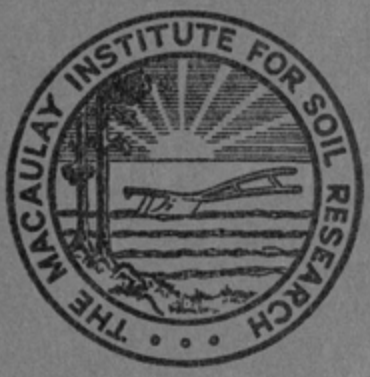
THE MACAULAY INSTITUTE FOR SOIL RESEARCH



FOUNDED 1930

ANNUAL REPORT 1959-1960

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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(Founded 1930)

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J. Evans (Colonial Office, London).
M. M. Guha (Rubber Research Institute, Kuala Lumpur, Malaya).
R. J. Hance (Ministry of Agriculture, Fisheries and Food, London).
C. Luna ("Augustin Codazzi" Institute, Bogota, Colombia, South America).
J. M. MacGregor (Department of Soils, Institute of Agriculture, University of Minnesota, U.S.A.).

CONTENTS

INTRODUCTION

The primary aim of the research in progress is to obtain from field, pot, greenhouse, and laboratory studies, information of value in the maintenance and improvement of soil fertility from the standpoint of both crop production and animal requirement. To this end fundamental and applied studies, both long-term and short-term are undertaken departmentally, inter-departmentally, and jointly with other research and educational organizations.

Progress in the construction of the new Institute premises has not been as rapid as was hoped when building work commenced in the summer of 1958. It is anticipated, however, that the first Phase of the building, which is to be occupied by the departments of Pedology, Soil Survey, Spectrochemistry and Biochemistry together with Library and Administration, will be completed early in 1961. Work on the second Phase of the building, which will accommodate Plant Physiology, Microbiology, Soil Fertility, Statistics and the Institute Workshop, was commenced in June 1960 and is proceeding satisfactorily. Although shortage of accommodation has led to certain difficulties, progress in the approved programme of research and in the publication of scientific results has been fully maintained. Titles and summaries of thirty-eight papers published during the year are appended. From the addendum to the staff list it will be noted also that, despite the accommodation difficulties, it has been possible to provide facilities for a limited number of visiting research workers both from this country and from overseas.

During the year the Institute has been well represented at conferences and meetings bearing on its scientific activities. From references made in the reports of the individual departments it will be seen that members of staff have had the opportunity to attend meetings and to visit other research centres in this country, in various Western European countries and in the United States of America. The services of members of the staff have also been utilized on technical committees appointed by the Secretary of State for Scotland and by such bodies as the Department of Agriculture and Fisheries for Scotland, the Agricultural Research Council, the Forestry Commission and the Colonial Office.

An Agricultural Research Council Visiting Group came to the Institute in May 1960 and The Council of Management take this opportunity of expressing to members of the Group their appreciation of the careful thought given to the programmes of work of the individual departments and of the helpful suggestions made in the course of the visit.

30th September, 1960.

PEDOLOGY

To date the mineralogical investigations in the department have been largely devoted to providing an inventory of the minerals present in the fine sand and clay fractions of the different soil series mapped by the Soil Survey. The former (the fine sand fraction) gives information upon the parent material, the latter (the clay fraction) upon the products of weathering of the parent material, and consequently upon pedogenesis and related aspects. The silt fraction has so far been neglected: consisting essentially of a mixture of primary and secondary material, it would be expected to add to the information provided by the other two fractions only in a quantitative determination of the intensity of weathering. The stage for such quantitative studies has not yet been reached.

An evaluation of the results so far obtained in soil-clay mineralogical studies has shown that, given the relevant Soil Survey information upon parent material, drainage, etc., the mineralogical composition of the clay fraction of a very considerable range of soil types can be predicted with a reasonable degree of accuracy. There are, of course, exceptions, and these, though infrequent, do necessitate a certain amount of standard clay mineralogical examinations. Other interesting observations from this evaluation were that differential thermal estimations of the quantitative composition of surface soils and immediate subsoils were normally lower than X-ray estimations and that some results obtained by the department of Soil Fertility upon phosphate relationships did not appear to fit in with what would be anticipated from the clay mineralogy of the soil. These, taken together with the fact that the hygroscopic moisture peak on the differential thermal curve was usually larger than could be accounted for by the mineralogy of the clay, led to the conclusion that either amorphous material or clay-organic complexes (or compounds) or both might play a greater part in Scottish soil clays than was originally anticipated.

The emphasis in soil-clay mineralogy has, therefore, shifted from inventorying the crystalline clay minerals in different soil series to the more intensive study of a limited range of samples, paying particular attention to amorphous materials and clay-organic compounds. This has necessitated the evaluation of methods for detecting and estimating these substances—with considerable success as will be seen from the reports of the sections concerned. In this work valuable assistance has been given by the department of Spectrochemistry who provided infrared data for many of the mineralogical problems under investigation.

The work of the other sections of the department has proceeded along the lines followed over the past few years. Close collaboration has continued with other departments of the Institute as well as with the Forestry Commission and the Scottish Peat Committee. Samples have been examined on

behalf of various overseas territories, F.A.O. Iran, the North of Scotland Hydro-Electric Board, the Hill Farming Research Organisation, the Nature Conservancy, the Scottish Home Department (Marine Laboratory) and the Universities of Durham and St. Andrews.

Members of staff have attended, *inter alia*, meetings of the Scottish Peat Committee (Moss Survey Group), the Royal Scottish Geographical Society's Standing Committee on River Flow, the British Ecological Society, and the Clay Minerals Group of the Mineralogical Society. In addition Dr W. O. Binns visited various centres in Holland to study current work on forest nutrition, and gave two lectures at a course organized for the Research Branch of the Forestry Commission.

SOIL MINERALOGY

The method in use for quantitative mineralogical analysis has been described in a paper[1] published during the year.

Rock Weathering. The studies on the weathering of and soil formation on basic igneous rocks in south-east Scotland have been completed. A description of the olivine pseudomorphs in the Markle basalt[2] has appeared and a further paper upon interstratified clay minerals in basic rocks[39] is in press. A study on pseudomorphs after olivine in Dunsapie basalt[40] has shown that the olivine has altered to aggregates in which saponite, goethite, and hematite have parallel orientation. Preliminary investigations on the weathering of basic and ultrabasic rocks in Rhum have provided results of considerable interest. One fine-sand fraction from the derived soils has been found to be composed almost entirely of olivine.

Collaborative work with the department of Microbiology on biological weathering has continued and a considerable number of natural minerals and synthetic silicates have been checked by optical and X-ray methods for identity and purity. Commercial samples of synthetic silicates of calcium, aluminium, zinc, and magnesium were all found to be amorphous and were therefore not suitable for experimental material, as their breakdown could not be followed by the method normally used[41].

Other Investigations. Further syntheses of phosphates containing iron, aluminium, and calcium have been made and a number of natural phosphates have been examined and added to the mineral collection.

Profile samples from Hong Kong on deeply-weathered granite contained between 40 and 80 per cent. of kaolinite in the clay fraction together with smaller amounts of illite, vermiculite, and gibbsite. A gibbsite sample from British Guiana contained a trace of anatase as the only impurity, while soil clays from the same country had a high gibbsite content. Gibbsite was also high in two soil clays from Tanganyika, which contained also some kaolinite and hematite. A number of soil samples from Eire were found to be illitic and in their clay mineralogy very similar to many Scottish soils. The suspended material in the River Atbara, a tributary of the Nile, was predominantly montmorillonitic.

In collaboration with the section of Physical Chemistry, a detailed study has been made of the mineralogy of varved glacial deposits of brick-clay at Tipperty, Aberdeenshire; this was described at a meeting of the Clay Minerals Group of the Mineralogical Society. The clay fraction (about 60 per cent. of the total) was composed largely of illite, while the coarser material contained quartz, micas, and felspars.

A number of limestone erratics collected in north-east Scotland are being sectioned and analyzed in an attempt to discover their origin, and thus to obtain more information upon the direction of glaciation in this area.

PHYSICAL CHEMISTRY

During the year there has been a change of emphasis from the systematic study of soil-clays to a more detailed study in which particular attention is being paid to soil clay-organic matter complexes and amorphous alumino-silicates. Most of the soil clays separated were for preliminary investigations on these two problems by differential thermal, infrared, and X-ray methods.

Differential Thermal Analysis. The controlled-atmosphere apparatus[3] is now being used exclusively. No major modifications have been made to the unit, but experience gained from its operation over the past two years has enabled a number of valuable design refinements to be incorporated in two control units at present under construction for the new building. One unit utilizes a microvolt pen-and-ink recorder to register the temperature difference while the other employs a photographic arrangement, and each is housed in a specially-designed steel cabinet. The construction of a furnace assembly, common to both panels and consisting of eight controlled-atmosphere furnace units in a separate cabinet, is almost complete.

Soil clays from north-east Scotland and a number of overseas countries were examined under inert-atmosphere conditions. In the Scottish soil clays the usual suite of minerals was observed, with illite predominating. Those from Trinidad were also predominantly illitic with less than 5 per cent. goethite; gibbsite was either absent or present in only very small amounts. This is in contrast to the results of previous examinations of tropical and sub-tropical soils, which invariably showed mineral associations of kandite or smectite with gibbsite and goethite, illite being very rare. This more usual tropical clay mineral assemblage has been found in soil clays from Tanganyika, the particularly high gibbsite content of one sample in all probability being responsible for the reported low fertility of the soil.

A number of minerals have been examined in some detail—*e.g.*, crocidolite, riebeckite, gypsum, calcite, magnesite, dolomite and gibbsite. The work on calcite and gypsum arose from a request from F.A.O., Teheran, to give an assessment of the suitability of differential thermal analysis for the rapid determination of gypsum and calcite, which are common constituents of some Iranian soils. The two-stage dehydration of gypsum was readily detectable (down to 2 per cent.) on the curve and was never masked by the clay-mineral hygroscopic-moisture peak. The carbonate in the soil samples checked was always calcite, but unlike pure calcite exhibited a doubling of the peak attri-

butable to particle size variation or degree of crystallinity. The gibbsite samples were examined at the request of the Geological Survey Department, British Guiana. In a recent paper[4] the significance of the exothermic peak on the curves for ferric oxide gels has been described; further work is in progress on alumina gels.

Dehydroxylation and rehydroxylation studies have continued and have been extended to kaolinite, pyrophyllite, talc, muscovite and saponite. Under the conditions employed only saponite appeared to rehydroxylate, but this is not supported by the infrared evidence and further work is in progress.

The identification by differential thermal analysis of crystalline and amorphous clay minerals in the upper horizons of soil profiles presents problems arising from the presence of organic matter. It has been found by differential thermal and by infrared methods that hydrogen peroxide treatment of the clay-organic matter fraction dispersed by ammonia leaves a residue containing complex oxalates which are removable by water washing. The unusual peaks found in clays from Wexford, Ireland, (Ann. Rep. 1958/1959) have been re-examined and can be related to the presence of these complex oxalates.

An account[5] of the investigation of peat and its component fractions in both oxidizing and inert atmospheres has been published.

Chemical Studies. The newly-developed semi-micro analytical techniques have been applied to specimens of saponite, vermiculite, illite, and to various samples of lacustrine clay from Tipperty, Aberdeenshire. A number of micro cation-exchange capacity determinations have been carried out in connection with work on the fixation of ions on montmorillonite, and also for determinative purposes. An assessment of the value of chemical data in clay mineralogical studies[6] has appeared.

Most of the chemical work carried out during the year has centred round the development of techniques suitable for the removal and determination of amorphous aluminosilicates. This is of importance not only in determination of the amorphous-material content of soil clays, but also in assessment of the reasons for the existence of induration in the lower illuvial horizons in many leached soils of the Temperate zone. It has been found, using a relatively pure allophane, kindly provided by Dr M. Fieldes, New Zealand, that digestion with a 5 per cent. sodium carbonate solution is the most efficient technique and has little, if any, effect on the crystalline clay minerals. This procedure has now been applied with success to a number of soil profile samples.

PEAT ECOLOGY

As in previous years, the main objects of the work have been the surveying and investigation of the fundamental properties of Scottish peat deposits, and the development of an experimental approach to problems affecting the rational treatment, productivity, and general utilization of peat land and associated soil types.

Ecology. Work on the responses of four upland soil and vegetation types to applied lime and phosphate has been completed[42]. In general terms, the

results emphasize the importance to upland pasture improvement of an ecological approach involving a knowledge of the specific responses of different plant communities to fertilizer application and grazing intensity.

Preliminary studies on the effects of burning on the base status of soils associated with Callunetum have involved the sampling of soil and herbage from three adjacent stands of heather of different ages. Analysis of leaf, stem, litter, and soil (on a volume basis) together with yield data should give some indication of the distribution and variability of total nutrients in each system.

In collaboration with the Hill Farming Research Organisation, investigations of a hydrological nature have been continued and extended at two field centres in Lanarkshire. Data recorded from the peat catchment at Blacklaw Moss in 1959 have been used to study the relationship between rainfall and run-off at different seasons of the year. During the second year of characterization, fluctuations in ground water level have also been recorded and a detailed vegetation survey of the catchment has been completed. It is intended that the botanical study should form a datum to which changes resulting from the surface treatments of the proposed five sub-catchments can be related. Recording at Coalburn Moss has continued along the lines previously reported. The different moisture regimes are now clearly affecting species balance in both the improved and unimproved series of plots. Growth increments and the flowering capacity of *Calluna* and associated species are also showing marked treatment responses.

In collaboration with the section of Radioactivity, investigations on the rooting of plants growing on deep peat have continued using the radioactive tracer technique. Placement and sampling have been completed on a grass/clover sward in plots where the water-table has been artificially controlled at different depths. This is an extension of work carried out last season, the results of which have now been published[7]. Investigations are also in progress in different vegetation communities where *Calluna vulgaris* is the dominant or co-dominant plant to determine the rooting habit of heather in relation to soil type and other species.

A new development has been the collaboration with the department of Plant Physiology in their work on the cation-exchange capacity of plant roots and mineral analysis of the plants and soils over a wide range of organic and mineral soil types.

Pollen Analysis and Quaternary Research. The policy of obtaining pollen analytical data covering Scotland as widely as possible has continued, with the analyses of samples from Achnacree, North Connel; Barcaldine, Benderloch; Moine Mhor, Crinan; and Torran, Ardgour, all in Argyllshire. These deposits are all of the raised moss type and each rests on the 25 ft. raised beach.

In connection with an archaeological excavation, a pollen diagram has been completed from a series of samples taken from a basin peat adjacent to the site of a hut circle at Dalnaglar, Perthshire. This diagram shows several features thought to indicate the effect on the native vegetation of early culti-

vation and forest clearance. Evidence of this kind, as well as contributing to our knowledge of vegetational history, may help in the understanding and dating of this and other similar sites.

The study of forest history in the eastern Grampians has continued, with the Dalnaglar pollen diagram and one from Fir Bog in the Dee Valley; work is now being extended to include the Cairngorms. A paper on the forest history of the Beinn Eighe Nature Reserve[8] has now appeared.

Buried peats in the valleys of the Forth and Earn have been sampled with a view to further investigation of the age of the carse clay and the associated marine incursion. An attempt has been made[43] to work out rates of peat growth for both hill and low-level peat deposits, using as a basis palynological evidence obtained in north-east Scotland and radio-carbon dating of pollen zones at other sites as published by Godwin *et al.*

Other Investigations. In collaboration with the department of Soil Fertility, the grassland trials on deep peat have continued at Gardrum Moss where, in addition to yields and the chemical data on soils and herbage, the species balance in all plots is being systematically recorded using a clip quadrat technique.

Examination of the wider scientific, technical, and economic problems pertaining to the improvement and general utilization of peat land has progressed in association with the Scottish Peat Committee (Moss Survey Group). A tentative research programme and other reports have been prepared for this body.

Close association has been maintained with the Department of Agriculture and Fisheries for Scotland (Peat Section) in the survey of Scottish peat deposits. Analyses have been completed on over 2,000 samples received from the following areas: Harburn Moss, Midlothian and Lanarkshire; Dergoals, Annabaglish, Knock, Mindork, and Dirnean Fell, Wigtownshire. Physical and chemical determinations have also been carried out on peat and herbage samples from field experimental centres, and consultative work on many aspects of peat utilization has continued.

Using tomatoes as test plants, further trials have been laid down in the greenhouse beds in order to compare the horticultural value of different peats. Three distinct types, namely pure *Sphagnum* peat, *Sphagnum-Eriophorum* peat, and sedge peat, were tested in simple sand-peat mixes as defined by the University of California (U.C. System) and in the more familiar John Innes compost. Preliminary results suggest that the botanical origin of the peat is a relatively unimportant factor in the production of standard horticultural soils.

FOREST SOILS

Fertilizer Trials. At Culbin Forest, Morayshire, the slight beneficial effect of ground mineral phosphate applied to young Corsican pine in 1954 is still evident, and needle phosphate contents were higher in treated plots for the second year running. The large increase in height growth due to nitrogen applied in 1956 persisted during 1959, though the increase in needle nitrogen contents only lasted until 1957; for the first time there was a small response to

potash, also applied in 1956. Although the nitrogen response has so far lasted for three years (there was no response in 1956), the foliage analysis figures suggest that, for maximum growth, nitrogen should be applied every other year. A single dressing of phosphate and potash would appear to make good the slight deficiencies of these nutrients for some years. At Culbin one application of nitrogen at the right time, to speed up early growth and canopy closure, will probably be worth while, but for older crops further experimentation will be necessary to decide whether increased growth justifies the cost.

At the Lon Mor, Inchnacardoch Forest, Inverness-shire, potash fertilizer applied to 31-year-old lodgepole pine has produced an increase in diameter growth, and a considerable increase in needle potassium content. The large increase in diameter growth of 30-year-old Sitka spruce produced by potash, and the smaller increase produced by nitrogen, have persisted for the fourth growing season after application; foliage analysis at the end of the third growing season showed that needle potassium contents in the K plots were still higher than in the untreated plots, but that nitrogen differences had disappeared. In 12-year-old lodgepole pine, potash fertilizers gave an increase in height growth in the third growing season after application, and needle potash contents remained higher in the K plots; calcium cyanamide significantly reduced height growth in the first and second growing seasons after application, while lime slightly increased height growth in the first season, but not in the second.

Analysis of needles from 4-year-old Sitka spruce on deep peat in Blairadam Forest, Fife, which showed severe yellowing, suggested an extreme potassium deficiency; an NPK trial has been laid down by the Forestry Commission.

Tree Growth and Nutrient Content of Peat. As a result of the intensive study of changes in peat following afforestation (Ann. Rep. 1958/1959), and the demonstrations of potassium deficiency mentioned above, a survey has been started of deep peat areas recently afforested or proposed for afforestation. It is hoped that analysis of the top twelve inches of peat in two inch layers, and of the natural vegetation will make comparisons of fertility possible, and may help to explain differences in tree growth on apparently similar sites. Preliminary results[9] suggest that there are appreciable variations in potassium and inorganic phosphate contents in different areas, and show that there is a rapid decrease of these two nutrients with depth.

An experiment has been started in Glentrool Forest, Kirkcudbrightshire, to follow the changes taking place in freshly-ploughed peat. The effects of deep and shallow ploughing, trees, added phosphate, and added nitrogen will be studied.

Foliage Analysis in Fertilizer Trials. A large number of needle samples were collected in autumn 1959 from existing Forestry Commission fertilizer experiments, and analyses have now been completed. The results in general support those previously reported[10], and confirm that responses to fertilization can be fairly well predicted from low needle nutrient contents, but that there are occasional responses when levels appear adequate, especially for phosphate, and sometimes for potash.

Advisory Work. Fertilizer recommendations for both Forestry Commission and private nurseries, based on analyses by the department of Soil Fertility, have continued and about 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 1958 field season and the following determinations completed on 652 samples (125 profiles) collected during the 1959 season: loss on ignition, mechanical analysis, hydrogen ion concentration, exchangeable bases, readily soluble phosphorus, total carbon and total nitrogen. Total phosphorus determinations have been carried out on two-thirds of the 1959 samples and exchangeable hydrogen determinations on approximately half of these. In addition standard analyses have been carried out on 128 samples (25 profiles) of the 1960 soils and on 50 samples in connection with studies on forest soils.

Clay samples separated from 110 soils from various parts of Scotland have been analysed for total silica, iron and aluminium, and ultimate analysis of 50 samples of soil, peat ash, rock, etc., have been completed.

At the request of the Hill Farming Research Organisation, 196 samples of surface soil have been analysed, and textural analyses carried out on 10 samples sent in by the Scottish Home Department (Marine Laboratory).

In collaboration with the department of Soil Survey an investigation into the ability of an aqueous extract of pine needles to complex with sesquioxides has been initiated, with a view to obtaining information upon the process of podzolization.

SOIL SURVEY

The systematic survey of the soils of Scotland on a scale of 2·5 inches to 1 mile has continued in the areas previously reported. During the season a total of 420 square miles has been completed, together with 30 square miles on a scale of 6 inches to 1 mile. This includes some 100 square miles on Sheets 33 (Haddington) and 34 (Eyemouth), 110 square miles on Sheets 7 (Girvan) and 8 (Carrick), 40 square miles—together with 30 square miles of 6-inch mapping—on Sheet 39 (Stirling), 70 square miles on Sheets 48 (Perth) and 49 (Arbroath), and 100 square miles on Sheet 94 (Cromarty).

A general account of the semi-natural and natural vegetation of Sheets 57 (Forfar), 66 (Banchory), and 67 (Stonehaven) has been prepared for the memoir of the area. Studies have continued into the relationship between the vegetation, the soils, and the relief of two hills, Tom na Gabhar, Glenbuchat, Aberdeenshire, and Mount Shade in Kincardineshire. In Glenbuchat the soils are developed on till derived from basic igneous rocks and on Mount Shade from granitic till.

Ad hoc activities have included: (a) Preparation for the April Field Meeting of the British Society of Soil Science in Edinburgh; (b) Preparation of a Soil Survey demonstration for a Conversazione of the Royal Society of Edinburgh, which included the compilation of a survey of soils on a scale of 6 inches to 1 mile of some 6 square miles in the Moorfoot Hills to illustrate the use of air photographs as an aid to soil surveying; (c) Assistance given to the Soil Science Department of the University of Aberdeen at their field meeting at Edzell, Kincardineshire; (d) Examination of an Iron Age site at Dalnaglar, Perthshire, in collaboration with the Archaeological Department of the University of Edinburgh; (e) Assistance given to the Department of Soil Fertility of the Macaulay Institute and to the West of Scotland Agricultural College in selecting sites for field trials; (f) Collaboration commenced with the South of Scotland Electricity Board in the study of corrosion in the stub-ends of electric pylons; (g) Preparation of six selected profiles from the University Farm for demonstrations at the Centenary celebrations of the University of Aberdeen.

Maps and Memoirs. The memoir entitled *The Soils of the Country round Kelso and Lauder* (Sheets 25 and 26) was published in July[11]. A mimeographed memoir entitled *The Soils of the Country round Elgin* (Sheet 95)[12] has been prepared for local use. The final colour proof of Sheet 77 (Aberdeen) is awaited. A coloured line-proof copy of composite Sheet 87/97 (Peterhead/Fraserburgh) has been submitted. Sheet 57 (Forfar) has been revised and a new method of production involving the use of Astrascribe is being discussed with the Ordnance Survey. Work is proceeding on the Soil Memoir to cover Sheets 87/97 (Peterhead/Fraserburgh), 77 (Aberdeen) and 76 (Inverurie).

An account of air-space in some Scottish soils[13] has been published, and this work is being continued. A paper on the soils of north-east Scotland[14]

and one on soil conditions in Highland areas[15] have appeared during the year. A comprehensive report on the soils of Malta and Gozo[16] has been published.

Sheet 14 (Ayr)

Field work on Sheet 14 (Ayr) was completed in 1959, and it is now possible to give an account of the main soil types occurring in that area.

The area of approximately 390 square miles described as Central Ayrshire consists mainly of the south-western corner of the broad geographical feature known as the Midland Valley of Scotland and includes the districts around the towns of Ayr, Mauchline, Cumnock, Dalmellington, and Maybole. A triangular area of hilly ground in the south-east, some 40 square miles in extent, is part of the Southern Uplands.

A wide variety of parent materials, together with a considerable range of climate and relief, have produced a great diversity of soils. Major soil groups encountered include peaty podzols, iron podzols, and brown forest soils—each with their slightly gleyed counterparts, surface-water and ground-water noncalcareous gleys and peaty gleys. Skeletal soils, immature soils on alluvium and blown sand, and areas of hill and basin peat have also been mapped.

The chief factor affecting soil formation in the south-west Scotland region is the high rainfall. Although a narrow coastal belt from Troon to Ayr receives only some 30 inches, this figure rises rapidly inland and with increasing elevation to a maximum of 80 inches in the south-east. This, coupled with a preponderance of fine-textured parent materials, has produced a widespread development of surface-water gley soils and brown forest soils which are at best imperfectly drained and gleyed in the B and C horizons. A further effect is the tendency for surface organic accumulation and peat formation at the relatively low altitude of about 600 feet, above which the soils are dominated by the peaty podzol and peaty gley major soil groups. Strong westerly and south-westerly winds form another important element of regional climate and most of the farmland suffers from exposure to some degree.

The regional relief is determined by the underlying solid geology, although considerably modified by fairly intense glaciation. The highest ground is formed by the steeply folded Ordovician sediments south-east of the Southern Upland Fault where several summits exceed 1,700 feet, with Enoch Hill reaching 1,865 feet. Here the annual rainfall ranges from 50 to 80 inches and this has resulted in an extensive development of blanket peat, often of considerable thickness in concave sites, and frequently spreading over the summits of the more rounded hills. It carries an *Eriophorum-Calluna-Trichophorum* vegetation. The mineral soils are developed on till of variable thickness derived from the Ordovician greywackes and shales and belong to the Ettrick Association, with the peaty-topped Dod (peaty podzol) and Alemoor (peaty gley) the commonest series.

Immediately north-west of the Southern Upland Fault a belt of high ground formed of rocks of Old Red Sandstone age with hilltops exceeding 1,000 feet, consists mostly of moorland with again a good deal of hill peat. North-east of Dalmellington basic lavas give rise to soils of the Darleith Association

developed commonly on thin stony till or semi-residual drift with the Baidland Series (peaty podzol) dominant. South-west of Dalmellington, felsite sills, intruded into the red sandstone, form the prominent hills (Glenalla Fell, 1,406 feet) which carry similarly derived soils mapped as the Knockskae Association.

In the Old Red Sandstone country around Maybole in the south-west of the sheet, the high ground is determined in the north by more basic lavas (Brown Carrick Hill, 912 feet), and in the south by intrusions of dolerite and plagiophyre and the faulted Quarrel Hill inlier of Ordovician-Silurian rocks. Till derived from the Old Red Sandstones forms the parent material of the important Glenalmond Association soils which are nearly all cultivated.

A stretch of bleak moorland extending from Dalmellington and Patna to Cumnock, with a maximum width of 6 miles, is underlain by Coal Measures with subordinate Millstone Grit, but owes its elevation, 1,000 to over 1,500 feet, to the resistance offered to erosion by numerous thick sills of teschenite and kylite intruded into the sedimentary rocks. Outcrops of these igneous rocks form prominent "green" hills and mounds in an otherwise drab landscape of peat bogs and peaty moorland. Similar "green" hills formed by a series of volcanic vents of Permian age are a feature of the Patna area. Much of the high moorland is covered with deep peat, notably at Headmark and Glaisnock Mosses. Elsewhere the soils are developed on a clay loam to clay till derived mainly from Coal Measures shales and sandstones, and the dominant series is the peaty gley of the Rowanhill Association with abundant *Juncus*. On the igneous outcrops the soils again belong to the Darleith Association.

The north-eastern half of the part of Central Ayrshire lying north of the Southern Upland Fault is structurally a wide basin where most of the outcropping rocks are Coal Measures. The centre of the basin is in the north, near Mauchline, where the Coal Measures are overlain first by Permian volcanic rocks and then by the desert sandstones of Mauchline. A red sandy clay loam till from the latter, in which the rounded sand grains are readily recognizable, provides the parent material for the Mauchline Association of soils. The outcrops of the volcanic rocks (lavas and tuffs) is fairly well defined by an irregular ring of elevated ground rising as much as 400 feet above the surrounding coalfield. The Lanfine Association has been mapped on a parent material derived from Permian and Barren Red Measures sandstones with a considerable admixture of material from these igneous rocks. The Barren Red Measures are characterized by a predominantly red colour and comprise micaceous sandstones and marly shales which give a sandy clay loam till, the parent material of the Bargour Association. The Drongan series has been distinguished on a red silty clay till derived almost entirely from the marls.

The lithology of the Productive Measures, Millstone Grit, and Carboniferous Limestone Series is similar, consisting of alternations of sandstones, sandy shales and shales, with coal seams and limestone bands. Inevitably the till from these formations shows some variation in the relative proportions of the different types, but this is rarely reflected in the consequent soils which

have all been included in the Rowanhill Association. Locally, an Ashgrove Series has been recognized on till derived mainly from the dark shales. South-east of Ayr, on the lower ground, a wide outcrop of the Calciferous Sandstone Series has provided a dark purplish-brown clay loam till on which soils of the Glenpark Association have developed.

The glaciation which affected the area was fairly complicated. Ice travelling southwards from the Firth of Clyde swung eastward and invaded Ayrshire. Relics of a shelly boulder clay indicate that it reached as far up the valley of the river Ayr as Sorn. This Clyde ice was presumably deflected by the front of the ice sheet moving northwards from the Southern Uplands, and there would have been some fluctuation of the line of contact and the angle of deflection as the power of the respective ice sheets varied. The composition of the till, already complex because of the variety of rock types, has been further complicated in the area of the contact by this fluctuation. North of Cumnock soils on a very mixed till containing Coal Measures, Barren Red Measures, Permian sandstone and lava have been assigned to the Auchinleck Association, and a variant of the Rowanhill Series containing some red marl has been mapped west of Airds Moss. These ice movements effected the usual landscape modifications, rounding the outlines of the higher hills and filling many depressions with till. The resistant volcanic rocks of the sills, plugs, and vents now stand up prominently from the mantle of till and often give rise to "crag and tail" features. Typical drumlin topography is well-developed over wide areas, notably around Maybole and Kirkmichael and north-east of Ayr. Deposits associated with the retreat stages of the ice-sheets are relatively few in this area. The Maybole Association has been mapped on a spread of angular sandstone moraine in the vicinity of Maybole and small areas of the Darvel Series on fluvio-glacial sand and gravel occur sporadically. Several small alluvial flats mark the sites of late-glacial ponding, with brick-clays at Ochiltree and Pant. A coastal raised beach platform up to 2 miles wide is an important feature between Troon and Ayr and a similar platform extends from Culzean southwards to Girvan. The Dreghorn Association has been mapped on the raised beach deposits which are commonly of a sandy loam texture. The soils are valuable agriculturally, being ideally suited to market gardening and the growing of early potatoes. Blown sand overlies the raised beach deposits at Prestwick and Turnberry and provides the Links for the famous Ayrshire golf courses.

In all, 20 soil associations have been distinguished, *viz.*:

Association	*Parent Material*
Auchinleck:	Mixed till derived from Barren Red Measures sandstones and marls, Permian sandstones and basic lavas and Coal Measures sandstones and shales.
Bargour:	Till derived from Barren Red Measures sandstones.
Blair:	Mixed till derived from Ordovician greywackes and Old Red Sandstone sandstones with a variable addition of felsite and basic lava.

Darleith:	Till derived from basic igneous rocks.
Darvel:	Fluvio-glacial sand and gravel.
Dreghorn:	Raised beach deposits.
Drongan:	Till derived from Barren Red Measures marls.
Ettrick:	Till derived from Ordovician and Silurian greywackes and shales.
Glenalmond:	Till derived from Old Red Sandstone sandstones.
Glenpark:	Till derived mainly from sedimentary rocks of Calciferous Sandstone series.
Kilmarnock:	Mixed till derived from Carboniferous sandstones and shales and basic igneous rocks.
Knockskae:	Till derived from felsite.
Lanfine:	Till derived from Barren Red Measures and Permian sandstones, lavas, and tuffs.
Largs:	Till derived from Lower Old Red Sandstone sandstones.
Maybole:	Morainic deposits derived from Lower Old Red Sandstone sandstones.
Mauchline:	Till derived from Permian sandstones.
Reppoch:	Till derived from Downtonian sandstones.
Rowanhill:	Till derived mainly from Carboniferous sandstones and shales.
Sorn:	Mixed till derived from Old Red Sandstone and Calciferous Sandstone sedimentary rocks.

These associations comprise 62 series, many of which are of small extent and important only in that they represent major soil groups corresponding to the more widespread series. Other small areas of soils mapped on Sheet 14 belong to series which occupy large areas in North Ayrshire. It is significant that only 13 series can be considered freely drained, and of these four are peaty podzols with iron pan which usually show some signs of gleying in the A_2 horizon. They are generally found on thin, coarse-textured, stony drift in the vicinity of outcrops, with 4 to 6 inches of raw humus and a well-developed A_2 horizon. The iron pan may not be strongly developed or continuous. Of the iron podzols, the Meadownay, Tranew, and Redcraig series are developed on till derived from the various red sandstones and are usually cultivated. A B_2 horizon and an indurated B_3 horizon are always present although the degree of induration rarely attains that of the podzols of the north-east.

Four series with free drainage have been allocated to the brown forest soil of low base status group. The Dreghorn and Darvel series occur on sandy deposits which contain a good deal of shale and basic igneous material. The profiles show little horizon differentiation and are of a fairly uniform brown

colour throughout. The Darleith and Linhope series are usually found on the hill tops and steeper slopes, the areas often shown by a change to a grassy vegetation with *Nardus* and patches of *Pteridium*. The thin drift which forms the parent material is often partly colluvial and a feature of the profile is a well-developed crumb structure in the A horizon.

Brown forest soils with gleyed B and C horizons are found in the Bargour, Mauchline, Largs, and Glenalmond Associations, all of which are developed on red sandy clay loam tills. A high proportion of coarse sand in the sand fraction makes the soils more amenable to cultivation; the arable farming in areas where they dominate, around Maybole and Mauchline for example, contrasts sharply with the grassland farming which is the more common practice in the region. The Glenalmond Series is representative of this group. It occurs on undulating topography but requires tile drainage. The S horizon is normally 9 inches of brown loam with a weak blocky structure, readily friable to a good crumb. The next 6 inches is of similar material but slightly gleyed and low in organic matter. The B(g) horizon is a compact sandy clay loam with well-developed coarse prismatic structure, grey structure faces and abundant fine grey and ochreous mottling within the peds. At 30 inches the prisms are only crudely defined and pass into massive till. The pH and base saturation values increase steadily down the profile (pH range 5·0-6·8, base saturation 34-90 per cent.). Exchangeable bases are never conspicuously high or low and show no notable trends, although occasional high magnesium values probably indicate the presence of some basalt in the till.

Other series classified as brown forest soils with gleyed B and C horizons are developed on fine-textured parent materials which, in the prevailing climatic conditions, normally develop gley soils. In limited areas, however, where the slopes are steeper, the soils are sufficiently less gleyed to merit the separation of imperfectly drained series. The distinction in many cases is only slight, but is important from the agricultural viewpoint. The pH and base saturation values (pH 7.0 and base saturation 100 per cent. in the C horizon) in this group are invariably higher than in the brown forest soils of low base status, and, in general, there are correspondingly higher values for exchangeable calcium and magnesium. A feature is a consistent increase in the clay content of the B horizon relative to the S and C horizons. The only series of any extent are the Glenpark and Lanfine which occur in areas with marked drumlin topography, and where the parent material has a clay content of 30-35 per cent. in contrast to that of the Caprington and Drongan Series where it may exceed 40 per cent. In profile morphology these soils resemble the Glenalmond Series, but the prismatic structure is better defined and the gleying is more intense in the B(g) and C(g) horizons.

Surface-water gleys form the largest group, some 32 series having been placed in this category. Of these, 18 are non-calcareous low humic gleys and 14 peaty gleys. Most of the tills contain a good deal of readily weathering material and under the wet conditions it seems that decomposition of the rock fragments has taken place so that the clay content of these gleys is considerably higher than that of the corresponding better-drained series. Most stones are

in a soft and friable condition and much of the apparent mottling in the Bg horizon is due to the weathering of ferro-magnesian minerals in basic igneous rock fragments. Typical of the group, the Rowanhill Series has, under grassland, an 8 to 10 inch S horizon of grey-brown clay loam with sub-angular blocky structure which may be improved to crumb under older grass. Below this, gleying is most strongly developed and a weakly-structured uniformly grey A_2g horizon several inches thick is not uncommon. The Bg horizon which follows has the highest clay content of the profile (up to 45 per cent.), a weak, coarse, prismatic structure, plastic consistence, and the ground colour of the till entirely masked by grey and yellow mottling. Below 30 inches the structure fades to massive and with increasing depth the mottling becomes less prominent and finer, the yellow darkening to rusty-brown and olive brown and the light grey to a bluish grey. The dark grey-brown colour of the parent material is apparent in the Cg horizon. The profiles of the Sorn, Pennyland, Amlaird, Altiwan, Ashgrove, Fail, and Cleuch Series are similar in most respects. Their main chemical characteristics are high pH, generally exceeding 6·0 in the S horizon and increasing down the profile, often approaching 8·0 in the Cg horizon. The base saturation is correspondingly high and there is a marked increase in the readily soluble phosphate in the Cg. In the cultivated soils the tendency is for a rather low organic content in the S horizon. The agricultural practice on these soils is restricted to long ley grassland which, however, is well suited to dairy farming for which the region is renowned. Adequate drainage is a serious problem and fields are apt to become infested with rushes.

At higher elevations and with increased rainfall the surface water gleys tend to develop a peaty top and most of the series in the group above have an equivalent peaty gley. These soils have 6 to 12 inches of peaty humus overlying a strongly leached A_2g horizon which is more marked than in the low-humic gley. The Bg and Cg are similar but generally show more intense gleying. The Glaisnock Series of the Rowanhill Association is typical of the peaty gley on a fine-textured till, but peaty gleys have been mapped in the Ettrick, Darleith, and Glenalmond Associations where excessive rainfall rather than impervious till has induced peat formation.

Ground-water gleys are comparatively scarce, most of the sites where they might have occurred being occupied by alluvium. Hill peat, as indicated, is fairly extensive on the high ground, but the only basin peat of any importance lies in the Doon Valley just north of Dalmellington.

SPECTROCHEMISTRY

The determination of constituents occurring in trace amounts at considerable dilution in some carrier presents many analytical difficulties which do not arise in determinations at micro levels free from major diluents. This is the problem presented by most materials encountered in biological and soil investigations. Two groups on which the Institute is represented are engaged in examining the problems involved. The A.R.C. Group on Comparison of Methods of Analysis of Mineral Elements in Plants is considering methods applicable to plant materials, whilst a sub-committee of the Society for Analytical Chemistry is examining the methods which can be used for fertilizers and feeding stuffs.

Considerable thought has been given to the design of laboratories for trace element work in the new department which is now approaching completion; some details are given later in this report. In soil and plant work one of the main problems is the avoidance of contamination, as many of the biologically essential trace metals are present as major constituents of commonly used materials which are readily corroded under laboratory conditions. Only in a properly designed laboratory can comprehensive analyses be successfully carried out; in the past the work of the department has been restricted by unfavourable laboratory conditions.

Visiting workers who have spent extended periods in the department include Mr M. M. Guha from the Rubber Research Institute of Malaya, Dr Carlos Luna of the Augustin Codazzi Institute, Bogota, Colombia, and Prof. J. M. MacGregor of the University of Minnesota.

Members of the staff presented papers at the 1960 Annual Symposium on "Modern Methods of Analytical Chemistry" of the Louisiana State University in Baton Rouge, the Seventh International Congress of Soil Science in Madison, Wisconsin, the Society of Chemical Industry Symposium on "Advances in the Chemical Analysis of Fertilizers, Soils, and Plants" in London, the Society for Analytical Chemistry Symposium on "Analytical Chemistry in the Service of Agriculture" in Nottingham, and the meeting of the Nutrition Society Scottish Group on "Minor Elements in Nutrition" in Ayr, in addition to attending various scientific meetings relating to trace elements, spectrochemical methods, and ultraviolet and infrared absorption techniques.

Trace Elements in Soils, Plants, and Biological Materials

Soils and Soil Parent Materials. A brief account[17] of the distribution of trace elements in Scottish soils and the factors affecting uptake by plants has been presented to the Scottish Group of the Nutrition Society. The opportunity was taken to emphasize once more the complexity of the geological parent materials from which the soils have developed, and the impossibility of summarizing adequately the distribution of trace elements on a small scale map. The factors affecting the distribution of trace elements

are discussed in a paper[44] which is now approaching publication. Many of the points raised by the findings reported therein have been studied in more detail during the past year. In this connection the results obtained in the previously reported study of the contribution of the different soil size fractions are of particular significance. The most effective methods of presenting for publication the great mass of information available are now being considered.

The results of many analyses of agricultural soils made during the year again serve to confirm the general conclusion that the soil parent material is the major factor in establishing trace element status, while drainage conditions during soil formation control the mobilization and plant availability of many trace elements.

Following upon the detailed soil survey of Rhum made last year by the department of Soil Survey on behalf of the Nature Conservancy, a comprehensive trace element examination of the soils has been carried out. As was to be expected from the diversity of parent materials, very great differences in trace element contents in different areas have been found, and these are now being related to the trace element contents of the herbage from selected areas.

Some soil profile analyses have also been carried out on samples taken from rice areas of different drainage status in Hong Kong. The results appear to suggest that soil drainage factors operate in a manner similar to that observed in Scotland. The high extractable zinc content of these soils possibly requires further consideration.

Soil Status and Plant Uptake. Investigations have continued in collaboration with the department of Soil Fertility on the relationship between soil content and plant uptake. These long-term studies are proceeding satisfactorily, and the results are being correlated as far as possible with the work on the mode of occurrence of trace elements in soils. The general methods of approach and the practical problems involved were outlined in last year's report.

The agricultural problems related to trace elements at present recognized as being of importance in the North of Scotland College of Agriculture area concern such elements as cobalt, copper, manganese, molybdenum, nickel and boron. Recently the department has been represented on an A.R.C.-sponsored group studying the importance of selenium deficiency. It appears probable that this element must be added to those recognized as essential in animal nutrition and that selenium deficiency may occur in certain areas in Scotland. So far no work has been done on selenium in Scottish soils, apart from an assessment of possible deficient areas based on geochemical considerations. Little work is currently being done on boron, but analysis for the other elements mentioned, as well as for elements toxic in large amounts, such as zinc and lead, is being carried out on a routine scale. Many instances of soils likely to carry cobalt deficient herbage and copper deficient cereals have been found in the course of the examination of soils submitted for investigation. Occasional instances of molybdenum contents high enough to produce herbage toxic to animals have been observed; there has however been no indication of the occurrence of molybdenum deficiency in the area.

The analysis of herbage samples from a field experiment on the effect of cobalt supplements added as sulphate and EDTA chelate in the presence and absence of lime have been completed as far as the first two years are concerned. Samples of third year herbage have been taken this season by the department of Soil Fertility, and will be examined before any conclusions are reached. This simple investigation involves the analysis of over 100 samples each year, as species variation and seasonal changes must be considered.

Two studies of trace element uptake by trees are in progress. A 30-year-old Scots pine is being analysed comprehensively, the needles, shoots, bark, and wood of each branch being examined separately. Trunk and roots are also being subsampled. From the complete results it will be possible to calculate the total amount of each trace element in the tree, and possibly to estimate the annual uptake and deposition. The analysis of the trace elements normally determined is nearing completion, but it is hoped to extend the work to a number of other trace elements, as well as to include the usual major constituents in order to obtain a more complete picture of mineral element distribution in the tree.

In another investigation by a visiting research worker, leaves of three species of deciduous trees are being examined periodically from different levels on the trees, at three locations on different soil associations. These results are showing interesting seasonal and locational differences for a number of the trace elements.

Spectrochemical Methods of Analysis

The application of direct reading methods is still restricted to flame, spark, and a.c. arc emission sources. Before this technique can be applied to analyses involving d.c. arc sources, which are generally necessary for the determination of such trace elements as cobalt, nickel, molybdenum, tin, lead, and vanadium, equipment based on an instrument with greater dispersion than the Hilger Medium Quartz Spectrograph will be required. Within their capabilities, the instruments in use have proved very satisfactory, and it is hoped in due course to introduce equipment suitable for other trace elements. It must be realized, however, that commercially available instruments can seldom be employed without modification, as the requirements for which they were designed are often less stringent than those for trace analysis.

The card index of literature references to all types of spectrochemical methods of analysis is being kept up to date, and now includes some 15,000 references, indexed by subject and author. The section on flame photometry alone accounts for some 1,500 references.

Flame Emission. Flame photometric determinations of potassium, sodium, and calcium have been carried out on a scale similar to that of previous years in extracts of soils and plant materials on behalf of the departments of Soil Fertility, Pedology, and Plant Physiology. Determinations of magnesium by flame methods are considered unsatisfactory, and this element is being determined exclusively by porous cup solution spark technique.

Further work has been done on interference effects, particularly the factors

affecting the depression of calcium by phosphate. Variables studied in the present investigations have included atomizer design, gas mixture composition, and flame position, as well as the ratios and absolute contents of the constituents concerned.

Arc Emission. The arc methods developed in the department have been continued without significant change. The cathode layer d.c. arc technique after concentration by mixed organic reagents and the method for the direct examination of plant ash together make the greatest contribution to the analytical trace element determinations, and are the methods on which the work of the department is based.

The modified step resistances employing mercury relays, described in last year's report, have proved satisfactory in service, and a further modification has been the introduction of a mechanized control for the subsidiary continuously variable resistance, enabling it to be sited more conveniently.

Direct Photometry. Magnesium has been determined in over 10,000 samples during the year by means of the two channel direct reading attachment constructed for the Hilger Small Quartz Spectrograph. Several other institutes have shown interest in this instrument, and at least one copy has been built.

The direct reader based on the Hilger Direct-reading Attachment for the Medium Quartz Spectrograph has been extensively used for the determination of several elements in soil extracts by the porous cup solution spark method. This technique is very suitable for copper, manganese, and zinc, while aluminium can be determined directly in acetic acid soil extracts without further concentration. The method has also proved useful for the determination of zinc, manganese, iron, aluminium, and copper in small samples of bacterial cells, mycelia, and media submitted by the departments of Microbiology and Biochemistry.

A tentative method has been worked out for the determination of several elements in plant ash, employing as one electrode of an a.c. arc or interrupted d.c. arc source a rotating pressed disk of plant ash, graphite powder, cellulose, and a spectroscopic buffer. This is described in papers[45], [46] discussing the applications of direct photometry which are at present awaiting publication.

Laboratory Facilities. The contamination problems that arise in the preparative work have been described in a paper[47], now awaiting publication, which also discusses those arising during sampling and transport. As far as drying and milling of soils and plant materials are concerned, the most acceptable metals with which the samples are allowed to come into contact would appear to be aluminium and iron, all alloys being avoided as far as possible. There would appear to be no convenient alternative to iron (carbon steel) for plant mills, which should be fitted with aluminium feeder trays and plastic knobs to replace the brass fittings usually supplied. Aluminium has been specified for ovens, drying racks, and cool rooms in the new building.

In the laboratories, exposed metal is being eliminated as far as possible, being either replaced by plastic materials, such as polythene for cold water pipes

and drains, or covered by polyvinylchloride or epoxy resin or silicone-based resin paints. Remote controlled, plastic-handled service taps and plastic covered electric lighting fittings have been specified. The fume cupboards are to be polyvinylchloride lined. A trial water-bath made of polypropylene has proved very satisfactory in service and these will be used throughout for trace element work. As this type of bath cannot be allowed to overheat, a magnetically switched level control has been fitted in a remote constant-level chamber, which ensures also that the efficiency of the bath is increased by eliminating the unnecessary introduction of cold water into the bath itself. Hot plates of aluminium-magnesium alloy (Al—5 per cent. Mg) have proved reasonably satisfactory in service over several years. Wherever possible silica sheathed electric heaters are employed in place of gas bunsen burners which, where used, will be fitted with silica burner tubes.

Many commonly used types of paint have surprisingly high contents of such biologically important trace elements as zinc, lead, and cobalt, as well as other metals. In the new laboratories the specification calls for the exclusion of the more objectionable of these, but permits the use of titanium-based paints. In the laboratories an epoxy resin based paint will be employed.

Absorption Spectrometry of Soil Constituents

Although infrared spectroscopy has found its principal applications in the field of organic compounds, there has been steadily increasing interest, particularly in Russia and U.S.A., in the use of this technique to identify minerals and to provide information on their structure. In this department the particular problems associated with the characterization of mineral constituents of the soil are being explored, and it has been established that useful information can be obtained additional to that given by X-ray diffraction and differential thermal analysis. Co-operative work involving the use of all three techniques is in progress. This includes efforts to distinguish the relative amounts of amorphous and crystalline silicates in the clay fraction of soils, particularly in horizons with high organic matter contents. Changes in the infrared spectra of clays and related compounds following heat treatment are being studied, as such changes may assist in identifying the types of clay present. Work on the characterization of insoluble iron and aluminium phosphates, which may play a role in phosphate fixation, is continuing.

The results of co-operative studies with the department of Biochemistry on *Phragmites* peat and its humic acid have now been published[18], as has work on the infrared spectra of 4-hydroxycoumarins[19], which are of interest as models for certain possible structures in humic acids. Studies on chemical changes produced by the action of fungi on aromatic compounds related to lignin have continued in collaboration with the department of Microbiology. This has led to the identification of aromatic-alcohol oxidase activity in the growth medium of *Polystictus versicolor*[20], and the possibility that this enzyme plays some part in the breakdown of lignin is being explored.

New techniques developed include a spectrophotometric method for the determination of total haematin in plants. This has been applied in published work[21] with the department of Plant Physiology, on changes associated with

chlorosis in plants. Critical studies on the pressed disk technique, which is used in preparing solid samples for infrared examination, have continued. The possibility of interaction between sugars and alkali halides in pressed disks has been pointed out[22]. Evidence has also been found for the adsorption on alkali halides of compounds containing complex condensed aromatic rings. This observation is of importance, as humic acids are thought to contain such structures. The interpretation of the infrared spectra of amines in solution in pyridine, which is one of the few effective organic solvents for humic acids, has been discussed in a recent publication[23].

BIOCHEMISTRY

Early investigations (Ann. Rep. 1947/1948) showed that a water-soluble polysaccharide fraction, which must be a mixture of many substances, can be obtained from most soils. No great differences were found between such fractions from a wide variety of soils, and all were shown by hydrolysis with acid to be composed mainly of glucose, galactose, mannose, arabinose, xylose, and uronic acids. These sugars are abundant in plants and micro-organisms and some are found also in animal tissues, so their presence threw no light on the origin of the polysaccharide fraction, commonly supposed at that time to be formed by bacterial action.

Later (Ann. Rep. 1950/1951 and 1952/1953) it was found that smaller amounts (less than 1 per cent.) of rhamnose, fucose, and several partly methylated sugars were also present. This strengthened the belief that the polysaccharides were at least in part bacterial in origin, because methylated sugars were not known to occur in plant material, and although rhamnose and fucose had occasionally been found they were not believed to be widely distributed in plant polysaccharides.

In recent years, however, partly methylated sugars have been identified in water-soluble polysaccharides from several plants, and it seemed necessary to reconsider the whole position. The use of chromatography on charcoal has therefore been developed to permit the identification and estimation of small amounts of the methylated sugars in the presence of large amounts of the commoner ones. The results have shown that 2-*O*-methylxylose and 2-*O*-methylfucose occur in all the plant tissues examined, although the amounts present are in all cases only of the order of 10 mg. per 100 g. dry matter. They are mainly contained in a polysaccharide fraction which is extracted to some extent by hot water, but more readily by dilute alkali. This fraction also contains rhamnose and fucose.

It could therefore be argued that the great similarity between the water-soluble polysaccharide fractions from a variety of soils could be simply a reflection of the fact that in all cases these are derived from plant residues rather than from bacterial action. Although chemically more labile than cellulose and xylan, there is no reason why this type of polysaccharide should not be more resistant to biological action, for in view of the persistence of free nucleic acids in soil it can no longer be supposed that all added organic matter is immediately and rapidly broken down by the soil microflora.

By stating the case in these terms one is perhaps tipping the balance too far against the older idea that soil polysaccharides have a bacterial origin. In this department one of the methylated sugars has this year been shown to be a 2-*O*-methylrhamnose, which is so far known only in certain Mycobacteria, and another, although it very closely resembles 2-*O*-methylxylose, has not so far been induced either to crystallize or to form a crystalline derivative through which it could be positively identified. What is clear, however, is that the

question is still an open one. If, as some suppose, the water-soluble polysaccharide fraction is one factor which maintains the crumb structure of soils, a more complete answer to this question cannot fail to broaden our understanding of the processes which improve the physical structure of soils.

The alkaline nitrobenzene oxidation method for the detection of lignin residues in humic acids has been improved: higher yields of aldehydes, especially syringaldehydes, have been obtained and the corresponding acids also measured. A start has been made with hydrolyses of humic acid under relatively mild conditions; it is hoped that these will throw light on the nature of the nitrogenous components.

Biochemistry of Micro-Organisms. Work on the part played by 2-keto-gluconic acid in the mineral-dissolving action of micro-organisms[24], [41] has continued in collaboration with the departments of Spectrochemistry and Microbiology, and is described in the reports of those departments.

Plant Biochemistry. In collaboration with the department of Plant Physiology a study of the metabolism of organic acids in plants, especially in mustard, is being continued. A method for the assay of aconitase[48] applied to leaves of plants receiving toxic levels of nickel showed that the enzyme activity was considerably higher than in normal leaves. This suggests that the action of nickel cannot be simply to induce a deficiency of iron, because in iron-deficiency the aconitase activity is depressed.

Micro-methods have been used to follow changes in the levels of malic and citric acids in mustard leaves growing under various conditions. These studies, which are complementary to an earlier examination of the influence of iron deficiency, are intended to tell us more about the relationship between organic acid metabolism and the mineral composition of leaves.

At the invitation of the Centre Nationale de la Recherche Scientifique, Dr Bacon contributed a paper (on oligofructosides[49], [25], [26]) to a symposium on "La Biochimie des Glucides" held at Gif-sur-Yvette, near Paris, in July 1960.

PLANT PHYSIOLOGY

The work of the department is largely concerned with elucidation of plant nutrition. Optimal conditions for absorption of applied nutrients, interaction of one nutrient upon another, as well as the inherent physiological pattern of the plant must be studied, otherwise the value of experimental work may be greatly reduced. It is also important to realize that advances in the design of apparatus for physiological research has opened many fields of investigation, and operation of these instruments is often possible by suitably trained technicians.

During August, Dr P. C. DeKock attended the VIIth International Congress of Soil Science at Madison, Wisconsin, U.S.A., and the opportunity was taken to visit research stations in various states. Other members of staff made visits to research stations in Britain. Dr I. R. MacDonald left by invitation to spend a year on research in the Department of Horticulture, University of California, Los Angeles. Dr A. Amberger of the Agrikulturchemisches Institut, Weihenstephan, Germany, spent some months in the department.

Mineral Nutrition. Changes in mineral nutrition in relation to iron deficiency continue to receive considerable attention. A detailed study of the interaction between the elements phosphorus, iron, potassium, and calcium in mustard leaves has been published[28] and an evaluation of the physiological significance of these interactions given[29]. Such interactions are being extended to include variations in the manganese and copper contents of mustard leaves. A preliminary investigation into magnesium deficiency has begun. An analytical survey of iron-deficient and healthy plants contributed from all parts of Britain is in progress. Collaborative work is being carried out with the Alice Holt Forest Research Station on manganese deficiency in pine needles and beech leaves. Changes in mineral composition of leaves with time have been studied using *Heracleum mantegazzianum*. Papers on the mineral composition[50] of plants and on trace elements[51] in plants have been contributed by invitation.

Organic Acids. A paper on glyceric acid in the broad bean[27] has been published. Further evidence of the accumulation of malic acid in the leaf with increased iron level in the nutrient medium has been obtained. Also changes in the pattern of organic acids in the leaf with time have been further studied. Studies on aconitase have continued in collaboration with the department of Biochemistry[48].

Soil Organic Matter. A paper surveying the influence of soil organic matter on plant growth[52] was contributed to the VIIth International Congress of Soil Science.

Work on the effects of growing tree seedlings on peat and peat-sand mixtures with various fertilizer regimes has been continued in collaboration with the section of Forest Soils.

Enzymic Studies. Further studies on peroxidase and catalase in healthy and chlorotic leaves have been carried out. A method for measuring the total haematin in plant material has been devised in collaboration with the department of Spectrochemistry and the relation between haematin and chlorophyll studied. The results have been published[21].

Metabolic Changes in Storage Tissue Disks. The studies on metabolic changes in disks of sugar beet, red beet, carrot, turnip, and potato have been continued during the year. Papers dealing with their capacity for selective absorption of cations from tap water[30] and the relationship between their cation-exchange properties and pectin content[31] have been published. A third paper, dealing with the changes in pectic substances in the disks with time[53], has been accepted for publication.

Levels of trichloracetic-acid-insoluble compounds of nitrogen and phosphorus have been followed in disks of sugar beet, red beet, carrot, and turnip maintained in running tap water, and have been shown to increase in varying degree in all tissues. The presence of free nitrate (0.1 p.p.m.) in the tap water appears to promote synthesis (TCA-insoluble nitrogen). The increase is less in insoluble nitrogen and phosphorus compounds than in total water-insoluble compounds, indicating the synthesis of cell-wall materials. Fresh weight increases of up to 70 per cent. are shown to be co-extensive with the synthesis of protein. It is concluded that the metabolic changes occurring in the disks are most accurately characterized in terms of renewed growth. This work has been accepted for publication[54].

Cation-Exchange Properties of Plant Roots. Two aspects of plant root exchange reactions have received attention during the past year. This study has been extended by measuring the cation-exchange capacity-pectin gradient along the root, using leek roots as experimental material. In common with respiration and protein nitrogen, cation-exchange capacity and pectin are highest at the root tip and decrease rapidly along the root away from the tip. This work has been accepted for publication[55].

It has been implied in published work that the cation-exchange capacity of a plant root has a characteristic value, although this has never been put to a rigorous test. Results obtained from a range of monocot and dicot natural vegetation growing in either sand, granitic soil, calcareous soil, or peat, have shown that the cation-exchange capacity of any particular plant falls within very narrow limits irrespective of the growth medium from which it was taken. In addition, the cation-exchange capacity-pectin relationship has been found to hold for this wide range of plants involving some 80 species. The pectin content is invariably higher than the cation-exchange capacity, due partly to the methyl pectin fraction and to substances in the roots yielding carbon dioxide yet not pectic in nature.

At present it is not clear whether the cation-exchange capacity of the root can influence the mineral composition of the plant. Using excised plant roots, Swedish workers have demonstrated that the root cation-exchange capacity affects the relative proportions of monovalent and divalent cations adsorbed in accordance with the Donnan equilibria principles. The use of

intact plants in which translocation processes have taken place makes demonstration of the relationship less easy. Results obtained in this laboratory with sand-cultured plants or oats grown in Mitscherlich pots have been inconclusive.

The valence effect is favoured by dilution of the medium and there seems a likelihood that the above substrates were too concentrated. Recourse has therefore been made to vegetation growing under natural conditions since nutrition of these plants is at a very low level. Although the plants range in cation-exchange capacity from 3·5 up to over 50 me./100 g. dry roots, a preliminary examination of the leaf composition does not show any clear-cut evidence in favour of the valence effect operating even under these conditions. Translocation processes may in part be responsible for this and it also seems probable that subsequent root analysis would not reflect the original sorption ratios of the monovalent and divalent cations for the same reason.

RADIOACTIVITY

An account has been published of the radioactive method of studying the effect of drainage on the root systems of plants growing in deep peat[7]. Further experiments have been done in collaboration with the section of Peat Ecology.

The radioactive method has been applied to the determination of values of residual phosphate in soil, in pot experiments with the department of Soil Fertility.

MICROBIOLOGY

The study of phosphate-dissolving micro-organisms in soil and in the root region has been continued, as have the fundamental investigations on the breakdown of lignin and related molecules by fungi and on the soil actinomycete *Nocardia opaca*, which has been found useful for studying the β-oxidation of certain selective herbicides. Collaboration with the departments of Soil Fertility and Biochemistry in the former study and with the departments of Spectrochemistry and Biochemistry in the latter studies has been maintained.

In addition there has been initiated, in collaboration with the departments of Biochemistry, Pedology, and Spectrochemistry, a study of the possible role of soil micro-organisms in the biological weathering of naturally occurring minerals and rocks.

Dr D. M. Webley attended the VIIth International Congress of Soil Science which was held in Madison, Wisconsin, U.S.A. in August, 1960.

Microbiology of the Root Region. Work reported last year on the bacteriology of the root region of the oat plant with particular reference to phosphorus-dissolving bacteria has been published[32], [33]. A paper[56] was read at the VIIth International Congress of Soil Science, Madison, Wisconsin, U.S.A., on the plate technique used in the above studies for detecting the phosphate-dissolving micro-organisms. Detailed study of the chelating ability of 2-ketogluconic acid, which is produced from glucose by the most active of the phosphate dissolvers, has continued in collaboration with the department of Biochemistry and a note on this work[24] has been published. These organisms generally belong to the genus *Pseudomonas*.

Attempts have been made in collaboration with the department of Soil Fertility to establish one of the 2-ketogluconic acid-producing strains in the root region of the oat plant grown under Mitscherlich pot conditions. For this purpose the soil was partially sterilized by steaming before inoculation with the organism. Vermiculite proved to be a very useful carrier for the organisms for soil inoculation. The seed was surface sterilized and dipped in a suspension of the organism before planting. Although successful initial establishment of the organism in the root region took place, as the plants grew the results showed that the organism was reduced in numbers. This is presumably due to competition from the normally developing root region microflora.

It was found possible to produce 2-ketogluconic acid in unplanted, partially sterilized soil inoculated with the organism and to which glucose had been added. The 2-ketogluconic acid was further broken down in the soil.

Attempts are now being made, with some success, to study the localized production of the acid in the vicinity of pellets of rock phosphate buried in soil.

Soil Micro-Organisms and the Weathering of Rock Minerals. Using a modification[41] of the plate method for detecting phosphate-dissolving micro-organisms referred to above, it has been found that certain synthetic and naturally occurring silicates can be dissolved by a number of soil bacteria and fungi. Naturally occurring minerals which are attacked in this way are now being studied in more detail in collaboration with the departments of Biochemistry, Pedology, and Spectrochemistry. It has already been shown[24] that 2-ketogluconic acid-producing bacteria can chelate calcium from wollastonite (natural and synthetic), chabazite (natural), synthetic tobermorite and xonotlite. This work is being extended to a wide range of naturally occurring minerals and to various types of rocks.

With the help of the department of Soil Survey, an ecological study of the microflora of rock surfaces and weathered or decomposing "stones" found in profiles has been started.

Fungi. Two fields are under investigation. These are the decomposition of lignin, which is a continuation of previous work, and the solubilization of natural and synthetic silicates, which was initiated during the year.

In connection with the former, the studies on the influence of trace elements on the metabolism of aromatic compounds related to lignin have been concluded and a paper has been accepted for publication[57]. The elements studied were copper, iron, manganese, and zinc, of which only iron showed any effect on the metabolism of and on the accumulation of intermediate products of metabolism from catechol, *o*-, *m*-, and *p*-hydroxybenzoic, *o*-, *m*-, and *p*-methoxybenzoic, 3:4-dimethoxybenzoic and vanillic acids. Intermediate products of metabolism not previously identified for fungi were: protocatechuic acid from *m*-hydroxybenzoic acid and catechol from *o*-hydroxybenzoic acid.

Also concerned with lignin-decomposition, the studies on yeast-like organisms have included growth experiments, respiration experiments in the Warburg apparatus, and resting-cell experiments, the latter for the identification of intermediate products of metabolism. The principal fact arising from the work is that these organisms also are capable of growing on and metabolising aromatic compounds. The nature of their morphology has made possible their use for the extension of the present investigations into enzymatic studies on the metabolism of aromatic compounds.

A paper[20] on the aromatic-alcohol oxidase released by *Polystictus versicolor* has been published. The collaborative work with the department of Spectrochemistry into the possible action of this fungus in the initial decomposition of lignin is being continued. The paper[34] presented at the Symposium on the Ecology of Soil Fungi in Liverpool in 1958 has now been published.

Preliminary results from investigations into the solubilization of synthetic and natural silicates indicate that fungi may play a role in pedogenesis.

Actinomycetes. Last year it was reported that iron, zinc, and manganese are essential for the optimum growth of the soil actinomycete *Nocardia opaca*. Further work has shown that these trace elements are required for the growth

of the organism on the following substrates: glucose, sucrose, glycerol, glutamate, and phenylacetate. Iron deficiency gives the greatest reduction in the amount of cell material obtained on all substrates. Deficiency of manganese causes marked morphological changes in the organism during growth on all substrates. A paper[35] containing full details of these results together with photo- and electron-micrographs has been published. Work is now in progress, in collaboration with the department of Biochemistry, on the physiology of these trace metal deficient cells. In this connection, zinc deficiency has a marked effect on the carbohydrate metabolism of the organism.

SOIL FERTILITY

The research programme, based on concurrent development and integration of field, pot, and laboratory studies covering different soil types and the main agricultural crops, has been continued and extended. Advances have been made in studies on the organic and inorganic phosphate relationships of soils, the sulphur, carbon, and nitrogen contents of different soil types, the long-term effects of various liming materials, the effects of fertilizer placement, and the manurial requirements of grassland. Ten publications in these fields are referred to below, and progress has also been made in investigations on the magnesium and trace element status of soils, the nutrient requirements of crops, and the influence of factors such as time and frequency of application of fertilizers.

Importance continues to be attached to practical application of results through advisory soil testing in collaboration with the North of Scotland College of Agriculture, contributions to the agricultural press, and talks and demonstrations to agricultural and horticultural bodies. An article on practical aspects of liming[58] and revised editions of two advisory leaflets issued by the Department of Agriculture and Fisheries for Scotland are in press. Representation has been maintained on the Field Trials and Grassland Committees of the Scottish Agricultural Improvement Council, the Scottish Sub-Committee of the Sugar Beet Research and Education Committee, and Agricultural Research Council Working Parties on manurial questions. Contact has also been maintained with the Agricultural Research Council Unit of Statistics in the preparation of reports on the Survey of Fertilizer Practice carried out by the Scottish Colleges of Agriculture, and collaboration has continued with the Hill Farming Research Organisation, the Animal Diseases Research Association, and other research and technical bodies.

Mr R. J. Hance, Ministry of Agriculture Research Scholar, has continued studies on soil phosphorus relationships with special reference to the organic fraction, in candidature for the degree of Doctor of Philosophy from the University of Aberdeen. During a stay of one year Mr John Evans, Colonial Service Trainee, studied field, pot, and laboratory techniques and contributed to investigations on the fractionation of inorganic soil phosphorus.

Dr E. G. Williams attended and contributed a paper[61] at the VIIth International Congress of Soil Science in Madison, Wisconsin, U.S.A., and Dr J. W. S. Reith visited research stations and advisory centres in Denmark, Netherlands, and West Germany.

Grateful acknowledgement is made of the willing and efficient co-operation of farmers in carrying out the field programme, comprising some 70 experiments involving about 4,500 plots of cereals, potatoes, swedes, turnips, and grass, distributed over different soil types at centres chosen in consultation with the department of Soil Survey.

Inorganic Phosphorus. Long-term field experiments on the residual effects of phosphate in different soil types, including the effects of lime, have been continued, and further comparisons have been made of a range of phosphate fertilizers on swedes, potatoes, oats and grass. The effectiveness of different forms of phosphate and the availability of residues from field plots, including evaluations with the aid of ^{32} P in collaboration with the section of Radioactivity of the department of Plant Physiology, have again formed major items in the pot experiment programme, and collaboration has been maintained with the department of Microbiology in laboratory and pot studies on the effects of phosphate-solubilizing organisms.

Laboratory studies have been continued on the inorganic phosphorus relationships in different soil types, and an account of influences of parent material and drainage conditions has appeared[37]. A paper examining some aspects of phosphate retention and availability in acid soils[61] was presented at the VIIth International Congress of Soil Science in Wisconsin, U.S.A., and will be published in the Transactions. The main points covered are the relative influence of soluble aluminium and iron in determining the magnitude of phosphate retention and the firmness of binding, the significance of phosphate retention capacity in relation to crop responses and placement effects, the importance of degree of saturation with phosphate as a criterion of phosphate status, and the probability that in acid surface soils much of the active aluminium occurs in intimate association with organic matter.

Organic Phosphorus. Investigations in this field have been continued and extended. A paper[38] on factors affecting the estimation of phosphate esters in soil was presented at a symposium on advances in chemical analysis of soils, fertilizers, and plants, held in London in April, 1960. Another paper[63], in press, describes a method which has been developed for determining the purine and pyrimidine bases in soil humic acid fractions. Analysis of a variety of soils gave values for the total bases ranging from 14 to 61 μmoles per 100 g. soil, accounting for up to 32 p.p.m. nitrogen in the soil. The relative proportions of the bases indicate that they were probably present in polynucleotides derived by enzyme or chemical attack on deoxyribonucleic acid, mainly of bacterial origin, and on this basis such polynucleotides would account for 0·6 to 2·4 per cent. of the soil organic phosphates.

Progress has been made in the fractionation of alkali soluble soil organic phosphate, and an account of this work[64] has been submitted for publication. The phosphate esters have been divided into three main classes: an acid insoluble fraction precipitated at pH 0·2, and two acid soluble fractions, one of which is precipitated at pH 2·9 in the presence of excess aluminium, while the other remains in solution. The acid insoluble fraction includes deoxyribonucleic acid or related polynucleotides and a category of organic phosphate, possibly phospho-protein, which is readily mineralized on incubation in alkali. The acid soluble fraction precipitated by aluminium includes inositol phosphate. Other as yet unidentified esters occur in all three fractions.

Further studies have been carried out on the soil lipid fraction, and on the adsorption and precipitation of inositol phosphates in acid solution. Considerations concerning the importance of the degree of saturation of soil with phosphate in relation to phosphate status, mentioned above[37, 61], suggest that organic phosphates like inositol hexaphosphate may fulfil a useful function by combining with active aluminium and iron, thereby partially satisfying the phosphate retention capacity and helping to raise the degree of saturation. This view is compatible with other results[62] which show that the total organic phosphorus gives poorer relationships with carbon than does the total sulphur, probably mainly due to varying accumulation of compounds like inositol hexaphosphate which are stabilized by aluminium and iron.

Calcium and Magnesium. A paper[59] summarizing the long term effects, extending up to 14 years, of a range of liming materials on the yield and mineral composition of crops and on soil properties has been accepted for publication. There were no differences in the yield produced by ground burnt lime, ground burnt magnesian lime, ground limestone of varying fineness, dried paper works lime, and shell sand, but blast furnace slag was consistently somewhat inferior. Liming generally increased the calcium contents of the crops and the removal of other nutrients. Burnt magnesian lime produced crops with magnesium contents about 50 per cent. higher than from other forms. Depending on the rate of application, the average annual loss of calcium and magnesium ranged from about 1·25 to 2·5 cwt. CaO, and about 5 to 90 lb. MgO, per acre. Another paper[58] covering the main aspects of the need for lime to maintain and improve the fertility of Scottish soils, has been prepared for the Department of Agriculture and Fisheries for Scotland. The amount of lime applied annually is now greater than the estimated losses, but without a further considerable increase in consumption it will be a long time before outstanding deficiencies are overcome.

Further experiments have been commenced to measure the effects of various magnesium treatments on the yield and composition of crops, and to examine the influence of nitrogen and potassium. The preliminary indications are that normal dressings of potassium have very little effect, and even with abnormally heavy applications the only noticeable effect so far has been a slight decrease in the magnesium content of herbage.

Nitrogen. An account of the interrelationships of total nitrogen with carbon, sulphur, and organic phosphorus in soils derived from different parent materials is in press[62]. Field studies, including a preliminary comparison of the effects of applying nitrogen in one, two three, and four dressings, have been continued on the effects of fertilizer nitrogen on the clover content of swards, with particular reference to the fixation of atmospheric nitrogen.

Trace Elements. Field and pot experiments on the residual effects of trace element additions, including copper, cobalt, and manganese, on the yield and composition of grass and arable crops have been continued; information is also being obtained on the effects of lime and fertilizers, especially nitrogen,

on uptake. The soil and crop analyses involved continue to be carried out by the department of Spectrochemistry.

Crop Responses to Fertilizers. Further factorial experiments comprising 64 plots representing all combinations of four levels of nitrogen, phosphate, and potassium have been carried out on oats, swedes, and potatoes to measure responses and two-factor interactions. Factorial designs are also being used to examine in more detail the effects of farmyard manure on the responses of swedes to nitrogen and phosphate.

A paper[60] prepared in collaboration with the section of Statistics has been accepted for publication, summarizing results of regional grassland manuring experiments co-ordinated by the Grassland Committee of the Scottish Agricultural Improvement Council. Yield data are given from six collaborative experiments carried out by the North of Scotland College of Agriculture, the Edinburgh and East of Scotland College of Agriculture, the Hannah Dairy Research Institute, and the Macaulay Institute, covering the effects of various dressings of nitrogen, phosphate, and potash on grassland regularly cut for conservation. The results show that while nitrogen can produce very large increases in yield, an adequate supply of potash is essential if full returns are to be obtained from heavy dressings. Where the response to potash was substantial, there was a large positive interaction between the two nutrients. The need for potash was much greater at the highest rate of 348 lb. N than at rates below 100 lb. N per annum, and was more obvious in the second and third years of the experiments than in the first season. The results suggest that where grass is being regularly cut for conservation about 1 lb. K_2O is required for each lb. N applied. Phosphate, on the other hand, had practically no effect on dry matter yield, either in the presence or absence of nitrogen.

Methods and Times of Fertilizer Application. A paper[36] summarizing results of comparisons of broadcast and band application of fertilizers for swedes and turnips grown in ridges has appeared, and further experiments have been carried out to compare broadcast and band application of different forms of phosphate for swedes and oats. Further comparisons of broadcast and combine drilled dressings of NPK fertilizers for oats and barley have been carried out, and work has continued on the time of application of nitrogen for barley, including comparisons of urea in solid form and in solution.

Advisory Activities

Advisory analyses of soils, crops, liming materials, composts, and farmyard manure have continued. During the year a record number of over 13,500 soil samples were examined, representing an increase of about 1,000 over the previous highest total. These included a number of samples from forestry areas, but the great majority were taken from agricultural and horticultural land by the staff of the North of Scotland College of Agriculture, the increase resulting mainly from the operation of the Small Farmers' Scheme. As in the past, the departments of Spectrochemistry and Plant Physiology

GROUPING OF ADVISORY SOIL SAMPLES FROM AGRICULTURAL LAND ACCORDING TO THEIR CONTENTS OF LIME, PHOSPHATE AND POTASH.

All figures are percentages of the samples examined from 1st January, 1958 to 31st December, 1959.

County	No. of Samples	Lime			Phosphate			Potash		
		S.*	S.L.	L.	S.	S.L.	L.	S.	S.L.	L.
All Counties and Islands	17597	22	64	14	16	53	31	33	66	1
Kincardine	1739	25	61	14	33	56	11	40	60	—
Aberdeen	6267	16	67	17	12	58	30	32	67	1
Banff	1455	18	69	13	9	47	44	36	63	1
Moray and Nairn	1039	31	59	10	32	50	18	28	70	2
Inverness (Mainland)	1284	19	67	14	8	49	43	22	76	2
Ross and Cromarty (Mainland)	1036	21	65	14	14	61	25	22	75	3
Sutherland	868	28	57	15	16	49	35	23	75	2
Caithness	1340	20	66	14	8	45	47	28	72	—

*S.=satisfactory: S.L.=slightly low: L.=low or very low.

collaborated in the examination of soil and produce samples from areas with special problems concerning animal health and crop production.

Classification and recording of advisory soil analyses continues. As indicated in previous reports there has been a gradual improvement in lime and potash status during the past 15 years, but only a very small improvement for phosphate. As shown in the accompanying table, it is also noteworthy that there are large differences between counties. The proportion of soils with satisfactory lime content is higher for Moray and Nairn, Sutherland, and Kincardine, while the position for phosphate is best in Kincardine and Moray and Nairn, and poorest in Banff, Inverness, and Caithness. The position for potash is appreciably better in Kincardine, Banff, and Aberdeen, but the distribution generally is more favourable than for lime and phosphate, only 1 to 3 per cent. of the samples being in the low potash category.

STATISTICS

The section provides a statistical service for the Institute and during the year collaboration with other departments has increased. Nevertheless the work of the section is principally concerned with the field experiment programme of the department of Soil Fertility. In addition to crop yield measurements, some experiments in the programme are also concerned with measurements of crop composition and soil characteristics.

The 48 designs for experiments commenced in 1960 include randomized blocks, split-plot randomized blocks, Latin squares, factorial designs with and without confounding, and lattice squares. Data will be collected from 23 experiments continued from previous years. Among the designs of these are to be found randomized blocks, split-plot randomized blocks, Latin squares, lattice squares, factorials, and confounded factorials, some of which have fractional replication. In the analysis of experiments the hypothesis of proportional response is frequently used when several times or methods of application or forms of a fertilizer are being tested. Through the courtesy of the Agricultural Research Council Unit of Statistics and the Department of Statistics at Rothamsted Experimental Station, the data from a few field experiments have been transferred to punched tape and analysed on the Elliott 401 electronic computer.

The re-examination of a series of NPKD factorial experiments has been completed as a result of interest in some components of high-order interactions involving D (farmyard manure) which had previously been included in the estimate of experimental error. An account of this work is being prepared for publication. It contains a detailed description of a general method for computing estimates of confounded treatment contrasts together with their standard errors. The relative information on these partially confounded contrasts freed from block effects is also presented.

Correlation and regression analyses were used in a comparison of three methods of advisory soil analysis. Linear regression equations provided predictions of any one from any other of the three methods for each of P_2O_5, K_2O, and MgO values. This allowed a comparison of the class boundaries used in the three methods of assessing the phosphate, potash, and magnesium status of soils.

The botanical composition of the sward and the chemical composition of the dominant species from experiments on the establishment of grassland on deep peat were examined on behalf of the section of Peat Ecology. In order to make the variance independent of the mean, the angular transformation was used when the botanical composition data were expressed as percentages and the square root transformation was used for tiller counts.

Several factorial experiments have been designed during the year for the section of Forest Soils. Some of these are in complete blocks, while others are confounded and have split plots. Experiments continued from previous

years include a number of factorial designs with factors at two levels, fertilizer trials in randomized blocks, and a split-plot randomized block design. Measurements of needle nutrient content and height increment obtained from these experiments have been examined and the significance of the results assessed. Analyses of covariance on the pre-treatment annual height increment are made to increase the precision of the treatment comparisons for height increment measurements.

Accounts of collaborative work with the departments of Plant Physiology, Spectrochemistry, and Soil Fertility have been published[21], [28], [60].

The analysis of data and reporting of results from NPK factorial experiments on potatoes is being continued on behalf of the Crop Husbandry Department of the West of Scotland Agricultural College. At one centre, where there was an eelworm infestation in some of the plots, an analysis of covariance failed to show any direct relationship between the yield of tubers and the number of eelworm cysts with larvae. Designs for another series of six experiments have been produced. In two of these the rate of bulking of the potato crop is also being investigated.

A further randomized block experiment was designed in collaboration with the Entomology Department of the North of Scotland College of Agriculture for a study of wheat bulb fly control. The yield of wheat grain and crop damage measurements of a previous insecticide trial have been analysed and a report on the results submitted.

The section is at present accommodated in the Department of Statistics of the University of Aberdeen. Acknowledgment is made to the University of Aberdeen, and in particular to Dr D. J. Finney, F.R.S., for the courtesies shown.

LIBRARY

The Institute maintains a small specialized library with a stock of books and journals covering most branches of soil science and related fields of interest. Books are classified by the Universal Decimal Classification scheme, and a classified catalogue is provided.

The library is primarily for the use of staff, but every effort is made to comply with requests for loans and information from other libraries and individuals, whether received by direct application or through the agency of the Science Library and National Central Library inter-library loan schemes in which the Institute participates.

Exchange arrangements are of particular importance to the library and much of the material added to stock is obtained in this way. Annual reports and reprints of papers published by members of staff are supplied free of charge to anyone interested in the research activities of the Institute. Lists of available reprints are issued and distributed to individuals and institutions in every part of the world, and arrangements can be made for anyone wishing to receive these to be placed on the mailing list.

PUBLICATIONS

(A) *Published—*

1. A method for quantitative mineralogical analysis by X-ray powder diffraction. By W. A. Mitchell. (*Miner. Mag.*, **32,** 492-499, 1960).

   A method of quantitative analysis by photometry of X-ray powder diffraction patterns is described. Co-Kα radiation is used and absorption difficulties are overcome by using thin diluted specimens containing an internal standard. An arbitrary universal intensity scale has been established and the values for the stronger lines of a number of minerals are given. Within individual patterns these are consistent with published data obtained by counter diffractometry.

2. Pseudomorphs after olivine in Markle basalt. By Wilma W. Smith. (*Miner. Mag.*, **32,** 324-331, 1959).

   Pseudomorphs after olivine in Markle basalt from Holyrood Park, Edinburgh, consist of an intimate mixture of hematite and chlorite, along with a small percentage of quartz. A definite relationship exists between the orientations of the two main constituents and is dependent upon their structures.

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

   The apparatus described enables investigations to be carried out in any desired gas or vapour at pressures not far removed from atmospheric. Two specimen-holder blocks have been developed: a nickel one for use with inert gases and high sensitivity of recording, and a ceramic one for use with active gases and vapours and rather lower sensitivities. Evacuation of the system to pressures of less than 0.05 mm. Hg is also possible. The temperature control system consists of a commercial anticipatory temperature controller and a motorized auto-transformer; the differential curve is recorded photographically. Some results are given to illustrate the high sensitivity of the apparatus, its application to highly-organic soil-clays and to the study of combustion reactions.

4. The ageing of sesquioxide gels. I. Iron oxide gels. By R. C. Mackenzie and R. Meldau (Güterloh, Germany). (*Miner. Mag.*, **32,** 153-165, 1959).

   The gels prepared by adding ammonium hydroxide rapidly to ferric chloride solutions to various pH values are shown to consist of amorphous material and crystalline goethite; no other iron oxide was definitely identified in the present experiments. The goethite grows as acicular crystals on ageing at all pH values, but the rate of growth is greater at higher pH values. The exothermic peaks appearing on differential thermograms of such gels are apparently due to coalescence of extremely minute hematite particles to give larger particles, the sharpness of the peak indicating to some extent the size of the original hematite particles. These observations are related to data for other iron oxides, and the morphology of ferric oxide polymorphs under the electron microscope is considered.

5. The differential thermal analysis of humic substances and related materials. By B. D. Mitchell. (*Sci. Proc. roy. Dublin Soc., Ser. A.*, **1,** 105-114, 1960).

   The complete-combustion differential thermal curves for peat are related to botanical origin and degree of humification, and the area under the exothermic peaks provides a measure of the calorific value. By studying, in both oxidizing and inert atmospheres, less complex substances related to those occurring in peat, it has been demonstrated that the major peaks on the thermal curves of peat and its principal components serve to differentiate between the carbohydrate and the complex aromatic materials present.

6. The evaluation of clay mineral composition with particular reference to smectites. By R. C. Mackenzie. (*Silicates Industriels*, **25**, 12-18, 71-75, 1960).

A technique is described whereby not only can the ionic formula of a smectite be deduced from the chemical analysis of an impure sample, but the mineralogical constitution of the sample may also be derived with reasonable accuracy. The information required is (a) a chemical analysis of the sample saturated with a known cation (*e.g.*, Ca^{2+}); (b) the cation-exchange capacity of the sample; (c) the amounts of free oxides present; (d) a limited amount of mineralogical data (obtained, *e.g.*, by X-ray examination). Although the technique is illustrated by its application to seven smectite clays, it could, with suitable modifications, be applied to any group of clay minerals.

7. Studies of root development in a grass sward growing on deep peat using radioactive tracers. By R. Boggie and A. H. Knight. (*J. Brit. Grassl. Soc.*, **15**, 133-136, 1960).

The experiment was designed to investigate the root activity of plants growing in deep peat. This was measured by the absorption of radioactive phosphate placed at different depths in the peat, and the method is described. The roots in the grass/clover sward were apparently confined to the surface 6 inches of the peat and no differences were detected between those growing next the ditch, where the water table was at its lowest, and those in the middle of the plot. These points are discussed, in relation to seasonal differences in the height of the water table, depth of cultivation, and application of lime and fertilizer.

8. Forest history of the Beinn Eighe Nature Reserve. By S. E. Durno and D. N. McVean (The Nature Conservancy). (*New Phytol.*, **58**, 228-236, 1959).

An attempt is made to relate post-glacial forest history, as revealed by pollen analysis and peat stratigraphical methods to the surviving forest vegetation and to the scanty historical records.

9. Scottish soils in relation to afforestation. By W. O. Binns. (*Inst. Biol. J.*, **7**, 18-20, 1960).

Peaty podzols and deep peat are considered, and the importance of ploughing and phosphate fertilizing on the former, and draining and phosphate fertilizing on the latter, are discussed. The use of foliage analysis to diagnose mineral deficiencies is mentioned, and it is suggested that trees on deep peat will probably need fertilizers other than phosphate.

10. Use of fertilizers in the afforestation of deep peat. By T. W. Wright. (*J. Sci. Fd. Agric.*, **10**, 645-650, 1959).

Phosphorus is frequently the primary limiting factor to tree growth on deep peat, and phosphate manuring is now routine Forestry Commission practice. Recent experiments have shown the value of foliage analysis in diagnosing phosphate deficiency, and suggest that, as the trees mature, natural supplies of other nutrients, particularly potassium, may be exhausted.

11. The soils of the country round Kelso and Lauder (Sheets 25 and 26). By J. M. Ragg. (*Memoirs of the Soil Survey of Great Britain: Scotland.* 1960. 202 pp. With soil maps. H.M.S.O., 35/-).

The memoir deals extensively with structural divisions, land form regions, climate, and geology, with particular reference to the soils. Vegetation, agriculture, and forestry are comprehensively covered, and there are chapters dealing with methods and definitions and analytical data. The keys to the two soil maps accompanying the memoir enable the major soil group, parent material, and drainage class of the soils to be easily determined.

12. The soils of the country round Elgin (Sheet 95). By R. Grant. (*Memoirs of the Soil Survey of Great Britain*: *Scotland.* 1960. 86 pp. Macaulay Institute for Soil Research, Aberdeen). *Interim memoir*: *restricted circulation.*

Pending the soil survey of the adjacent inland Sheet (Sheet 85, Rothes), the above memoir has been produced for the benefit of persons concerned with the area. The soil map is published and is obtainable from Ordnance Survey agents. The memoir deals with topics under headings similar to those used in the Kelso-Lauder and earlier memoirs, omitting the chapter on methods and definitions. *Only a very limited number of copies have been prepared.*

13. Some measurements of air-space in Scottish soils. By J. C. C. Romans. (*J. Soil Sci.*, **10**, 201-214, 1959).

Total air-space values are related to the hydrologic sequence of soils. The greatest differences within the profile are found in freely drained soils, where from a value of approximately 50 per cent. air space in the B_2 horizon there is a drop to 25-35 per cent. (depending on type of parent material) in the indurated B_3 horizon. Imperfectly drained soils have a slightly lower air-space in the B_2 horizon and the values decrease below. Poorly drained soils commonly have values between 35 and 40 per cent. and very poorly drained soils values between 30 and 35 per cent. The tendency for values to decrease in the lower horizons of a gley profile becomes less as the natural drainage conditions deteriorate.

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

The area referred to comprises the counties of Banff, Aberdeen, and Kincardine. Climate, solid and glacial geology, and the parent materials as affecting the soils of the region are described. A map showing the distribution of soil associations is given. Some morphological characteristics and chemical properties of a number of genetic soil groups in the main associations are described.

15. Soil conditions in Highland areas. By R. Glentworth. (*Inst. Biol. J.*, **7**, 9-11, 1960).

The soils of the Highlands are discussed with regard to three altitudinal climatic zones—above 2,500 feet, 1,000 to 2,500 feet, and below 1,000 feet. Parent materials, the distribution of the major soil groups, and the properties of the dominant soils in these zones are described. Attention is given to certain properties of the soils as affecting their utilization.

16. Soils of Malta and Gozo. By D. M. Lang. (Colonial Office: Colonial Research Studies No. 29. 1960. 112 pp. H.M.S.O., 42/-).

A publication of the Colonial Pool of Soil Scientists dealing with the geology and geomorphology of the contrasting limestone landscapes and with their extensive disturbance by quarrying, terracing, and carting of soil. The main part of the work deals with classification and description of the soils. Chapters on climate, agriculture, manuring, and vegetation, and a discussion of analytical results are included.

17. Trace elements in Scottish soils. By R. L. Mitchell. (*Proc. Nutr. Soc.*, **19**, 148-154, 1960).

A short review of the chief factors controlling the distribution of trace elements in Scottish soils.

18. Chemical and infrared studies on *Phragmites* peat and its humic acid. By V. C. Farmer and R. I. Morrison. (*Sci. Proc. roy. Dublin Soc., Ser. A*,, **1**, 85-104, 1960).

In peat derived from *Phragmites communis*, there are more carboxylic acid and unsaturated groups and less carbohydrate than in fresh grass. Most of the carboxylic acid groups are associated with unsaturated material which is concentrated in the humic acid and can be further freed from accompanying carbohydrates and peptides.

by acid or alkaline hydrolysis. The unsaturation lies partly in unchanged aromatic rings derived from lignin, and partly in a new unsaturated system formed during peat formation. The latter is largely reducible by sodium amalgam. Aromatic rings derived from lignin are not reduced by sodium amalgam. They reach their highest concentration in the alcohol/benzene soluble fraction of the humic acid. They are also concentrated in a fraction of the humic acid of low carboxyl content, which becomes insoluble in alkali after repeated methylation with dimethyl sulphate.

19. Spectra and structure of 4-hydroxycoumarins. By V. C. Farmer. (*Spectrochim. Acta*, **15**, 870-882, 1959).

4-Hydroxycoumarins contain a conjugated hydroxycarbonyl structure which makes them moderately strong acids. It has been suggested that structures of this type may occur in humic acids from peat and soil organic matter, and so contribute to their base exchange capacity. The spectra of eight 4-hydroxycoumarins, in dioxan solution and in the solid state, indicate that they have coumarin and not the tautomeric chromone structures. The spectra are very similar to those of carboxylic acids, but are distinguished principally by their out-of-plane hydroxyl vibration and by their C-O stretching vibration.

20. Aromatic-alcohol-oxidase activity in the growth medium of *Polystictus versicolor*. By V. C. Farmer, Moira E. K. Henderson, and J. D. Russell. (*Biochem. J.*, **74**, 257-262, 1960).

To gain a better understanding of the changes which plant lignins undergo in the soil, the fungal breakdown of aromatic compounds related to lignin has been studied. Solutions in contact with mats of *Polystictus versicolor* (a white rot fungus) showed oxidase activity, hydrogen being transferred from aromatic alcohols to molecular oxygen, with the formation of aromatic aldehydes and hydrogen peroxide. Activity was concentrated, but only partially recovered, by ammonium sulphate precipitation. β-Naphthyl carbinol, benzyl alcohol, and seven other ring-substituted benzyl alcohols were oxidized, but three secondary 1-phenylethanols were not. Glucose, ethanol, butanol, and L-amino acids were not oxidised. Enzyme activity was little affected by *p*-chloromercuribenzoate, cyanide, or azide ions. Activity was estimated either by oxygen uptake or by spectrophotometric estimation of the rate of aldehyde formation. Lignin is known to contain aromatic alcohol groupings, and these may undergo oxidation by enzyme systems of this type during decomposition in the soil.

21. Interrelationships of catalase, peroxidase, hematin, and chlorophyll. By P. C. DeKock, K. Commisiong, V. C. Farmer, and R. H. E. Inkson. (*Plant Physiol.*, **35**, 599-604, 1960).

A study has been made of the catalase and peroxidase activities and chlorophyll and total hematin contents of mustard plants grown in nutrient culture with different iron, potassium, calcium, and nitrogen levels as well as leaves of nickel-toxic and variegated plants. It appears that catalase and peroxidase show an inverse relationship to each other. The relationship between chlorophyll and hematin is linear, a ratio of sixty to one being found. A spectrophotometric method is reported for determining total hematin compounds as pyridine hemochrome in acetone residues derived from leaves.

22. Interaction between sugars and alkali halides in pressed disks. By V. C. Farmer. (*Chem. & Ind.*, 1306-1307, 1959).

High quality infrared spectra of solid samples of biological or mineral origin can be obtained using the pressed disk technique. The method must be used with caution, however, as samples may be altered during the preparation of the disks. It is shown that altered spectra given by sugars in potassium-bromide disks are due to the presence of traces of sodium bromide in the potassium salt. Polyhydroxy steroids are found to be readily made amorphous by vigorous mechanical grinding.

23. Inter- and intra-molecular hydrogen bonding in anilines. By V. C. Farmer and R. H. Thomson (Chemistry Department, University of Aberdeen). (*Spectrochim. Acta*, **16**, 559-562, 1960).

As pyridine is one of the few efficient solvents for humic acids, its suitability as a solvent for infrared studies has been explored by the study of some simpler compounds in pyridine solution. In this paper spectra obtained for aniline, *N*-methylaniline, their *o*-nitro derivatives, and *o*-ethoxycarbonyl-*N*-methylaniline in pyridine solution are shown to provide information on the molecular environment of amino groups in these compounds. Intramolecular hydrogen bonding is established for the *ortho*-substituted anilines.

24. 2-Ketogluconic acid as a natural chelator produced by soil bacteria. By R. B. Duff and D. M. Webley. (*Chem. & Ind.*, 1376-1377, 1959).

In this Institute it has already been shown that solubilization of mineral phosphates can be effected by bacteria, in soil and the rhizosphere, producing 2-ketogluconic acid. The present work has shown that release of calcium from mineral phosphates and silicates (synthetic and natural) is accompanied by a marked chelation of this cation in the medium as the latter becomes acid during growth of the organism. This chelation can easily be detected by paper chromatography. It seems that the presence of 2-ketogluconate-producing bacteria may help in the weathering and solubilization of minerals to the ultimate benefit of plant growth even in acid soils.

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

By a combination of adsorption and partition chromatography 1^{F}-β-fructosylsucrose and 6^{G}-β-fructosylsucrose have been isolated and identified in aqueous extracts of the four plants examined: *Allium cepa*, *A. porrum*, *Lolium multiflorum*, and *Arrhenatherum elatius* var. *bulbosum*. Evidence was obtained for the presence of smaller amounts of a third fructosylsucrose (6^{F}-β-fructosylsucrose) in the last two species. The distribution of the trisaccharides and other oligosaccharides in the bulb of *A. cepa*, and changes in them following the infiltration of glucose, fructose, and sucrose are described. These findings are discussed in relation to possible mechanisms of fructosan biosynthesis in the monocotyledons.

26. Carbohydrates of the rampion, *Campanula rapunculus* L. By J. S. D. Bacon. (*Nature*, **184**, 1957, 1959).

Earlier work has shown that fructose polysaccharides from the Campanulaceae resemble those from the Compositae. Here, in the case of *C. rapunculus*, the similarity is shown to extend to the oligosaccharide fraction as well. These facts indicate a close evolutionary connection between the two groups.

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

Results are given for levels of D-glyceric acid determined in leaves and other parts of broad bean plants grown under various conditions. It is apparent that it is one of the major organic acids accumulated by the plant.

28. 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. (*Plant & Soil*, **12**, 128-142, 1960).

Mustard plants were grown in nutrient solutions containing 3 levels of Fe, 4 ratios of K/Ca, and 2 ratios of P/N, the iron in each experiment being applied as the chloride, the ethylene diamine tetra-acetic acid or the ethylene N, N′-*bis* (2-*o*-hydroxyphenol) glycine chelate. It was found that increases in the iron level decrease the values of both P/Fe and K/Ca as estimated on the leaf ash when iron was an element limiting the growth of the plants.

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

The importance of the ratios of (total) phosphorus to iron and potassium to calcium in plant leaves is related to the ratio of citric acid to malic acid and the practical implications of such metabolic balances discussed.

30. Variations in the mineral content of storage tissue disks maintained in tap water. By I. R. MacDonald, P. C. DeKock, and A. H. Knight. (*Physiol. Plant.*, **13**, 76-89, 1960).

When maintained under suitable conditions of temperature and aeration, disks of sugar beet, red beet, swede, and carrot absorb large quantities of cations from tap water. The absorption is selective to a marked degree, each tissue consistently exhibiting a characteristic absorption pattern, notably a Na affinity by beet tissue where a Na absorption ratio of 2,300 is attained and a K affinity by swede with an absorption ratio of 14,000. So far as is known these values are higher than any previously recorded for Na or K uptake by plant tissue. Anions are not absorbed in equivalent amounts and cation-anion balance is maintained by an increase in organic anions.

31. Cation exchange properties and pectin content of storage tissue disks. By W. M. Crooke, A. H. Knight, and I. R. MacDonald. (*Plant & Soil*, **13**, 55-67, 1960).

Cation exchange capacity (C.E.C.) of disks of storage tissue of sugar beet, red beet, potato, carrot, and swede turnip kept in running tap water at constant temperature, has been measured using an acid-washing technique. The pectin content of the disks has been estimated by measuring the CO_2 evolved on decarboxylation. There is quantitative agreement between exchange capacity and pectin content of the disks provided the former is measured on a tissue volume basis and also provided that in assessing the latter, the substances yielding CO_2 yet not participating in cation exchange are first removed from the tissues by boiling in water. The C.E.C. and pectin content of the disks increase with time and reach a maximum 3-4 days after the disks are cut from the parent tissue.

32. The bacteriology of the root region of the oat plant grown under controlled pot culture conditions. By H. A. Louw and D. M. Webley. (*J. appl. Bact.*, **22**, 216-226, 1959).

The bacteriology of the root region of the oat plant grown under controlled conditions has been studied. Superphosphate application which increased plant growth also produced an increase in the numbers of bacteria in the root region. This was probably due to the increased plant growth as no such effect was observed in uncropped soil. The numbers of acid producing and dicalcium phosphate dissolving bacteria were increased in the root region, but the latter were not preferentially stimulated.

33. A study of soil bacteria dissolving certain mineral phosphate fertilizers and related compounds. By H. A. Louw and D. M. Webley. (*J. appl. Bact.*, **22**, 227-233, 1959).

Over a hundred isolates which could dissolve calcium carbonate or dicalcium phosphate were obtained in pure culture from the root region of the oat plant. Of these 50 per cent. were pleomorphic and this group contained the highest proportion of isolates which could produce clear zones on agar plates containing certain insoluble inorganic phosphates. Using an analytical method, it was also shown that 82 per cent. could release phosphate from gafsa rock phosphate. The nature of the organic acids produced from glucose by 26 of the isolates was also investigated. The majority produced lactic acid, but a few were shown to give 2-ketogluconic acid. These latter proved to be the best dissolvers of gafsa rock phosphate.

34. Studies on the physiology of lignin decomposition by soil fungi. By Moira E. K. Henderson. (pp. 286-296 of "*The Ecology of Soil Fungi*": an international symposium. Edited by D. Parkinson and J. S. Waid. Liverpool University Press, 1960).

Present day knowledge of the structure of lignin, its occurrence in soil and its decomposition by micro-organisms is surveyed briefly. An outline is given of studies,

made by the author, concerning the ability of various fungi to decompose lignin and to grow on and metabolize compounds related to it. A possible pathway for lignin decomposition by fungi is suggested.

35. The effect of deficiency of iron, zinc, and manganese on the growth and morphology of *Nocardia opaca*. By D. M. Webley. (*J. gen. Microbiol.*, **23**, 87-92, 1960).

Soil micro-organisms, like higher plants, need trace elements for optimum growth and development. This has lead to the use of certain organisms for assaying the availability of certain elements in soils. In the present work it has been shown that a soil nocardia (*Nocardia opaca*) requires iron, zinc, and manganese for optimum growth. It has also been found possible, by morphological examination, to detect cells which are deficient in some of the above mentioned elements. Such deficient cells may be useful for furthering our understanding of the role of trace elements in biological systems.

36. Fertilizer placement for swedes and turnips. By J. W. S. Reith. (*Emp. J. exp. Agric.*, **27**, 300-312, 1959).

Field experiments were carried out over a period of 8 years to compare the effectiveness of fertilizers placed in narrow bands in various positions near the seed with normal broadcast application. Results are given for the effects on the yield and composition of the roots and for nutrient uptake. Superphosphate was most effective placed directly below the seed and the geological nature of the soil parent material had a marked influence on the differences between the two methods of applying this fertilizer. There was no advantage from band placement of sulphate of ammonia and muriate of potash and sometimes placing the former directly below the seed was inferior to broadcasting. The benefits and disadvantages of placing NP, PK, and NPK mixtures are also discussed.

37. Influences of parent material and drainage conditions on soil phosphorus relationships. By E. G. Williams. (*Agrochimica*, **3**, 279-309, 1959).

Influences of parent material and drainage conditions, illustrated with results for Scottish soils, are reviewed with particular reference to their significance in relation to (1) the distribution of organic and inorganic phosphorus in topsoils, subsoils, and particle-size separates, (2) soil properties and constituents governing phosphate sorption, (3) interrelationships and significance of readily soluble phosphorus values by some conventional extraction methods, and (4) some practical aspects of phosphate manuring.

38. Factors affecting the estimation of phosphate esters in soil. By G. Anderson. (*J. Sci. Fd. Agric.*, **11**, 497-503, 1960).

Methods available for the determination of organic phosphate in soils are critically reviewed. Differences between the behaviour of an acid and a calcareous soil are shown. The procedure of Mehta *et al* (*Proc. Soil Sci. Soc. Amer.*, **18**. 443, 1954) is modified by use of a mild alkaline extraction before the acid extraction to obviate the hydrolysis of inositol hexaphosphate, glycerophosphate, glucose-1-phosphate, and nucleic acids.

(B) *Submitted—*

39. Some interstratified clay minerals from basic igneous rocks. By Wilma W. Smith. (To appear in *Clay Min. Bull.*, **4**, 182-190, 1960).

40. Structural relationships within pseudomorphs after olivine. By Wilma W. Smith. (To appear in *Miner. Mag.*).

41. A plate method for studying the breakdown of synthetic and natural silicates by soil bacteria. By D. M. Webley, R. B. Duff, and W. A. Mitchell. (To appear in *Nature*, **188**, 766-767, 1960).

42. Response of some hill pasture types to lime and phosphate. By R. A. Robertson and I. A. Nicholson (Hill Farming Research Organisation). (To appear in *J. Brit. Grassl. Soc.*).

43. Evidence regarding rate of peat growth. By S. E. Durno. (To appear in *J. Ecol.*).

44. Trace element distribution in soil profiles. By D. J. Swaine and R. L. Mitchell. (To appear in *J. Soil Sci.*, **11**, 347-368, 1960).

45. The application of direct photometry to agricultural analysis. By R. O. Scott. (To appear in *J. Sci. Fd. Agric.*, **11**, 584-592, 1960).

46. Application of direct-reading spectrochemical methods to soil analysis. By R. O. Scott. (To appear in *Trans. VII Int. Congr. Soil Sci.*).

47. Contamination problems in soil and plant analysis. By R. L. Mitchell. (To appear in *J. Sci. Fd. Agric.*, **11**, 553-560, 1960).

48. The measurement of aconitase activity in the leaves of various normal and variegated plants. By J. S. D. Bacon, M. J. Palmer, and P. C. DeKock. (To appear in *Biochem. J.*, **78**, 198-204, 1960).

49. The oligofructosides. By J. S. D. Bacon. (To appear in *Bull. Soc. Chim. Biol.*).

50. Mineral content of plant leaves. By P. C. DeKock. (To appear in *The Biochemists Handbook*, Edited by C. Long. London: Spon.).

51. Trace elements in plant nutrition. By P. C. DeKock. (To appear in *Symposia on Trace Elements*, University of Cape Town).

52. Effects of natural and synthetic chelating substances on the mineral status of plants. By P. C. DeKock. (To appear in *Trans. VII. Int. Congr. Soil Sci.*).

53. Changes in the pectin (uronic acid) content of storage tissue disks. By A. H. Knight, W. M. Crooke, I. R. MacDonald, and H. Shepherd. (To appear in *J. exp. Bot.*).

54. Metabolic processes associated with growth in storage tissue disks. By I. R. MacDonald, A. H. Knight, and P. C. DeKock. (To appear in *Physiol. Plant*).

55. Cation-exchange capacity and pectin gradients in leek root segments. By W. M. Crooke, A. H. Knight, and I. R. MacDonald. (To appear in *Plant & Soil*).

56. Evaluation of the plate technique in use for studying phosphate-dissolving micro-organisms. By D. M. Webley. (To appear in *Trans. VII. Int. Congr. Soil Sci.*).

57. Influence of trace elements on the metabolism of aromatic compounds by soil fungi. By Moira E. K. Henderson. (To appear in *J. gen. Microbiol*, **23**, 307-313, 1960).

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