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MACAULAY INSTITUTE FOR SOIL RESEARCH

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1944-1945

ANNUAL REPORT

THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

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1944–1945

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* Dr. W. G. Ogg acted as Hon. Director until July, 1945.

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1944–45

DURING the year there have been several changes in the personnel of the Institute. Dr. W. G. Ogg—who, since his appointment as Director of Rothamsted Experimental Station, acted as Hon. Director of the Macaulay Institute—was co-opted a member of the Council of Management. Principal S. J. Watson, D.Sc., representing the Edinburgh and East of Scotland College of Agriculture, and Mr. Maitland Mackie, representing the North of Scotland College of Agriculture, joined the Council of Management. The Council record their appreciation of the services rendered by the two former representatives, the late Principal E. Shearer, B.Sc., and Dr. J. F. Tocher. Dr. Alexander Muir, Head of the Soil Survey staff, and Miss I. M. Anderson, Librarian, resigned on accepting appointments to the staff of the Rothamsted Experimental Station. Dr. Muir, before leaving for Rothamsted, was granted leave of absence to attend the 220th anniversary of the foundation of The Academy of Sciences in Moscow. During his visit to the U.S.S.R. he took the opportunity of visiting various institutes in Leningrad and elsewhere. On 1st July, 1945, Dr. D. N. McArthur assumed office as Director of the Institute, while Dr. A. B. Stewart, Head of the Advisory and Field Experimental staff, was appointed Deputy Director. Dr. Stewart was granted leave of absence at the request of the Government of India to enable him to accept an invitation to investigate and advise upon problems of soil fertility in India. It is expected that he will be in India during the winter and will be absent for six months. Miss A. M. B. Geddes was appointed Librarian and Assistant Secretary, and Dr. H. G. Dion, a graduate of Wisconsin, U.S.A., joined the staff of the Soil Survey. With the aid of a special grant given by the Agricultural Research Council, Dr. D. M. Webley joined the Soil Organic Matter staff to study microbiological problems. In view of the limited accommodation at Craigiebuckler it was found necessary to secure alternative space outside the main laboratories. Through the courtesy of the University of Aberdeen and the co-operation of Professor J. R. Matthews, Dr. Webley has started his investigation in one of the laboratories of the Botany Department, King's College, Aberdeen.

The Council of Management has given serious consideration to the provision of additional accommodation at Craigiebuckler and has submitted to the Department of Agriculture for Scotland proposals for a temporary extension of the laboratories. A permanent extension is urgently required and it is hoped that, as soon as building operations permit, new laboratories will be provided.

Special consideration has continued to be given to problems of practical importance and the advisory services have been fully maintained. Co-operation and collaboration was continued with other institutions, including the North of Scotland College of Agriculture, the Animal Diseases Research Association, H.M. Geological Survey and the Forestry Commission. The

Institute continued to be represented in the Agricultural Research Council conferences on

(*a*) trace elements and mineral deficiencies affecting plants and animals.
(*b*) fertilizer placement.
(*c*) feeding value of pasture.

The Council of Management tender their 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 1945.

SOIL FERTILITY AND ADVISORY WORK

Advisory Work

The advisory service has been maintained and during the year approximately 4,200 samples of soil have been tested, relevant advisory reports being issued on the treatment likely to be most suitable for the areas sampled. As in previous years, most of the samples have been drawn from ordinary agricultural land, but work has also been undertaken on horticultural soils, forest nurseries, landing grounds and sports grounds. In addition, analyses have been carried out on materials such as limestones, calcareous sands, slags and other by-products likely to be of value on the land. Liming, manuring and other problems of practical importance have also been dealt with in lectures and in contributions to the agricultural press.

The comparison of the lime, phosphate and potash contents of the soils of arable rotation land and old grassland in the North of Scotland, which has been referred to in previous years' reports, has been extended to include advisory samples taken in 1944. On the basis of their contents of plant food substances the soils have been grouped as satisfactory, slightly low or low in relation to the needs of a rotation of crops of cereals, roots, hay and pasture which is common in the area. A separate grouping has also been made according to the geological origin of the soils and the results are given in Table I. From this table it will be noted that :

Lime. Lime deficiency continues to be widespread in both arable rotation and old grassland and is most pronounced in soils derived from slates and shales. As could be expected, lime shortage is least pronounced in soils of basic igneous origin, but even in these the majority would be improved by the application of lime.

Phosphate. Phosphate deficiency is considerably more widespread in old grassland than in arable rotation soils and there are very few in either group where a response to the application of phosphate dressings would not be obtained. As with lime, the phosphate position is less unsatisfactory in the basic igneous group than in the others. Soils of peaty nature and those derived from slates and shales and quartz-rich rocks are particularly liable to be low in phosphate.

Potash. Unlike phosphate, potash is less deficient in old grassland than it is in ordinary rotation land. Soils derived from peat, basic igneous rocks and quartz-rich rocks are more liable than others to be low in potash, whilst the most satisfactory potash contents are found in the soils of the slates and shales group. The position in regard to the potash contents of the soils in the North of Scotland continues to be relatively more satisfactory than it is in respect of either lime or phosphate. Nevertheless the majority of the soils are likely to be improved by the application of maintenance dressings of potash, and as soon as the supply position permits it would be well for most farmers, especially those who have been cropping their land intensively during the past few years, to aim at applying potash not only for crops such as potatoes and turnips but also for the sow-out crop on land which is being returned to grass.

TABLE I

GROUPING OF ADVISORY SOIL SAMPLES ACCORDING TO THEIR CONTENTS OF LIME, PHOSPHATE AND POTASH. THE FIGURES UNDER THE VARIOUS HEADS ARE PERCENTAGES OF THE SAMPLES EXAMINED

Geological origin.	No. of samples examined.		Lime.						Phosphate.						Potash.					
			S.†		S.L.		L.		S.		S.L.		L.		S.		S.L.		L.	
	R.*	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.
All formations excluding peat	11992	1731	4	3	59	62	37	35	14	8	48	31	38	61	14	37	71	55	15	8
Acid igneous rocks	4704	772	3	3	55	63	42	34	13	7	55	34	32	59	15	36	69	57	16	7
Acid sandstones (O.R.S.)	3772	401	8	5	64	60	28	35	18	7	50	33	32	60	12	35	71	55	17	10
Slates and shales	1850	246	1	0	48	52	51	48	2	2	26	13	72	85	17	52	74	45	9	3
Basic igneous rocks	1270	229	1	1	76	75	23	24	29	25	48	36	23	39	12	26	71	62	17	12
Quartz-rich rocks	396	83	5	3	47	60	48	37	6	3	35	22	59	75	13	42	71	48	16	10
Peat	205	58	15	9	62	74	23	17	5	2	6	2	89	96	8	11	34	48	58	41

† S. = satisfactory ; S.L. = slightly low ; L. = low or very low.
* R. = arable rotation land ; G. = old grassland being ploughed for cropping.

Soil Fertility Investigations.

General Experiments. Field, pot and laboratory experimental work has been continued on the lines described in previous years' reports with the aim of (1) obtaining from the field experimental data a check on various methods of laboratory examination of soils suitable for use in advisory work and (2) measuring the residual effects of lime and fertilizers through crop rotations on different soils. From these experiments information is being obtained on points such as the following :

(*a*) the relative liming values of materials such as limestone of varying grades, magnesian limes, dried paper works lime and calcareous shell sands.
(*b*) the manurial and liming values of blast furnace and other industrial slags.
(*c*) the comparison of fertilizers in granular and powdered forms.
(*d*) the manurial value of potash in a crushed biotite-schist.
(*e*) the nutrient requirements of forest tree seedlings. This work is being undertaken in collaboration with the Research Branch of the Forestry Commission in Scotland and includes long term experiments on the effects of liming, manuring, green-cropping, the use of composts and partial soil sterilization.

Phosphate Fixation. The general scheme of work on this problem is to carry out field, pot and laboratory experiments on different types of soils. Direct answers are being sought to questions such as the residual effects of heavy dressings of phosphate and the efficiencies of various measures intended to alleviate fixation, such as the application of lime and silicates, and the use of reverted, granular and organic forms of phosphate. General analytical data are being accumulated for soil and produce samples from the field and pot experiments to provide the necessary basis for more detailed laboratory examination of certain aspects of the phosphate relationships of the different soils. The investigation of the effects of lime on the fixation and subsequent extraction of phosphate under laboratory conditions, referred to in last year's report, is nearing completion. Information has been obtained on the effect of lime on the rate of extraction of phosphate by different methods, on the fixation of phosphate from solutions of varying *p*H, and on the total organic phosphate content. Certain points arising from the results made it desirable to investigate the effects of cations other than calcium with a view to differentiating between possible specific calcium and general cation effects. For this purpose fixation curves have been obtained for completely desaturated soil and soil partially resaturated with different cations. A comparison is also being made of samples limed in the field with corresponding samples limed under laboratory conditions. A full account of this work is to be submitted for publication during the coming year. In connection with the investigation of anion effects preliminary work has been done on the extraction of phosphate with fluoride solutions.

The examination of samples of soil and produce from a series of experimental areas at Craibstone, the North of Scotland College of Agriculture farm, has also been continued and samples of the different crops grown during the rotation are being analyzed.

Fertilizer Placement. In last year's report it was mentioned that, as part of a general study of the response of crops to fertilizers applied in different ways, a series of experiments was commenced in 1943 with the aid of a special grant from the Agricultural Research Council. An account of experiments carried out in 1943 and 1944 has been given[1] and it has been shown that (1) with *cereals* on phosphate deficient soils a saving in phosphate can be effected by drilling phosphate with the seed, (2) with a suitable drill there would appear to be a strong case for drilling phosphate along with grass and clover seeds on phosphate deficient land which is being *reseeded*, and (3) in preliminary experiments with *potatoes* there were no significant differences between zone or band placement and ordinary broadcast application of fertilizer mixture.

Experiments have been continued during the year with particular reference to the measurement of residual effects, the comparison throughout a rotation of full dressings broadcast with half dressings drilled and the maximum rates at which nitrogenous fertilizers and fertilizer mixtures may be safely drilled with seed. A few preliminary experiments have also been laid down to study the effect on turnips of drilling a concentrated fertilizer compound.

An account of the principles involved in the maintenance of soil fertility has been published.[7]

SOIL SURVEY

ABERDEENSHIRE

The reconnaissance survey on the scale of 2·5 inches to one mile has been extended to the area west of Aberdeen and covers the district between the rivers Dee and Don as far west as a line passing through Kildrummy and Tarland. Approximately 320 square miles have been mapped.

The soils of this area were found to fall into six previously established associations, Countesswells, Tarves, Foudland, Kemnay, Cuminestown and Corby.

1. *Countesswells Association.* The Countesswells Association of soils developed on granitic and gneissic boulder clay was found to extend westward from Aberdeen between the rivers Dee and Don and has been mapped as far as a line through the west side of Bennachie to Tarland. In general, the Countesswells Association, as mapped this year, conforms to the soil descriptions given in the Annual Report 1943–44, with the well-drained and slightly poorly-drained soils predominating. The surface horizon is a brown to dark brown medium loam to sandy loam and contains a noticeable amount of quartz and rock particles which give it a gritty feel. A marked feature of the phytomorphic soils of the association is an indurated B_2 horizon. Throughout this association many large erratic boulders occur ; on the west side of the Cairn William hills, south of Pitfichie, as many as fifty or more boulders occur in a five acre field. While this area is excessively stony, stoniness is a characteristic feature of the whole association. There are considerable areas with soils developed on thin drift or rock and having surface horizons of stony loam texture and of free to excessive drainage. Some of the granite masses within this area are deeply weathered to a coarse granitic sand and the soils on this material are very coarse textured. Certain areas west and north of Aberdeen and north-west of Blackburn have soils developed on deep drift of clay loam texture.

2. *Tarves Association.* Soils of the Tarves Association, developed on boulder clay derived from acid and basic igneous and metamorphic rocks, lie to the south of Chapel of Garioch and more extensively to the west of the Cairn William hills in the Howe of Alford extending south-west and occupying the parishes of Leochel-Cushnie and parts of Kildrummy, Towie, Glenbuchat, and Logie Coldstone. The topography of this area is in general more hilly than that of the Tarves district where the association was originally described : it is also at a higher average altitude, being above 500 ft. The country is well dissected by valleys and the drainage flows to the Don. In the Chapel of Garioch area the phytohydromorphic associate is extensively developed on sloping ground and has a stony clay parent material heavier than is normal for the association. In the western area the phytomorphic associate tends to occupy the higher sloping ground with the poorly drained associate occupying the well-defined areas of lower and flatter land in the valley bottoms. The phytomorphic soil has a brighter brown A horizon than the Countesswells and is of a heavier and smoother texture. Indurated B_2 horizons of light texture and a grey khaki colour are general, below which is a stony, fine-sandy, boulder clay. The phytohydromorphic associate has

a grey-brown, cloddy surface with a grey and brown mottled, cloddy, clay loam gley horizon.

3. *Foudland Association.* North of the Alford basin, on the west side of Bennachie, is an area of soils developed on a boulder clay derived mainly from knotted schists. Topographically the area is broadly rolling to hilly and the soils were found to be typical Foudland associates with the phytomorphic associate most extensively developed. This soil has a grey-brown surface of a fine-sandy-loam texture and contains more silt than clay. The B horizon is ochreous brown coloured on khaki fine-sandy drift with a relatively high proportion of schist fragments.

4. *Kemnay Association.* The parent material of this association is recent alluvium of sandy texture. The soils are generally immature and are subject to flooding with deposition of fresh material. Texturally the soils range from loamy sands to very fine sandy loams with varying amounts of gravel. Very deep soils occur in localized areas alongside the Don from Kemnay to Hatton of Fintray, and also near Alford. The drainage of these soils is generally free to slightly poor. The most extensive areas of this association are beside the Dee and Don, but elsewhere, along the lesser streams, stretches of alluvium are also found in which the soils have variable drainage.

5. *Cuminestown Association.* The Cuminestown Association was originally described in the Annual Report 1942-3. About Kildrummy, similar soils are developed on a relatively light textured boulder clay derived mainly from sandstones of the Old Red Sandstone formation. The phytomorphic soils have a dull red-brown A horizon, generally of a sandy loam or stony loam texture, on a characteristically reddish-brown, sandy loam parent material. The soils tend to be of a heavier texture east of Kildrummy Castle and Church.

6. *Corby Association.* The Corby Association is developed on fluvio-glacial sands and gravels and tends to be widespread throughout the area occupied by the Countesswells Association, generally lying below the 300 ft. contour. On the western side of the mapped area the Corby Association is found at higher altitudes. To the west of Aberdeen between the Dee and Don there are many interconnected spreads of this association. From Monymusk on the Don through Cluny, Loch of Skene and Garlogie there is an extensive area of this association. Similar occurrences lie to the north and south of Kemnay, connecting through to the Don at Kintore, and extending to Blackburn. Less extensive areas are to be found on Deeside, south of the Hill of Fare and stretching west to Torphins, and also about Aboyne. The topography is characterized by smooth stretches alternating with hummocks. The phytomorphic soils are light sandy loams to gravelly loams and on the hummocks are excessively drained, whilst in the hollows, the drainage is poor to very poor.

Reconnaissance Survey of Parts of West Lothian and Midlothian

A reconnaissance survey of parts of West Lothian and Midlothian has been carried out and some 100 square miles covered. This area is underlain by igneous and sedimentary rocks of Carboniferous age and these are covered almost entirely by surface deposits of boulder clays, fluvio-glacial sands and gravels, and alluvium.

Two freely-drained soil types on the boulder clay, which is the most extensive deposit, have been distinguished. In the west from Bathgate to Linlithgow and stretching eastwards to Winchburgh there is an area of clay drift with soils of heavy texture (heavy loam to clay loam). The boulder clay to the east is of a lighter texture and the surface soils are mainly medium loams. Areas of gleyed soils are found associated with both types.

The igneous rocks are most extensive in the west but are also found outcropping throughout the area, forming the high ground and providing small areas of residual soils.

There is an extensive spread of sands and gravels from Linlithgow eastwards, giving rise to loamy soils with good to excessively free drainage. The largest spread of alluvium is in the valley of the River Almond, stretching from Kirkliston to Turnhouse, and is subject to flooding. The soils are generally sandy loams to fine sandy loams. There is only a narrow belt of raised beach alluvium in this area apart from the districts between Blackness and Abercorn and east of Dalmeny House. The soils vary from sands to silty clays.

There is no extensive development of peat, the only peat areas being those associated with alluvium.

Stirlingshire and Perthshire

A detailed survey on a scale of 6 inches to one mile of thirteen farms in the counties of Stirling and Perth has been carried out at the request of the National Institute of Agricultural Engineering, Askham Bryan, York.

The soils were derived mainly from alluvium, both recent and marine (carse land), from till derived from rocks of the Old Red Sandstone and Carboniferous formations and from fluvio-glacial sands and gravels. Texturally the soils varied from stone-free clay loams to stony sandy loams.

Sutherland

An area on the Skibo Estate, Dornoch, was visited at the request of the Forestry Commission, where some newly established plantations were dying out. Lack of adequate drainage was thought to be the cause of the trouble and ploughing as a pre-treatment to planting was advocated.

Kirkcudbrightshire

An area about Criffell mountain was examined where cobalt deficiency disease in sheep is prevalent. Profile descriptions were made on a number of farms where pining varies from very bad, probably present, to completely absent. Sufficient data were collected to indicate that a more detailed soil survey is desirable.

There has been co-operation with the Fertility Department in the selection of sites for certain field trials on soil types in Aberdeenshire, and also in the provision of a classification of parent-material-groups for the compilation of advisory data collected in Aberdeenshire. In co-operation with The West of

Scotland Agricultural College, localities for experimental plots on various soil types were fixed in Stirlingshire.

A general account of the methods used in soil surveying in Scotland is in preparation.[14]

Laboratory Investigations

Laboratory work has been continued on representative profiles from the various associations established in which the aim has been to characterize the various drainage associates within an association and the differences between associations. Work has been done on methods of analysis. A colorimetric method for the determination of aluminium in soils has been developed. A more rapid and convenient method for the determination of exchangeable hydrogen by a modification of Brown's method—by a *p*H determination on a suspension of a soil in barium acetate solution—has been investigated. Studies on the determination of alcohol and water contents of treated clays have been made in co-operation with the X-ray Department.

Soil Mineralogy

The mineralogical composition of the fine sand fractions of soils and their parent materials from areas underlain by rocks of the Old Red Sandstone formation is being investigated. The parent materials are glacial drifts, generally boulder clays, presumed to be mainly derived from the underlying sediments of this formation. The samples examined were taken from areas in the North, North-East and Central Scotland, ranging from Sutherland to Stirlingshire.

Samples from Ross-shire showed a higher proportion (9 per cent.) of minerals of the ferromagnesian silicate group than any of the other areas in the north, where the average content is fairly low (about 2 per cent.). In an area of red drift in the north-east of Scotland, however, the content of such minerals is very much higher (about 15 per cent.), but the drift was found not to be of uniform composition since it had been partly derived from schistose and igneous rock types.

In the samples from Central Scotland the proportion of ferromagnesian silicate minerals and iron oxides was also found to be low, averaging about 1 per cent.

The content of the orthoclase group in the samples examined is very variable. The highest proportion was found in samples from Ross with 6 per cent., but other samples in this area gave only 0·5 per cent. The average content of this group throughout was only 2·3 per cent.

In general, the results so far obtained show a variable but low content of ferromagnesian silicate minerals and iron oxides and a relatively low proportion of felspathic minerals.

A number of samples from soil profiles collected during soil surveys in the north-east of Scotland were also examined mineralogically in order to characterize the glacial drifts, from which the soils were derived.

PEAT SOILS AND SOIL ORGANIC MATTER

Peat Survey

At the suggestion of H.M. Geological Survey (Scotland) the area over which this season's survey has been made is that comprised in the "¼-in." Geological Survey maps nos. 5 and 6, covering most of the counties of Caithness and Sutherland. Apart from bare rock, some 80 per cent. of the total area of these counties is covered by peat. The greater part of this has been surveyed. Here the peat-moors belong in the main to the *Scirpus caespitosus* (Deer grass) blanket moss series. The depth of peat varies as a rule between 4 feet and 10 feet, although greater depths (up to 20 feet) have been observed, and are not uncommon over small areas. The type of peat is, as a rule, pseudo-fibrous scirpus peat, yellow brown in colour when fresh but rapidly becoming darker on exposure. When dried it forms dark brown to almost black firm masses, the texture varying from porous and fibrous in the surface peat to amorphous compact and heavy in lower layers. The major variation of a regional character consists of a greater tendency on the north-east and east coasts towards the development of darker and more compact peat accompanied by greater abundance of heather (calluna) on the surface. On the flatter land of Caithness and especially at moderate elevations, and in the interior, flow-moss covers wide areas (that is, water lying for prolonged periods on the surface induces hagging and local surface erosion). True basin peat with *Phragmites* beds at lower levels is only occasionally found; and sphagnum moss peat is only occasionally found. Limonitic deposits in the peat are frequent in some districts.

As a result of circumstances outwith the control of the Institute, publication of the second wartime pamphlet on peat deposits in Scotland has been delayed.

Peat and Compost Investigations

Growth tests using peat and potting composts made up with peat. These have been continued as before, but produced no new feature of special interest.

Acidity of peats and potting composts. Investigation of irregularities in connection with acidity and liming of potting composts and peat were continued. As a result of an extensive experiment with various forms of lime and varying modes of application to potting compost, it is concluded

(*a*) that with moderately free drainage, liming materials containing equivalent amounts of calcium oxide produce similar *p*H values. This holds provided care is taken in the initial mixing and so long as the degree of subdivision is sufficiently fine.

(*b*) that the laboratory lime-requirement figure is lower than the actual amount of lime necessary to produce the same *p*H value in practice throughout the season.

(*c*) that, as a rule, a gradient in *p*H may develop in 4-inch pots during the season under ordinary watering practice; the *p*H at

the soil surface may be 0·5 unit lower than at the bottom of the pot, but with heavier liming no gradient, sometimes even a reverse gradient, has been noted.

(*d*) that after initial watering little loss of particulate lime occurs. (In seed boxes this type of loss was very high especially with some peats used alone—a fact previously noted (*Ann. Rep.*, 1943–44).)

(*e*) that the tolerance of the tomato test plant towards variation in *p*H and lime-content in both potting composts and in peat alone appears to be higher, in young plants at least, than is generally stated, optimum growth taking place over a considerable variation of *p*H and lime content. Attempts to procure a satisfactory tomato plant for extension of greenhouse compost work, from the pot stage to the garden, have not yet been successful. Additional greenhouses accordingly are desirable.

The use of glass flower-pots. It was considered that, provided there were no harmful effects, special advantages as regards cleanliness should accrue from the use of glass instead of earthenware pots. Accordingly an experiment to compare the effect of growing seedling plants in glass pots and in earthenware pots has been conducted. In a preliminary trial plants were grown from the seedling stage in 4-inch pots, one set glass and the other earthenware. It was found that the rate of growth of young plants in glass pots was uniformly better than in ordinary pots. Seeds of tomatoes and transplants of other freely growing plants were then tried with similar results. On re-potting into 7-inch pots, however, the subsequent growth was faster in earthenware than glass pots. The experiment using 4-inch pots was repeated under ordinary market garden conditions. Results were similar to those obtained in the preliminary trial. It was found, incidentally, that there was no effect on rate of growth from using the common practice of setting transplanted seedlings close to the side of the pot either in glass or in earthenware pots.

Compost investigations. An investigation of the microbiology of the process of composting was commenced as little systematic microbiological work has been carried out on composts. Fresh grass cuttings are being used as the raw material as data have already been collected at the Institute regarding the chemical changes taking place in these during composting. The material is kept in 3 ft. × 3 ft. concrete drain pipes modified so that they are suitable either for aerobic or for anaerobic decomposition to take place. These were coated internally with waterproof asphaltic paint.

The following microbiological observations of general interest have been made :—

(*a*) The internal temperature of the aerobic compost reaches about 65° in less than two days, after which it gradually falls to approximately atmospheric temperature.

(*b*) At the peak of this rise in temperature there is a marked reduction in the aerobic mesophilic flora originally present on the fresh cuttings. The surviving mesophils are mainly spore-forming bacteria present as spores.

(*c*) An aerobic thermophilic flora is also present. Some of its

members have been isolated in order that they may be identified and a study of their physiological character made.

(*d*) When the internal temperature of the compost falls below 40° C. a very rapid growth of aerobic bacteria takes place. The dominant organisms of this flora are almost entirely in the vegetative condition. The more abundant dominants have been isolated and a study of the physiological characters of these is to be undertaken.

(*e*) After some months no evidence has been obtained of marked fungal development at any stage.

This work is still in progress. An anaerobic compost has also been established but has so far not been studied in so great detail, largely because of the amount of material which has accumulated for laboratory investigation from the aerobic compost, and the work required for its collection and preparation.

Investigations into the replacement of farmyard manure by peat fortified with artificial manures. In the season 1944 an experiment was laid down on sandy boulder clay in order to ascertain the significance of the mode of application, comparing fortified peat with farmyard manure. The manure was applied (*a*) on the stubble and (*b*) in the drill before turnips. No immediate differences in yield were observed between the two modes of application whether of farmyard manure or of peat. In this experiment the farmyard manure gave a slightly lower (10 per cent.) average return than the fortified peat but the difference is probably not significant, due to soil variation. The large number of experiments carried out in this series has led to the same general conclusion, namely, that soil variation from plot to plot is greater than the slight differences, in yield that ensue from the use of peat in place of farmyard manure. Thus it would appear that peat along with the requisite quantity of artificial manure may be safely used in place of farmyard manure, at least so far as immediate results are concerned.

On a market garden soil, receiving large applications of farmyard manure, several dressings of peat and artificials have now been applied without detrimental results on yields or detectable differences in the general character of the soil. On the other hand, in the small allotment experiment at the Institute on which specially heavy dressings have been applied (equivalent to 20 tons of farmyard manure), and where lime applications have been kept low, it is now apparent that both peat with artificials and artificial fertilizers alone are giving with onions, peas, beet, beans and lettuce reduced yields as compared with farmyard manure. This result may be related to an increased acidity of the soil.

LABORATORY INVESTIGATIONS.

(*a*) Routine analyses and examination of peats from the areas surveyed, of various organic samples received, and of the various soils and materials used in experiments have been made.

(*b*) Previous work on the polyuronide content of soil organic matter is being revised in the light of a detailed examination of the results obtained and reported in last year's *Annual Report.*

It has become obvious that data, obtained by the Waksman method for cellulose, are of limited value. Norman's chlorination procedure gives more useful results, but it is extremely tedious owing to the necessity for repeated filtering or centrifuging and to the presence in some soils of chlorine-resistant humic matter. The Kurschner and Hoffer method (*Chem. Zeit.*, **55**, 161, 1931) of determining cellulose by removal of lignin by nitration has been shown (Reid and Lynch—*Ind. Eng. Chem. Anal.*, **9**, 570, 1937) to give results of the same order as Norman's method when used with plant materials. The method was applied to organic soil and was found to give results similar to those obtained by Norman's chlorination method. The advantages of the method are its extreme simplicity and rapidity, a set of determinations being completed in some three hours.

Work on the " humic acid " fraction of soil, peat and compost has continued. Methods of acetylation, methylation, nitration, and reduction have been used to determine the characteristics of the reactive groups present and thus to make a comparison of the structures of humic acids from different sources. The " fulvic acid " fraction (that is the alkali-soluble fraction not precipitated by mineral acids) is also being investigated. A method has developed for the further fractionation of this complex. Four distinct fractions have been separated from it by the use of selective adsorption and elution. These are as follows :

(1) *Simple water soluble substances.* Simple substances, which include sugars, amino-acids, etc., are obtained as a colourless mixture greatly facilitating their further study.

(2) *A Glycosidic Constituent.* This component is composed of glycosides of sugar and phenolic substances.

(3) *A Polyuronide Constituent.* From this pure polyuronides have been isolated. These are being subjected to the techniques of carbohydrate chemistry. The actual isolation of polyuronide is a definite proof of the presence of these compounds in soil. Their presence has long been suspected from the studies of the carbon-dioxide evolution of soils when treated with acids.

(4) *A Nitrogenous Constituent.* This constituent is under investigation and although rich in nitrogen does not seem to contain any proteid compounds.

This series of organic compounds was obtained in quantity from a wide variety of soils and soil organic matter.

(*c*) Ash-free humus, for experimental purposes, has been prepared by electrodialysis using a trough of synthetic resin. It is thought that this technique may be found useful for the fractionation of soil organic matter.

SPECTROGRAPHIC INVESTIGATIONS

The Cathode Layer Arc Method

The cathode layer arc method has proved satisfactory for the determination of trace constituents in soils and plant materials, and the principles involved in the spectrographic aspects have been studied further. In particular the effect of the major constituents of the material analyzed on the results obtained for the trace constituents has been investigated. It was known that some effects could be expected and in order to study these in the cathode layer arc source, series of standard mixtures containing fourteen trace constituents in seven different materials (Al_2O_3, SiO_2, NaCl, Na_2CO_3, $Na_4P_2O_7$, $CaCO_3$, $Ca_3(PO_4)_2$) which might be involved in the analysis of soil or plant materials either before or after chemical pre-treatment, were prepared. The results, which have been published,[2] indicate that whilst for one or two elements (e.g. Co, Ni) a standard curve prepared for the Al_2O_3 base can be used without appreciable error for any of the other bases, this is not generally so and precautions to ensure correspondence between standard and unknown are generally necessary. Thus the intensity of the lines of chromium in a calcium carbonate base is similar to that given by five times as much chromium in a silica base. In the course of this investigation the favourable properties of Al_2O_3 as a base for the determination of most trace constituents became obvious, and the compound is now employed in our concentration methods, replacing sodium chloride and silica, both of which had previously been employed (*Ann. Rep.*, 1942–43, p. 20). The use of NaCl made it unfeasible to determine several elements, such as Zn, whose line intensity was greatly depressed, and in addition the powder showed some tendency to stickiness on grinding. The variable content of Al_2O_3 in precipitates from soil extracts also rendered the use of Al_2O_3 base desirable.

The variable internal standard method of photometric evaluation of the amount present in any sample has been studied in relation to the methods for background correction already reported (*Ann. Rep.*, 1943–44, p. 18) and this, together with the behaviour of the slopes of the working curves and internal standard correction curves is discussed in a paper which will be ready for publication shortly.[8] In this, shortened methods which are possible in the preparation of working curves for different trace constituents and bases are described. The method of background correction described in the appendix to last year's report has been employed for this and other work and a note drawing attention to its usefulness has been submitted for publication.[9]

The concentration method, using 8-hydroxyquinoline for Co, Ni, Mo, Zn, and Cu, has been developed by the use of mixed organic precipitants. Suitable conditions for the precipitation of Cr, V, Sn, Pb, Ag, Ga, Cd, Ti, Mn, Be, Ge and Tl in addition to the above elements have been found using tannic acid and thionalide as additional precipitants, with Al as the carrier precipitate and Fe as internal standard, and it is hoped that an account of this procedure will shortly be available.[10] The combined chemical and spectrographic errors of single determinations from standard solutions by

this method seldom exceed ± 10 per cent. and in most instances the ranges of constants present in plant materials are satisfactorily covered.

The accurate determination of copper by a concentration method has been found impossible with the laboratory facilities available, owing to contamination, and a method for its direct determination, together with barium and strontium, in plant ash has been developed, to take the place, where necessary, of the semi-quantitative assessments previously used.

Determination of Trace Constituents in Soils and Plants

The investigation of the uptake of various trace constituents by plants has been continued, with particular reference to cobalt, in view of its importance in the nutrition of sheep and cattle. An account of the behaviour of cobalt and nickel on extraction from soils with different extractants and the relation of the amounts extracted to the uptake of the plant has been published.[3] Further work on these lines, with attention being paid to the effect of liming on the availability of trace constituents is in progress. Collaboration with other institutions, particularly the Animal Diseases Research Association, has led to some determinations, on behalf of the Agricultural Research Council Trace Element (Plant and Animal) Group, of cobalt and nickel in organs of animals from pining areas some of which had received cobalt doses. Further work on seasonal variation of trace element content in herbage has emphasized the desirability of taking samples during the main growing season, preferably between June and September, in view of the changes which occur in dead and dying vegetation. This effect makes a suitable method for diagnosis of trace element deficiency or excess from soil examination particularly desirable.

In collaboration with the Veterinary Investigations Officer for the North of Scotland, work is being carried out in an area where a very low copper content in the herbage (2·5 p.p.m.) has been found and on which cattle do not thrive. With the Animal Diseases Research Association further investigations into the copper, lead and other trace element contents of soils and pastures on which swayback in sheep has occurred have been carried out.

Two series of igneous rocks and their constituent minerals have been analyzed by the semi-quantitative method in order to obtain further data on the geochemical origin of trace constituents in soils and plants and so to anticipate, from geological data alone, possible trace element deficiencies or excesses. This line of work is proving very instructive and a short note of some of the results obtained has been published.[4] Professor V. M. Goldschmidt has prepared a short account of the principles involved in the distribution of trace constituents in soils, rocks and minerals.[5]

The Lundegardh Flame Emission Method

The Lundegardh flame method of spectrographic analysis is not, as is the cathode layer arc method previously considered, a method for the determination of constituents in trace concentrations. It takes the place of chemical methods for the determination of alkali and alkaline earth metals, magnesium and manganese in solution, giving results more speedily and with a greater accuracy than routine chemical determinations. The results of the series of experiments which have been made on the interference

effects of various salts confirm that for the determination of the alkalis and alkaline earths in soil extracts or solutions of plant materials, the errors of single determinations should seldom, if ever, exceed ± 5 per cent. The equipment has been modified slightly by the adoption of a slit type platinum iridium burner tip in place of the original circular aperture which needed a series of platinum gauzes to stabilize the flame. The modified burner, described elsewhere by Lundegardh and Philipson, simplifies the handling of the apparatus and appears to improve its performance.

The main output of results from this method has been of easily soluble potassium for the advisory work of the Institute, and of potassium, magnesium, manganese and sodium in soil extracts and plant materials for soil fertility investigations. The results obtained are covered in the reports of the appropriate departments.

Other determinations have included those of exchangeable cations from soil profiles for the soil survey department and of total bases present in peats.

The total number of determinations made has been of the same order as in previous years—namely, some 450 plates each carrying 16 solutions in which from one to four constituents were determined.

This represents the output of two technical assistants who have at the same time to prepare standard solutions, photographic developers, etc., and keeps one spectrograph and one densitometer in full use.

A general review of the methods of spectrographic analysis and of the results of their application to plant and soil problems, is in course of preparation.[11]

X-RAY INVESTIGATIONS.

The work on the complexes which montmorillonite forms with organic substances, mentioned in last year's report, has been continued. Halogenated and aromatic hydrocarbons, as well as monohydric and polyhydric alcohols, have been investigated in this way. A series of photographs has been taken of samples of montmorillonite containing varying quantities of water and glycol, in order to obtain data on the corresponding variations of the basal spacing. Determinations of the water and glycol contents in these samples have been made.

It has been found that the basal spacing of halloysite, like that of montmorillonite, is affected by treatment with organic liquids, and the effect of various organic liquids, mostly monohydric, polyhydric and halogenated alcohols, has been investigated.[12] The results form an interesting contrast to those with montmorillonite. Highly polar substances, which form a two-layer structure with montmorillonite, seem to form a one-layer structure with halloysite ; and less polar substances, which form a one-layer structure with montmorillonite, are not absorbed at all by halloysite. It is believed that the halloysite results throw some light on the structure of halloysite and its relation to kaolinite ; our conclusions agree essentially with those at which Brindley and Robinson (University of Leeds) had arrived independently.[13] The results of the halloysite experiments are of some value for the identification of halloysite in clays.

In connection with the work on clay-alcohol complexes, the structure of ethylene glycol crystals has been investigated. Weissenberg and rotation photographs have been obtained and the unit cell and probable space groups deduced. This work was done in the Dewar Crystallographic Laboratory, Edinburgh, by kind permission of Dr. C. A. Beevers. It is hoped to proceed to a full structure determination later.

The new method for identification of montmorillonite mentioned in last year's report has been described in a recent publication.[6] In order to get further data on the identification of montmorillonite by this method a series of powder and aggregate photographs of standard montmorillonite-kaolinite and montmorillonite-hydromuscovite mixtures has been made.

A series of powder photographs of standard felspars, kindly provided by the Department of Geology and Mineralogy of the University of Aberdeen, has been made. These should give data which will be useful in the identification of the felspars in soil clays.

A number of Scottish soil clays, with low silica-sesquioxide ratio is at present being investigated.

SPECIAL INVESTIGATIONS

Joint Work with the Animal Diseases Research Association

(*a*) *Cobalt manuring and pining in stock.* This investigation, to which reference has been made in previous years' reports, has been continued and extended during the year to an area in south-west Scotland. In the latter there has been, as in parts of the North of Scotland, a marked response to the application of a manurial dressing of a cobalt salt. It is hoped to publish an account of these experiments in the near future.

(*b*) *Other stock disease problems.* An examination is being made of samples of soil and produce from various areas where there is reason to suspect mineral, particularly trace element, deficiency or excess as a causal agent in the occurrence of diseases such as lactation or grass tetany in cows and swayback in lambs. A soil-vegetation examination has also been made of a number of hill areas where "yellowsis" in sheep is prevalent, and an attempt is being made to correlate the incidence of the disease with the type of grazing.

Studies on Soil Drainage Water

Analytical work on the composition of the drainage waters from the Craibstone lysimeters has been continued during the year, the analyses being carried out on quarterly collections.

Rainfall, including snow, during the year 1st October, 1944, to 30th September, 1945, totalled 39·43 inches, of which from 25 to 32 per cent. appeared as drainage.

The crop during 1944 was oats, with seeds for hay in 1945. Lysimeters 2 and 3 were each given, per acre, 1 cwt. muriate of potash, 3 cwt. superphosphate, 1 cwt. sulphate of ammonia. The oats did not germinate well and the crop was very poor. The dry yields per acre were :—

	Grain		*Straw and Chaff*	
	cwt.	*lb.*	*cwt.*	*lb.*
Lysimeter 1 . .	1	17	1	56
2 . .	4	12	6	23
3 . .	6	20	6	42

1 cwt. per acre sulphate of ammonia was applied to lysimeters 2 and 3 for the hay crop of 1945.

PUBLICATIONS

Issued during the year—

1. " Comparison of Broadcast and Drill Applications of Fertilizers." By A. B. Stewart and J. W. S. Reith. (*Scot. J. Agric.*, **25**, 167-171, 1945.)
2. " The Effect of Extraneous Elements on Spectral Line Intensity in the Cathode Layer Arc." By R. O. Scott. (*J. Soc. Chem. Ind.*, **64**, 189-194, 1945.)
3. " Cobalt and Nickel in Soils and Plants." By R. L. Mitchell. (*Soil Sci.*, **60**, 63-70, 1945.)
4. " Distribution of Vanadium, Chromium, Cobalt and Nickel in Eruptive Rocks." By L. R. Wager (Geological Department, Durham) and R. L. Mitchell. (*Nature*, **156**, 207, 1945.)
5. " The Geochemical Background of Minor-Element Distribution." By V. M. Goldschmidt. (*Soil Sci.*, **60**, 1-7, 1945.)
6. " The Identification of the Montmorillonite Group of Minerals by X-Rays." By D. M. C. Macewan. (*Nature*, **154**, 577-8 1944.)
7. " Balanced Manuring." By W. G. Ogg and H. Nicol (Imperial Bureau of Soil Science). (*Scot. J. Agric.*, **25**, 76-83, 1945.)

In preparation—

8. " The Spectrographic Determination of Trace Elements in the Cathode-Layer Arc by the Variable Internal Standard Method." By R. O. Scott. (To appear in *J. Soc. Chem. Ind.*)
9. " Background Correction in Spectrographic Analysis." By R. L. Mitchell, R. O. Scott and V. C. Farmer. (To appear in *Nature.*)
10. " 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.*)
11. " Spectrographic Analysis of Plants and Soils." By R. L. Mitchell. (To appear in *Biolog. Reviews.*)
12. " Halloysite-organic Complexes." By D. M. C. Macewan. (To appear in *Nature.*)
13. " The Nature of Halloysite Crystals." By G. W. Brindley (University of Leeds), K. Robinson (University of Leeds) and D. M. C. Macewan. (To appear in *Nature.*)
14. " Soil Survey in Scotland." By R. Glentworth and H. G. Dion. (To appear in *Scot. Geog. Mag.*)

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