	54.8 - -
September	50.6 55.0 53.7	52.3 53.3 54.2	52.1 - -	53.5 - -	53.2 57.4 55.1	54.1 55.7 56.0	54.6 - -	54.5 - -
October	44.4 47.3 45.7	45.7 46.6 46.9	45.8 - -	48.4 - -	44.6 47.3 45.6	46.0 46.9 47.0	46.7 - -	49.8 - -
November	40.0 42.2 41.9	41.2 41.8 42.0	41.5 - -	44.4 - -	39.4 40.5 39.8	40.5 40.9 40.5	40.7 - -	44.2 - -

BOGHALL Soil Temperatures (Continued)

	1930. 4".	8".	1'.	4'.
December (1929)	37.3	38.1	38.3	41.6
	37.9	38.4	-	-
	37.1	38.2	-	-
January	35.7	36.7	36.8	38.4
	36.1	36.8	-	-
	35.9	36.8	-	-
February	-	-	33.7	37.2
	-	-	-	-
	-	-	-	-
March	35.7	36.2	36.5	37.5
	38.1	36.9	-	-
	36.9	37.2	-	-
April	43.1	42.3	42.7	41.5
	47.1	43.5	-	-
	44.4	44.6	-	-
May	48.6	48.0	48.5	46.1
	56.3	50.7	-	-
	52.0	51.7	-	-
June	56.5	55.9	56.4	52.8
	64.4	58.6	-	-
	57.6	60.0	-	-
July	57.6	57.1	57.5	55.0
	62.7	59.2	-	-
	60.3	60.0	-	-
August	55.6	55.5	56.0	54.1
	60.8	57.2	-	-
	58.1	57.8	-	-
September	52.0	52.7	53.4	54.1
	55.7	53.9	-	-
	54.0	54.4	-	-
October	44.9	46.3	46.9	50.1
	48.2	47.1	-	-
	46.3	47.3	-	-
November	37.6	38.9	39.8	44.9
	38.7	39.1	-	-
	38.1	39.2	-	-

TABLE showing RAINFALL per month (in inches) December 1927 to November 1930 at BANGOUR (Plot E.).

	Rainfall 1928.	Rain Days 1928.	Rainfall 1929.	Rain Days 1929.	Rainfall 1930.	Rain Days 1930.
December (1927)	1.01	13	2.64	21	4.59	30
January	4.57	31	0.91	12	4.06	27
February	2.98	21	1.17	16	0.50	8
March	1.92	22	0.52	9	2.23	17
April	1.01	17	2.03	14	1.01	18
May	1.96	11	1.79	14	1.51	14
June	5.17	22	2.42	19	2.06	17
July	2.30	17	3.08	16	3.61	22
August	4.66	23	4.66	25	5.65	23
September	2.97	16	0.85	11	3.61	14
October	4.00	24	3.50	24	3.97	27
November	3.13	24	4.64	28	4.48	20

TABLE showing MEAN TEMPERATURES (Max. and Min.) per month
December 1927 to November 1930 (in degrees Fahrenheit)
at BANGOUR (Plot E.)

	1928.		1929.		1930.	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
-ecember (1927)	36.6	28.7	41.4	30.9	43.1	34.0
-anuary	43.1	33.3	37.5	28.8	42.3	32.4
ebruary	43.4	33.6	37.2	26.6	38.2	27.4
=arch	42.8	34.3	50.6	33.5	42.9	32.0
=pril	49.0	36.7	47.2	33.1	49.0	37.6
=ay	54.4	39.4	56.2	40.4	54.2	39.2
-une	57.1	42.1	60.4	43.9	63.3	45.1
-uly	61.3	48.8	64.3	47.8	62.9	48.7
-ugust	63.2	48.5	61.1	47.6	62.7	48.8
=eptember	58.3	42.5	61.0	46.1	58.3	46.1
=ctober	52.2	39.6	50.8	38.7	51.7	41.5
-ovember	47.3	37.0	45.7	35.3	43.4	32.8

TABLE showing RAINFALL per month (in inches) December 1927 to November 1930 at MARCHMONT (Plots F. and G.)

	Rainfall 1928.	Rain Days 1928.	Rainfall 1929.	Rain Days 1929.	Rainfall 1930.	Rain Days 1930.
December (1927)	2.72	23	1.99	21	3.34	24
January	4.64	27	2.17	19	2.12	25
February	2.56	21	1.84	15	1.57	17
March	4.12	27	0.17	6	2.35	17
April	1.45	19	1.54	17	2.18	21
May	1.13	13	1.71	13	0.95	12
June	5.39	21	2.12	14	1.64	13
July	1.58	11	3.88	15	3.59	16
August	4.40	20	4.64	22	4.70	24
September	1.51	15	0.21	9	4.49	24
October	3.86	25	2.90	22	3.85	23
November	3.42	21	3.61	26	4.38	16

TABEE showing MEAN TEMPERATURES (Max. and Min.) per month December 1927 to November 1930 (in degrees Fahrenheit) at MARCHMONT (Plots F. and G.).

	1928.		1929.		1930.	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum.
December (1927)	37.5	30.1	41.5	30.5	43.4	33.7
January	43.8	32.6	38.7	29.5	43.1	31.8
February	45.3	32.8	36.9	26.6	40.0	28.6
March	43.8	34.4	53.6	33.7	44.8	32.3
April	50.6	37.0	47.7	34.4	49.1	38.1
May	55.3	41.0	58.6	40.5	55.8	39.6
June	58.0	43.3	61.4	44.9	66.4	45.7
July	64.3	49.0	64.9	49.1	63.8	50.1
August	63.7	49.2	63.5	48.8	65.1	49.7
September	59.4	44.7	64.2	47.1	58.3	47.7
October	52.6	39.6	51.9	39.7	53.4	41.4
November	48.5	37.7	47.4	35.9	45.3	33.8

Seasonal fluctuations in yields of grasses and clovers on limed and unlimed plots. (pasture cuts.)
December 1929 to November 1930.

——— Limed section of plot.

– – – – – Unlimed " " "

PLOT 11. (3015.)

	Oct. 1928.	Apr. 1930.	Unlimed.
Reaction (pH.)	5·76	5·65	5·55
Lime Requirement	0·188		
Exchangeable Calcium	0·053		
Loss on ignition	7·226		
Coarse sand.	55·42		
Fine sand + silt	19·91		
Fine silt + clay	15·06		

Total annual rainfall. 40·38 ins. (1930.)
Mean annual temperatures
Max. 51·0°F.
Min. 39·9°F.

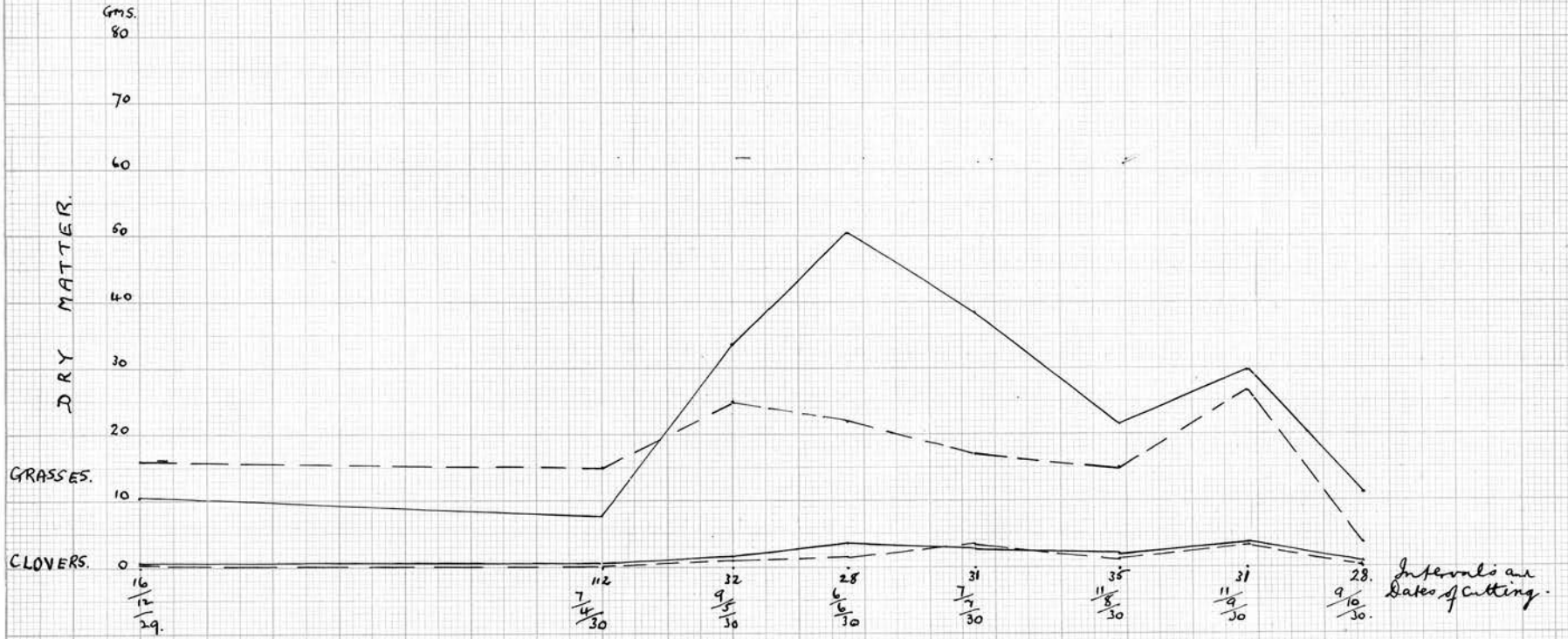


Fig. 1. — [illegible] Seasonal fluctuations in yield of grasses and clovers on limed and unlimed plots. (pasture cuts.) December 1919 to November 1930.

——— Limed section of plot.

— — — Unlimed " " "

DATA (SOILS.)

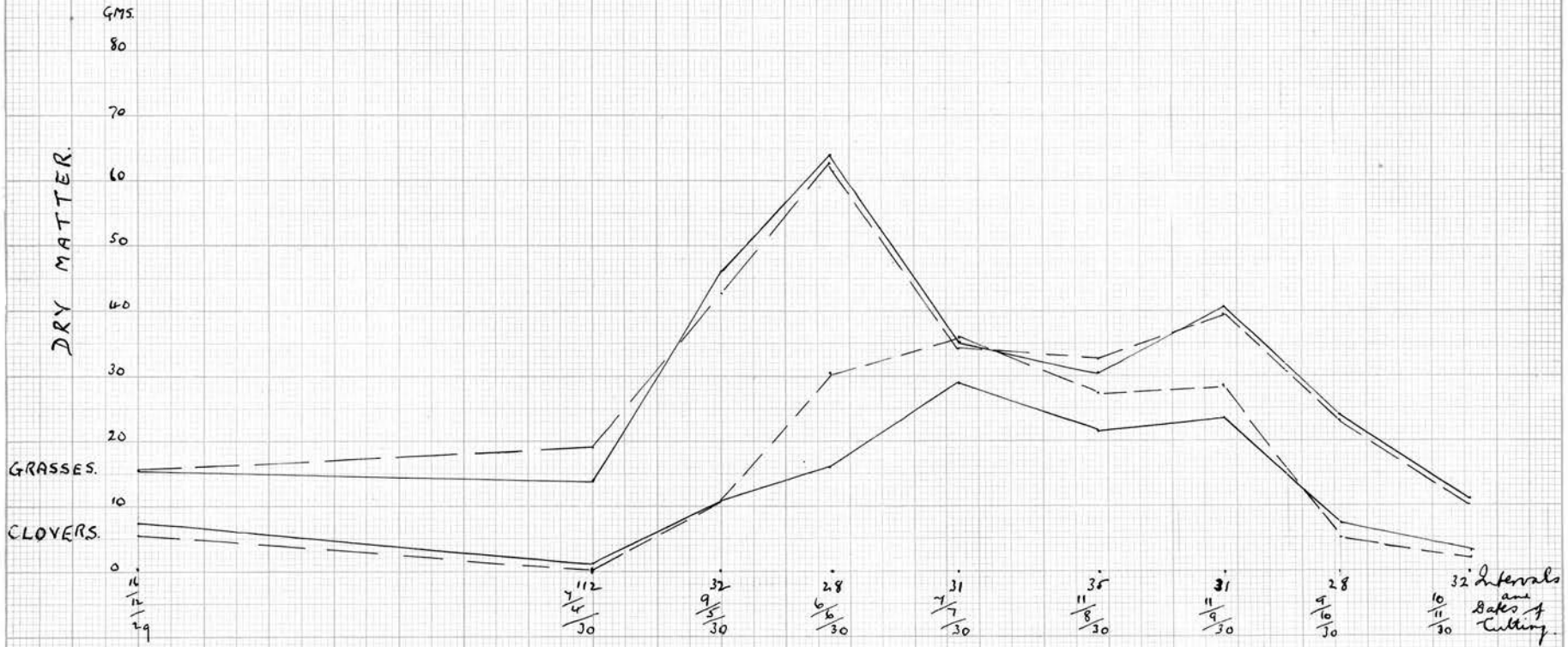
	Oct. 1928	April 1930.	Unlimed.
Reaction (pH.)	6·57	6·62	6·19.
Lime Requirement	0·068		
Exchangable Calcium	0·112		
Loss on ignition	6·195		
Coarse sand	28·50		
Fine sand + silt	38·09		
Fine silt + clay	24·42		

Total annual rainfall 40·38 ins. (1930.)

Mean annual temperatures

Max. 51·0° F.

Min. 39·9° F.



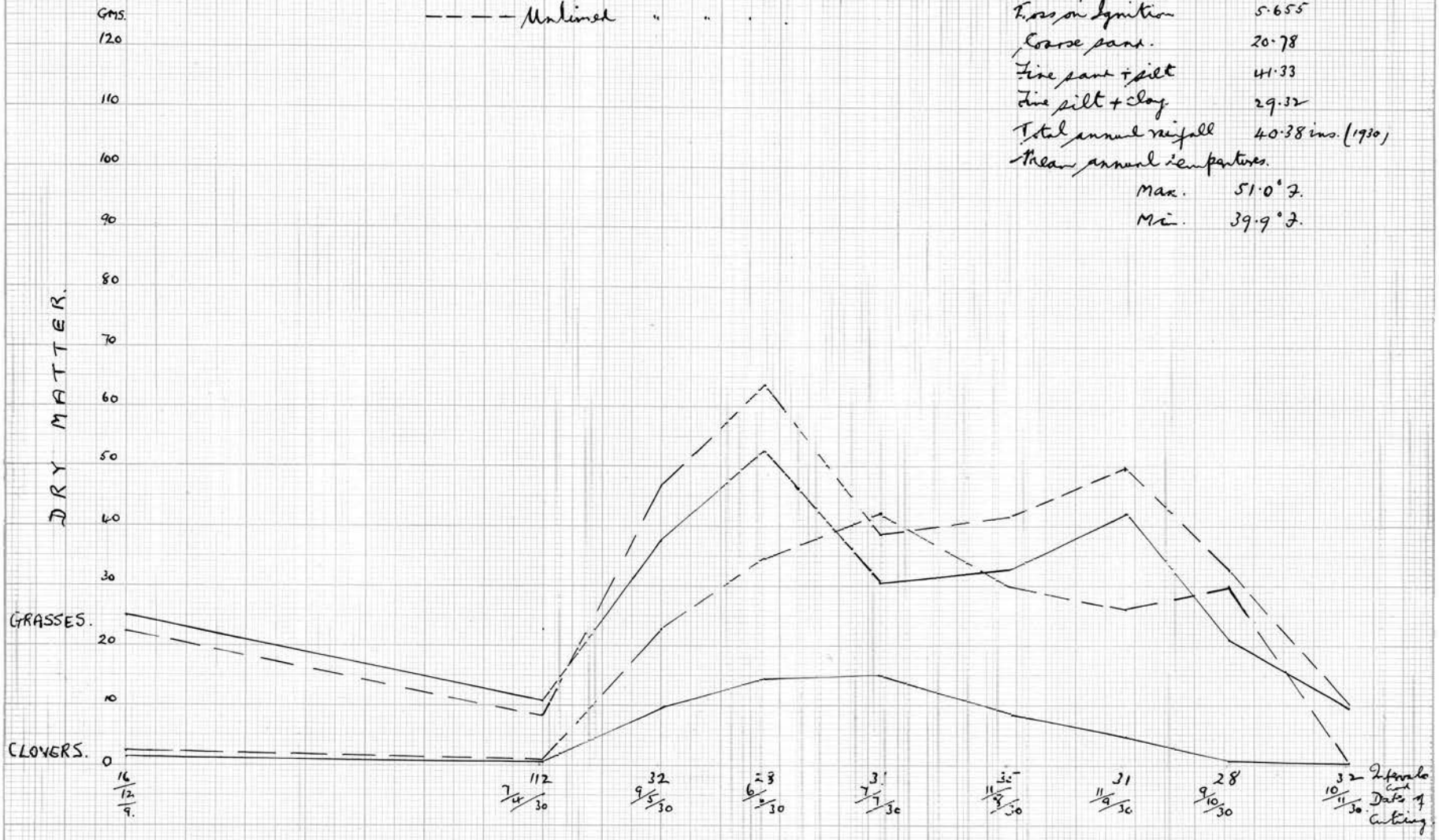
Seasonal fluctuations in yield of grasses and clovers on limed and unlimed plots (fractional cuts) December 1929 to November 1930.

——— Limed section of plot.

– – – – Unlimed " " "

DATA. (Soil.)

	Oct. 1928.	Apr. 1930.	Unlimed.
Reaction (pH.)	5.97	6.00	5.72.
Lime Requirement		0.110	
Exchangeable calcium		0.080	
Loss on Ignition		5.655	
Coarse sand.		20.78	
Fine sand + silt		41.33	
Fine silt + clay		29.32	
Total annual rainfall		40.38 ins. (1930)	
Mean annual temperatures.			
Max.		51.0° F.	
Min.		39.9° F.	

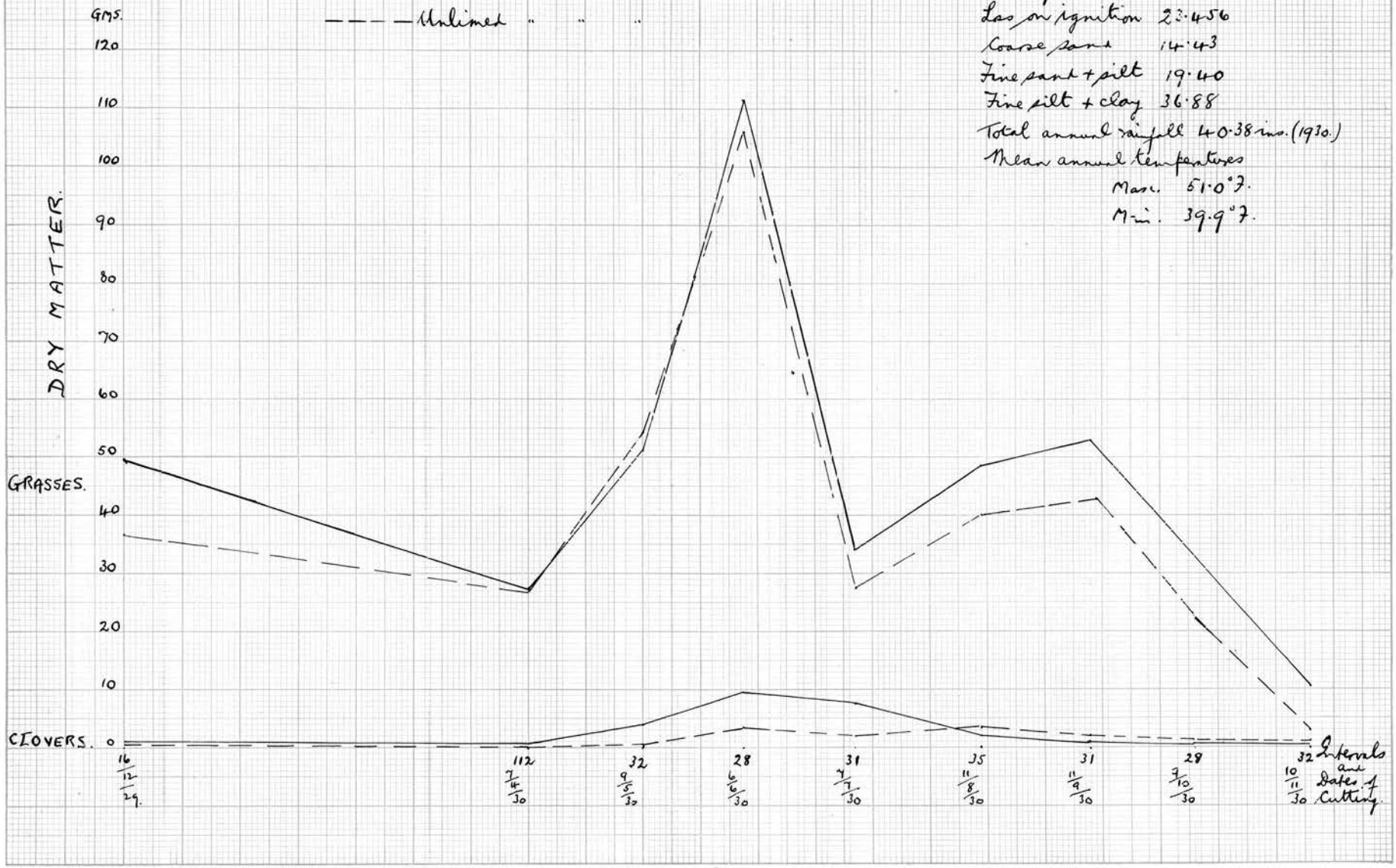


PLOT D. (CROFTS.) Seasonal fluctuations in yield of grasses and clover on limed and unlimed plots. (pasture cuts.)
December 1929 to November 1930.
——— Limed section of plots.
– – – – Unlimed " " "

DATA (SOILS.)

	Oct. 1928.	Apr. 1930.	Unlimed.
Reaction (pH.)	5.77	6.26	5.77

Lime Requirement 0.376
Exchangeable calcium 0.310
Loss on ignition 23.456
Coarse sand 14.43
Fine sand + silt 19.40
Fine silt + clay 36.88
Total annual rainfall 40.38 ins. (1930.)
Mean annual temperatures
Max. 51.0°F.
Min. 39.9°F.



LEVEL. { BANGOR } Seasonal fluctuations in yield of grasses and clovers on limed and unlimed plots. (pasture cuts.)
December 1929 to October 1930.

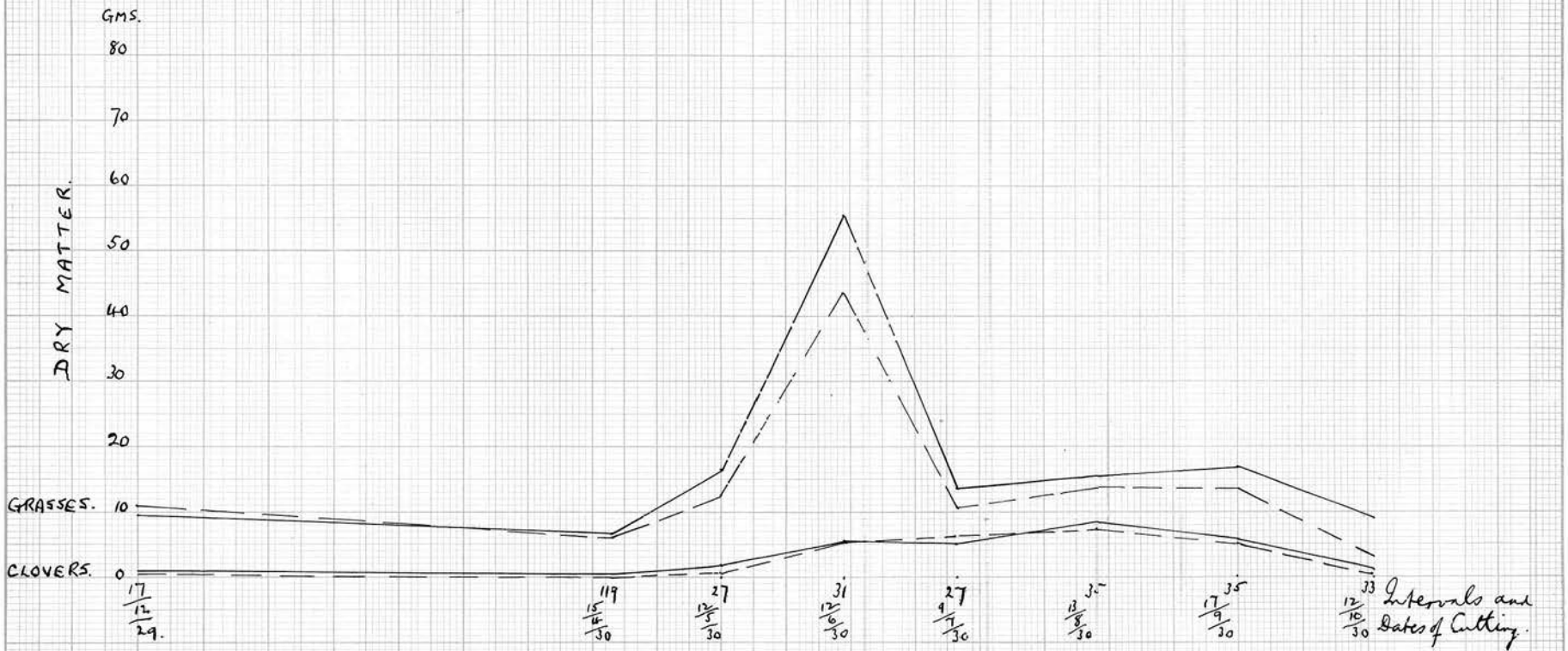
——— Limed section of plot.

– – – – Unlimed " " "

DATA. (SOILS.)

	Oct. 1928.	Apr. 1930.	Unlimed.
Reaction (pH)	6·59	6·45	6·33.
Lime Requirement	0·094		
Exchangeable calcium	0·141		
Loss on ignition	10·895		
Coarse sand	24·59		
Fine sand + silt	29·19		
Fine silt + clay	31·64		

Total annual rainfall 37·24 ins. (1930.)
Mean annual temperature.
Max. 51·0°F.
Min. 38·8°F.



ILUVIAL {WEDDERLIE} Seasonal fluctuations in yield of grasses and clovers on limed and unlimed plots. (pasture cuts.)
December 1929 to October 1930.

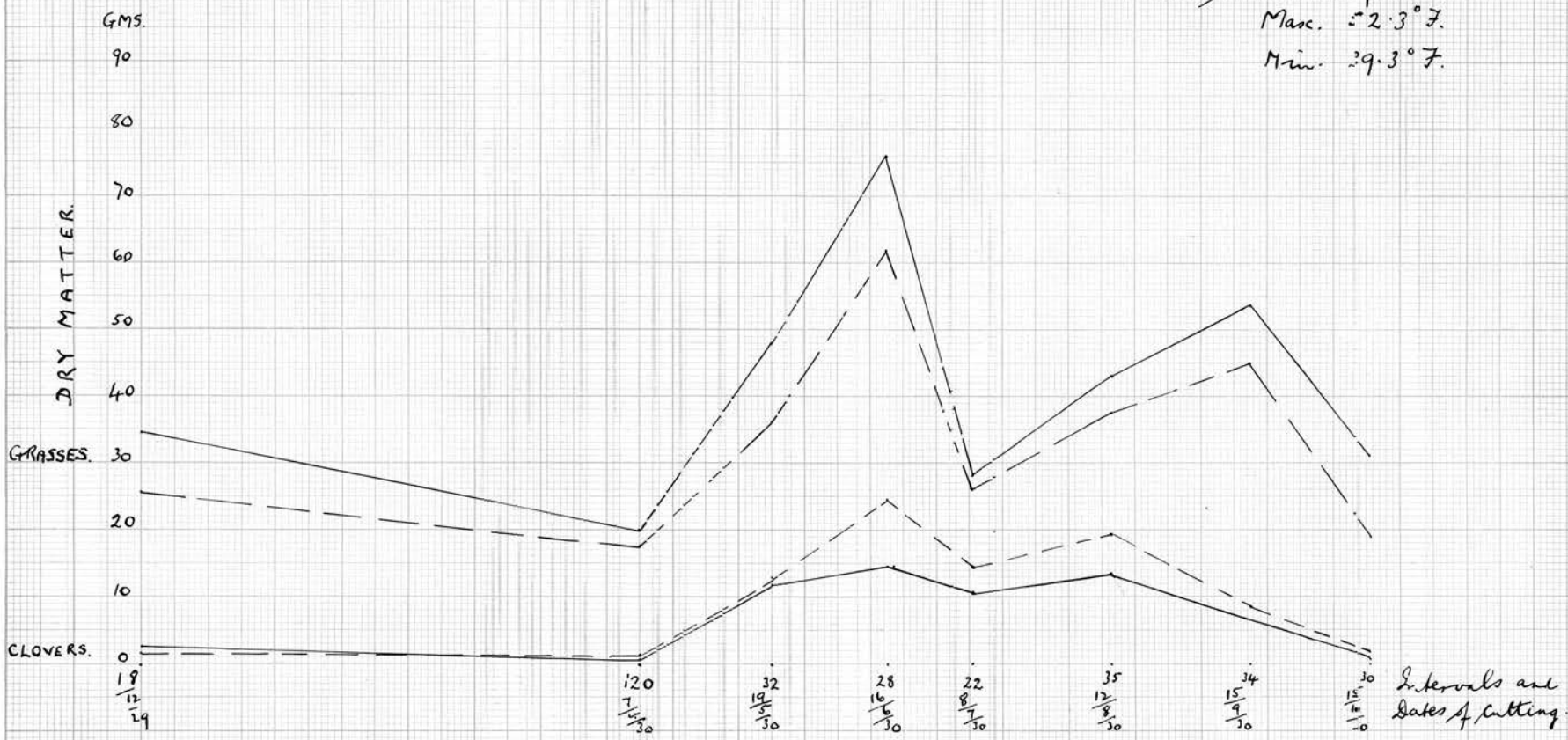
——— Limed section of plot.

– – – – Unlimed " " " .

DATA (Soils.)

	Oct 1928.	Apr. 1930.	Unlimed
Reaction (pH.)	5·51	5·30	5·24
Lime Requirement	0·251		
Exchangeable Calcium	0·038		
Loss on ignition	7·662		
Coarse sand	15 78		
Fine sand + silt	37·44		
Fine silt + clay	36·50		

Total annual rainfall 35·16 ins. (1930.)
Mean annual temperatures
Max. 52·3° F.
Min. 39·3° F.



PLOT [HAMMERLAWS] Seasonal fluctuations in yield of grasses and clovers on limed and unlimed plots. (pasture cuts.)
December 1929 to October 1930.

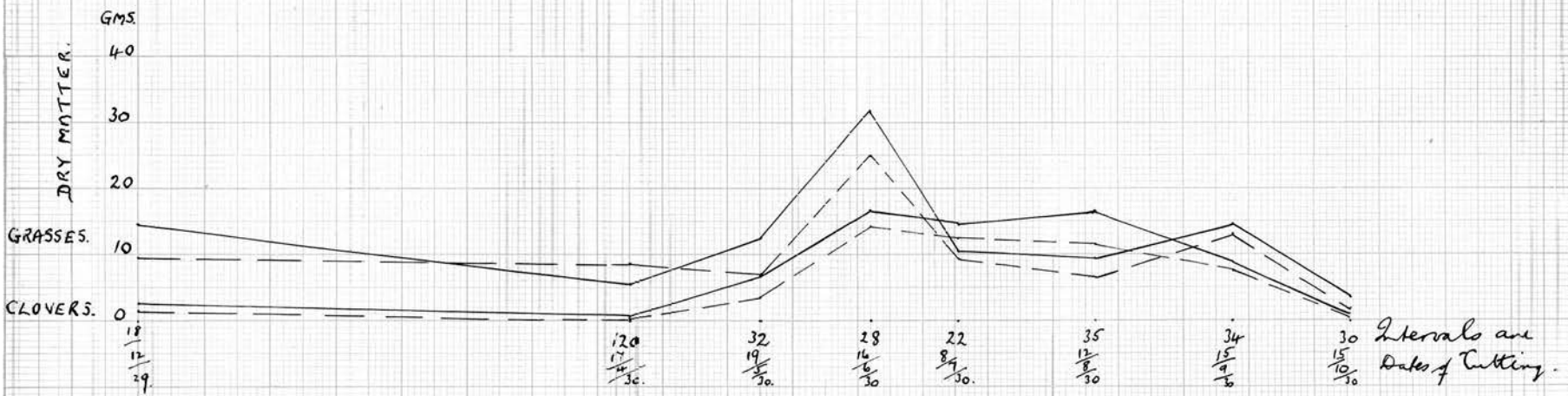
——— Limed section of plot.

– – – – Unlimed section of plot.

DATA (SOILS.)

	Oct. 1928.	Apr. 1930.	Unlimed.
Reaction (pH.)	5·53	5·41	5·36.
Lime Requirement.	0·313.		
Exchangeable Calcium.	0·080.		
Loss on ignition	11·483		
Coarse sand	17·90		
Fine sand + silt	45·67		
Fine silt + clay	22·72		

Total annual rainfall 35·16 ins. (1930.)
Mean annual temperatures.
Max. 52·3°F.
Min. 39·3°F.



Photograph No. 1. illustrating type of fenced plot described on page 33; herbage outside plot was normal; grazing was mixed - cattle and sheep.

Photograph No. 2. illustrating condition of herbage within the treated plot as compared with bleached condition beyond the fence. The left hand half of the plot was limed (WEDDERLIE centre) see pp. 109-111. The main field was grazed by sheep only.

Photograph No. 3. illustrating reversion of pasture to Agrostis-Holcus association (WEDDERLIE and CAMMERLAWS centres). Compare with condition of herbage within plot in photograph No.2. see pp. 109-111. The field was grazed with sheep only.