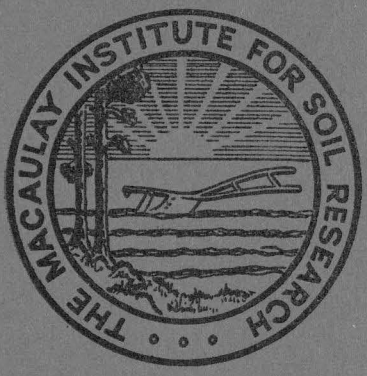
THE MACAULAY INSTITUTE FOR SOIL RESEARCH



FOUNDED 1930

ANNUAL REPORT 1958-1959

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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R. L. FOX (University of Nebraska, U.S.A.).
R. A. D. GOMEZ (Mineralogical Museum, Lisbon, Portugal).
M. M. GUHA (Rubber Research Institute, Kuala Lumpur, Malaya).
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D. R. HOMER (Colonial Office, London).
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F. J. SOWDEN (Department of Agriculture Science Service, Chemistry Division, Ottawa, Canada).
J. R. D. WALL (Colonial Office, London).

CONTENTS

INTRODUCTION

In the summer of 1958 the Council of Management obtained official approval to proceed with the erection of a new Institute building. It is gratifying to be able to report that since then good progress has been made and it is hoped that the first phase of the building will be ready for occupation in 1960 by the Departments of Pedology, Soil Survey, Spectrochemistry, Biochemistry, and Administration. Despite shortage of accommodation, which will persist until completion of the new premises, progress in the programme of scientific work has been well maintained.

The Institute has as one of its primary aims the acquisition of such information on the soils of the country as will be of assistance to the farmer, the forester, and others interested in soil and land use. In particular, by adding to the basic knowledge of soils and the needs of crops, it is the aim of the Institute to help towards the efficient maintenance and improvement of soil fertility from the standpoint of both crop production and animal requirement. To achieve this objective it is necessary to undertake both fundamental and applied work and to cater for specialized studies in both the field and the laboratory. Many of these studies are of necessity long term in nature, and their applicability to the day to day problems of agriculture or forestry may not always be immediately obvious or indeed direct. Although field experiments on such problems as the manuring of potatoes or fertilizer placement for swedes and turnips may give results of direct interest to farming practice, the method of approach in the laboratory examination of samples from experimental areas frequently involves indirect procedures. For instance, to obtain information on the constitution and genesis of soil organic matter, preliminary investigational work on simple compounds related to soil constituents has to be undertaken. Examples of these methods of approach and of the investigational techniques involved will be found in the report and in the summaries of the papers which have been published.

From the staff list it will be noted that there have been several resignations and new appointments during the year. Dr R. C. Mackenzie who, since he joined the Institute staff in 1944, has specialized in the study of clay minerals and methods of differential thermal analysis, has been appointed head of the Department of Pedology embracing soil mineralogy, physical chemistry, peat ecology, forest soils, and general soil analysis. Soil Survey now constitutes a separate department under Dr R. Glentworth.

It is with great sorrow that the death in a climbing accident of Mr Jeremy Smith, one of the senior soil surveyors and a young man of great promise, is reported.

The Institute has been well represented at conferences and meetings bearing on its scientific activities and references to attendance by members of the staff at such meetings are made in the reports of the individual departments. On behalf of the Colonial Office the Director, as a member of the Colonial

Agricultural Research Committee, attended a meeting of the East African Agricultural and Fisheries Research Council in Muguga and visited various research and experimental centres in Kenya and Uganda.

Volume V and Supplementary Volume A of the Collected Papers of the Institute have now been published; titles and summaries of twenty-seven papers published during the year are appended to the report. From the addendum to the staff list it will be noted that the facilities offered for post-graduate study and research continue to attract research scientists both from this country and from overseas. Several applications from prospective visiting workers have, however, unfortunately had to be refused because of shortage of accommodation. Theses for the Degree of Doctor of Philosophy by four of the workers at the Institute have been accepted by the University of Aberdeen.

As in previous years the services of members of the Institute staff have again been utilized on technical committees appointed by the Secretary of State for Scotland and by such bodies as the Department of Agriculture for Scotland, the Agricultural Research Council, the Forestry Commission, and the Colonial Office.

30th September, 1959.

PEDOLOGY

The Department of Pedology as now constituted covers a range of disciplines from essentially academic research on inorganic materials to applied research upon organic soils. Nevertheless, the work of each section is of fundamental pedological significance.

The studies on clay minerals and soil clays by the Sections of Soil Mineralogy and Physical Chemistry are directed largely towards a better understanding of the mechanism of soil formation from inorganic materials. Since clay mineralogy is a relatively young science, this work has necessitated much research on the minerals themselves in order to obtain information on their differences and inter-relationships. Their modes of formation in the soil are being assessed from a study of the weathering processes undergone by rocks and of the minerals in the different soil types, and this in turn helps to explain the pedological processes at work in soil genesis. It is hoped to extend this work by studies on synthesis and on clay-organic complexes; so far only preliminary results are available on these subjects.

In Scotland deep peat covers some 10 per cent. of the land surface and highly organic soils a very much greater proportion. Considerable attention is therefore being given to pedological and other problems relating to such soils. For example, the work of the Section of Peat Ecology and part of that of the Section of Forest Soils is concerned with botanical studies and the investigation of the water relationships and other problems related to the utilization of peat land in agriculture and forestry. The Section of Forest Soils also works in close collaboration with the Forestry Commission, investigating the factors affecting tree growth and the effect of tree growth on the soil. This work, of necessity, ties up to some extent with that of the Department of Soil Fertility, but the problems with a long-term crop such as forest are somewhat different from those relating to agricultural crops.

One of the main functions of the Section of Soil Analysis is to provide information on the composition and constitution of the samples collected by the Department of Soil Survey. This is of value not only in characterizing the soils, but also in disclosing trends of pedological importance.

Close collaboration has continued with other departments within the Institute as well as with the Forestry Commission and the Scottish Peat Committee. Investigational work has also been undertaken on behalf of the National Coal Board, the Road Research Laboratory, the Hill Farming Research Organization, and the Nature Conservancy.

During the year members of staff have attended, *inter alia*, meetings of the Scottish Peat Committee (Moss Survey Group), the Institute of Biology, and the Clay Minerals Group of the Mineralogical Society, as well as conferences on humic acids in Dublin, and on X-ray analysis methods in London. In addition, Mr R. A. Robertson visited the Norwegian Bog Association to inspect peat reclamation and research work in Norway.

SOIL MINERALOGY

The installation of a Raymax 60 X-ray generator during the year has improved the quality of the X-ray diffraction diagrams, particularly those of soil clays. The work of the section can be conveniently considered under the following headings:

SCOTTISH SOILS

Mineralogical analyses of clay and fine sand fractions of soils sampled by the Department of Soil Survey have continued, using X-ray diffraction and optical methods. Most of the samples studied have been from east Aberdeenshire and the mineralogy has proved to be similar to that of other soils from similar parent materials in north-east Scotland, with illite predominating in the clay.

ROCK WEATHERING

The examination of pseudomorphs after olivine in the Markle basalt has been completed by assessing the extent of disorientation in the alteration products from a series of Weissenberg photographs, and a possible reason for the disorientation has been deduced. A paper on this subject[28] is in press. A similar study of olivine pseudomorphs from Dunsapie basalts has been commenced. The thermal behaviour of mixed-layer minerals in some fresh igneous rocks has confirmed that most are interstratified chlorite-montmorillonites. A thesis on the weathering of basic igneous rocks has been accepted by the University of Aberdeen for the degree of Doctor of Philosophy.

Of some rock samples examined for the Forestry Commission, one, a quartz-mica schist, was found to be particularly susceptible to weathering and to contain mixed-layer illite-vermiculite in the clay-mineral separate.

PHOSPHATE FIXATION

The study of mineralogical aspects of soil phosphate economy has continued in collaboration with the Department of Soil Fertility and several additional phosphate minerals have been obtained and examined. A thesis on this investigation has been accepted by the University of Aberdeen.

OTHER INVESTIGATIONS

A granite soil has been separated into a large number of particle-size fractions in order to determine the particle-size distribution of the minerals present. Various miscellaneous samples have been examined, including microgram quantities of crystalline sugar derivatives and specimens of synthetic and natural minerals for the Departments of Biochemistry and Microbiology.

PHYSICAL CHEMISTRY

The work has proceeded along the lines specified in last year's report. Clays have been separated from soil samples from north-east and south-west Scotland and from Ireland for examination by X-ray and differential thermal methods.

DIFFERENTIAL THERMAL ANALYSIS

The two techniques referred to in the previous annual report are still in use, but, because of its advantages, the controlled-atmosphere procedure has been adopted as standard, the normal technique being used only for some routine and specialized studies.

Controlled-Atmosphere Technique

No major modifications have been made to the apparatus[29] during the year but substitution of an inconel tube for the nickel foil previously used for earthed screening in the furnaces has produced a marked improvement in the regularity of the base-line and enabled use of higher sensitivities.

In inert atmosphere several soil clays from surface and sub-surface horizons from Aberdeenshire and Ayrshire as well as from Wexford, Ireland, and various localities in the British Commonwealth (the latter at the request of the Road Research Laboratory) have been examined. The tropical and sub-tropical clays showed the usual mineral associations of goethite, gibbsite and kandite, or a smectite with small amounts of other minerals, and quantitative estimations of the main minerals were carried out where possible. The curves for the Irish clays were difficult to interpret because of peaks of unknown origin and these samples have been submitted for examination by X-ray methods. In the Scottish soil clays the usual suite of minerals was observed with illite in predominance; nevertheless, an area around Auchnagatt in Aberdeenshire proved of particular interest because of the high kandite content of the soil-clay—up to 75 per cent. in certain instances. A detailed investigation of the clays delineated the boundaries of the kandite-rich area and showed that it apparently cut across geological boundaries, thus suggesting some hydrothermal action.

Among minerals examined were a large number of synthetic iron oxides, allophane, amosite, crocidolite, riebeckite, and zircon. The iron oxides, kindly provided by Professor J. D. Bernal, F.R.S., and his colleagues at the Department of Physics, Birkbeck College, London, proved of very considerable interest in showing the type of variation induced in the differential thermal curve by the method of preparation of the oxide, the curve for maghemite (γ-Fe_2O_3) being particularly variable. It has not yet been possible to interpret these variations in detail. The dehydroxylation and rehydroxylation of a large series of monoionic montmorillonites have also been investigated and have shown that rehydroxylated normal montmorillonite is not identical with abnormal types. Further work is in progress. At the request of the National Coal Board, samples of fireclays from Carboniferous strata have been examined.

Pyrolysis curves for organic compounds and peat and its fractions have also been determined in a nitrogen atmosphere.

Using the complete combustion technique, examination of peat samples from Lochar Moss, Dumfriesshire, and Glenamoy, Ireland, confirmed that the differential thermal curve depends upon both the botanical origin of the peat and its degree of humification. Similarly, for various fractions of peat and soil organic matter it has been possible to distinguish the carbohydrate

fraction from the polyphenols such as humic acid. Humic acids from soils give different curves from those obtained from peat[30], but heterocyclic compounds separated from peat give rather more complex curves than either peat itself or the conventional fractions.

Various simple homologous series such as saturated hydrocarbons, long-chain alcohols, and carboxylic acids have been examined with a view to interpreting the fundamental significance of the exothermic peak system obtained on combustion. This subject is briefly discussed in a paper[30] in press, and the products of partial combustion are being further studied in collaboration with the Department of Biochemistry. Samples of graphite and graphitic acid have been compared with the products of partial combustion, but while there are similarities no strict analogies are apparent.

Normal Technique

Several of the soil clays from the Auchnagatt area referred to above have also been checked using the standard technique in order to clarify certain aspects of interpretation of results. The examination of Hong-Kong soil clays has been completed; most of these are highly kaolinitic with varying amounts of goethite and gibbsite.

The bulk of the minerals examined during the year have been montmorillonites saturated with various cations; an account of part of this work has appeared[2], but further investigations with abnormal types are still in progress. Other minerals examined included kaolinites, vermiculites, and allophane from different localities.

It has been considered for some time that suitable pretreatment of samples should render differential thermal curves more diagnostic, and a thorough study of the effect of piperidine treatment on the curves for various minerals has been commenced. This investigation is still in its preliminary stages.

A paper on the significance of the exothermic peaks on the differential thermal curve of ferric oxide gel[31] will appear shortly.

CHEMICAL STUDIES

Much time during the year has been devoted to the study of rapid, accurate semi-micro methods of silicate analysis. A colorimetric method has been found most satisfactory for silica, while for iron one of the EDTA methods has proved admirable in practice. Several methods using EDTA have been tried out for aluminium, and while some were satisfactory at Al_2O_3 concentrations of 10 per cent. or over, only one has been found where small amounts down to <0.5 per cent. can be determined with any accuracy on a 100 mg. sample. The use of an Eel Titrator has greatly improved the reliability of the EDTA methods for calcium and magnesium (using murexide and Eriochrome Black T) in the range normally found in our clays. This work is continuing with particular reference to TiO_2. A paper dealing with the role of chemical analysis in clay mineralogy[32] is in press.

Preliminary attempts to synthesize sepiolite and palygorskite have been made during the year, but although the materials obtained in several trials

appear similar to sepiolite from their differential thermal curves, X-ray investigation failed to confirm this. Some preparations, in fact, appeared to be mixed gels, while some resembled zeolites.

A considerable number of micro cation-exchange capacity determinations have been carried out, with particular reference to the fixation of ions on montmorillonite.

PEAT ECOLOGY

ECOLOGY

The origin, development, and nature of Scottish peat deposits are being studied in conjunction with regional surveys, while investigations of related problems concerned with the improvement of the natural vegetation and general utilization of peat bogs and associated soil types have been continued and extended.

During the year the main emphasis has been placed on field experiments dealing with the water relationships in peat, which are being carried out at two centres in collaboration with the Hill Farming Research Organization. At Coalburn Moss botanical analyses of improved and unimproved plots have been completed and a further series of levels taken in order to ascertain the effects of the different moisture regimes. A system of specially designed sumps has been installed to investigate the behaviour of the water table in relation to changes in drainage conditions. Records from tensiometers and soil thermometers are providing additional useful information.

The preliminary work on the measurement of run-off from a catchment area on deep peat at Blacklaw Moss has made considerable progress. A new "half-ninety" V-notch, calibrated by the Department of Engineering, University of Aberdeen, has been installed to replace the original 90° notch. This should allow a more accurate measurement of run-off particularly at low rates of flow. Complete records of flow and meteorological data have been obtained since 1st January, 1959. In order to correlate this information with the level of the water table in the bog, an automatic recording meter is being set up.

In collaboration with the Section of Radioactivity, investigations are in progress on the rooting of plants growing on deep peat. Both the natural bog species and grasses in a sown sward are being considered especially in relation to depth of cultivation and drainage conditions. The method used depends upon the accurate placing of a radioactive isotope (^{32}P) at different depths in the peat. Growing tips of plants are subsequently sampled and analysed for radioactivity. This provides a semi-quantitative measurement of the root activity of different species at varying depths in the peat.

POLLEN ANALYSIS AND QUATERNARY RESEARCH

Numerous samples from a wide variety of sites and conditions have been collected or received for examination during the current year. For example, the Soil Survey of England and Wales and the Nature Conservancy have submitted samples from Southport, Lancashire, and St. Kilda, respectively. Pollen diagrams representing profiles from a basin peat near Stonehaven, a

buried peat uncovered at a building site in Old Aberdeen, and the upper peat from the Loch Droma site previously reported have been completed. A buried peat in south-east Perthshire has also been examined and assigned to the early Boreal period.

Further palynological work has been carried out on samples from a number of sites in the county of Angus including Restenneth Moss, Forfar Loch, and Kirkbuddo, in an attempt to elucidate the chronology of marl beds and the development of soils which are being studied by the Department of Soil Survey in that area. In addition, some material, mainly of archaeological interest, has been taken from the cairn fields at Hill of Migvie, Angus, and Garrol Hill, Kincardineshire, and from a hut circle excavation at Dalnaglar, Perthshire. Unfortunately, the nature of the partially inorganic material is not conducive to the preservation of pollen grains but at Dalnaglar it was possible to provide the archaeologist concerned with some information and further work is in progress.

At the request of the Forestry Commission a series of maps showing the probable extent of different forest types in north-east Scotland during the Boreal, Atlantic, and sub-Atlantic climatic periods was prepared jointly with the Department of Soil Survey.

A paper on the pollen analyses of peats in the eastern Grampians[3] has been published, and a joint paper on the forest history of the Beinn Eighe Nature Reserve[33] is in the press.

BOG CULTIVATION AND RECLAMATION

The grassland trials at Gardrum Moss have been continued and extended. Again this year three cuts have been taken to determine yield and chemical composition of the herbage from the various treatments. Further ditching has proceeded satisfactorily and several new strips have been prepared. On one of these an experiment designed to investigate the effect of low to medium rates of lime on the establishment and subsequent growth of a grass sward has been established. Eight different species of grasses and clovers have been sown on a series of replicated plots on an adjacent area where it is intended to investigate the effect of their rooting systems on the structure of the peat.

A survey of the basal soils of Moine Mhor bog in Argyllshire has been completed and samples taken for analysis. The task of co-ordinating work on problems concerned with the agricultural utilization of deep peat has continued in association with the Scottish Peat Committee (Moss Survey Group).

LABORATORY INVESTIGATIONS

Analyses of samples supplied by the Department of Agriculture for Scotland (Peat Section) have continued. During the year a total of over 1,100 peat samples were received from the following areas:—Altnabreac, Caithness; Achnacree and Moine Mhor, Argyllshire; Drumuie, Skye; Blacklaw Moss, Lanarkshire. Chemical and physical analyses of a large number of peat and herbage samples from the field experimental areas have been completed and the microscopical examination of peat structure is in progress.

In association with the Department of Plant Physiology, progress is being made in determining the suitability of different peat types for horticultural purposes. A short paper[4] dealing with some of the broader aspects of this work has been published.

FOREST SOILS

FOREST FERTILIZER TRIALS

Determination of height growth and foliage nutrient content of young Corsican pine growing on sand dunes at Culbin Forest, Morayshire, treated with inorganic fertilizers in 1954 and 1956, has continued. In the 1954 phosphate experiment, the slight increase in height growth in the treated plots was maintained, needle phosphate contents being significantly higher for the first time. In the 1956 NKMg experiment, a very significant increase in height growth due to the nitrogen treatment was observed for the second successive year, and this effect was greater in the presence of magnesium. The nitrogen treatment increased needle dry weight, and also needle phosphate and potash, and caused an apparent decrease in needle calcium due to a "dilution" effect. The potash and magnesium treatments increased needle potash and magnesium respectively. While therefore nitrogen applications would clearly benefit trees growing on sand dunes, it is unlikely to be an economic proposition because of the rapidity of leaching of highly soluble fertilizers, and the length of time the response persists will therefore be of great interest.

Analysis of foliage samples collected at the end of the second growing season from Lodgepole pine and Sitka spruce in the NKMg fertilizer trials on deep peat at the Lon Mor, Inchnacardoch Forest, Inverness-shire (Experiments 128 P. 46 and 74 P. 29) has established that the spruce, which grew well earlier as a result of repeated phosphate dressings, was suffering from acute potash deficiency. Needle potash content increased in the plots with potash and needle colour improved greatly. Needle nitrogen contents have been slightly increased by the nitrogen treatment. Diameter growth during the third growing season has shown an increase in the plots with potash. In the Lodgepole pine, the nitrogen treatment has caused an apparent reduction in needle phosphate, calcium, and magnesium, and the potash treatment has increased the needle potash. There have been no significant effects in the first growing season after applications of aqueous ammonia, granite dust, calcium cyanamide, and limestone to young Lodgepole pine in April 1958.

TREE GROWTH ON DEEP PEAT

The intensive study of the effects of Lodgepole and Scots pine on peat at the Lon Mor has been completed (Experiments 47 P. 28 and 19 P. 26). The results may be summarized as follows:

Tree growth has greatly dried out the peat, the extent depending on the depth of the peat and the vigour of the trees, and there has been considerable shrinkage which has resulted in the formation of underground cavities rather than a general settling of the surface. Vigorous trees may suffer from seasonal moisture shortage later in the rotation. Lodgepole pine on the plot fertilized

with phosphate has removed significant amounts of potash and inorganic phosphate from the upper layers of the peat. No such effect was detected under the less vigorous Scots pine.

Diameter growth in the fertilized plots has fallen off since 1950 in the Scots pine, and since 1955 in the Lodgepole pine. Foliage analysis suggested that this was due to exhaustion of the applied phosphate, or a deficiency of potash, or both. A PK trial was therefore laid down in May, 1959, on the Lodgepole pine experiment, and measurement of diameter growth during 1959 suggests that potash is the limiting factor, as has been found for checked spruce on the same area.

MINERALIZATION OF PEAT NITROGEN

The study of differential growth of young Lodgepole pine and Sitka spruce on deep and shallow plough ridges at Wauchope Forest, Roxburghshire, has been completed. While it has been shown that in 1957 and 1958 the needles of both species contained more nitrogen when growing on deep ridges, and that the peat in the rooting zone contained significantly more moisture and ammonia nitrogen during the growing season, it is not possible to separate completely the effects on height growth of nitrogen mineralization, moisture, and shelter in the early years; a new investigation is therefore to be started on freshly ploughed ground.

FOLIAGE ANALYSIS IN EXISTING FERTILIZER TRIALS

Analysis of needle samples collected in October 1957 from Lodgepole pine and Sitka spruce in existing Forestry Commission fertilizer experiments has been completed, and the main conclusions discussed in two papers[5, 34]. The investigation has shown that if allowances are made for year-to-year variations in needle nutrient content and for interactions between nutrients, it is possible to establish fairly broad ranges of major nutrient content over which growth is satisfactory, and below which a practical response to fertilizers is obtained. In some peat areas, dressings of phosphate heavier than the normal 1½ to 2 oz. of ground mineral phosphate per tree are required, and potash deficiencies have also been observed. Nitrogen nutrition on these peats appears to be adequate if sufficient phosphate is present and liming peat at rates of up to 4 tons of ground limestone per acre has not only had no effect on nitrogen uptake or tree growth, but has also reduced the availability of phosphate.

ADVISORY AND COLLABORATIVE WORK

Fertilizer recommendations for both Forestry Commission and private nurseries, based on analyses carried out by the Department of Soil Fertility, have continued, and over 300 samples were dealt with during the year.

SOIL ANALYSIS

Analytical determinations have been completed on the soils collected by the Department of Soil Survey during the 1957 field season, and the following determinations have been completed on 482 samples (123 profiles) collected

during the 1958 season: loss on ignition, mechanical analysis, exchangeable bases, total and readily soluble phosphorus, total carbon and total nitrogen. Hydrogen ion concentration and exchangeable hydrogen determinations have been carried out on nearly one-third of the latter samples. In addition to these, standard analyses have been carried out on 49 samples from the Isle of Rhum.

Clay samples separated from 111 soils from north-east Scotland have been analysed for total silica, iron, and aluminium, and ultimate analysis of 37 samples of soil and rock from various parts of Scotland have been completed. Free oxides have been determined on 36 samples from Hong-Kong.

At the request of the Hill Farming Research Organization, 170 samples of surface soil have been analysed.

SOIL SURVEY

The normal survey programme involving mapping on a scale of 2.5 inches to 1 mile has continued in areas in north-east, central, south-east, and south-west Scotland. On Sheets 33 (Haddington) and 34 (Eyemouth) some 120 square miles have been mapped, 70 in eastern Berwickshire and 50 in the Midland Coal Basin. Some 65 square miles have been mapped on Sheets 7 (Girvan) and 8 (Carrick), mainly in the regions south and east of Barrhill with a smaller area in the central northern sector of Sheet 8. About 15 square miles on Sheet 48 (Perth) have been covered in areas west and north-east of Perth, and 40 square miles on Sheet 39 (Stirling). Ten square miles have been mapped in the Dingwall end of the Black Isle on Sheet 83 (Inverness).

Progress has also been made in describing the more extensive natural and semi-natural vegetation communities and their relationships to the major soil groups, particularly in north-east Scotland. A special study is being made of a small hill in Glenbuchat, Aberdeenshire, to clarify the relationships between the vegetation, soils, and relief and to assemble data which can be compared with results of similar surveys elsewhere on different soil types. In these the results of randomised plots one foot square are recorded by the ten point quadrat method.

Two senior surveyors have collaborated with surveyors of the Soil Survey of England and Wales in examining representative soils developed on Carboniferous parent materials in England. Special projects have included *ad hoc* surveys of the area affected by the Turret-Grangemouth Water Scheme, the Dalnaglar Hut Circle, Glen Shee, Perthshire, and the Roman Marching Camp, Wigg Street, Kirkbuddo, Angus. An account of soil conditions in the Highlands was given at a symposium on conservation in the Scottish Highlands held in Glasgow by the Institute of Biology, Scottish Branch.

Field and laboratory work has been completed on Sheets 87 (Peterhead) and 97 (Fraserburgh). A fair copy of Sheet 77 (Aberdeen) has been submitted to the Ordnance Survey and Sheet 76 (Inverurie) has been published. Work on the memoir to cover these four sheets has commenced and it is now possible to give a general appreciation of the soils of this part of Aberdeenshire.

The area covered by the four sheets amounts to 1,010 square miles. On the coastal sheets the greater part is devoted to arable agriculture; on the Inverurie sheet, moorland, planted land, and rough ground account for a much higher proportion, approximately fifty per cent., of the total area.

The arable region has an average annual rainfall of between 32 and 35 inches; a narrow belt along the coast, extending from Fraserburgh to Aberdeen, has less than 28 inches. Rather more rain falls in the last six months of the year, but the monthly average is approximately 2½ inches. The mean annual average temperature is 45°F. With increasing altitude towards the west the rainfall increases and there is a markedly greater range of temperature.

North of the Highland Boundary Fault, which crosses the coast north of Stonehaven, are ancient rocks of pre-Cambrian age—the Highland Schists—considered to have been originally marine sediments, sands, silts, clays, and siliceous marls, since metamorphosed to varying degree by pressure and heat. In the Buchan district of Aberdeenshire, in the area covered by Sheets 87 and 97 (Peterhead/Fraserburgh), these rocks underlie the denuded peneplain which forms a gently sloping incline from west to east. Two divisions of these rocks are recognized, (i) the Banff Division of low grade metamorphism, with argillaceous-schists and various kinds of spotted schists such as andalusite-schist, and (ii) the Keith Division of strongly metamorphosed rocks such as quartzite, quartz-schist, and mica-schist. Very many varieties of the Highland Schists occur. In places igneous sills of Old Red Sandstone age have been intruded through the metamorphosed sediments of the Highland Schists; these vary in composition from granite to basic igneous gabbro and ultra-basic rocks such as serpentine and picrite, and in extent from one square mile to several hundred square miles.

Rocks of the Old Red Sandstone formation are thought to have covered the whole of the north-east at one time, but now only remnants are found, mainly of Middle Old Red Sandstone age. These have been protected by being faulted-in, as for instance in the Gamrie-Turriff outlier which extends to the Moray Firth coast about Gamrie and Pennan (Sheet 97: Fraserburgh).

There is evidence of three glacial periods having affected this region, with an interglacial period between the first and second. The ice movement in each of the three periods was from a different direction and the first and second movements were affected by the presence of a Scandinavian ice-sheet off the east coast. In the first period ice passed across Aberdeenshire from north-west to south-east, bringing with it a black Jurassic clay out of the Moray Firth from the direction of Brora; this now forms a basal deposit seen at Whitehills Brick and Tile Works and the Boyndie Limestone Quarry, and reported as far south as Aberdeen.

Marine clays, known as the Coastal Deposits, which were laid down in the interglacial period between the first and second Ice Ages, can be seen about Bogtown Farm, Sandend, Banffshire, (Bogtown Association) and north of St. Fergus, Aberdeenshire (Blackwater Complex).

The second ice sheet is believed to have travelled from south to north and to have brought the red-coloured drift which occurs on the seaboard side of Aberdeenshire, extending from Balmedie to the eastern side of Mormond Hill. This red-coloured drift, which in some areas consists of boulder clays and in other large areas of lacustrine clay, has obviously been derived from rocks of the Old Red Sandstone formation. The deposit has hitherto been considered to have been transported from Strathmore and carried northwards by glacial ice, hemmed in to the coast by the Scandinavian ice sheet which filled what is now the North Sea. The extent and thickness of the Strathmore Drift—coastal sections fifty feet thick occur about Peterhead—is, however, contrary to the observations of glacial carry for the rest of Scotland. An alternative explanation is that this material was pushed in from the north-north-east by Scandinavian ice. An extension of the line of the Highland

Boundary Fault, which crosses the coast just north of Stonehaven, would suggest that rocks of the Old Red Sandstone formation form the bed of the North Sea off eastern Aberdeenshire at no great distance from the coast. The large lacustrine areas, as found about Balmedie and between Ellon and the Toll of Birness, clearly indicate that glacial lakes were impounded between the land ice and the Scandinavian ice sheet. Alternations in strata of red bands, and to a lesser extent of yellow bands, are probably due to an alternation of melt waters from the seaward and landward ice. Evidence points to a discharge of drainage to the north.

The third ice sheet followed the line of easiest flow and travelled from north-west to south-east along the valleys. It was less extensive than in either the first or second glacial period and failed to reach the coast in Aberdeenshire, except in the vicinity of Aberdeen. Hummocky mounds of moraine from the retreating glacial tongues are a common feature in the Highland glens, indicating the probable persistence of glaciers for some considerable time after the low ground was clear of ice.

Reference is made later to certain pre-glacial Pliocene deposits which form the parent material of the Skelmuir Association of soils.

The altitudinal range of the country described rises from sea level to 2,500 feet, and two broad climatic zones can be recognized. The first extends roughly to 1,000 feet where arable agriculture stops. The second lies between 1,000 and 2,500 feet, and here the summits and slopes of the hills tend to be covered with hill peat. The occurrence of peat is correlated with a region of high rainfall, high humidity, and parent materials derived from acid rocks. On these parent materials the peat-forming tendency does, in fact, extend down to sea level. Associated with the hill peat are peaty podzol soils, supporting a wet heath and moorland vegetation, in which a continuous and strongly developed iron pan has formed. The pan is situated beneath the bleached horizon and frequently caps the "indurated horizon"—a singularly compact layer of widespread occurrence in Scottish soils. The effect of the iron pan is to deflect the drainage laterally down slope in what was formerly a naturally vertically free-draining soil and to promote more readily surface water-logged conditions. Thus the formation of hill peat of a depth of 8 or 9 feet may build up on top of the peaty podzol. This soil normally has a 9 to 12 inch layer of organic matter, some 6 inches of which is black, greasy, well-decomposed humus. Peat is mapped as such when greater than 12 inches. The peaty podzol also extends to low altitudes on acid parent materials. It has a pH of 3.5 to 4.5 in the A horizon, rising to 5.5 in the C, and is the most widespread genetic soil in Scotland. Iron podzol soils supporting a heath or open Scots pine forest type of vegetation occur on the steeper slopes. They have well-defined A_2 and B horizons, but no iron pan. The arable region below 1,000 feet has a greater diversity of soils comprising iron podzols and brown forest soils of low base status together with non-calcareous ground water and surface water gleys and peaty gleys. Parent material and relief are largely responsible for the type of soil formed, but cultivation has modified many of the original characteristics of the soils. Profile descriptions of the major soil groups represented are given in the Annual Report for 1956/1957.

In view of the effect of the three glacial movements over the rather variable solid formations, it is not surprising to find the north-east of Scotland described as the "riddling heap of creation."

Mention has been made of the major soil groups represented, *viz.*, peaty podzols, iron podzols, brown forest soils of low base status, non-calcareous ground water and surface water gleys, and peaty gleys. The mapping units distinguished by the Soil Survey are known as soil series, each series being representative of a major soil group. The series are grouped on a parent material basis into soil associations, a soil association consisting of a range of soil series developed on parent material from similar rocks or combination of rocks. It contains soils which differ widely in profile character and in hydrologic conditions, ranging from soils with naturally free drainage to those with very poor drainage. The soil association is a cartographic unit.

The following soils are found in the area:

Associations

Leslie:	Till derived from ultra-basic rocks, mainly serpentine.
Insch:	Till derived from basic igneous rocks.
Tarves:	Till derived from mixed acid igneous, acid metamorphic, and basic igneous rocks.
Ordley:	Mixed till derived from Old Red Sandstone and argillaceous-schist rocks.
Bogtown:	Interglacial clays.
Fraserburgh:	Raised beach shelly sand.
Strichen:	Till derived from quartz-mica schists.
Foudland:	Till derived from argillaceous-schists and schistose grits.
Countesswells:	Till derived from granite and granitic gneiss rocks.
Hatton:	Till derived from Old Red Sandstone conglomerate and sandstone rocks.
Cuminestown:	Till derived from arenaceous Old Red Sandstone rocks.
Peterhead:	Clayey till derived from Old Red Sandstone sediments containing metamorphic and igneous stones and Old Red Sandstone conglomerate cobbles.
Tipperty:	Lacustrine clays and silts derived from Old Red Sandstone.
Collieston:	Red water-sorted bands of various textures overlying sand or gravel.
Skelmuir:	Stony till containing a high proportion of Cretaceous flints and quartzite cobbles.
North Mormond:	Till of mixed acid metamorphic and Old Red Sandstone rocks.
Boyndie:	Fluvio-glacial sand.
Corby:	Fluvio-glacial and morainic gravel.

Durnhill: Till derived from quartzite and quartz-schist.
Auchinblae: Red fluvio-glacial sand and gravel.
Lochter: Upper terrace fine sandy alluvium.

Miscellaneous Soils

Blackwater Complex: Sand on raised beach dark grey silty clay.
Links.
Dunes.
Alluvium.
Mixed bottom land.
Hill and basin peat.

The main associations found in Aberdeenshire are the Countesswells, Foudland, Tarves, and Insch. Also extensive is the area of Old Red Sandstone deposits occurring along the east coast which has been referred to as the Strathmore drift; this was formerly named the Cruden Association, but has now been separated into the Peterhead, Tipperty, and Collieston Associations (see above). The Corby Association, found along river and stream terraces together with scattered morainic mounds is locally extensive. At opposite extremes in basicity and acidity are the Leslie and Insch Associations on serpentine and basic igneous till and the Durnhill Association on quartzite. Descriptions of the Durnhill, Insch, and Foudland Associations have been given in the Annual Report for 1956/1957, and the character of the Countesswells, Tarves, and Skelmuir Associations will be dealt with in this report.

The Countesswells Association, on granitic boulder clay, has an undulating to hilly relief, with several hill masses exceeding 1,500 feet. Conifer plantations on iron podzols or gley soils on the flanks give place to heather moorland on peaty podzols on the upper slopes. Rock outcrops frequently occur on the summits. The arable land is divided into fields, often irregularly shaped, by stone walls (dykes) built from large boulders cleared from the fields; many fast boulders remain in the fields. Rock outcrops occur throughout the association, and many patches of rough ground—often planted—indicate conditions which are too bouldery for arable agriculture. Small streams normally provide an adequate field water supply.

The common soil texture of this association is a stony coarse sandy loam. Fragments of felspar and quartz are conspicuous in the soil. Originally derived from iron podzol and peaty podzol soils, the surface soil of the arable land is dark brown in colour when moist, drying to grey brown. Non-calcareous gley soils are not extensive but are scattered throughout the association in concave sites. Some of the best arable land occurs on gently sloping sites and has imperfect drainage; it is derived from an iron podzol with a gleyed B horizon. The association covers a large part of the southern portion of the Aberdeen and Inverurie sheets.

The Tarves Association, developed on till containing a wide mixture of stones derived from acid igneous, acid metamorphic, and basic igneous rocks, is more generally confined to areas of subdued, gently rolling topography.

In the western part of the Inverurie sheet, however, hills exceeding 1,700 feet fall within the association. They are utilized in a similar manner to the hills of the Countesswells Association with conifer plantations on the slopes and sheep grazing on the heather moorland of the summits. Peaty podzol soils occupy the plateau-like summits, and iron podzols occur on the flanks. The latter give place to brown forest soils of low base status on the foot slopes, and the greater part of the well-drained arable land is of this group.

This association, as found on the coastal sheets on gently rolling to undulating topography, presents a complicated jig-saw pattern of brown forest soils on the convex relief, brown forest soils with gleyed B horizon on gentle slopes, and gley soils on the concave or flatter sites. Approximately 40 per cent. of the association is covered with non-calcareous ground water gleys. The texture of the surface soils of the well drained series is a loam and that of the poorly drained series a sandy clay loam; the former soils are brown in colour and the latter grey-brown. Boulders are not generally a problem in this association. The soils of the Tarves Association, being of medium texture and moderate base status, may be considered modal or most typically representative of the arable lands of north-east Scotland.

The Skelmuir Association occurs over the Corse of Balloch, south-west of Peterhead, and is developed on parent material of pre-glacial age containing a high content of quartzite and rolled flint cobbles in an almost white clayey matrix. The material, which resembles a till deposit, is considered to be of Cretaceous origin accumulated as a pre-glacial shore line or littoral deposit. It occupies a gently rolling, flattened hill feature at a height of 350-450 feet. The soils are extremely acid. Probably the whole area of the association was at one time covered with hill peat of which some 3 square miles still remain. The dominant soil is a peaty podzol, with peaty gleys and non-calcareous gleys also present. The arable surface soil is dark grey in colour, being derived from the mixing of the black organic horizons with the white A_2 horizon. Cultivation has failed in many places to eliminate the lower part of the A_2 horizon and the iron pan which occur below plough depth. The land, which is inherently very low in nutrients and very stony, is mainly occupied by small crofts.

In the main the soils of north-east Scotland are of light to medium texture with clay contents of 10 to 20 per cent. Exceptions to this are the Peterhead and Tipperty Associations and parts of the Blackwater Complex which are clay-textured—up to 70 per cent. clay. The poorly drained members of all associations tend to have a higher clay content than the freely drained and are commonly of sandy clay loam or clay loam texture as compared with loam or sandy loam in the freely drained soils. All the freely drained soils exhibit B_2 horizons enriched by sesquioxide accumulation, whether derived from peaty podzols, iron podzols, or brown forest soils of low base status, and all have a lower B_2 horizon which is strongly indurated. The cultivated surface soils of these major soil groups have a crumb structure in the surface horizon which passes into subangular blocky in the B horizon. The succeeding change into the indurated layer is sharp and clear; the induration decreases with depth. The cultivated gley soils tend to have a subangular blocky structure

in the surface, an angular blocky A_2g horizon, and a coarse prismatic Bg horizon. Pale grey and ochreous yellow mottled colours are characteristic of the subsurface horizons.

Of the clay minerals present in the soils, illites are commonest, followed in order of abundance by kaolinites, vermiculites, and montmorillonites. The distribution of these minerals in the major soil groups does not as yet show any consistent characteristic trend as between the podzol with free drainage and the non-calcareous gley with poor drainage for the Countesswells Association on granite boulder clay, the Strichen Association on quartz-schist till, and the Foudland Association on argillaceous-schist. All show illite to exceed 50 per cent., with kaolinite consistently accounting for 20-25 per cent., and vermiculite varying from a trace to 30 per cent. On base rich parent materials montmorillonite and vermiculite occur together. In the brown forest soils of the Insch Association the vermiculite content is high and is greatest in the top layers of the profile. In the gley soils of this association, montmorillonite tends to increase, especially in the lower layers. Illite in this association varies between 40 and 60 per cent. The clay minerals in the Tarves Association tend to be intermediate between the Countesswells, Foudland, and Strichen Associations on the one hand and Insch on the other, with trioctahedral illite very high (70-80 per cent.) in the basal layers of the brown forest soil and vermiculite high (60 per cent.) in the surface layers. Kaolinite is consistent at 20-25 per cent. in both the brown forest soil and the gley. On the more acid parent materials, as for instance in the Durnhill and Skelmuir Associations, dioctahedral illite is dominant with kaolin invariably taking second place. All associations derived from Old Red Sandstone sediments are notably high in illite.

The pH ranges of the virgin soils are—peaty podzols, 3·5-4·5; iron podzols, 4·5-5·5; brown forest soils of low base status, 4·5-6·0. The gley soils tend to have a range of 4·5-6·0. Commonly the pH rises about 1 pH unit from surface to C horizon. In the non-calcareous gley soils the amount of exchangeable magnesium approaches and sometimes exceeds that of calcium, but in the freely drained brown forest soils and iron podzols it is commonly one-fifth to one-tenth that of calcium. The pH level of the arable soils is now generally between 5·5 and 6·5.

Marked differences in phosphate relationships occur between soils with free drainage (brown forest soils and iron podzols) and those with poor drainage (non-calcareous gleys). A report of investigations on these and on differences in the distribution of amorphous sesquioxides has been given by the Department of Soil Fertility in the Annual Report for 1954/1955. The total P_2O_5 of most of the soils of this area is about 0·25 per cent., but in the Insch Association values may be two or three times as high.

A striking difference in the distribution of extractable trace element cations has been found in comparing soils with free drainage and soils with poor and very poor drainage (peaty gley) on the Insch, Countesswells, Tarves, and Foudland Associations. Cobalt, extracted by 2·5 per cent. acetic acid and by neutral normal ammonium acetate in parts per million oven dry matter, is 1 p.p.m. or less in the freely drained soils but rises to 10-20 p.p.m. in the lower

layers of the very poorly drained soils. The distribution of nickel is similar to that of cobalt. Work on this subject is continuing and has been dealt with comprehensively in a recent paper[37]. Nickel in unusually high amounts occurs on the Leslie Association derived from serpentine rock, and is also present in adjacent deep peat areas which are cultivated. Values of 49-403 p.p.m. nickel, extracted by dilute acetic acid, have been found on the mineral soils with poor drainage, and 114-289 p.p.m. on the peat. This condition adversely affects the growth of oats and turnips, particularly on the peat where the pH is low—4·5. Molybdenum in amounts sufficient to cause disorders in cattle has been found in soils with poor and very poor drainage on the Foudland and Tarves Associations.

From the results of chemical studies and from the evidence from field trials in the work of the Department of Soil Fertility, it is clear that the series distinguished by the Soil Survey are valid units which differ in their response to applied fertilizer.

SPECTROCHEMISTRY

Although the application of spectrochemical methods developed within the department to the determination of trace elements in soils and plant materials has now been in progress for over 15 years, many of the problems of availability of trace elements to plants have still to be elucidated. For certain of the biologically important elements, such as copper and cobalt, a relatively sure diagnosis can be made, but the main effort in trace element work will probably have to be directed to this aspect of the problem for a number of years before equally reliable information is available for other important elements. There are complications with molybdenum and manganese, for instance, which make the development of an extractant suitable for all normal Scottish soil types particularly difficult. Work is proceeding on these lines, and the use of chelating extractants and other modern reagents would appear to offer a promising line of approach.

Considerable work on the spectrochemical equipment is being carried out in order to facilitate the forthcoming transfer to new laboratories. Some of the modifications are detailed below. In general, the opportunity afforded by the interruption in work will be taken to introduce a number of changes in technique, and the preliminary work required for these has been in progress throughout the year.

Facilities for training visiting research workers have again been inadequate, and this aspect of the work has been further restricted by the resignation of Dr D. J. Swaine, who left the Department in June, 1959. Until the occupation of the new spectrochemical laboratories and the subsequent re-calibration of the instruments have been completed, no improvement in these facilities can be envisaged. Visiting workers who have spent extended periods in the department during the year include Mr M. M. Guha, Rubber Research Institute of Malaya, Miss Ma Ma Lay, Union of Burma Applied Research Institute, and Mr R. A. D. Gomez, Mineralogical Museum, Lisbon. Members of the staff of the department attended the meeting of the F.A.O. Co-operative Research Project on Trace Elements in Dublin, the 8th International Spectroscopic Colloquium in Lucerne, the International Symposium on Humic Acid in Dublin, in addition to meetings of the Institute of Physics Industrial Spectroscopy Group, the Interservices-D.S.I.R. Panel on Emission Spectroscopy, the sub-committees of the Society for Analytical Chemistry and Agricultural Research Council on trace element determinations. Lectures on spectrochemical methods have been given to specialized courses at Robert Gordon's Technical College, Aberdeen, and the Northampton College of Advanced Technology, London.

TRACE ELEMENTS IN SOILS, PLANTS, AND BIOLOGICAL MATERIALS

Soils and Soil Parent Materials

Sufficient information has now been obtained from the examination of soil profiles, made available by the Department of Soil Survey, to draw reasonably

definite conclusions regarding the occurrence of trace elements in the soils derived from the more common soil parent materials. It would appear well established that the total content of any trace element in a soil can be related primarily to the rock from which its parent material was derived. In general, artificial effects can be disregarded unless there has been the addition of quite abnormal amounts of trace-element-rich extraneous materials. An example is sewage sludge which can be dangerously high in available amounts of toxic metals such as zinc. All such additives should be used in moderation, and only on the advice of qualified advisory officers.

While the total soil contents of trace elements are related to the soil parent material, the readily extractable amounts are dependent on pedological factors such as the soil type and particularly the prevailing soil drainage conditions. The various factors affecting total and extractable trace element contents have been discussed in a paper[37] now awaiting publication. As has been indicated in previous reports, the local drainage conditions very markedly affect extractable trace elements, and problems arising from both deficiencies and excesses can be related to this factor. Recent results confirm that there should seldom be cobalt deficiency in areas which are naturally poorly-drained, while on soils plentifully supplied with nickel or molybdenum disorders due to excesses may arise on those which at some stage of their development have been poorly drained.

It should be realized that, under Scottish conditions, it is impossible to describe trace element contents on a wide geographical or topographical basis, as the geology and other local factors such as drainage are so complex. Maps purporting to show areas of trace element deficiencies on a county basis, for instance, are misleading and dangerous if used to assess the status of individual farms. In many areas the requirement must be ascertained on a field to field basis.

Some geochemical investigation on typical rocks and minerals has been continued, and an account of some Swiss granites[38], carried out in collaboration with Professor T. Hügi of Bern, is awaiting publication.

Soil Status and Plant Uptake

In collaboration with the Department of Soil Fertility and the North of Scotland College of Agriculture the long-term investigation of the effect of fertilizer treatment on plant uptake of trace elements has been continued. Samples from series of experimental plots, including some sprayed by air, covering cobalt, copper, manganese, and other trace elements have been examined, and it is hoped in due course to identify the various factors which control the effects of soil treatment on plant uptake. At present, trace element soil therapy is carried out largely on an empirical basis, and little is known of the possible long-term effects. It is known, however, that deleterious effects have been experienced with continuous use of copper-containing sprays in orchards overseas, while, on the other hand, the introduction of organic pesticides may be eliminating a source of useful trace elements.

The trace element uptake of forest trees is of considerable interest, particularly in view of the high content of the litter layers of organic soils, and the

possible effects of organically bound trace elements in pedological processes. Two investigations are in progress, one a study of the trace element distribution in a 30 year old Scots pine and the soil carrying it, and the other an investigation of the seasonal variation of leaf content of three species of deciduous trees, at different points on the tree.

The examination of soil and plant samples from areas where trace element disorders are suspected has been continued on a serial basis in collaboration with the Department of Soil Fertility. Other samples have been examined on behalf of various regions of the National Agricultural Advisory Service and other educational and research organizations.

SPECTROCHEMICAL METHODS OF ANALYSIS

There has been a considerable increase from around 2,300 to over 3,000 in the number of samples of soils and plant materials examined during the year by spectrochemical methods, up to 15 determinations of trace elements being made on each sample. The increase is due largely to the introduction of direct reading equipment for the determination of extractable copper in soils. Corresponding increases occurred when the direct reading technique for magnesium was introduced.

Flame Emission

In the past year only direct reading methods have been employed for flame emission work, the medium quartz spectrograph having been taken out of service to make it available for porous cup spark excitation methods. This has restricted the elements determined by flame methods to K, Na, and Ca. It is proposed in due course to resume flame spectrographic work, in view of its use for such elements as Sr and Mn. One of the flame photometers has been used to continue the investigation of interference effects on Ca determination in soil and plant extracts. The other instrument is fully utilized for the determination of K, Na, and Ca in acetic acid soil extracts and in acid extracts of plant materials.

A brief account of the design and application of the two multichannel flame photometers and of the redesigned multifunction microphotometer at present under construction[6] has now been published.

Arc Emission

No significant changes have been introduced into the method employed for trace element determination in the cathode layer arc after chemical concentration. One modification concerns the current controlling resistances for the D.C. arc sources which have up to now been operated by a manually controlled stud resistance. This restricted the location of the resistance unit to a position near the arc source where its heat dissipation of over a kilowatt is objectionable near temperature-controlled direct-reading equipment. For use in the spectrochemical laboratories now in course of erection a unit has been modified for remote operation, having been fitted with a series of solenoid-operated mercury switches controlled by a small rotary switch at the source unit. This enables the main resistance unit to be located in a ventilated

position away from the spectrograph and at the same time eliminates the possibility of copper contamination due to arcing or wear at the studs. A contribution has been made to a discussion on the coincidence of spectral lines of calcium and vanadium[7].

Direct Photometry

The two-channel direct-reading attachment to the Hilger Small Quartz Spectrograph for the determination of magnesium has now been in continuous operation for three and a half years, and is providing a trouble-free analytical service for all departments of the Institute. A description of the equipment[8] has been published.

The Hilger direct-reading attachment for the medium quartz spectrograph has proved satisfactory for the determination of certain elements by the porous cup solution spark method. The damping of the profiling circuit as supplied proved inadequate, and in order to average out fluctuations of the spark source employed in the positioning of the exit slits, a small amount of capacitance damping has been added. This has facilitated more accurate setting of the exit slits relative to the spectral lines. Another modification has been the incorporation in the output meter circuit of a switched shunt which gives an extension of the concentration range by a factor of about three times.

A method is being developed for the determination of zinc, silicon, boron, phosphorus, iron, manganese, aluminium, and copper in plant materials, by the use of a pressed rotating disk electrode composed of the plant ash, graphite powder, cellulose and a spectroscopic buffer. Reproducibility is good, but the accuracy, compared to contents derived from other spectrographic or chemical methods, is averaging about ± 10 per cent. for the above elements. Values for accuracy are however difficult to assess because of dubiety regarding the true content of any element in the plant samples and the difficulty in preparing comparable artificial standards.

ABSORPTION SPECTROMETRY OF SOIL CONSTITUENTS

The principal contribution of absorption spectrometry to the work of the Institute during the past year has been in studies on the constitution and genesis of soil organic matter and peat. The results of co-operative work with the Department of Biochemistry on *Phragmites* peat[39] have been presented at a symposium on humic acid in Dublin and will be published. Infrared spectroscopy has proved valuable in rapidly characterizing the products of various chemical treatments and fractionations, so indicating which avenues are most profitable to explore, and which substances merit quantitative organic analyses. In agreement with previous chemical studies, this work has indicated that more unaltered aromatic rings derived from lignin persist in peat than in soil organic matter. A new observation is that these aromatic rings are concentrated in the less acidic fraction of peat humic acid, whilst the more acidic fraction consists largely of unsaturated material formed during the process of peat formation. The rather different picture presented by soil humic acids is now being examined in detail.

The interpretation of the complex infrared spectra of soil components is based on the study of simpler compounds of known structure. There are many important groups of compounds which have as yet been little investigated. Among these, compounds containing enolic β-dicarbonyl structures are of particular interest, as such structures have long been postulated to occur in soil organic matter. Advantage has therefore been taken of an opportunity to study the spectra of some 4-hydroxycoumarins (enolic β-ketolactones)[40] which were made available by work in the Chemistry Department of the University of Aberdeen. The spectra of many of these have features which are usually considered distinctive for carboxylic acids; these results emphasize the caution necessary in the interpretation of infrared spectra. The presence of β-ketoacids or β-ketoesters in humic acids could account in part for their decarboxylation under mild conditions.

There is little doubt that lignin from plants, altered by fungal and microbial action, makes an important contribution to soil organic matter. Studies on chemical changes produced by the action of fungi on aromatic compounds related to lignin has continued in collaboration with the Department of Microbiology, whose report deals in more detail with published work[9, 41] and with work in progress in this field, where both ultraviolet and infrared spectroscopy have found considerable application. Further work on β-oxidation of phenoxybutyric acids, in collaboration with the Departments of Microbiology and Biochemistry, has been published[10], as has a short study of the effects of hydrogen bonding on the infrared absorption of amino groups[11]. The infrared spectra of a number of substances isolated from soil, plants, and micro-organisms have been examined to obtain information on their structure on behalf of other departments. Work of this kind has helped to identify 6-*O*-acetylglucose, a product from *B. megaterium*[12]. A paper on the cause of spectral changes shown by some sugars in pressed alkali halide disks[42], previously reported, has been accepted for publication.

In the inorganic field a study has been made of the infrared spectra of some illites and montmorillonites which show abnormalities when examined by differential thermal analysis: their spectra also show some unusual features. The structural significance of these spectral differences must await a better understanding of silicate spectra. The origin of some puzzling features which appear in the infrared spectra of soil clays and hydrous sesquioxides, near 7μ, and which do not arise from the main structural framework of these materials, is being explored. It appears possible that the problem may be best answered by examining some hydrous calcium silicates, which show similar absorption bands. Their structures are related to soil clays, but they have the advantage that they can be synthesized under controlled conditions.

BIOCHEMISTRY

When a plant goes short of an essential nutrient changes can often be seen in its leaves; the nature of the mineral deficiency can sometimes be decided simply by looking at the plant. However, these changes are only the visible part of a general disturbance which is fundamentally chemical in character.

If the missing element is supplied in a suitable form the plant is once more able to grow normally. Sometimes the element needs to be supplied only in minute amounts, recalling the action of a catalyst, and so the idea has grown that it is required for the formation of one or more biological catalysts (enzymes) vital to the metabolism of the plant.

In the annual report of the Department of Plant Physiology for 1954/1955 it was suggested that in iron-deficiency, which leads to the development of chlorophyll-deficient, yellow leaves, the enzyme aconitase may be affected. Aconitase brings about certain changes in citric acid and related organic acids (the Krebs cycle) which are part of the process by which sugars are oxidized in the plant. As mentioned in last year's report, a method has therefore been developed for measuring the activity of this enzyme in extracts made from small samples of leaves.

When this test was applied to the leaves of mustard plants grown in nutrient solution it was found that at a low level of iron (0·1 p.p.m.), which gives severely chlorotic leaves, the aconitase activity was less than half what it was in normal leaves, The green colour and the aconitase activity can be restored by painting the leaves with solutions containing iron.

The activity of malic dehydrogenase, another enzyme of the Krebs cycle, was only slightly depressed, suggesting that the effect of iron deficiency is not a general one on the metabolism of sugars, but specific to aconitase.

As far as these observations go it cannot be said that the effect of iron-deficiency on aconitase is the key to its effect on the plant, because other enzyme systems containing iron which occur in leaves are also affected by the deficiency. Aconitase is nevertheless of particular interest because it is closely concerned with energy production and the processes of cell construction. Because it is directly implicated in organic acid metabolism, the effect of iron-deficiency on the organic acid content of leaves is being examined in more detail.

An account of this work, which has been carried out in collaboration with the Department of Plant Physiology, was given to the Biochemical Society at its meeting in Aberdeen in September 1959. Two papers on amino acids[13] and organic acids[14] in chlorotic leaves have now been published, and two others, on the trisaccharides of monocotyledons[43] and on the occurrence of D-glyceric acid in the broad bean[44], have been accepted for publication.

SOIL ORGANIC MATTER

Dr F. J. Sowden of the Canadian Department of Agriculture Science Service Laboratories, Ottawa, spent two months working in the department

and succeeded in isolating crystalline L-rhamnose from the complex mixture of sugars obtained by acid hydrolysis of a polysaccharide fraction from peat.

The co-operative studies with the Department of Spectrochemistry on the effect of chemical treatment on the infrared spectra of humic acids have been continued. Some results were presented to an international symposium on humic acids held in Dublin in September, 1959, and will be published in due course[39].

BIOCHEMISTRY OF MICROORGANISMS

Certain bacteria isolated from soil and the rhizosphere by the Department of Microbiology have been found to produce appreciable amounts of 2-ketogluconic acid when grown on simple media containing glucose. This acid chelates calcium and thus brings into solution insoluble calcium salts, a process which may bear upon the utilization of phosphate fertilizers and the weathering of minerals. A preliminary note on this[45] has been accepted for publication.

Studies of the excretion of pentose cycle intermediates by *Nocardia opaca*[15] and of the formation and breakdown of 6-*O*-acetylglucose by *Bacillus megaterium*[12] have now been published, and also a note[10] giving additional information about the oxidation of herbicides by *N. opaca*.

Dr Bacon spent two months of 1958 in the Institute of Biology, Prague, at the invitation of the Czechoslovak Academy of Sciences. A note[55] has been published describing some experiments on the liberation of enzymes from yeast cells subjected to the action of snail digestive juice.

PLANT PHYSIOLOGY

Progress in the work of the department has been maintained. Co-operation with other departments—mainly the Department of Biochemistry—has proved most fruitful, and earlier findings have been substantiated and extended.

ORGANIC ACIDS

Papers[13, 14] on the amino and organic acids of plant leaves in relation to iron status as measured by the phosphorus-iron ratio have been published. In an experiment with mustard in nutrient culture, employing 3 levels of iron, 4 ratios of potassium to calcium, and 2 ratios of phosphorus to nitrogen[47], the concomitant changes in citric and malic acid were measured by colorimetric and spectrophotometric techniques. The amount of citric acid in the leaf was shown to vary inversely with iron level, whereas malic acid varied directly. Further experiments are in progress. Aconitase activity of mustard leaves in relation to iron status has also been investigated and a preliminary report given to the Biochemical Society (Aberdeen Meeting, September 1959).

The finding that the broad bean contains considerable quantities of glyceric acid[44] has led to studies with labelled carbon to elucidate the part it plays in cellular metabolism. Investigation of other plants containing abnormal amounts of particular acids has shown that the *Fumariaceae* are characterized by high contents of fumaric acid and of δ-N-acetylornithine. Neither acid has been detected in quantity in any member of the *Papaveraceae* so far examined. Work on this problem is continuing.

Advances have been made in the field of iron nutrition of plants, and the relationship between chlorophyll content of mustard leaves and total haemochromogen pigments has been explored. This work and the associated peroxidase-catalase results are being prepared for publication. A paper on the sensitivity to various respiratory inhibitors of young and old animal and plant tissues[17] has been published, in collaboration with the Department of Zoology of the University of Aberdeen.

PEAT UTILIZATION

Further studies on the use of Scottish peat as a medium for plant growth have been conducted in conjunction with the Section of Peat Ecology and a successful exhibit was staged at the Scottish Horticultural Education Conference at Dundee. An iron deficiency in tomato plants grown in peat, reported in the literature as having been induced by adding elemental sulphur, was investigated and found to be due to the unavailability of calcium and consequent high potassium-calcium ratios.

METABOLIC CHANGES IN STORAGE TISSUE DISKS

Three papers[18, 19, 20], reporting the results of earlier studies on disks of sugar beet, red beet, carrot, turnip, and potato have been published during the year. A theory put forward in these papers that synthetic mechanisms are initiated in some storage tissue disks maintained in aerated tap water was confirmed during the current year by the observation that there is an overall increase in the water-insoluble organic matter of disks with time. This was demonstrated in simple manner by measuring the dry weight of disks boiled for 10 minutes. Analyses of the disks showed that this increase in organic matter was largely due to an increase in protein N and pectic substances.

Mineral analyses showed that disks absorb large quantities of cations from tap water. The absorption is selective to a marked degree, each tissue exhibiting a characteristic absorption pattern, notably a Na affinity by beet tissue and a K affinity by swede. Anions are not absorbed in equivalent amounts and cation-anion balance is maintained by an increase in organic anions. This work has been accepted for publication[48].

Work on the cation exchange capacity of plant roots, outlined in last year's annual report, has been extended to disks of storage tissue, in an endeavour to test the hypothesis that cation exchange capacity and pectin content are related. The exchange capacity of fresh disks was measured using an acid washing technique, followed by titration of the disks to pH 7 with 0·01 N KOH. Pectic substances were estimated in dried disks by decarboxylation. Using 1 mm. thick disks it was found that the pectin content, in terms of me. H^+, was always greater than the cation exchange capacity. Correlation was obtained only when disks were thin enough (0·5 mm.) for the cation exchange capacity to be measured on a volume basis and the pectin content was corrected for substances yielding carbon dioxide yet not contributing to the cation exchange capacity.

The changes in the exchange capacity of disks of sugar beet, red beet, carrot, turnip, and potato with time were followed. In general the changes were small. The cation exchange capacity and pectin content of the disks increase and reach a maximum 3-4 days after the disks are cut from the parent tissue. This work has been prepared for publication.

A paper dealing with the effect of heavy-metal toxicity on the cation exchange capacity of plant roots[21] has now been published.

RADIOACTIVITY

An account[22] of the radioactive methods of studying root development in the field has appeared. In collaboration with the Section of Peat Ecology, the effect of drainage on the depth of rooting of a grass-clover mixture growing in deep peat has been investigated.

Further work, with the Department of Soil Fertility, has been done on the measurement of the phosphate status of soils by the use of ^{32}P. Radioactive carbon has been used in organic acid studies now in progress.

MICROBIOLOGY

Soil micro-organisms form an essential link in soil-plant relationships since they are the principal agents responsible for the breakdown of organic matter in nature. Further, in the vicinity of plant roots, where their numbers (particularly bacteria) are markedly enhanced, they may play a more direct role in plant nutrition. The main lines of investigation, as in past years, have been concerned with certain aspects of the above, for example, the breakdown of lignin and related substances by fungi and the study of phosphate-dissolving bacteria in the root region. In addition, studies of the physiology and morphology of specific soil organisms, some of them concerned in the above processes, continue to be carried out. One of these organisms, *Nocardia opaca*, which has proved so useful in past years in understanding the influence of chemical structure on β-oxidation of the fatty acid side chain of certain selective hormonal herbicides, has yielded further information in this connection. The visiting research worker, H. A. Louw from South Africa, left during the year after his thesis dealing with the bacteriology of the root region had been accepted by the University of Aberdeen for the degree of Doctor of Philosophy.

ACTINOMYCETES

Last year it was reported that the rate of β-oxidation of the fatty acid side-chain of certain ω-aryl and ω-aryloxy-n-alkylcarboxylic acids (hormonal herbicides) by washed suspensions of *N. opaca* was dependent on the nature of the ring substituents. It has now been found that substitution in the fatty acid side-chain also affects the process. Thus the substitution of CH_3- for H- on the γ carbon atom of the γ-phenoxybutyric acids further retards β-oxidation. This effect, as with ring substitution, is most marked with a short fatty acid side-chain. These results have been published[10] jointly with the Departments of Spectrochemistry and Biochemistry. They suggest, by analogy, that many plants which β-oxidize γ-(4-chloro-2-methylphenoxy) butyric acid (M.C.P.B.) will fail to convert DL-γ-(4-chloro-2-methylphenoxy) -γ-methylbutyric acid to the herbicidal DL-γ-(4-chloro-2-methylphenoxy)-γ-methylacetic acid, and this has since been found to be the case.

The study, in collaboration with the Department of Biochemistry, on the production of intermediates of the pentose pathway in *N. opaca* and other saprophytic soil nocardias and mycobacteria has been published[15].

The investigation of the trace element requirements of *N. opaca* has shown that iron, zinc, and manganese are essential for optimum growth of the organism. The effect of deficiency of these elements on the morphology and physiology of the organisms is under investigation.

The details of a defined medium for the growth of the thermophilic actinomycete *Micromonospora vulgaris*[23] have been published. This organism,

which has already been the subject of several publications from the Institute, is principally concerned with the decomposition of organic nitrogenous material in composts during the high temperature phase.

FUNGI

Lignin decomposition in soil continues to be the basis for mycological investigations. For these, aromatic compounds related to lignin have been used and various aspects of their metabolism by fungi have been studied.

A paper[9], in collaboration with the Department of Spectrochemistry, on the reduction of certain aromatic acids to aldehydes and alcohols by *Polystictus versicolor* has been published. The extracellular oxidase produced by this fungus has been studied and a joint paper[41] on it has been accepted for publication. This enzyme was found to oxidize β-naphthyl carbinol, benzyl alcohol, and seven other ring-substituted benzyl alcohols to the corresponding aldehydes, hydrogen being transferred to molecular oxygen with the formation of hydrogen peroxide. Oxidation was followed by measuring the oxygen uptake in the Warburg apparatus and by spectrophotometric estimation of the production of aldehyde. Three secondary 1-phenylethanols were not oxidized, nor were glucose, ethanol, butanol, and L-amino acids. This aromatic alcohol dehydrogenase differed from alcohol dehydrogenase. It was not possible to identify its prosthetic group, although its properties indicated that it might be a flavoprotein. It is possible that enzyme systems of this type, produced by fungi, may be active in the soil in the oxidation of the aromatic alcohol groupings known to be present in lignin.

Studies on the effects of trace elements on the metabolism of aromatic compounds have been continued and the work has been extended to additional fungi.

The paper[49] presented to the Liverpool University Symposium on Soil Fungi is to be published in the Symposium Proceedings.

Various soil yeasts have recently been isolated and growth and metabolic experiments with these have been initiated. Results indicate that these organisms are also capable of utilizing aromatic compounds as a source of energy.

MICROBIOLOGY OF THE ROOT REGION

The results of the study on the bacteriology of the root region of oats grown in Mitscherlich pot experiments, set up in collaboration with the Department of Soil Fertility, have been accepted for publication[50, 51]. In this work it was shown that, when grown in a medium containing glucose, organisms with good ability to dissolve gafsa rock phosphate produced an acid with chromatographic properties similar to 2-ketogluconic acid. Further study of these organisms is being continued in collaboration with the Department of Biochemistry. Large and small scale growth experiments have been set up for this purpose, and insoluble natural and synthetic silicates included as well as mineral phosphates. The results have shown that the 2-ketogluconic acid produced by the organisms can chelate calcium from these substances and may thus help to make certain difficultly soluble minerals

more available to plants. These findings, which may also be of significance in pedogenesis, have been accepted for publication[45].

Preliminary attempts, in collaboration with the Department of Soil Fertility, to establish phosphate-dissolving bacteria in the root region of the oat in Mitscherlich pots are under way. It is hoped to continue this work.

Details of a plate method for detecting phosphate-dissolving and acid-producing bacteria in soil have been published[24]. This method, although useful when a large number of soils are to be examined, underestimates the total number of phosphate-dissolving bacteria. It is too insensitive to detect organisms dissolving small amounts of the insoluble materials.

CULTURE COLLECTION

The technique for preservation of stock cultures of bacteria by lyophilization has been established. To date over 40 species and strains of the genera *Nocardia*, *Mycobacteria*, and *Bacillus* in the collection have been treated in this way.

OTHER INVESTIGATIONS

The fluorescent technique for the direct examination of viable organisms in soil has been put on a quantitative basis. The results obtained are in good agreement with the Jones and Mollison aniline-blue staining method generally used for this purpose.

Cell material for chemical analysis of the polysaccharide produced by the acetylglucose synthesizing strains of *Bacillus megaterium* has been prepared for the Department of Biochemistry. A joint paper[16] on the metabolism of this organism has been published.

SOIL FERTILITY

The activities of the department include consultative duties as well as research work. The latter provides the basis for the former, the research programme being directed towards the improvement of manurial practice and crop production through better understanding of (a) the lime and nutrient status of different soils and the significance of soil properties and pedological factors, especially parent material and drainage conditions, and (b) the fertilizer requirements of different crops and the influence of factors such as form, frequency, time, and method of application. The experimental approach therefore continues to be the concurrent development and integration of field, pot, and laboratory investigations covering major soil groups and the main agricultural crops. The field experiment programme has again included over 70 experiments, distributed over different soil types and carried out with the valued and efficient co-operation of farmers.

Advisory soil testing has been continued in collaboration with the North of Scotland College of Agriculture, and revised editions have been prepared of two advisory leaflets (Nos. 4 and 18, new series) issued by the Department of Agriculture for Scotland entitled *Improvement of Marginal Land* and *Fertilizers and Crop Production*. Information has also been contributed to the revised edition of the bulletin on *Efficient Use of Fertilizers*, edited by V. Ignatieff and H. J. Page, and published by F.A.O., Rome, 1958. Practical implications of results have again been dealt with in contributions to the agricultural press and in talks and demonstrations to agricultural and horticultural groups. Contact has been maintained with the Agricultural Research Council Unit of Statistics in the preparation of reports on the Surveys of Fertilizer Practice carried out by the Scottish Colleges of Agriculture, and collaboration has continued with other research organizations and technical bodies including the Field Trials and Grassland Committees of the Scottish Agricultural Improvement Council and the Scottish Sub-committee of the Sugar Beet Research and Education Committee. The department also contributed to a conference on experiments with farmyard manure convened by the Agricultural Research Council and is represented on the working party subsequently formed to consider this question.

Within the Institute, co-operation has been continued with the Department of Soil Survey in the choice of field experiment areas, with the Section of Statistics in the design of experiments and evaluation of results, with the Department of Spectrochemistry in analytical work and trace element investigations, with the Department of Plant Physiology in the application of plant analysis to advisory problems, and with the Department of Microbiology and the Sections of Mineralogy and Radioactivity in phosphorus investigations.

Mr R. J. Hance, Ministry of Agriculture Research Scholar, joined the department in October 1958 to undertake an investigation into soil phosphorus

relationships with special reference to the organic fraction, in candidature for the degree of Ph.D. from the University of Aberdeen. During short visits, Mr C. V. Fife, Massey Agricultural College, New Zealand, and Dr R. L. Fox, Department of Agronomy, University of Nebraska, contributed to laboratory studies on phosphorus and nitrogen relationships of soils respectively.

During the year Dr G. Anderson visited the Institute of Soil Biochemistry, Volkenrode, Brunswick, the Laboratory of Biological Chemistry, Faculty of Pharmacy, University of Paris, and the National School of Medicine and Pharmacy, Academy of Rennes, Angers. Dr J. W. S. Reith attended the sixth Easter School, Symposium and Colloquium on Measurement of Grassland Productivity, held at the University of Nottingham in April, 1959.

CROP RESPONSES TO FERTILIZERS

Further experiments in the NPK factorial series, distributed over five major soil groups and including four levels of each nutrient, have been carried out on potatoes, swedes, and oats to measure responses and two-factor interactions. An account[25] of earlier experiments on potatoes, including effects of dung, has been published in collaboration with the Section of Statistics.

The responses of oats, potatoes, swedes, and turnips to nitrogen, phosphorus and potassium are also discussed in the above mentioned advisory leaflet on fertilizers and crop production, which includes mean values derived from over 350 field experiments carried out by the department during the past 16 years.

METHODS AND TIMES OF FERTILIZER APPLICATION

An account of co-operative field experiments on times of application of nitrogen for oats, co-ordinated by the Field Trials Committee of the Scottish Agricultural Improvement Council, has been published[26], and parallel experiments on barley have been continued. Further field work has also been done to compare the effects of combine-drilling and broadcasting nitrogenous fertilizers and NPK mixtures for oats and barley.

A paper[52] summarizing results of comparisons of broadcast and band applications of fertilizers for swedes and turnips grown in ridges has been accepted for publication. The main conclusions from this work may be recapitulated as follows: Placing sulphate of ammonia to the side of the seed row gives similar results to broadcasting, but placement in bands directly below the seed sometimes gives lower yields, especially if dry weather follows seeding. Placement directly below the seed gives no advantage or disadvantage for potash but is clearly superior for superphosphate, the best position being at a depth of 3 to 3·5 inches. The superiority of placed phosphate in this position depends not only on the rate of application but also on the type of soil, being greatest on soils of basic igneous origin, intermediate on the slate group, and least on soils derived from Old Red Sandstone and granitic drifts; other work[53] indicates that in this respect the placement effect runs parallel to, and can be broadly interpreted in terms of the mean phosphate

sorption capacities of the soil groups. The apparent recovery of fertilizer phosphate is substantially greater from band placement. With NPK mixtures, placement is superior only where, as on many of the basic igneous soils, there is a very marked increase from placing phosphate. Further work is in progress to compare broadcast and band application of different forms of phosphate for swedes and oats.

TRACE ELEMENTS

Field and pot experiments have been continued on the effects of copper sulphate, cobalt sulphate, cobalt-EDTA complex, manganese sulphate, borax, and sodium molybdate on the yield and composition of crops, including mixed herbage, and on the influence of supplementary liming and manuring. Clear cases of copper deficiency in cereals, especially oats, have been encountered on freely-drained soils from several parent-material groups. Experiments are in progress to compare varying rates of copper sulphate broadcast at seedtime with sprays applied when the crop is 6-8 inches high. The complementary analytical work on soils and crops continues to be undertaken by the Department of Spectrochemistry.

Contact has been maintained with the Animal Diseases Research Association in problems relating to animal health.

MAGNESIUM

As mentioned in last year's report, no convincing yield responses to magnesium have so far been obtained, even on soils with relatively low contents of readily-soluble magnesium, but field and pot experiments are being continued to examine the status of different soil types, the effects of incremental dressings of magnesium on the yield and composition of crops and grass, and the influence of other fertilizers and of lime.

NITROGEN

A paper[54] has been accepted for publication describing the relationships of nitrogen with carbon, sulphur, and organic phosphorus in ten surface soils from each of five parent-material groups (calcareous, granite, slate, Old Red Sandstone, basic igneous) in north Scotland. The overall limits for total nitrogen and organic carbon contents are 0·16-0·46 and 1·6-7·1 per cent., respectively, and except that the calcareous soils contain about 40 per cent. less carbon there are no significant differences in the group means, which range from 0·24 to 0·34 per cent. for nitrogen and 2·8 and 5·0 per cent. for carbon. Nitrogen and carbon give the very high overall correlation coefficient of 0·940 ($p<0·001$), but the C:N ratio varies inversely with the base status of the parent material, ranging from 11·3 in the calcareous group to 17·0 for the granite soils. The total sulphur content of the forty non-calcareous soils ranges from 0·022 to 0·069 per cent., while the group means fall in the narrow range of 0·040-0·048 per cent. The values for the calcareous soils are much higher due to the presence of varying amounts of water-insoluble sulphate, closely related to the calcium carbonate content. But when the non-sulphate sulphur is taken for the calcareous soils and the total

sulphur for the others, there is a very close overall relationship with both nitrogen and carbon, the correlation coefficients ($p<0{\cdot}001$) being 0·938 for N-S and 0·866 for C-S. The corresponding mean C:N:S ratio for the fifty soils is 140:10:1·4, and very similar to ratios from other countries. The results support the view that nitrogen, sulphur, and carbon are closely associated in soil organic matter, and it seems possible that the proportions may be defined within moderately narrow limits by microbial decomposition. The relationships of organic phosphorus are more variable but it gives significant ($p<0{\cdot}001$) overall correlations with both nitrogen (0·639) and carbon (0·607).

Attention continues to be given to the role of clover in the nitrogen relationships of mixed swards and to laboratory procedures for measuring mineralization of soil nitrogen.

PHOSPHORUS STUDIES

Inorganic Phosphorus

Field work and supplementary pot experiments have been continued on comparisons of autumn and spring applications of phosphate, the effectiveness of different forms of phosphate, the significance of ploughing and cultivations in relation to positional availability, and the residual effects of phosphate in different soil types, in the presence and absence of lime. A major part of the 1959 pot experiment programme was devoted to detailed examination of the availability of phosphate residues in bulk samples of soil taken from plots of long-term field experiments on different soil types, including evaluations of labile phosphate with the aid of ^{32}P, in collaboration with the Section of Radioactivity, and comparisons with synthetic aluminium and iron phosphates prepared by the Section of Mineralogy. Included also was a small preliminary experiment in collaboration with the Department of Microbiology on the inoculation of soil with an organism capable of dissolving rock phosphate.

Complementary laboratory studies on phosphate retention and solubility in various soil types have been continued, and a paper on the influences of parent material and drainage conditions[53] is in press.

Organic Phosphorus

Laboratory studies on the organic phosphorus fraction in soils have been continued and extended.

The purines and pyrimidines characteristic of deoxyribonucleic acid have been obtained from soil humic acid and an account of this work[27] has been published. A method for their quantitative estimation has now been evolved and is being applied to a range of soils in order to establish the proportion of soil phosphorus and nitrogen likely to be present in the form of deoxyribonucleic acid.

Studies on the adsorption of inositol hexaphosphate by clay minerals have been continued in co-operation with the Section of Mineralogy, and a supplementary investigation on solubility relationships in certain iron and aluminium phytate systems is in progress.

A comparison has been made of methods for the estimation of total soil organic phosphate, to assess their relative merit and find the most suitable for the general analysis of Scottish soils. An account of this work is in preparation.

Work is also in progress to find more effective methods for the estimation of phospholipids in soil. The quantities found by established techniques are very small, but it seems likely that the presence of large amounts of surface active colloidal material in the soil may interfere with extraction by the usual liquid solvents, and that the real amount of phosphorus in this form is higher than supposed. Work has also continued on the fractionation and characterization of other categories of soil organic phosphorus. The need for more information of this kind is emphasized by the fact that the relationships of organic phosphorus with carbon, nitrogen, and sulphur are rather variable, and it seems to be a less integral part of the bulk organic matter[54]. One reason for this is probably varying accumulation of resistant organic phosphorus compounds, such as inositol phosphate. More detailed information on the nature and distribution of such compounds in different soils and on the soil properties and conditions governing their accumulation is necessary to clarify this aspect.

CONSULTATIVE WORK

Advisory examination of soils has been continued and about 10,500 samples were tested during the year. As in the past, a substantial number came from forest nurseries throughout Scotland, but most were taken from agricultural and horticultural land by the staff of the North of Scotland College of Agriculture. Samples of soil and produce from areas with special problems involving crop growth or animal health continue to be dealt with in conjunction with the Departments of Spectrochemistry and Plant Physiology. It is noteworthy that excess molybdenum has been found in a few isolated fields in the north-east. The EDTA method for estimating readily available copper in soils is proving most useful, giving good predictions of low copper areas.

The soil data continue to be classified according to lime and nutrient status. As indicated in previous reports the lime and potash contents of the samples from arable land show appreciable improvements over the past 15 years, but there is very little change in the phosphate. This illustrates the continuing need for applying more phosphate, especially on the more deficient soils. This is also borne out by estimates for Scotland as a whole (D.A.S. Leaflet No. 18). The total annual amounts considered necessary to maintain and improve the fertility of the arable land and permanent grass are estimated to be 55,000 tons nitrogen (N), 57,000 tons potash (K_2O), and 93,000 tons phosphate (P_2O_5), while the total consumption in 1957-1958 was 43,000 tons N, 49,000 tons K_2O, and 76,000 tons P_2O_5.

STATISTICS

The main work of the section arises from the field experiment programme of the Department of Soil Fertility. Over 500 sets of data arising from the field experiment programme during 1958-1959 have been examined and the significance of the results assessed. These were approximately equally divided between measurements of crop yield, crop composition, and soil characteristics.

Among the 44 experiments commenced during 1958-1959 there are several randomized block designs, some with split-plots and factorial designs both with and without confounding. When several times or methods of application or forms of a fertilizer are being tested and the number of treatments is large, incomplete block arrangements such as the lattice square are used. Due to the greater control of the variability within replicates, these designs usually give considerable gains in information compared with randomized blocks. In such experiments comparisons are of the type involving interactions of quality and quantity, and differences between different qualities of treatment might be expected to increase with the quantity of the applied treatment instead of remaining constant for all quantities. For each individual case the appropriate orthogonal sets of coefficients have been evaluated for the model based on the hypothesis of proportional response. Where the levels of fertilizer used in an experiment are not equally spaced, a set of orthogonal polynomial coefficients has been obtained to permit a more critical examination of the components of the fertilizer response curve. A number of such sets have been constructed thus obviating the sometimes undesirable restriction of using equally spaced levels of a treatment factor.

One series of experiments in the current programme on seed-time and late dressings of nitrogen for barley is of lattice square design and also provides for interactions of quality and quantity. A previous series dealing with the same subject for the oat crop has been concluded and in collaboration with the Department of Soil Fertility an account of the results[26] has been published.

A number of groups of experiments with factors having at least three levels provided responses to N, P_2O_5, and K_2O for oats, potatoes, and swedes. By fitting Mitscherlich or quadratic response curves to groups of experiments with the same set of levels of fertilizer, responses of the three crops to standard dressings of the nutrients were obtained.

Since the publication of the first report on a series of NPKD factorial experiments[25], a further examination of the data has been carried out. This resulted from recent interest in some components of high-order interactions involving D (farmyard manure) which had previously been included in the estimate of experimental error.

A preliminary study has been made of the correlations between soil and herbage contents of a number of elements.

In collaboration with the Departments of Plant Physiology and Biochemistry, designs for the experiments and analyses of the data have been completed on a number of factorial experiments to test the effects and interactions of the factors Fe, K/Ca, and P/N on catalase, aconitase and dehydrogenase activities, citric acid, and malic acid and their ratio in plant leaves. Catalase, expressed as the rate of reaction, was estimated for an ageing series in the leaves of *Heracleum giganteum* from unfolding to death and its relationship with time was investigated by fitting a polynomial regression. Also in collaboration with the Department of Plant Physiology further work on the effect of varying concentrations of metabolic inhibitors on the respiration of old and young plant tissues, examined as the ratio of inhibited to control respiration rates, has been included with earlier results in a joint paper[17].

Measurements of needle nutrient content and height increment have been examined and the significance of the results assessed for the Section of Forest Soils. These measurements were obtained from a number of NKMg factorial experiments and a phosphate manuring experiment. Regression analyses have been carried out in investigating the dependence of tree height on needle properties for *Pinus contorta*. A linear relationship was found for tree height and average needle weight and a parabola adequately described the relationship between tree height and the P content of the needles. Two new experiments were designed for 1959. One is of Latin square design and will compare ground mineral phosphate applied to roots at time of planting with the normal method of application. The other is a split-plot arrangement superimposed on an existing randomized block experiment and will compare different forms of potash.

Botanical analysis and soil analysis results from experiments on the top-dressing of hill land were examined on behalf of the Section of Peat Ecology. The experiments are of a factorial design with all combinations of three levels of lime and three levels of phosphate. In dealing with the botanical composition the angular transformation was used to make the variance independent of the mean since the data were expressed as percentages.

CONSULTATIVE WORK

Yield measurements and other results from a group of four NPK factorial experiments have been examined and a report submitted to the Crop Husbandry Department of the West of Scotland Agricultural College. This work was initially planned in collaboration with the Department of Soil Fertility. 3^3 factorial designs for a further group of four experiments on the same subject were produced for the 1959 potato crop.

Co-operation with the Department of Agriculture of the University of Aberdeen in the design and analysis of lamb feeding trials in pasture evaluation studies has continued.

Collaborative work with the North of Scotland College of Agriculture has included the analysis of a barley variety trial and the combination of results over a number of years. The analysis of results has been carried out for randomized block experiments testing insecticides for the control of carrot

fly and wheat bulb fly. A further randomized block experiment was designed for a study of wheat bulb fly control.

The section is at present accommodated in the Department of Statistics of the University of Aberdeen where a course of statistical technique lectures on biometric practice in agriculture has been given. The course was attended by post-graduate students of Soil Science. Acknowledgment is made to the University of Aberdeen, and in particular to Dr D. J. Finney, F.R.S., for the courtesies shown.

PUBLICATIONS

(A) *Published—*

1. The Macaulay Institute for Soil Research, Aberdeen. By A. B. Stewart. (*Scot. Agric.*, **39**, 20-22, 1959).

2. The montmorillonite differential thermal curve. II. The effect of exchangeable cations on the dehydroxylation of normal montmorillonite. By R. C. Mackenzie and B. M. Bishui. (*Clay Min. Bull.*, **3**, 276-286, 1958).

   Examination of the differential thermal characteristics of a normal montmorillonite saturated with a series of monovalent and divalent cations shows that the temperature of the main dehydroxylation peak is independent of valency but is apparently a parabolic function of ionic radius. NH_4+, Cs+, $Zn^{2}+$, and $Cd^{2}+$ give anomalous results, but the apparent discrepancy of the former two ions can be fully accounted for. The results are believed to be consistent with evolution of water molecules through the hexagonal holes in the sheet surface and diffusion between the layers to the micelle edge. The significance of variation in the 800-1000°C region of the curve is briefly considered.

3. Pollen analysis of peat deposits in the eastern Grampians. By S. E. Durno. (*Scot. geogr. Mag.*, **75**, 102-111, 1959).

   Pollen analysis from five sites is used to examine the history of vegetation (mainly arboreal) in two areas of the eastern Grampians lying respectively north and south of the Lochnagar-Cairn-mon-Earn watershed. Brief comparison is made between these areas and the southern Pennines for which data have been published by Dr Conway.

4. The peat story. By R. A. Robertson. (*Gdnrs' Chron.*, **145**, 245, 1959).

   The origin, distribution, and general botanical features of peat deposits in Britain are briefly discussed and factors which affect the horticultural value of different peat types mentioned. The properties of a good general horticultural peat are summarized.

5. Forest soils in Scotland. By T. W. Wright. (*Emp. For. Rev.*, **38**, 45-53, 1959).

   The extensive post-war afforestation programme in Scotland is mainly on poorer upland heath and deep peat soils. Rupture of iron pans and indurated layers and surface cultivation may be needed on heathlands, and drainage is essential on deep peat. Chemical deficiencies also occur and phosphate is now applied as a routine on many of the poorer soils, with the result that trees have been successfully established on all but the worst sites. Present work includes fertilizer trials on older trees, a search for slow-acting fertilizers, and a study of the effect of the new forests on the soils.

6. Spectrochemical applications of electronics in soil research. By A. M. Ure. (*Brit. Commun. and Electronics*, **5**, 846-849, 1958).

   A short description is given of a multi-function microphotometer giving as alternatives two types of non-recording microphotometer operation and cathode ray tube display. For the latter, electronic and not mechanical scanning is employed. Also described briefly is a three channel flame photometer for the simultaneous determination of calcium, sodium, and potassium in solution samples.

7. Further comments on the vanadium-calcium lime coincidence at 3185A. By R. O. Scott and D. J. Swaine. (*Geochim. cosmochim. Acta*, **16**, 195-196, 1959).

A note pointing out (a) that this coincidence is reported in several publications prior to Shaw's comments (*Geochim. cosmochim. Acta*, **15**, 159-161, 1958) and (b) that the enhancement of vanadium by calcium in the arc is considered a real effect and not due entirely to the coincidence of their lines.

8. The determination of magnesium in solution by direct photometry. By R. O. Scott and A. M. Ure. (*Analyst*, **83**, 561-570, 1958).

The spectrochemical determination of magnesium in solution by the porous-cup-spark method has been greatly facilitated by the direct photometer described. The magnesium line at 2802A is used with the strontium line at 4077A as internal standard. Solutions containing from 0.3 to 24 p.p.m. of magnesium are analysed directly with a coefficient of variation of about ±2.0 per cent. at a rate of forty determinations per hour. Interferences are found to be negligible for most types of agricultural samples, such as extracts of soils and plant materials.

9. Reduction of certain aromatic acids to aldehydes and alcohols by *Polystictus versicolor*. By V. C. Farmer, M. E. K. Henderson, and J. D. Russell. (*Biochim. biophys. Acta*, **35**, 202-211, 1959).

Continuing previous studies on the action of fungi on compounds related to lignin, it has been found that *Polystictus versicolor* can reduce benzoic *o*-, *m*-, and *p*-methoxybenzoic, 3, 4-dimethoxybenzoic, and β-naphthoic acids to either alcohols or mixtures of alcohols and aldehydes. Both *o*- and *p*-hydroxybenzaldehydes were reduced to alcohols. 2, 4-Dimethoxybenzoic, phenylacetic, and γ-naphthoic acids were not reduced. The aromatic rings of cinnamic, β-naphthoic, *o*- and *p*-hydroxybenzoic acids were markedly attacked. Some demethylation of *o*-, *m*-, and *p*-methoxybenzoic acids, and of 2, 4-dimethoxybenzoic acid was detected. The fungus produced an extracellular alcohol dehydrogenase.

10. Effect of substitution in the side chain on β-oxidation of aryloxy-alkylcarboxylic acids by *Nocardia opaca*. By D. M. Webley, R. B. Duff, and V. C. Farmer. (*Nature*, **183**, 748-749, 1959).

It has been shown that the substitution of CH_3- for H- on the γ carbon atom of the fatty acid side chain of certain γ-phenoxybutyric acids further retards their β-oxidation by washed suspensions of soil nocardias. By analogy it is suggested that many plants which β-oxidize M.C.P.B. will fail to convert DL γ-(4-chloro-2-methylphenoxy)-γ-methylbutyric acid to the herbicidal DLγ-(4-chloro-2-methylphenoxy)-γ-methylacetic acid.

11. The influence of hydrogen bonding on tautomerism in diazoaminobenzenes. By V. C. Farmer and R. L. Hardie and R. H. Thomson (University of Aberdeen), (pp. 475-482 of *Hydrogen Bonding: papers presented at Ljubljana, August 1957*. Pergamon Press).

The structures of a number of *o*-substituted diazoaminobenzenes, in solution and in solid state, have been determined by measuring the frequency shifts of their NH, C=O, and NO_2 absorption bands. Chelated NH groups show enhanced absorption but rather small shifts in frequency: when linked to a nitro group the displacement is only ca. 10 cm $^{-1}$ although the bond is moderately strong. The proton attracting power of polar groups can be compared by studying the equilibria in 2:2-disubstituted diazoaminobenzenes.

12. Identification of 6-*O*-acetyl-D-glucopyranose in *Bacillus megaterium* cultures: synthesis of 6-*O*-acetyl-D-glucopyranose and 6-*O*-acetyl-D-galactopyranose. By R. B. Duff and V. C. Farmer. (*Biochem. J.*, **70**, 515-519, 1958).

This paper deals with the chemical characterization and definitive synthesis of the unique crystalline carbohydrate ester (6-*O*-acetyl-glucopyranose) produced by a cobalamin producing strain of *Bacillus megaterium* originally isolated from soil. Other acetylated sugars were also synthesized. Examination of the infrared spectrum of the metabolite shows that it exists in α, β_1, and β_2 anomers. The spectrum of synthetic 6-*O*-acetylgalactose is also given.

13. The metabolism of chlorotic leaves. I. Amino-acids. By P. C. DeKock and R. I. Morrison. (*Biochem. J.*, **70**, 266-272, 1958).

The free amino acid content of healthy and chlorotic leaves has been studied. Iron deficient chlorotic leaves have contained enhanced amounts of free amino acids, even when the iron deficiency has been induced by heavy metals or has been due to genetical causes. In iron-toxicity chlorosis, however, the content of free amino acids has not been very different from that of healthy leaves. It would appear that the free amino acid content of leaves depends upon their iron status as reflected by the phosphorus: iron ratio.

14. The metabolism of chlorotic leaves. 2. Organic acids. By P. C. DeKock and R. I. Morrison. (*Biochem. J.*, **70**, 272-277, 1958).

Organic acids in healthy leaves and leaves chlorotic due to iron deficiency, heavy-metal toxicity, ageing, virus-infection and genetical constitution have been quantitatively studied. All types of chlorotic leaves have contained more citric acid relative to malic acid or oxalic acid, except in virus yellows in sugar beet where the reverse has been true. The citric acid:(malic+oxalic acid) ratio of leaves has been found to vary as the phosphorus:iron and potassium:calcium ratios. The total amount of organic acid also varies inversely as the phosphorus content of the leaf. Green leaves apparently contain large quantities of either malic or oxalic acid.

15. Production of pentose intermediates during growth of *Nocardia opaca* and other saprophytic soil nocardias and mycobacteria. By R. B. Duff and D. M. Webley. (*Biochim. biophys. Acta*, **34**, 398-406, 1959).

It has been found that *Nocardia opaca* and other saprophytic soil nocardias and mycobacteria in simple media produce considerable amounts of sedoheptulose, ribulose, and dihydroxyacetone from glucose and various other substrates. This work is the first demonstration of the excretion of these "pentose cycle" intermediates in quantity from growing cells. Hitherto the significance of the pathway in the life processes of organisms has been demonstrated only by showing that the enzymes required for the various stages exist in cell free extracts.

16. Metabolism of 6-*O*-acetyl-D-glucopyranose and other monoacetyl sugars by strains of *Bacillus megaterium* and other soil organisms. By R. B. Duff and D. M. Webley. (*Biochem. J.*, **70**, 520-528, 1958).

Describes the production of 6-*O*-acetylglucopyranose (*See No.* 12) by growing and resting cells of *B. megaterium* (strain 8508). The ester is a major metabolite of this strain but not of other strains of the species or of other soil organisms. The isolation of the ester is described. A 6-*O*-acetylglucose deacetylase is present in cell free extracts of the bacteria and is specific because even very closely related compounds (*e.g.* 6-*O*-methylgalactopyranose) are not hydrolysed. Various commercial enzyme preparations failed to hydrolyse 6-*O*-methylglucose. A scheme for the biosynthesis of the ester is suggested. This work represents the first isolation of an acetylated monosaccharide from natural sources, although acetylated polysaccharides have been found in nature.

17. The effect of age on the responses of animal and plant tissues to metabolic inhibitors. By C. Muir and L. L. DeKock (University of Aberdeen), P. C. DeKock and R. H. E. Inkson, (*Experientia*, **15**, 354-357, 1959).

Young tissues of rats show a greater sensitivity to different concentrations of respiratory inhibitors than do older tissues. Similar results have been obtained using young and old leaves of tomato plants. The results are statistically highly significant. It is concluded that no new metabolic system is formed during the life of the organism but rather that during ageing changes in equilibria of existing systems take place.

18. An apparatus for maintaining disks of tissue in a uniform environment. By I. R. MacDonald and A. H. Knight. (*Ann. Bot., n. s.* **22**, 423-427, 1958).

An apparatus is described in which tissue disks may be conveniently maintained in uniform environmental conditions. Particular attention is paid to temperature control.

19. Temperature control and metabolic drifts in ageing disks of storage tissue. By I. R. MacDonald and P. C. DeKock. (*Ann. Bot., n. s.*, **22**, 429-448, 1958).

The respiratory drifts of various tissue disks have been determined, the general picture being a hyperbolic curve the steepness of which depends upon the temperature of pretreatment. A considerable conversion of sucrose to reducing sugars takes place, and the concentration of reducing sugars shows a correlation with rate of respiration.

20. Changes in sensitivity to inhibitors of disks of storage tissue. By I. R. MacDonald. (*Ann. Bot., n. s.*, **23**, 241-256, 1959).

Sensitivity of disks of tissue to various respiratory inhibitors depends upon the temperature of pretreatment. There is a rapid decrease in cyanide sensitivity of disks and stimulation may be observed, but subsequently sensitivity redevelops. Disks containing cambial tissues show increasing cyanide sensitivity with time and there therefore appears to be an essential difference in cyanide sensitivity between growing and non-growing tissue.

21. The effect of heavy-metal toxicity on the cation-exchange capacity of plant roots. By W. M. Crooke. (*Soil Sci.*, **86**, 231-240, 1958).

Heavy-metal toxicity produces changes in the cation-exchange capacity (C.E.C.) of plant roots. For the five crops studied, excess Ni, Co, and Zn has produced an increase and Mn a decrease in C.E.C. Excess Cu has caused an increase in root exchange in the case of oats and sunflower, and a reduction in the case of tomato, pea, and bean. The heavy metals have behaved consistently towards oat and tomato, increasing Ca absorption, and towards pea, where a reduced Ca absorption resulted. The changes produced in C.E.C. by the individual heavy metals have not been accompanied by systematic changes in the levels of monovalent and divalent cations found in roots and tops.

22. Studies of root development in the field using radioactive tracers. Pt. I. Communities growing in a mineral soil. By R. Boggie and A. H. Knight. Pt. II. Communities growing in deep peat. By R. F. Hunter (Hill Farming Research Organization) and A. H. Knight. (*J. Ecol.*, **46**, 621-639, 1958).

A method using radioactive tracers for studying *in situ* the rooting habit of the plants forming communities on mineral soil or on deep peat is described, as is the rooting habit of 25 species as determined by the method. Considerable differences among the rooting habits of different species growing together in the same community have been noted and the importance of the top 10 cm for root absorption of nutrients has been very noticeable in communities growing on mineral soil. The differences in root habit among the principal species of peat communities is thought to give weight to the idea that the root habit of a species is a characteristic of it which is adapted to the edaphic conditions of the environments in which its growth is most favoured and in which it may most readily achieve dominance.

23. A defined medium for the growth of the thermophilic actinomycete *Micromonospora vulgaris*. By D. M. Webley. (*J. gen. Microbiol.*, **19**, 402-406, 1958).

Biotin and methionine are essential growth factors for the aerobic thermophilic actinomycete *Micromonospora vulgaris*. Biotin can be partially replaced by Tween 80 (sorbitan mono-oleate). No aerial growth is obtained in the absence of methionine. A chemically defined medium containing mineral salts, phosphate buffer (pH 6.8), soluble starch, a mixture of 18 synthetic amino acids (including methionine) and biotin will support growth of the organism.

24. A plate method for estimating the numbers of phosphate-dissolving and acid-producing bacteria in soil. By H. A. Louw and D. M. Webley. (*Nature*, **182**, 1317-1318, 1958).

    The method uses finely divided suspensions of insoluble phosphates or carbonates prepared by grinding in a ball mill in the presence of gum arabic. One ml. of the required suspension is added to 9 ml. of the medium being used for the dilution plate count just prior to pouring the plates.

25. The effects of fertilizers and dung on potatoes. By J. W. S. Reith and R. H. E. Inkson. (*J. agric. Sci.*, **51**, 218-224, 1958).

    Results are given for a series of factorial experiments measuring the responses to and the two-factor interactions between nitrogen, phosphate, potash, and dung. The responses are moderately large but quite variable from centre to centre. Dung has practically no effect on the average responses to nitrogen and phosphate, but it reduces the response to potash by about two-thirds. There is a general trend for both nitrogen and potash to produce a small increase in the response to phosphate, but there is no interaction between nitrogen and potash. The response to dung is much larger in the absence than in the presence of fertilizers. Suitable fertilizer dressings are suggested for potatoes grown in north-east Scotland.

26. Seed-time and late nitrogen for oats. By J. W. S. Reith and R. H. E. Inkson. (*Scot. Agric.*, **38**, 186-190, 1959).

    This paper reports the results of 21 experiments carried out in various parts of Scotland to test the effectiveness of nitrogen applied at four times, *viz.* (1) all on seed bed immediately before sowing, (2) all four to six weeks after sowing, (3) all eight to ten weeks after sowing, and (4) half on seed bed and half eight to ten weeks after sowing. Applying all the nitrogen late has sometimes produced less grain and straw than the other three treatments which have given very similar yields. The results show no advantage either in yield or in the nitrogen content of the grain and straw from split dressings, and it is concluded that under normal conditions all the necessary nitrogen should be applied at seed time.

27. Identification of derivatives of deoxyribonucleic acid in humic acid. By G. Anderson. (*Soil Sci.*, **86**, 169-174, 1958).

    The purine bases guanine and adenine, and the pyrimidines cytosine, thymine, and uracil have been identified in the hydrolysates of humic acid from agricultural soils. The bases were probably present in deoxyribonucleic acid (DNA) and a trace of ribonucleic acid (RNA), and there was evidence that the DNA was of microbial rather than plant origin. The amount of DNA phosphorus in one soil was estimated to be 5 p.p.m., accounting for 0.6 per cent. of the soil organic phosphorus.

(B) *Submitted for publication—*

28. Olivine pseudomorphs in Markle basalt. By W. W. Smith. (To appear in *Miner. Mag.*).

29. An apparatus for differential thermal analysis under controlled-atmosphere conditions. By B. D. Mitchell and R. C. Mackenzie. (To appear in *Clay Min. Bull.*, **4**, 31-42, 1959).

30. Differential thermal analysis of humic substances and related materials. By B. D. Mitchell. (To appear in *Sci. Proc. roy. Dublin Soc.*).

31. The ageing of sesquioxide gels. I. Iron oxide gels. By R. C. Mackenzie and R. Meldau (Gütersloh, Germany). (To appear in *Miner. Mag.*, **32**, 153-165, 1959).

32. Evaluation of clay mineral composition with particular reference to smectites. By R. C. Mackenzie. (To appear in *Silicates Industriels*).

33. Forest history of the Beinn Eighe Nature Reserve. By S. E. Durno and D. N. McVean (The Nature Conservancy). (To appear in *New Phytol.*).

34. Use of fertilizers in the afforestation of deep peat. By T. W. Wright. (To appear in *J. Sci. Fd. Agric.*).

35. The geography and soils of north-east Scotland. By R. Glentworth. (To appear in *Agric. Progr.*, **33**, 58-64, 1958).

36. Some measurements of air space in Scottish soils. By J. C. C. Romans. (To appear in *J. Soil Sci.*).

37. Trace element distribution in soil profiles. By D. J. Swaine and R. L. Mitchell. (To appear in *J. Soil Sci.*).

38. The geochemistry of some Swiss granites. By T. Hügi (University of Bern) and D. J. Swaine. (To appear in *Geochim. cosmochim. Acta*).

39. Chemical and infra-red studies on *Phragmites* peat and its humic acid. By V. C. Farmer and R. I. Morrison. (To appear in *Sci. Proc. roy. Dublin Soc.*).

40. Spectra and structure of 4-hydroxycoumarins. By V. C. Farmer. (To appear in *Spectrochim. Acta*).

41. Aromatic-alcohol oxidase activity in the growth medium of *Polystictus versicolor*. By V. C. Farmer, M. E. K. Henderson, and J. D. Russell. (To appear in *Biochem. J.*).

42. Interactions between sugars and alkali halides in pressed disks. By V. C. Farmer. (To appear in *Chem. and Ind.*).

43. The trisaccharide fraction of some monocotyledons. By J. S. D. Bacon. (To appear in *Biochem. J.*, **73**, 507-514, 1959).

44. Glyceric acid in broad bean (*Vicia faba L.*). By R. I. Morrison and P. C. DeKock. (To appear in *Nature*, **184**, 819, 1959).

45. 2-Ketogluconic acid as a natural chelator produced by soil bacteria. By R. B. Duff and D. M. Webley. (To appear in *Chem. and Ind.*, 1376-1377, 1959).

46. Nutrient balance in plant leaves. By P. C. DeKock. (To appear in *Agric. Progr.*, **33**, 88-95, 1958).

47. A relation between the ratios of phosphorus to iron and potassium to calcium in mustard leaves. By P. C. DeKock, A. Hall, and Margaret McDonald. (To appear in *Plant and Soil*).

48. Variations in the mineral content of storage tissue disks maintained in tap water. By I. R. MacDonald, P. C. DeKock, and A. H. Knight. (To appear in *Physiol. Plant*).

49. Studies on the physiology of lignin decomposition by soil fungi. By Moira E. K. Henderson. (To appear in *Proceedings of the Symposium on the Ecology of Soil Fungi*, Liverpool, 1958).

50. The bacteriology of the root region of plants grown under controlled conditions. By H. A. Louw and D. M. Webley. (To appear in *J. appl. Bact.*).

51. Study of soil bacteria which dissolve mineral phosphates and related compounds. By H. A. Louw and D. M. Webley. (To appear in *J. appl. Bact.*).

52. Fertilizer placement for swedes and turnips. By J. W. S. Reith. (To appear in *Emp. J. exp. Agric.*).

53. Influences of parent material and drainage conditions on soil phosphorus relationships. By E. G. Williams. (To appear in *Agrochimica*).

54. Carbon, nitrogen, sulphur, and phosphorus in some Scottish soils. By C. H. Williams, E. G. Williams, and N. M. Scott. (To appear in *J. Soil Sci.*).

(C) *Collaborative work (Foreign)*—

55. Liberation of invertase from disintegrated yeast cells. By M. Burger (Czechoslovak Academy of Sciences), E. Elizabeth Bacon (Aberdeen), and J. S. D. Bacon. (*Nature*, **182**, 1508, 1958).

THESES

The following theses have been accepted by the University of Aberdeen for the degree of Doctor of Philosophy:

An investigation of the reactions of soluble inorganic and organic phosphates with soil minerals. By E. Z. Arlidge.

The physical and chemical properties of deep peat in relation to afforestation. By W. O. Binns.

A study of the bacteriology of the root region, with special reference to bacteria dissolving certain insoluble inorganic phosphate fertilizers and related compounds. By H. A. Louw.

A study of the weathering of some basic igneous Scottish rocks and their derived soils. By Wilma W. Smith.