

MACAULAY INSTITUTE
FOR SOIL RESEARCH

1945-1946

ANNUAL
REPORT

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

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1945-1946

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

ANNUAL REPORT

1945-46

It is with regret that the Council has to record the death of Mr. James Dunlop, a member of the governing body since 1937, and also of Dr. J. F. Tocher whose retiral from office was recorded last year. Dr. J. M. Caie, representing the Department of Agriculture for Scotland, and Professor C. M. Yonge, representing the West of Scotland Agricultural College, joined the Council of Management. Dr. D. M. C. MacEwan of the X-ray Department resigned on accepting an appointment in the Department of Pedology at the Rothamsted Experimental Station and Mr. G. F. Walker succeeded him as from 1st January, 1946. Dr. H. G. Dion resigned as from 31st March, 1946 on his appointment as Associate Professor in the Department of Soils, University of Saskatchewan.

The Deputy Director—Dr. A. B. Stewart—was in India during the winter months and since returning in May, 1946 has submitted a comprehensive report to the Imperial Council of Agricultural Research, Government of India, dealing with the organization of soil research and its development in India.

The Council regrets to record that, consequent upon the prohibition of building, the temporary extension has not been erected and that the development of the post war programme of work has been seriously hampered. In spite of these difficulties some progress has been made with the development of spectrographic analysis and the Council feels gratified that The Macaulay Institute is designed to play an important part in such specialized work.

The Institute continued to be represented in the Agricultural Research Council Conferences on

- (a) trace elements and mineral deficiencies affecting plants.
- (b) fertilizer placement.
- (c) feeding value of pasture.
- (d) land drainage.

The Council of Management tenders thanks to the Agricultural Research Council and the Department of Agriculture for Scotland for grants received, to the Forestry Commission for grants in aid, to the Carnegie Trust for grants for special apparatus and to other benefactors.

September 1946.

SOIL FERTILITY AND ADVISORY WORK

SOIL FERTILITY INVESTIGATIONS.

The ultimate objective of the investigations is the improvement of fertilizer practice and of methods for assessing the nutrient status and requirements of soils. In the experimental approach to these problems an integration of field, pot and laboratory experiments is desired for which the establishment of an adequate field experiment background is regarded as a fundamental necessity. During the year there has been a total of 60 field experiments in progress from which about 1200 soil and 1200 produce samples were taken for laboratory examination, and work has been continued and extended along the following general lines :

General Manurial Experiments. Investigation of the effects of lime and fertilizers on the yield and composition of different crops and on soil properties with particular reference to :

- (a) the nutritional requirements of individual crops.
- (b) the interactions of nitrogen, phosphate and potash.
- (c) the rotational needs of different soil types.
- (d) the practical interpretation of laboratory analyses.

These investigations are inherently of a long-term character and are not yet sufficiently advanced for definite conclusions to be drawn.

Phosphate Relationships of Soils. Investigation of the phosphate relationships of different soil types with particular reference to :

- (a) the occurrence, nature and significance of phosphate fixation.
- (b) the interaction of lime and phosphate.
- (c) the relative efficiencies and residual values of various dressings of different types of phosphate fertilizers, measured with the aid of different indicator crops.
- (d) the efficiency of various measures designed to reduce fixation and promote higher utilization of applied phosphate, e.g. the use of silicates and granular phosphates.

The general pattern of the phosphate relationships of some of the more clearly defined soil types is now emerging. With responsive crops, such as roots, yield increases of the order of 50-100 per cent. following the application of dressings of 40-80 lb. P_2O_5 per acre are common on several types of phosphate deficient soils but the residual effects, even of much heavier dressings, are generally small, especially on soils derived from granitic drift. These have a high capacity for fixing phosphate in unavailable form and absolute crop failure is frequently encountered where no phosphate is applied. The granitic soils also exhibit a characteristic behaviour in that where lime has been applied the response to phosphate is generally greatly reduced. On soils of basic-igneous origin, on the other hand, the effects of lime and phosphate frequently tend to be additive. In establishing the general response to phosphate on limed and unlimed samples of different soils, in

measuring the residual effects of field dressings and in comparing different forms of phosphate, pot experiments of the Mitscherlich type provide a useful supplement to the field trials and have again been extensively employed. A considerable amount of field, pot and laboratory data on the relative efficiencies of various phosphate fertilizers, e.g. superphosphate, reverted-superphosphate, mineral phosphate, bone fertilizers and silicophosphate, and of powdered and granular forms of phosphates have now been accumulated for different soils and crops. It is hoped to submit an account of these results for publication during the next few months.

In the laboratory further analytical data have been obtained for soil and produce samples from the field and pot experiments. The acetic-soluble phosphate values for the soil samples are in general agreement with subsequent yield data in that they show little residual effect of normal dressings of phosphate, especially on granitic soils, and are largely independent of the form in which the phosphate was applied. Crop analyses show that the increased yields following the application of phosphate are generally paralleled by increases in the phosphate content of the produce. Work has also been continued on specific aspects of the phosphate relationships of some of the soil types. Publication of the results of the investigation of the effect of lime on the fixation and subsequent extraction of phosphate under laboratory conditions, referred to in last year's report, has been delayed because of apparent differences in the behaviour of soils limed in the laboratory and in the field. The significance of these differences is not yet clear and is being investigated. Further work has been done on the extraction of soils with fluoride solutions. Several of the soils examined appear to contain considerable amounts of "fluoride-soluble" phosphate, but the relationship of this to the field behaviour remains to be established.

Fertilizer Placement. The general study of the effects of different methods of applying fertilizers, started in 1943, has been continued and extended with the aid of a grant from the Agricultural Research Council to whom a report on the 1945 experiments has been submitted. The results obtained may be summarized as follows :

Cereals :

- (a) There were no significant differences in the residual effects of broadcast and drilled fertilizers applied in 1944.
- (b) Further evidence was obtained in favour of drilling phosphate with seed.
- (c) There appeared to be no difference between drilled and broadcast applications of up to $1\frac{1}{2}$ cwt. per acre in the case of sulphate of ammonia and up to 5 cwt. per acre in the case of NP fertilizers.
- (d) There was some indication that 5 cwt. per acre of an NPK mixture was less effective when drilled, but with dressings up to 3 cwt. per acre drilling and broadcasting proved equally effective.

Direct Reseeding :

- (a) Further evidence was obtained in favour of drilling phosphate with grass and clover seeds on phosphate deficient land.
- (b) With N, NP and NPK fertilizers drilling produced no obvious advantage but the existing results are insufficient to be conclusive.

Roots :

Preliminary trials showed no significant difference in the effects of band and broadcast applications of Canadian granular ammonium phosphate.

During 1946, experiments have been continued on the comparison throughout a rotation of full-dressings of phosphate broadcast with half-dressings drilled and additional experiments are being carried out on the drilling of N, N P and N P K fertilizers. The efficacy of soaking oat seed in phosphate solutions as a means of applying phosphate is also being investigated.

Comparisons of Liming Materials. The materials under test include ordinary limestone of varying fineness, magnesian limestone, magnesian lime, shell sand, and a falling haematite slag. The results to-date indicate that on the basis of their effects on both soils and crops the differences between the various materials are small compared with the overall effect of liming which is marked on acid soils of most types, especially with the more sensitive crops.

Forest Nursery Investigations. Co-operative work with the Research Branch of the Forestry Commission on various aspects of Nursery practice has been continued along the lines indicated in last year's report.

ADVISORY WORK

Field and laboratory examination of soils for advisory purposes, with particular reference to problems of liming and manuring, has been continued and extended. During the year over 6,300 samples have been tested and reports have been issued on the treatments likely to be most suitable for the areas in question. The majority of the samples continue to be drawn from ordinary agricultural land, but work has also been undertaken on market garden and other horticultural areas, forest nurseries and sports grounds. In addition advisory analyses have been carried out on limestones, calcareous sands and various industrial by-products likely to be of value on the land.

In previous years the results of the soil tests were used to group soils on the basis of their contents of plant food substances, viz.: satisfactory, slightly low or low as related to the requirements of a rotation of cereals, roots, hay and pasture which is commonly practised in the North of Scotland. A separate grouping was also made according to the geological origin of the soils and results for old grassland and arable rotation land were compared. These results indicated widespread deficiencies in lime and phosphate, with deficiency in potash markedly less widespread but tending to increase somewhat in areas which had been cropped intensively during the war years. Compared with arable rotation soils old grassland soils were generally better supplied with potash but lower in phosphate. Variations resulting from differences in geological origin showed reasonably good agreement with theoretical expectations, and it was obvious that continued grouping of the soils on the above basis would serve only to improve the average percentage values without materially affecting the general conclusions drawn in past reports. In view of the fact that a reconnaissance soil survey of Aberdeenshire on the scale of 2.5 inches to 1 mile has now been completed, it was decided to alter the basis of grouping to follow the soil map and to make a

start with recent data available for this county. In Aberdeenshire 20 soil associates have been distinguished to-date, and results for the various samples are meantime being recorded according to these associates which have been derived from a range of parent materials of varying geological origin, e.g. acid igneous, intermediate and basic igneous, water sorted sediments, Old Red sandstones, siliceous deposits, etc. The data recorded are as yet insufficient to permit of correlation with individual soil types, but it is obvious that, in the area as a whole, deficiencies, particularly of lime and phosphate, continue to be widespread.

SOIL DRAINAGE

Analytical work on the composition of the quarterly collections of the drainage waters from the Craibstone Lysimeters was continued, and progress was made with the analyses of the dried crops.

Rainfall, including snow, during the year 1st October, 1945 to 30th September, 1946, totalled 36.48 inches, of which from 27 to 37 per cent. appeared as drainage.

The crop during 1945 was hay, lysimeters 2 and 3 each receiving per acre, $1\frac{1}{2}$ cwt. sulphate of ammonia. The crop was cut three times, and the yields of dry matter determined. The results, per acre, were

Lysimeter	1		2		3	
	cwt.	lb.	cwt.	lb.	cwt.	lb.
3rd July	23	17	22	32	22	28
25th September	7	12	9	80	9	63
5th November	4	46	6	27	6	60
Total	34	75	38	27	38	39

Clovers were more plentiful on lysimeter 1 than on either of the other two.

The crop during 1946 was pasture, lysimeters 2 and 3 each receiving per acre, 6 cwt. sulphate of ammonia applied in four dressings of $1\frac{1}{2}$ cwt. at intervals throughout the year. The crop was cut three times (May, July and September) the total yields of dry matter, per acre, being

Lysimeter 1	24 cwt. 32 lb.
Lysimeter 2	29 cwt. 10 lb.
Lysimeter 3	28 cwt. 87 lbs.

Treatment with sulphate of ammonia appeared to diminish the proportion of clovers.

SOIL SURVEY, CLASSIFICATION AND PEDOLOGICAL STUDIES

SOIL SURVEY

ABERDEENSHIRE.—The reconnaissance soil survey of Aberdeenshire on the scale of 2.5 inches to 1 mile was completed by the mapping of the western part of the county. The area mapped stretches in a line from east of Huntly through Kildrummy and Towie on the Don to Aboyne and Ballogie in the Dee valley. The area covered was approximately 300 sq. miles. Much of this area is hill land afforested or under heather moors and the survey has been mainly confined to the arable land. About Huntly in the Drumblade district and down the Bogie valley to Rhynie, in areas below 600 ft. excellent farm land is to be found. Sheep farming with stock raising and afforestation is of great importance in the higher lying areas.

The soils mapped fit into the previously established soil associations with the exception of areas on drift derived from bedded quartzite to be called the Durnhill association and an area of drift on andesite lavas to be known as the Gartly association. In the Countesswells association area on the Dee there are areas of calc-silicate rock, which influence the drift but the establishment of an independent association will depend on further data. The associations mapped this year include Countesswells, Tarves, Inch, Foudland, Cuminstown, Corby, Kemnay, Durnhill, Gartly and Leslie.

1. *Countesswells Association.* This association, developed on granitic and gneissic boulder clay was found to extend westwards along the Dee and its tributary valleys and has been mapped as far as Inverey. A small area also occurs south of Clatt. In general the soils conform to the associates found to the east, especially in the Garlogie area. The surface soil is a medium dark brown loam to gritty sandy loam and is generally bouldery and stony with frequently a thin iron pan above an indurated B₂ horizon. On the steeper slopes the iron pan occurs immediately under the cultivated A horizon. In parts the morainic drift becomes so light textured that the line between the Countesswells and the Corby associations becomes difficult to delineate.

The topography of this area on Deeside is hilly and in part mountainous so that there is a very extensive area of hill-land covered by this association. Areas of thin rubbly drift and residual granite or gneiss occur on the higher ground with occasional areas of deeply weathered granite. Because of the steep and rocky nature of the ground rotational farming is mainly confined to the valley bottoms. Sheep farming and afforestation become of increasing importance from Aboyne westwards. Between Banchory and Ballater in the valley of the Dee there are areas of a metamorphic limestone rock. The glacial drift of this area contains a large proportion of granite and schistose rocks as well as fragments of the limestone. The drift is also similar in texture to that of the granitic areas and until further data are obtained the soils of this area are included in the Countesswells association.

2. *Tarves Association.* An extensive area of this association which is developed on boulder clay derived from acid and basic igneous and metamorphic rocks was found to stretch westwards from Tarland nearly to

Morven and over by Towie into the Don valley. It extends into the valleys of the Buchat, the Nochtly and the Deskry waters. Smaller areas are found to the south of Ballater in Glen Muick, around Knock and the Coyles of Muick, and also on the east and west sides of Glen Gairn. The topography is hilly and much of the higher ground is uncultivated. The glacial drift is a stony fine sandy loam to sandy clay loam, with the heavier texture generally in the wet associate. The surface texture is generally a heavy loam. The drainage conditions are variable but extensive areas of poorly drained associates tend to predominate. Another area of this association has also been mapped to the north-east of Huntly. The topography of this area is gently undulating resulting in the development of slightly poorly drained to poorly drained associates. The altitude of this area is 350 to 550 ft. and this area may be considered good to very good agricultural land. In the area between the Dee and the Don the altitude is higher, from 650 to 1,000 ft., which detracts from the agricultural value of the land.

3. *Insch Association.* This association, developed on drift derived from basic igneous rocks or residual on basic igneous rocks, is extensively found north of Huntly. The topography is rolling to hilly and the arable soils tend to be the slightly poorly drained to poorly drained associate. Localized areas of the freely drained associate occur with the characteristic bright brown A horizon. The area is very bouldery. The soils of the afforested land in this area have been described by Muir.

In the Cabrach under a roughly undulating to hilly topography another area of this association occurs. The freely drained associate tends to be predominant with bouldery conditions throughout. Considerable areas have been abandoned to permanent grassland. The high altitude (650 to 1,350 ft.) is a handicap to crop production although the area has a high reputation for stock raising.

An extensive area of this association was found around the mass of basic igneous rocks stretching from Morven into Glen Buchat and extending over into the Cabrach. The topography is similar to the above areas, being much hillier than in the typical areas of the *Insch* association in central Aberdeenshire. The cultivated soils are found on fairly steep valley sides and much of the higher ground is rocky and is generally uncultivated. Much of the valley sides is slightly poorly drained with the wetter associate predominating on the flatter slopes.

There is no sign of a bleached horizon under heather. The characteristic colour of the cultivated A horizon of the freely drained associate is a bright brown but is greyer when poorly drained. The texture is a heavy loam.

5. *Foudland Association.* This association is developed on a boulder clay mainly derived from argillaceous schists. The area surveyed extends from the Hills of Foudland through Clashindarroch to the county boundary and south from the *Insch* association boundary through the Correen Hills to Alford. The area has a characteristic smooth, broadly rolling to hilly topography, with convex slopes. The main associate is freely drained and there is a relatively small proportion of the poorly drained associate. The texture of the surface soil is a silty fine sandy loam. There is a complete absence of boulders, which facilitates ploughing on the hill land for afforestation. A feature of the area covered by this association is the large,

regular fields with wire fences rather than stone dykes. Water shortage is common over this area.

In the district about Auchernach in Glen Nochtly there is a development of soils derived from black schist drift. The soils generally resemble those of the Foudland association in profile characteristics but the surface layer is very much darker and even black to dark grey in colour.

6. *Cuminestown Association*. The area covered by this association, which is developed on drift over Old Red Sandstone rocks, was found to extend along the Bogie valley from Kildrummy to north of Rhynie. The soils are generally freely drained with sandy loam and loamy sands predominating and of a reddish dark brown colour. The soils occur at a uniform altitude of between 700 to 800 ft. and the topography is strongly dissected.

7. *Corby Association*. A very extensive development of this association, which is developed on water-sorted sands and gravels, occurs in the Bogie valley between Lumsden and Rhynie. The topography is morainic. Under natural vegetation the soil is a freely drained podzol, with pan developed. It also occurs about Huntly on a high terrace and at the Corse of Kinnoir. Gravelly sandy loam is the predominant texture. This association was also found extensively developed in the area of the Countesswells association in the Dee valley. A large stretch occurs from Aboyne westwards about Dinnet and to the east side of Morven. There is also an extensive development on the south side of the Dee, in the valley of the Feugh and about Marywell and Birse. In the Don valley from Towie westward and in the side valleys of the Buchat, Nochtly and Ernan this association is also found. The soils are loamy sands to gravelly loams in texture on a mounded or ridged topography with occasional fairly flat areas.

8. *Kemnay Association*. The soils of this association are developed on alluvium and recent alluvium and show little or no differentiation into horizons within the profile. They occur alongside stream channels and are very widespread about Huntly and alongside the Bogie and Deveron. The general drainage is slightly poor to poor and the texture ranges from sandy loam to loam. Where flooding is not a problem these soils are very productive. There is also an extensive development of this association in the valleys of the Dee and Don and their tributary streams. The alluvium is on the whole a gravelly sand with occasional areas of silt and fine sand. The soils are generally light textured and gravelly, loamy gravelly sands and gravelly sandy loams being common. The drainage is variable.

9. *Durnhill Association*. This association is developed on quartzites and highly quartzose schists or on glacial drift derived from them. It occurs at relatively high altitudes (700-1200 ft.) on a hilly topography. An area was found to the south-east of Keith about the Balloch Hill, in which the uncultivated land is strongly podzolized. The parent material is a whitish yellow stony loamy sand till. A number of small areas occur on hill tops west of Huntly. Another area occurs in the valley of the Nochtly with soils of a medium brown stony sandy loam on a very stony drift. The value of the agricultural lands over this association is poor and much of the area is uncultivated or afforested.

10. *Gartly Association*. An area of this association, which is developed on drift derived from andesitic lava, occurs in the Bogie valley near Gartly. The soil tends to have a purplish reddish brown colour and a clay loam

texture. It appears to be slightly poorly drained and has a firm cheesy consistency. The topography is undulating. Only a very small area is covered by this association.

11. Leslie Association. The parent material of this association is serpentine or drift largely derived from serpentine. It occurs near Leslie and is patchily spread on the north slopes of the Correen Hills. The freely drained soils have medium to heavy loam textures while the poorly drained associate is frequently of clay loam on a clay loam to clay drift. The hills of Towanreef and Creagdearg belong to this association and are uncultivated. A feature of these hills is the prevalence of juniper and extensive bare eroded areas.

On Donside up the valleys of the Kindie and Nochtly waters there are also areas of this association. The soils are generally medium to heavy loams on a boulder clay of a stony sandy clay loam texture. The soils are in the main poorly drained and strongly gleyed. Since little of the area is now cultivated, a humus layer 3 to 4 inches thick is a common feature.

Detailed Survey. A detailed survey on a scale of 6 inches to 1 mile was made for The Rowett Research Institute on East Side and Hope farms of Craibstone, Aberdeenshire. The associates mapped are those of the Countesswells association on granitic and gneissic boulder clay. The slightly poorly drained associate was predominant while the presence of an iron pan was a feature of the steeper slopes.

LABORATORY INVESTIGATIONS

Routine analyses have been continued on 67 representative profiles. As a result of the increasing number of profiles being sampled, more rapid methods of analysis have been tested. The "Walkley-Black" dichromate method for determining carbon and also a semi-micro method for nitrogen using the "Markham" distillation apparatus have been adopted for routine analyses.

During the past few years the possibility of determining phosphorus on the water soluble portion of the sodium carbonate fusion using a colorimetric finish has been investigated. The comparative figures below bear out the success of the method finally adopted. The critical factors are the amount of carbonate used, the time the melt is allowed to remain in fusion and the final acidity. The colour is developed by hydrazine sulphate and sodium molybdate. This method permits phosphate determinations to be carried out at the rate of 100 samples a week compared with 20 by the hydrofluoric acid method.

Soil	Per cent. P_2O_5								
	1	2	3	4	5	6	7	8	9
HF Method	0.269	0.211	0.351	0.165	0.310	0.189	0.256	0.156	0.316
Carbonate Method	0.270	0.211	0.358	0.158	0.305	0.195	0.255	0.162	0.320

The preliminary results obtained by the method of thermal analysis of clays in conjunction with the X-ray data should give a fairly complete picture of the physical characteristics of the soil clays present in the different soil associations and associates.

An account of the investigation, carried out in collaboration with the X-ray department, into the ethylene glycol-water-montmorillonite system

(*Ann. Rep.*, 1944-45) has been prepared for publication. An account of soil survey in Scotland has been published.⁵

SOIL MINERALOGY

The mineralogical investigations of the soils and their parent materials collected from the surveyed areas of western Aberdeenshire has been continued. The parent materials of the arable soils in this area are mainly glacial drifts underlain by metamorphic rocks with some acid and basic igneous rock intrusions. The fine sand fractions from the matrix of the drifts have been examined and the variations in mineralogical composition have served to characterize the drifts and so provide a basis for the classification of the soil associations. Much of the glacial drift of this area is of mixed rock origin but from the mineralogical examination it has been found possible to characterize them and to assist in delineating areas of uniform composition. The fine sand fractions of the soils have also been examined and similar variations in composition, according to the type of underlying drift, found. Changes through decomposition of the minerals by weathering have also been noted.

The study of the mineralogical composition of the fine sand fractions of soils and basal materials from areas underlain by rocks of the Old Red Sandstone formation was continued on samples from Aberdeenshire and Perthshire. The parent materials are glacial drifts, generally boulder clays. The comparatively low content of ferromagnesian silicate minerals is a feature of these soils and is in agreement with previous results. This investigation is being continued.

X-RAY INVESTIGATIONS

A study of the clay fractions of the Inch Association of soils is being made. The Inch Association consists of soils derived essentially from basic igneous parent materials. It is hoped that X-ray methods will throw some light on the role of parent materials and drainage conditions in determining the type of clay mineral produced. Clay fractions from a number of soil profiles, collected and fractionated by the Soil Survey Department, have been photographed with $\text{CuK}\alpha$ radiation. The presence of amorphous material, particularly iron oxides and hydroxides, tends to produce a heavy background on the photographs and hence to make their interpretation difficult. The removal of free iron oxides is therefore being carried out on these clays and some are being rephotographed with $\text{FeK}\alpha$ radiation.

The predominant clay mineral of these Inch clays gives a diffraction pattern similar to that of vermiculite. Kaolinites and illites are often abundant but, so far, no members of the montmorillonite group have been recorded. In several cases, mixed structures of illite and vermiculite (?) have been noted. The presence of vermiculite in these clays is of considerable interest. Recent statements in the literature suggest that vermiculite may have a more widespread distribution in soil clays than has been hitherto supposed. A sample of true vermiculite recently tested in the laboratories gave a very high total base exchange capacity—of the order of that obtained for the montmorillonites. The X-ray diffraction pattern of vermiculite is somewhat similar to that of montmorillonite, but the two can be distinguished

by means of the glycerol-saturation technique developed by MacEwan while working in these laboratories and mentioned in last year's report. Glycerol enters into the lattice of the montmorillonite causing an expansion in the c-direction whereas vermiculites remain apparently unaffected by the treatment. The free iron oxides present in the clays seem to be mainly amorphous although, in some cases, crystalline forms such as goethite and hydrohematite have been observed.

The changes taking place in the biotite of the fresh rock on weathering are also being investigated. Yellow flakes of altered mica occur in the sand fractions of some of the soils. X-ray diffraction photographs show that the altered flakes have a greater basal spacing than the fresh biotite probably due to the presence of water between the sheets. Present indications are that the biotite alters through hydrobiotite to an end-product near vermiculite.

During the year further progress has been made in the collection of standard data for interpreting photographs of soil clays. Apart from photographs of single minerals, a complete series of aggregate photographs of binary mixtures containing kaolinite, montmorillonite and hydrous mica has been prepared and the kaolinite-montmorillonite, hydrous mica-montmorillonite and kaolinite-vermiculite series have been photographed by the powder method.

SOIL ORGANIC MATTER INCLUDING PEAT STUDIES

CHEMICAL INVESTIGATIONS

Routine analysis has been carried out on peats, organic soils, and miscellaneous samples of organic matter submitted, as well as on various soils and materials used in experimental work. As stated in last year's report a simplified and more rapid method of cellulose determination has been applied in the routine analyses. A scheme for the rapid analysis of the samples has now been applied for about one year and has given very satisfactory results and duplicates are generally in excellent agreement. The following determinations are now made :

- (1) pH, moisture, lime requirement, carbon, nitrogen, ash.
- (2) Alcohol-benzene solubles, cellulose, lignin, total carbohydrate, and acid-insoluble nitrogen.

This system of analysis gives a fair picture of the state of the soil organic matter. The "alcohol/benzene solubles" estimation (extraction with alcohol/benzene 1/1 for 36 hours) is the only time-limiting factor since it is possible to complete all the other analyses of the previous set while the extraction is proceeding.

In special cases estimations of the methoxyl and pentosan content are also made.

In collaboration with the microbiological section the chemical changes taking place during composting have been studied. Not only have analyses been made to outline the general course of the decomposition, but special determinations have been made to give pointers as to the biochemistry of the different sequential microbial flora. In this way the order of the proteolytic and also cellulose decomposing flora in the sequence found by microbiological methods has been corroborated by chemical analysis.

The preliminary explanatory work on the isolation, purification and characterization of the humus complexes has been completed and it is hoped that a paper on the subject will shortly appear.¹³ It became apparent early in the work that a much more stringent criterion of purity than had hitherto been in use must be applied before freedom from extraneous matter could be assumed. However, it has now been found possible to prepare humus gels and sols of a high degree of purity such as will be suitable for colloid chemical studies. Organic chemical studies on these substances have shown that while the various "humic acids" from diverse soil types have similar internal molecular structure the number and kind of reactive groups present depend on the condition and length of time under which the humus has been forming. This work is being extended to include typical examples of moor heath, moor, forest and agricultural soils of the North-east.

A paper dealing with the more soluble complexes of soil organic matter has been accepted for publication.¹⁴ The general trend of this work was reported last year (*Ann. Rep.*, 1944-45). During the past year this work has continued as an intensive investigation into the application of chromatography to aqueous solutions of complex organic anions. The possibilities

of other physical methods of separation have also been investigated. Efforts have been made to trace soil constituents of apparent microbial origin to some particular group of organisms.

PEAT AND COMPOST INVESTIGATIONS

Growth tests using peat and potting composts made up with peat from last year's survey. Peats obtained during last year's survey have been tested as regards their value for pot work, where a new feature has been the use of brown glass flowerpots in place of the usual type. It has been found that in these pots nutrient deficiencies in the peat are much more readily observed than in clay pots in which traces from previous soils tend to obscure such deficiencies. These deficiencies are of little consequence if the peat is used as a constituent of potting composts. Seeds grown in peat to which normal amounts of lime, phosphate, potash and nitrogen have been added are unable to grow beyond the early seedling stage, or if they do, show signs of deficiency disease. On the other hand, plants grown in potting composts from the same peat show normal growth. Where toxicity from peat is involved (affecting germination and early root development) there is a reduced growth of plants in the potting composts. Further work within the space available has been devoted to pot trials to test the availability of organic nitrogen.

Compost Investigations. These have been continued and considerably extended, the general scheme of the work being oriented round studies of the microbial and chemical changes occurring during the decomposition of garden refuse and other vegetable matter.

Microbiology of Composting. In the Annual Report of last year, a short initial account was given of the microbiological changes taking place during the process of composting of fresh grass cuttings. The observations were made on samples from the centre of composts prepared in specially adapted concrete drain pipes. This work has been continued and considerably expanded. In particular alongside the microbiological observations routine chemical analyses, etc. have been carried out on the material. In this way it has been possible to get a more complete picture of composting from both the chemical and microbiological aspects than has hitherto been possible. The results obtained from both aspects have been in close agreement. In addition to those reported last year the following new observations may be recorded :

(1) *Moisture Content.* The moisture content in this particular material varied little over the composting period. It is thus possible to express numbers of bacteria as millions per gram of fresh material.

(2) *Behaviour of the material at the high temperature phase.* While the temperature of the compost is high a dark coloured liquor oozes from the material and flows down the aeration channels made in the platform on which the pipe rests. This material has been collected and studied. In addition a new technique has been evolved for studying the production of this liquor from fresh grass cuttings on a small scale in the laboratory under conditions very similar to those obtaining in the compost. As a result of this work it has been possible to demonstrate one of the functions of the thermophilic flora.

(3) *Microbiological Observations.* It has been confirmed that a marked reduction of the organisms, originally present on the fresh cuttings, takes

place at the high temperature (65° C.) reached in the compost. A preliminary technique has been developed to show the percentage of the remaining aerobic mesophilic bacteria which are present as spores.

(4) *Thermophilic Flora*. A more detailed study has been made of the aerobic thermophilic flora which is present at this stage. Its presence can be shown by the use of the Cholodny buried slide technique, osmic acid and Bouin's fluid being used as fixatives and Heidenhem haematoxylin for staining purposes. This technique is limited to the study of the microflora during the very early stages of composting. When the material has decomposed to some extent the slides become covered with organic matter which also takes up the stain. Its use has been discontinued therefore apart from studying the thermophilic flora. For this purpose it is only necessary to leave the slides buried for short periods.

Using the well-known dilution method a number of isolates of the thermophilic flora have been obtained on nutrient agar, the plates being incubated at various temperatures. These isolates have been purified and appear to fall into two groups :

- (a) *True Thermophiles* which grow well at 65° C. and 55° C. in 24 hours but show no or very little growth at 37° C. and 25° C. even after a fortnight.
- (b) *Facultative Thermophiles* which grow well at 55° C. and 25° C. in 2-3 days.

All the isolates studied of both groups appear to be rod-shaped aerobic spore-forming bacilli and in the case of the true thermophiles all the isolates obtained have the same colony characteristic. Morphologically their appearance is similar to the organisms developing on the buried slides, viz., rod-shaped spore-forming bacilli. Physiologically the main characteristic of both groups is their ability to attack protein matter (e.g. peptone) with liberation of ammonia. Cellulose in the presence of organic and inorganic nitrogen does not appear to be attacked. The true thermophiles require a very high degree of aeration for maximum growth and liquid cultural methods had to be modified for their study.

The thermophilic flora is very noticeable as a white covering on the grass cuttings in the top layer of the compost.

(5) *Mesophilic flora developing on nutrient agar*. It was recorded in the last report that when the temperature of the material fell below 40° C. a very rapid growth of mesophilic aerobic bacteria took place. This has been confirmed several times and a study made of the physiology of the dominant organisms. After this rapid increase there is a marked decline in numbers. Turning of the material at this stage does not appear to influence the decline.

(6) *Fungi*. As reported last year, no marked fungal phase has been observed. Some fungal growth does appear for a short time after the high-temperature phase near the periphery of the compost just below the surface layers.

(7) *Aerobic cellulose decomposition*. The numbers of aerobic cellulose-decomposing organisms have been followed using the well-known filter paper strip dilution method.

The results parallel those obtained for the general bacteriological picture described above. There is a marked reduction of cellulose decomposers at

the peak of the rise in temperature followed by a very marked increase when the temperature falls below 40°C . No thermophilic cellulose decomposers have been found in this type of compost by the techniques so far employed.

Besides attempting to clear up some outstanding points in the microbiology of grass composting, attention has now been diverted to a study of straw composting. For this purpose, the same composting arrangement is being used. The material employed is barley straw cut to about the same length as the grass cuttings. The moisture content of the straw has been adjusted to that of the grass compost. Ammonium nitrate is used as a source of extra nitrogen. Already a number of interesting differences have been noted from the microbiological and other aspects in the behaviour of the material as compared with that of the grass cuttings. The work is being continued.

During the year some microbiological work has been done in connection with the partial sterilization experiments which are being carried out by the Forestry Commission. The result of a suggested plot experiment is being awaited.

Investigations into the use of peat fortified with artificial manures as a substitute for farmyard manure. The results of this investigation in its short-time aspect are being submitted as a report to the Agricultural Research Council. In brief, it has been found that, due consideration being given to the difficulty of assessing the rate of availability of organic nitrogen, peat with an equivalent amount of artificial manure and organic nitrogen can be used in place of farmyard manure as an occasional dressing and over the period of a single rotation. Even in market-garden practice, where farmyard manure is applied in larger amounts and at frequent (almost annual) intervals, no untoward effects have been produced in the soils treated with peat, in so far as crop results or routine analyses demonstrate. Secondary causes of trouble arising from the use of peat alone or artificials alone on soil from which the turf had been removed seem to be related to the removal of trace elements in the turf. These may be replaced by treatment with farmyard manure but not by peat or artificials.

Attempts to differentiate in the laboratory between peat and the more normal agricultural types of organic matter added to soil in these experiments have not been successful. Although the proportion of the various fractions varies in general with the type of organic matter the variations are neither so regular nor so great as to form a basis of separation. For example, the polyuronide content (of which a special study was made) is in general higher in the better types of organic matter but is nevertheless higher in some peats than in some cultivated soils.

This series of experiments has now been restricted to selected areas in which routine trials will be continued over a long period.

SPECTROGRAPHIC INVESTIGATIONS

THE CATHODE LAYER ARC METHOD

The scheme for the extension of spectrographic work on agricultural problems in Scotland, prepared by a committee of the interested institutions and approved by the Department of Agriculture for Scotland and the Agricultural Research Council, has involved the Institute in a considerable training programme as well as further routine and research investigations, in addition to the continuation of the normal lines of work covered in previous reports. A grant to cover these extensions has been approved and a new Hilger Large Quartz Spectrograph and Spectral Line Microphotometer have been installed. In this connection, it became necessary to increase the available direct current supplies for arc work, and tests have shown that a Westinghouse Westalite Rectifier supplying 14 amperes at 250 volts from a three-phase alternating current supply is very satisfactory for the operation of one arc unit. This instrument is much more convenient than the rotary converter previously employed, and the results obtained from the two sources are identical. For purposes of demonstration, the Hilger Spectrum Projector is proving useful, although for investigational purposes, a spectrum comparator is to be preferred. In view of the limited laboratory accommodation available, the saving of space obtained by the use of a Galvo-scale projector instead of the usual lamp and scale galvanometer has proved valuable, although it was found that a wall bracket support was necessary owing to the vibration transmitted by the floor.

The application of the cathode layer arc spectrographic method to the determination of trace constituents in concentrates from soils, plants and animal organs has been continued, and the methods further developed. In the concentration method involving the analysis of the precipitate from 8-hydroxyquinoline, tannic acid and thionalide¹² the relationship of electrode size and shape and the method of preparation of the concentrate have been studied. It has been found, that more reproducible burns can be obtained by increasing the carbon powder to sample ratio in the material filled into the electrode. This has involved the use of an electrode with a slightly wider bore, namely 1.0 instead of 0.8 mm., when a 2 : 1 ratio was employed, in order to keep the amount of the sample in the electrode constant. The reason for the less stable burn with these precipitates is not clear, although it may be due to the presence of sulphur from the thionalide. If part of the Al_2O_3 be added after precipitation the effect is considerably reduced.

A description of the simplified method for the evaluation of the results of the background correction method discussed in last year's report, and for which a table was given in the appendix, has been published.² The application of background correction to the variable internal standard method has enabled the relationship between relative intensity of the internal standard and analysis lines to be studied more closely. It has been found that for all the elements examined, a straight line working curve at an angle of 45° can be obtained. An account of this work has been published.⁸

The quality of the anhydrous sodium carbonate used for the fusions has

been rather unsatisfactory in recent batches. Analar grades have contained high iron contents, considerable impurities being visible as a sediment on solution whilst contents of nickel, lead, tin, silver, copper and sometimes even cobalt have also been quite high. Purification has been obtained by solution, filtration, and dithizone extraction, followed by freezing out of the sodium carbonate which is allowed to effloresce and then ignited at low temperature to give the anhydrous salt.

The method for the direct current determination of copper together with barium, strontium and manganese in plant ash has been further investigated, particularly in regard to the effects of variation of composition of ashes of different plant species on the results obtained. Whilst copper results are reasonably accurate (within ± 10 per cent. for single determinations) within the limits of variation found, larger deviations are occasionally obtained for the other elements. This is being studied further.

DETERMINATION OF TRACE CONSTITUENTS IN SOILS AND PLANTS

The above method, together with the concentration method has been employed for a study of the cobalt, nickel, molybdenum, zinc, chromium, vanadium, tin, lead, silver, titanium, copper, manganese, barium and strontium contents of crops from typical farms on soils of different geological origins, and therefore different trace element contents, in the north-east of Scotland. The crops investigated have included mixed pasture, rye grass, clover, oat grain and straw, barley grain and straw, turnips and turnip leaves, swedes and swede leaves, potatoes and potato leaves. The results of the determinations provide normal contents of trace constituents in healthy crops from the area, and are being correlated with soil data. They serve as a basis of comparison for other samples where abnormalities of plant growth or animal health may be due to trace element effects. At the same time the results permit the calculation of trace element intake of animals fed on diets made up of the crops analyzed.

Other investigations have included further studies of the relation of cobalt, nickel and molybdenum uptake by plants to the soil conditions and the relative uptakes of different plants at different acidity levels of the soil. Studies of the trace element contents of soils and pastures, in connection with specific problems affecting both plants and animals have been made, not only on samples from Scotland, but also in collaboration with several of the Agricultural Advisory Officers in England and Wales. Problems involving infertility due to excess of zinc and other elements would appear to be more frequent in certain areas of England and Wales than in Scotland. In this connection, work on the relationship of trace element content of soils to geochemical factors has been continued. An investigation of the distribution of trace constituents in a number of Scottish igneous rocks, in collaboration with Dr. S. R. Nockolds of the Department of Mineralogy of the University of Cambridge, is awaiting publication.¹¹

The analyses of certain organs of sheep from the pining areas of Ross-shire and the Solway area have been carried out in collaboration with the Animal Diseases Research Association, and have provided data on the content of these organs when the animals feed on areas with soils and herbage of different cobalt levels. Certain modifications of the analytical procedure

have been worked out for these materials which differ considerably in content from soil extracts and plant ashes.

A brief account of the applications of spectrographic methods to soil investigations has been published.⁷ A review article on the spectrographic analysis of soils and plants is in the press¹⁵ and a longer technical communication on the same subject for the Imperial Bureau of Soil Science is in preparation.¹⁸

THE LUNDEGARDH FLAME EMISSION METHOD

Determinations by the Lundegardh flame emission method have again been mainly routine analyses of extracts of soils and plant materials in connection with the advisory service for farmers. Other determinations have included exchangeable cations in soil profiles and analyses of various crops in soil fertility studies. The possibility of modifying the method in order to reduce the amount of chemical pre-treatment necessary in soil extracts has been investigated. In all, some 450 plates carrying over 7,000 solutions have been examined by the flame method during the year.

SPECIAL INVESTIGATIONS

COLLABORATION WITH THE ANIMAL DISEASES RESEARCH ASSOCIATION

The study of the relation of trace element contents of soils and plant materials to the incidence of disorders in animals has been continued in collaboration with the Animal Diseases Research Association. The presence of a low easily soluble cobalt content of the soil has been shown to be associated with a pining condition in sheep in several areas, and an account of this work in the Solway area has been published.⁶

The direct correlation of a trace element deficiency or excess with the disease of sheep known as swayback has not been established, but abnormal contents of one or more of several elements including copper, lead and tin are often observed where this disease occurs. It does not, however, appear to be related to the molybdenum content of the herbage⁴ as has been suggested in an Australian communication.

Other diseases being investigated include yellowsees of sheep, and lactation tetany, but so far no definite clue to a possible cause has been obtained.

COLLABORATION WITH THE ROWETT RESEARCH INSTITUTE

A joint field experiment is in progress in an area of reclaimed pasture, the copper content of which was regarded as low. The Macaulay Institute has been responsible for the sampling, analysis and manuring of the plots while the Rowett Institute has undertaken the management of the animals, and the relevant experimental work upon them.

COLLABORATION WITH THE FORESTRY COMMISSION

The study of the nutrient requirements of forest seedlings is being continued.

AGRICULTURAL RESEARCH COUNCIL

(a) Special research in aid of experiments to test the effect of placing different types and quantities of fertilizer. (Dr. A. B. Stewart.)

(b) Investigation into the microbiological changes occurring during the decomposition of organic matter in composts and in soils. (Dr. D. M. Webley.)

PUBLICATIONS

- (A) "Report on Soil Fertility Investigations in India with Special Reference to Manuring. (A review of the position to date with suggestions for the planning and conduct of future experiments.)" By A. B. Stewart. (Report submitted to the Imperial Council of Agricultural Research, Government of India.) *In press, India.*
- (B) *Issued during the year—*
1. "Halloysite-organic Complexes." By D. M. C. MacEwan. (*Nature*, **157**, 159-160, 1946.)
 2. "Background Correction in Spectrographic Analysis." By R. L. Mitchell, R. O. Scott and V. C. Farmer. (*Nature*, **157**, 193-194, 1946.)
 3. "The Clay Minerals Halloysite and Metahalloysite." By G. W. Brindley, K. Robinson (Leeds University) and D. M. C. MacEwan. (*Nature*, **157**, 225-226, 1946.)
 4. "Molybdenum and Copper Metabolism of Farm Animals." By J. Stewart (Animal Diseases Research Association), R. L. Mitchell and V. C. Farmer. (*Nature*, **157**, 442, 1946.)
 5. "Soil Survey in Scotland." By R. Glentworth and H. G. Dion. (*Scot. Geog. Mag.*, **62**, 16-23, 1946.)
 6. "Solway Pine: a Marasmic Condition in Lambs in Certain Districts of Kirkcudbrightshire." By J. Stewart (Animal Diseases Research Association), R. L. Mitchell and A. B. Stewart (Macaulay Institute) and H. M. Young (West of Scotland Agricultural College). (*Emp. J. Expt. Agric.*, **14**, 145-152, 1946.)
 7. "Applications of Spectrographic Analysis to Soil Investigations." By R. L. Mitchell. (*Analyst*, **71**, 361-368, 1946.)
 8. "The Spectrographic Determination of Trace Elements in the Cathode Layer Arc by the Variable Internal Standard Method." By R. O. Scott. (*J. Soc. Chem. Ind.*, **65**, 291-297, 1946.)
 9. "Research and the Farmer. I. The Soil." By D. N. McArthur. (*Scot. Agric.*, **26**, 100-103, 1946.)
 10. "The Identification and Estimation of the Montmorillonite Group of Minerals with Special Reference to Soil Clays." By D. M. C. MacEwan. (*J. Soc. Chem. Ind.*, **65**, 298-304, 1946.)
- (C) *In preparation—*
11. "The Geochemistry of Some Caledonian Plutonic Rocks: a Study in the Relationship Between the Major and Trace Elements of Igneous Rocks and their Minerals." By S. R. Nockolds (Cambridge University) and R. L. Mitchell. (To appear in *Trans. Roy. Soc. Edin.*)
 12. "Concentration Methods in Spectrographic Analysis. II. Recovery of Trace Constituents in Plant Materials and Soil Extracts by Mixed Organic Reagents." By R. L. Mitchell and R. O. Scott. (To appear in *J. Soc. Chem. Ind.*)
 13. "Characterization of the Humic Complexes of Soil Organic Matter." By W. G. C. Forsyth. (To appear in *J. Agr. Sci.*)
 14. "Studies on the More Soluble Complexes of Soil Organic Matter. Pt. I. A Method of Fractionation." By W. G. C. Forsyth. (To appear in *Biochem. Jour.*)
 15. "Spectrographic Analysis of Plants and Soils." By R. L. Mitchell. (To appear in *Biolog. Reviews.*)
 16. "Complexes of Clays with Organic Compounds. I. Formation Between the Clay Minerals Montmorillonite and Halloysite and Organic Liquids." By D. M. C. MacEwan. (To appear in *Trans. Faraday Soc.*)
 17. "Complexes of Clays with Organic Compounds. II. Investigation of the Ethylene-glycol-water-montmorillonite System Using the Karl Fischer Reagent." By R. C. Mackenzie. (To appear in *Trans. Faraday Soc.*)
 18. "The Spectrographic Analysis of Soils and Plant Material." By R. L. Mitchell. (To appear as *Tech. Comm. No. 44 of Imp. Bur. Soil Sci.*)
 19. "Activity of Thermophilic Bacteria in Composts of Fresh Green Material." By D. M. Webley. (To appear in *Nature.*)