THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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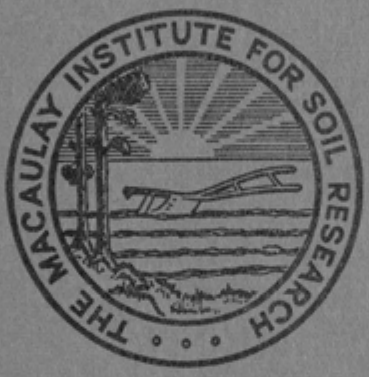

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1963-1964 ANNUAL REPORT

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THE MACAULAY INSTITUTE FOR SOIL RESEARCH

CRAIGIEBUCKLER, ABERDEEN

(Founded 1930)

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Linna E. Bentley (Department of Botany, Bedford College, London).

M. V. Cheshire (Department of Biochemistry and Soil Science, School of Agriculture, Bangor, Wales).

F. J. Coetzer (Stellenbosch-Elsenburg Agricultural College, Stellenbosch, South Africa).

R. L. Halstead (Soil Research Institute, Ottawa, Canada).

G. Hinga (The Scott Agricultural Laboratories, Nairobi, Kenya).

Mrs Alison M. Innes (University of Aberdeen Research Scholar).

E. A. Kirkby (Department of Agriculture, University of Leeds).

J. H. Kirkman (Ministry of Agriculture, Fisheries and Food Scholar).

R. B. McKercher (Soil Science Department, University of Saskatchewan, Saskatoon, Canada).

M. A. H. Naga (Faculty of Agriculture, The University, Cairo, Egypt).

J. B. Passioura (School of Agriculture, The University, Melbourne, Australia).

J. K. Powrie (Waite Agricultural Research Institute, University of Adelaide, Australia).

J. M. Stewart (Department of Biology, McMaster University, Hamilton, Ontario, Canada).

CONTENTS

INTRODUCTION

Steady progress has been maintained in the development of the research programme, the principal aim of which is to obtain by means of field, pot, glasshouse and laboratory studies of soils and plants information of value in the maintenance and improvement of soil fertility. In this work the investigation of specifically Scottish problems is combined with basic research contributing to general agricultural progress. Co-operative work with other research organizations and with the agricultural advisory services has continued, and valuable scientific contacts have been strengthened by Institute representation at conferences and meetings bearing on its research activities, by the provision of facilities for visiting workers from both home and abroad, and by an increasing exchange of publications.

Two members of the staff of the department of Soil Survey were seconded for the period October 1963 to March 1964 to assist in the soil survey of the Sudan. Eight members of staff attended the Eighth International Congress of Soil Science in Rumania, one member attended the Third European Conference on Electron Microscopy in Czechoslovakia and several members attended the International Botanical Congress in Edinburgh. Under Article IV of the Anglo-Soviet Cultural Exchange Agreement, Dr R. C. Mackenzie, head of the department of Pedology, visited Russia for three weeks in December 1963; a most rewarding and interesting programme of visits to research institutes concerned with pedological studies in the U.S.S.R. was arranged for him by the Soviet Ministry of Agriculture. On an invitation from Michigan State University and with the support of the National Science Foundation, Dr V. C. Farmer, department of Spectrochemistry, spent four months in the U.S.A. as a Research Associate assisting in a research project on complexes of clay minerals with simple nitrogenous compounds. Dr P. C. DeKock, head of the department of Plant Physiology, spent two weeks at Ankara University under the auspices of the International Atomic Energy Authority lecturing on the uses of radioisotopes in plant physiology and Mr A. H. Knight of the Radioactivity section of Plant Physiology spent several months at the American University of Beirut, as an International Atomic Energy Authority adviser to the Government of The Lebanon on the agricultural applications of radioistopes. In addition to receiving a very large number of short-term visitors from twenty-two countries, facilities for longer term work have been provided for visiting scientists from Australia, Canada, Egypt, Kenya and South Africa, as well as from centres in this country. Members of staff have again served on various technical committees appointed by the Secretary of State for Scotland and by such bodies as the Department of Agriculture and Fisheries for Scotland, the Ministry of Agriculture, Fisheries and Food, the Agricultural Research Council and the Forestry Commission as well as on other scientific panels and groups.

It is with deep regret that the death on 19th May 1964 of Dr M. J. Palmer is recorded. Dr Palmer joined the staff of the department of Biochemistry in February 1959 and quickly established himself as a popular colleague and as an extremely able and resourceful research worker in the field of plant biochemistry. His sudden death at the early age of thirty-one years is a very great loss to his wife and to a wide circle of friends and colleagues.

PEDOLOGY

There have been few new developments during the year and work has generally followed the lines previously established. The recommendations of the Scottish Peat Committee referred to last year are, however, now being implemented. Thus, a suitable punched-card system which will enable easy recording and ready retrieval of non-industrial information on peat has been developed and preliminary work towards the establishment of a peat survey has proceeded throughout the field season.

The customary amicable arrangements and close collaboration have continued with the Forestry Commission and the Hill Farming Research Organization, as well as with other departments of the Institute. Collaborative studies are also now in progress with the Hydraulics Research Unit, Wallingford. Samples have been examined for various outside bodies and organizations, including the Forestry Commission, the National Coal Board (Nottingham) and the Universities of Aberdeen, Durham and Newcastle.

Extended periods were spent in the department by Mr G. Hinga, Scott Agricultural Laboratories, Nairobi, Kenya, and Dr M. A. H. Naga, Faculty of Agriculture, University of Cairo, Egypt, who concentrated particularly on soil mineralogical techniques. Dr J. M. Stewart, Department of Biology, McMaster University, Hamilton, Ontario, Canada, is currently performing a post-graduate study of the stratigraphy of peat deposits in north-east Scotland, and Mr J. H. Kirkman, a Ministry of Agriculture, Fisheries and Food research scholar, has completed his study of the non-crystalline inorganic constituents of Scottish soils.

Meetings of the Faraday Society and the Clay Minerals Group of the Mineralogical Society have, *inter alia*, been attended by members of staff. Mr R. A. Robertson participated in the International Botanical Congress in Edinburgh, and Mr W. A. Mitchell took part in the discussion on *Experimental Pedology* at the Easter School in Agricultural Science, University of Nottingham; the latter also presented a paper[33] at a meeting of the N.A.T.O. Study Group on Soils at the University of Cambridge. Mr B. D. Mitchell represented the department at the Eighth International Congress of Soil Science in Bucharest, and joined in one of the pre-Congress excursions: at this Congress he was elected President of Commission VII—Soil Mineralogy. Dr E. A. C. Follett read a paper[1] before the Third European Conference on Electron Microscopy in Prague.

Under the provision of Article IV of the Anglo-Soviet Cultural Exchange Agreement, Dr R. C. Mackenzie visited research institutions in the U.S.S.R. for a three-week period during November-December 1963. The Soviet Ministry of Agriculture arranged a very comprehensive scientific programme with periods at Moscow, Baku and Leningrad. In Moscow the institutes visited were the Dokuchaev Institute of Soil Science, the Timiryazev Agricultural Academy, the Institute for the Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, the Kurnakov Institute of General

and Inorganic Chemistry and the Vernadskii Institute of Geochemistry and Analytical Chemistry. At Baku the Azerbaijanian Academy of Sciences played host and something of the work of the Institute of Agrochemistry and Soil Science, the Institute of Geology and the Institute of Chemistry was seen. Time at Leningrad permitted only short visits to the Central Soil Science Museum, the Institute of Silicate Chemistry and the Department of Crystallography of the University. At all these establishments Dr Mackenzie was received with great courtesy and carried out free and far-reaching discussions with many scientists. In addition, he saw a small section of the Exhibition of Economic Achievement and discussed work of mutual interest with Professor S. V. Zonn of the Forestry Research Station; Professor S. G. Sarkisyan of the Institute for the Geology and Exploitation of Mineral Fuels, and Professor L. G. Berg of the Department of Chemistry, University of Kazan. The contacts made were extremely valuable and enabled work in the U.S.S.R. on pedology generally, and on soil mineralogy in particular, to be set in perspective with respect to the conditions prevailing in that vast country. Grateful acknowledgement must be made to the Department of Agriculture and Fisheries for Scotland, the Agricultural Research Council and the Soviet Ministry of Agriculture for the efforts made to ensure the success of the visit.

Soil Mineralogy

Some alterations which have been made to the differential thermal apparatus have improved its performance considerably. Replacement of the earlier temperature control system by a saturable reactor removes the possibility of heat or voltage surges affecting results, and a modified specimen holder permitting gas-flow through the sample greatly improves reproducibility. Certain advantages have also been found to accrue from the use of matched pairs of metal-sheathed, mineral-insulated thermocouples in place of the normal exposed wires. Differential thermal analysis and thermogravimetry have proved valuable in understanding the effects of the exchangeable cation on montmorillonite and illite samples: for montmorillonite, for example, thermogravimetric results have enabled some assessment to be made of absolute hydration numbers for sorbed cations and, on a more practical level, how change in saturating cation might affect water availability in montmorillonitic soils[34]. A chapter describing thermal techniques has now been published in a book dealing with calcium silicates[2], but other two chapters[35, 36] for a book on soil-clay mineralogy are still in press. A supplement to the differential thermal analysis card index has also appeared[3].

The value of electron microscopy and electron diffraction in studies relating to the physical and chemical properties of clay and accessory minerals is becoming increasingly evident with time. Electronoptical and thermal techniques have now been successfully used in a study of the retention of colloidal ferric oxide on clay mineral surfaces and the ageing of this oxide film[37]; the degree of lattice order in a number of synthetic iron oxide samples has also been examined.

The nitrogen-adsorption method for measuring the specific surface areas of soil clays is now being supplemented by other techniques. Surface areas as measured by cetyl pyridinium bromide are similar to those measured by nitrogen adsorption for non-expanding minerals but are very considerably greater for expanding minerals and smaller for allophane. The possible use of this observation in detecting allophane is being investigated.

Pretreatment of Samples. The efficient removal of organic matter from soil clays without affecting the crystalline material present has developed into a major study. Physical techniques such as centrifugation and ultrasonic dispersion do not remove organic matter entirely and some chemical pretreatment appears to be necessary. Since hydrogen peroxide treatment has been considered to have some effect on the inorganic portion of the clay[4] the efficiency of solutions of sodium hypochlorite, a milder reagent, is being investigated.

Fine Sand Fraction. The optical examination of the fine sand fraction of Scottish soils has continued. A magnetic separator is now in operation and enables the heavy minerals to be subdivided into a number of fractions depending on their magnetic susceptibilities; in some instances separation of individual mineral species is possible.

Clay Fraction. The systematic examination of soil clays by X-ray diffraction and thermal methods has continued and samples from the Perth and Arbroath areas (Sheets 48 and 49) show the usual suite of minerals for Scottish soils. Some samples from north-east Scotland have been exhaustively studied to assess the extent of correlation between mineralogy and the pedogenic factors operative. The occurrence of gibbsite in these samples is receiving particular attention. A paper dealing with the techniques employed for clay mineral investigations and the broad results obtained for Scottish clays has been submitted for publication[38] and one dealing specifically with the red glacial deposits from eastern Aberdeenshire has appeared[5].

Soil clays from several overseas territories have also been examined. Some samples from Kenya were, as might be expected, highly kaolinitic, but also showed the presence of varying amounts of montmorillonite, whereas samples from Egypt and Syria were characterized by the presence of considerable amounts of palygorskite. The presence of large amounts of non-crystalline material in Japanese soil clays developed from volcanic ash has been confirmed by differential thermal analysis and further work is in progress. An account[6] of a detailed study of the mineralogy of soils from Ceylon has been published.

Phosphate-Mineral Interaction. Investigations into the reaction between phosphate and soil minerals have continued using X-ray diffraction and electronoptical methods to examine the effect of phosphate solutions, including aqueous extracts from compound granulated fertilizers, on specific minerals. Interactions at the surfaces of fertilizer pellets embedded in moist soils are also being studied.

Rock Weathering and Soil Formation. The parent phlogopite in an ultrabasic rock at Scotscalder, Caithness, has a 1-layer monoclinic structure and

alters in the soil to a 2-layer vermiculite. The structural rearrangements involved are discussed in a paper accepted for publication[39]. A study of the particle-size distribution of the various minerals in a soil profile developed on till derived from Old Red Sandstone sediments is in progress.

Non-crystalline Inorganic Material. The importance of non-crystalline inorganic material in soil clays is now recognized[40] and particular attention has been paid to the identification and estimation of such material in Scottish soil clays. None of the differential dissolution methods so far employed extracts amorphous material only—some crystalline material also seems to be soluble. Yet non-crystalline siliceous material such as allophane is readily dissolved in both cold and hot solutions of sodium carbonate whereas pure clay minerals are only slightly affected. The nature of the material extracted by this reagent from the zonal soil and the associated gley soils of north Ayrshire has been determined using all the instrumental techniques available, and it is clear that the alkali-soluble portion is not a separate phase in these soil clays. Rather it seems to be closely associated with the well-ordered crystalline material and to cement the particles of this together. Moreover, the allophanic material present also appears to prevent complete extraction of free iron oxides.

Organic and Biological Materials. Thermal methods have been applied to the examination of the leaves and pollen of both higher and lower plants, and certain relationships are clear within certain families and genera, as described in a paper submitted for publication[41]. Further studies on the characterization of peat profiles by thermal analysis are currently in progress.

Electron microscopy has been employed to examine in detail the cell surface of a non-fruiting myxobacterium[1]. Techniques employed included shadow-casting, preparation of carbon replicas and negative staining; moreover, the preparation of thin sections by the ultra-microtome enabled a study of the internal organization of the organism to be made.

Crystals of glucoside, isolated in the department of Biochemistry from *Buddleia* and *Plantago* have been characterized by optical and single-crystal X-ray diffraction techniques. The space group and unit-cell dimensions have been determined and the weight of the unit cell calculated.

Soil Analysis

Standard analytical determinations have now been carried out on all the soils collected by the department of Soil Survey during the 1962 field season and on about a tenth of those collected during 1963. Total carbon and loss-on-ignition determinations have been performed on the remainder of the 1963 samples and various other determinations are well in hand. Clay fractions separated from some 130 soils have been analysed for total silica, iron and aluminium and about 150 samples of soil, water, etc., examined for other departments of the Institute and for outside bodies.

Two papers giving an account of collaborative work with the department of Soil Survey on the ability of aqueous extracts of pine needles to complex with sesquioxides[42, 43] have been accepted for publication, and this work is being extended to cover extracts from other botanical species.

Peat and Highly Organic Soils

In view of the Institute's responsibility for the recording, exchange and co-ordination of information on peat in so far as agricultural, horticultural and soil aspects are concerned, a punched-card system for storing literature references has been devised. Methods of encoding peat survey data so as to facilitate the extraction of specific information are also being investigated. A paper detailing the origin, properties and horticultural use of peat[7] has now appeared.

A study of the magnitude and distribution of the nutrient fund in several stands of Callunetum has been completed. The results have been used to assess the significance of nutrient input by precipitation and removal by livestock production in relation to potential nutrient loss following heather burning. This work was undertaken in collaboration with the Hill Farming Research Organization and a joint paper[16] has been submitted for publication. Investigations of the environment and micro-habitat of a typical raised bog have continued at Moss Maud, Kincardineshire, and the broad pattern of soil moisture and temperature fluctations has been established.

Chemical and physical determinations on peat samples have continued.

A reconnaissance survey of 56 peat deposits of the basin type in the Kincardineshire area (Sheets 40, 42 and 43) has been completed and work is in progress to determine a suitable survey procedure which would be applicable to the large areas of hill peat within the region. It is anticipated that detailed surveys of representative deposits will be possible in the near future.

In connection with a joint experiment with the Forestry Commission on the effect of drainage on tree growth a detailed survey has been made of 44 acres of deep peat on Flanders Moss, Stirlingshire. Samples taken on a volume basis from five pits stratified in each of the 44 plots are being analysed to provide a general characterization of the experimental area prior to the introduction of various drainage (depth and spacing) and cultivation treatments. The area will soon be planted and assessments of soil conditions will be made at intervals of several years.

In order to facilitate future correlations between bog and peat types a collection of slides prepared by the direct mounting of samples from selected profiles is being built up as surveys progress. In addition, a satisfactory method of preparing thin sections of peat has been developed and direct comparison with reference slides prepared from living plant material is being used as an approach to the more fundamental problem of peat classification.

A detailed stratigraphical analysis of an isolated peat bank at Cruden Moss, Aberdeenshire, is in progress using the microscopical techniques of tissue analysis reported above. The utility of infrared photography for recording the stratigraphy of exposed peat profiles is also being assessed.

Hydrological Studies. Investigations on the water and nutrient balance of a deep peat catchment at Blacklaw Moss, Lanarkshire, have continued in collaboration with the Hill Farming Research Organization. During the year metering equipment calibrated by the National Institute of Agricultural Engineering, Edinburgh, has been installed in seven sub-catchments and their pretreatment characterization has begun. Acknowledgement must be

made to the Hydraulics Research Unit, Wallingford, for their co-operation and advice, particularly in relation to hydrograph analysis.

Pollen Analysis and Quaternary Research. Pollen analysis of peat from Cruden Moss forms part of an intensive investigation involving the examination of samples from adjacent profiles. The object is to trace the vegetational history of an isolated block of peat and to establish the micro- and macro-environmental conditions under which it developed.

Research on peat and soil development in montane conditions has continued with the examination of high level sites in the Cairngorms and surrounding areas.

Buried peats and peats on raised beaches in the west Highlands and along the Moray Firth are being investigated with a view to indicating their position in post-glacial chronology. Pollen analyses of material from archæological excavations in Sutherland and Perthshire are in progress.

Aeration and Drainage. The experiment at Lon Mor, Inverness-shire, which was set down last year to investigate the physical properties likely to be of relevance to tree growth, has been continued. New instruments have been installed to study the swelling and shrinkage of peat but measurements of oxygen and water-table levels have been temporarily suspended because of experimental difficulties.

Nutrients in Forest Soils

Research work is now concentrated on various aspects of nitrogen nutrition in the forest. In 1962 experiments comparing various levels and frequencies of nitrogen application were laid out in a 20-year-old Scots pine crop in Inshriach Forest, Inverness-shire, and in a 10-year-old mixed crop of Japanese larch and Sitka spruce in Broxa Forest, Yorkshire. Both these forests are on strongly podzolized upland heaths. Preliminary results from Inshriach are indefinite, but those from Broxa suggest that maximum growth of Japanese larch occurs at a foliage nitrogen content of about 3 per cent. and that at levels greater than this growth can be seriously depressed. The Sitka spruce shows increased growth with increasing nitrogen application up to a foliage nitrogen content of about 1·1 per cent., corresponding to an application of 120 lb. nitrogen per acre; beyond this point phosphorus becomes limiting and further applications of nitrogen have no effect. Similar experiments were laid out in 1961 in a 20-year-old Corsican pine crop on sand dunes in Culbin Forest, Morayshire. Applications of up to 180 lb. nitrogen per acre annually have increased height growth by about 120 per cent. and diameter growth by about 160 per cent. over the values for the control plots. Trees treated with a single application of 180 lb. nitrogen per acre at the start of the experiment were still producing annual increments about double those in the control plots three years later. Since, however, the growth curves indicate that greater responses could be obtained with higher applications, two further experiments were laid out this year. Treatments ranging from 75 to 450 lb. nitrogen per acre were applied in a 10-year-old stand and a 38-year-old stand and intensive sampling is being carried out to investigate the uptake and transference of the applied nitrogen and

the response in the growth of the various tissues of the tree. This work is being supplemented by pot experiments in the greenhouse. Investigations into the nitrogen fertilization of near-mature crops at Alltcailleach Forest, Aberdeenshire, are being continued.

About the usual number of foliage analyses have again been carried out for the Forestry Commission. Recommendations on fertilizer applications for forest nurseries, both Forestry Commission and private, based on analyses carried out by the department of Soil Fertility are being provided as previously and steps have been taken to improve this service. Collaborative studies with the departments of Soil Fertility and Plant Physiology have found significant relationships between nitrogen content of needles and root cation-exchange capacity[47]. A paper on nutrient deficiencies in conifers[8] has now appeared, while another[48] on the importance of the nutrient buffering capacity of forest soils in tree nutrition is in press.

SOIL SURVEY

An area of approximately 430 square miles has been surveyed, for the greater part of which air photographs on an approximate scale of 1 : 10,000 have been extensively used, the soil lines being subsequently transferred by Sketchmaster to the 2½ inch field sheets. A considerable reduction in the area surveyed was caused by the restriction of movement imposed by the Aberdeen typhoid epidemic. Of the 430 square miles mapped, 75 were on Sheets 103 (Golspie) and 110 (Latheron), 85 on Sheet 84 (Nairn), 31 on Sheet 85 (Rothes), 40 on Sheet 74 (Crieff), 50 on Sheets 40 (Kinross) and 41 (Elie/North Berwick), 55 on Sheet 32 (Edinburgh) and 100 on Sheets 3 (Stranraer) and 4 (Wigtown). Considerable revision has been done on Sheets 7 and 8 (Girvan and Carrick) and 39 (Stirling).

Detailed surveys have been made of the 25 square miles Candacraig Estate, Strathdon, Aberdeenshire, on a scale of 6 inches to 1 mile, and the Craibstone Experimental Farm of the North of Scotland College of Agriculture, on a scale of 25 inches to 1 mile.

Messrs J. W. Muir, R. Grant and J. C. C. Romans attended the Eighth International Congress of Soil Science at Bucharest where Mr Muir read a paper on a method for measuring the iron mobilizing capacity of aqueous extracts of plants[49]. Dr R. Glentworth gave a paper on soil survey in Great Britain and its possible application to problems in engineering[59] at a N.A.T.O. International Study Group on Soils held in July in Cambridge. A paper has now appeared containing a new assessment of the origin of the red glacial drift deposits of north-east Scotland[5], and an account of the soils of the ultra-basic rocks of the Island of Rhum[9] has also been published. Mr E. L. Birse and Mr J. S. Robertson attended the Tenth International Botanical Congress in Edinburgh. The joint Survey field meeting at Bristol and Exeter was attended by 15 members of the survey staff, and in addition to seeing typical soils in the area—of particular interest being those developed on granite head on Dartmoor—members had an opportunity to discuss classification and the revision of the field handbook.

Messrs J. H. Stevens and J. S. Bibby returned at the end of March after spending the six winter months on secondment to Messrs Hunting Technical Services Ltd. assisting in the soil survey of the Sudan.

A trainee student, Mr Ian C. Baillie, from the Department of Technical Co-operation, commenced work in August and is to spend one year with the Survey.

Sampling. The Proline Corer—a machine loaned by the Soil Survey of England and Wales—was used for extracting 180 cores, 3 feet deep, from selected sites in the Edinburgh, Perth and Stirling areas. Some of the cores are for use as monoliths for aiding the correlation of soils developed on Carboniferous drift and adding to the soil library; others are for micromorphological and chemical analysis. In addition 362 profiles have been sampled.

Maps and Memoirs. The memoir entitled *The Soils of the Country round Aberdeen and Fraserburgh* (Sheets 76, 77, 87 and 97) has been published[16], and the preparation of the memoir entitled *The Soils of the Country round Haddington and Eyemouth* (Combined Sheet 33, 34 and 41) is well advanced. Memoirs in various stages of preparation cover the Ayr, the Banchory/Stonehaven/Forfar, the Perth/Arbroath, the Stirling, and the Girvan/Carrick Sheets.

The soil map for Sheet 57 (Forfar) has been published. The colour proofs of Combined Sheet 33, 34 and part of 41 (Haddington, Eyemouth and part of North Berwick) and Sheet 14 (Ayr) are awaited. A line proof of Combined Sheet 66/67 (Banchory/Stonehaven) has been checked and returned to the Ordnance Survey; the colour proof is awaited. Base maps with 7th edition up-to-date topography have been received for Sheets 84 (Nairn) and parts of 83, 93 and 94 (Inverness, Alness and Cromarty).

Vegetation Surveys. The vegetation has been recorded on parts of Sheets 93 (Alness), 94 (Cromarty), 83 (Inverness) and 84 (Nairn) constituting Easter Ross and the Black Isle. In recording the vegetation of Tom na Gabhar, Aberdeenshire, and Mount Shade, Kincardineshire, it was realized that growth form and habit strongly influenced the number of times a species was 'hit' by the ten-point quadrat. To eliminate this bias three one-metre quadrats were set up on Tom na Gabhar and the set of ten needles was repeatedly placed within each quadrat and the hits on the species recorded. The vegetation was then completely removed to ground level from the quadrats and was subsequently separated into individual species or growth form groups and weighed. From the productivity samples of each species or growth form thus obtained it will be possible to equate the number of times a species is hit to a certain weight of material of that species. Thus, if one gram of *Calluna vulgaris* represents 100 hits by the ten points and one gram of *Vaccinium myrtillus* represents 25 hits, a correction factor, using *Calluna* as the standard, can be used to convert the hits on *Vaccinium* to the same weight basis, i.e. one hit on *Vaccinium* in the field would be equivalent to four hits.

Transect analysis has been continued on the Mount Shade survey.

A start has been made on a more intensive plant sociological investigation in which microchanges in community structure and environmental factors are analysed by means of transects. Mr J. S. Robertson is undertaking studies on this, with particular reference to the bryophytic synusiæ of the vegetation types and their variation in relation to community composition, in approved candidature for the degree of Doctor of Philosophy from the University of Aberdeen.

Micro-morphological Work. Laboratory work during the year has resulted in the production of some 650 thin sections of soil for micromorphological studies. Microscopic examination of thin sections of subalpine and lowland soils continues, with the object of obtaining an understanding of some of the processes involved in the development of the major soil groups. Twenty-five soil monoliths (from which some 100 impregnated

blocks have been taken for future work) have been prepared for inclusion in the library of Scottish soils.

Collaborative Work. Assistance has been given in locating and describing soils of trial plot sites for the three Colleges of Agriculture and the department of Soil Fertility of the Institute. A field day was held for agricultural advisory officers of the East of Scotland College of Agriculture, and another for the West of Scotland Agricultural College, in which commonly occurring soils were demonstrated. Other demonstrations of soils have been given in various areas to officers of the Forestry Commission and to a joint meeting of the West of Scotland and South of Scotland Grassland Societies. Archæological sites at Weem, Aberfeldy, Perthshire, and Helmsdale, Caithness, were visited. In the latter area a podzol with iron pan on granitic drift has been disturbed by the settlement and another podzol profile has formed with 12 inches of peat, A_1/A_2, iron pan, and B_2 horizons, and this now overlies the podzol of the original profile. Descriptions have been made and samples, including those for pollen analysis, together with a control profile, have been taken. Liaison with the Geological Survey regarding drift deposits has continued.

Sheets 7 (Girvan) and 8 (Carrick)

Mapping and revision of the soils of the area around Girvan and the Merrick Hills has been completed this year. This area occupies about 550 square miles of south-west Scotland, is covered by Ordnance Survey 3rd edition Sheets 7 (Girvan) and 8 (Carrick) and comprises roughly the historical district of Carrick and the northern part of Galloway. It is bounded in the west by the coastline, and in the north by a line which passes from just north of Girvan eastwards to the northern slopes of Cairnsmore of Carsphairn. The eastern margin runs from there, obliquely across the valley of the river Ken, to Cairn Edward Forest near New Galloway. The line from this point to Glen App defines the southern limit.

Much of the area consists of remote sparsely populated hills and moorlands. The main extent of high ground lies in the east where the steep slopes of the Merrick, Kells and Lamachan hill ranges rise to over 2,500 feet and dominate the scenery. West of the Minnoch Water the general elevation is below 1,000 feet, the slopes are more gentle and the topography is mainly rolling in character.

The vegetation over the major part of the area is semi-natural, having been modified by grazing and burning. *Molinia* grassland is widespread on peat and peaty gley soils in valleys and along the lower hill slopes, while on upper slopes and hill tops below about 2,000 feet the dominant species in the plant communities are usually *Trichophorum caespitosum, Eriophorum* sp., or *Calluna vulgaris*. Above 2,000 feet, the vegetation is commonly a type of montane grassland in which *Festuca ovina* (var. *vivipara*) is common: *Salix herbacea* and *Carex bigelowii* are also found in small areas above this altitude.

The three streams, the Girvan Water, the River Stinchar and the App Water, carry the major part of the north-east to south-west-flowing drainage

waters which debouch into the Firth of Clyde. A further part of the drainage water of the area flows into the Solway Firth, along the courses of the Luce Water, the Tarf Water and the rivers Cree and Dee, all of which have their sources in this area.

The climate is highly oceanic as in other parts of western Britain. Rainfall is high, over 90 inches per annum being the average recorded in the Loch Dee basin and 50 inches per annum usual over much of the rest of the area, with the exception of a narrow coastal belt where it does not normally exceed 30-35 inches per annum. Below 1,000 feet falls of snow are generally light and it does not lie for long. The prevailing westerly winds, blowing directly off the sea, maintain a fairly high relative humidity in the area.

All the consolidated rocks of the area belong to the Palæozoic era. The oldest and most extensive sedimentary rocks are the tightly folded steeply dipping greywackes, shales, mudstones and conglomerates of the Ordovician and Silurian systems. They cover the major part of the area south-east of the Southern Uplands Fault, except where interrupted by granitic intrusions. The conglomerates of the Barr series of Lapworth are worthy of particular note because of their base-rich nature. Sediments of Old Red Sandstone age are limited to the north-west of the area where they consist mainly of sandstone and conglomerate strata. Outcrops of Carboniferous sediments are small and limited to the Girvan valley, while the small Permian outcrop at Ballantrae is obscured by drift of a contrasting type.

The most extensive igneous rocks are the granitic masses of Loch Dee and Cairnsmore of Fleet, intruded during Old Red Sandstone times. In the vicinity of Straiton intrusions of felsite and acid porphyrite form a distinctive soil parent material. The remaining igneous rocks of the area are of a generally basic character, the more important being the intrusive ultrabasic rocks and spilitic lavas of the Girvan/Ballantrae district.

During the Pleistocene period the area was buried beneath the ice cap which covered northern and central Britain. The pre-existing soils were swept away, and the present soil cover is developed on the materials left after the retreat of the ice. The distribution of erratics in Central Ayrshire indicates that the area was not overriden by ice from the Highlands, but that snow and ice accumulated around the Merrick and Kells Hills from which ice moved radially outwards.

After the retreat of the ice much of the eastern part of the area was left as bare rock, with only a very thin covering of detritus. Differential erosion and the plucking of blocks of rock by ice probably account for the very rugged nature of much of this country. The strongly expressed microtopography had led to the development of complicated soil patterns which have been grouped into mapping units as soil complexes. In the Minnoch Valley and westwards across the moors moraines occur as an extensive field. The moraine is coarse textured, without indications of bedding, very stony, and strongly indurated. In the north-west of the area till has been deposited along most of the lower ground; it is generally of clay loam or sandy clay loam texture with a moderate stone content. South-west of Barrhill the till

occurs in the form of widely scattered isolated drumlins. These deposits are generally of loam texture and strongly indurated.

Post-glacial differential movements of land and sea have led to the exposure of several former beaches and their deposits at levels between 25 feet and 100 feet. Fluvioglacial outwash sands and gravels are of minor occurrence.

The soils have been grouped into associations according to the lithologic composition of their parent materials, as follows:

Association	*Parent Material*
Ettrick	Till, moraine, and other rock detritus derived from greywacke and shales of Ordovician and Silurian age.
Benan	Till and rock detritus derived from Benan conglomerate.
Darleith	Till and rock detritus derived from basic igneous rocks.
Glenalmond	Till, modified till, and rock detritus derived from Old Red Sandstone, Sandstone and conglomerate strata.
Knockskae	Till and rock detritus derived from felsitic rocks.
Dalbeattie	Till, moraine, and rock detritus derived from granitic rocks.
Blair	Till of mixed origin derived from sandstones of Old Red Sandstone age, Ordovician greywackes and shales, and felsitic rocks, with occasional additions of basic igneous material.
Yarrow	Gravels derived from Ordovician and Silurian greywackes and shales.
Darvel	Gravels of mixed origin, but with a considerable proportion of material derived from sediments of Old Red Sandstone and Carboniferous age, with some basic igneous and greywacke material.
Dreghorn	Raised beach deposits of light texture.
Balig	Gravels derived from basic and ultrabasic rocks.

In addition the following miscellaneous soils have been mapped:

Lindfern Complex	Moraine of mixed composition, chiefly greywackes, sandstones, and basic lavas.
Links	
Dunes	
Alluvium	
Blanket Peat	

The primary mapping units, the soil series, are also classified according to the soil morphology and sequence of horizons into Major Soil Groups. The soils in a major soil group owe their formation to similar pedological processes, and resemble each other in chemical as well as physical characters. Considerable progress has been made by the department of Pedology with the analyses of samples, taken from representative profiles in the area, for mechanical composition, loss on ignition, pH, base exchange capacity and exchangeable cations, organic content and composition, and total and acetic

soluble phosphorus. No results are however available as yet for silica: sesquioxide ratios, composition of the clay fraction, or micro-elements.

The high rainfall to which the area is subject, together with other factors, has led to the extensive development of peat. This occurs as hill peat on summits such as Benerairdh Hill, and is also widespread at lower levels, as in the Cooran Lane Valley and near Loch Ochiltree. The depth of peat varies from 12 or 15 inches to 14 feet. It has not yet proved possible to distinguish clearly defined basin peats or raised mosses, but the deposits seem to be invariably acid in nature.

The brown forest soils of the area are generally restricted to low altitudes or steep slopes, sites where the tendency to peat formation is least. These soils have an acid reaction, generally varying between pH 4·5 and 5·5, although values as low as pH 4·1 occur, and are usually allocated to the subgroup of brown forest soils of low base status. Two types of soil can however be distinguished on the basis of both morphology and chemical characteristics. The Linhope series, typical of the more strongly leached group, has a well-developed ochreous B horizon of high chroma (7·5YR/6-8), which contrasts strongly with the brown A horizon, while in the Darleith series the B horizon is much less strongly differentiated from the other layers in the profile. The base exchange capacities of both soils are similar in their surface horizons, ranging from 15 to over 30 m.e./100 g. soil depending on the amount of organic matter present. In the Linhope series, however, the exchange capacity falls with depth in the profile to very low values, often 5 m.e./100 g. soil or less, in the C horizon, whereas while the Darleith series may show some fall with depth, it is usually slight. Similarly the percentage base saturation of the Linhope series, although showing some variation, falls rapidly down the profile to as low as 1·0 per cent.

This contrasts with the Darleith series in which the base saturation often rises down the profile, to about 50 per cent in the C horizon. As would be expected, therefore, the content of cations in the exchange complex of the two soils is not dissimilar in their surface horizons, but the C horizon of the Linhope series in this area is extremely impoverished, while in the Darleith series the C horizon has a high content of exchangeable nutrient bases. The Darleith series has also a considerably higher content of exchangeable magnesium, which may be of some importance in relation to the problem of hypomagnesaemia in cattle.

The organic matter in the A horizon of the Darleith series is generally between 10 and 15 per cent., and has a carbon: nitrogen ratio between 10 and 12. Linhope series has a wider range in organic content, values between 9 and 23 per cent. being found, with the carbon: nitrogen ratio widening to 15 or 16 at the higher levels. Total phosphorus in the Darleith series averages about 300 mg. P_2O_5 per 100 g. soil while the values for the Linhope series are variable, but on the whole rather lower. The amounts of extractable phosphorus are however higher in the Linhope series in this area than in the Darleith series which generally has less than 1 mg. acetic soluble P_2O_5 per 100 g. soil.

At higher altitudes and in the peaty zones of the moorland tracts, peaty podzols are developed extensively on locally steep slopes and on light textured parent materials. The most widespread, and typical of the group, is the Dod series of the Ettrick Association. Leaching and horizon differentiation is much more intense than in the brown forest soils. The well-developed peaty surface horizon, generally between 5 and 11 inches thick, has very low pH values, usually below pH 4, and while there is some rise down the profile, pH 5 is rarely reached in the parent material. The organic content of the H layer is high, generally between 70 and 90 per cent., and the carbon: nitrogen ratio is in the range 20-27, reflecting the acid conditions. The base exchange capacity of this horizon is nevertheless fairly high, being generally between 70 and 100 m.e. per 100 g., and while the degree of saturation is low, generally below 10 per cent., the total amounts of exchangeable bases, although small may be comparable with those in the A horizons of some brown forest soils, 5 m.e. of exchangeable calcium per 100 g. soil being not uncommon in the area.

On passing down into the mineral soil the exchange capacity and amounts of exchangeable bases fall very sharply, total exchange capacities being generally below 20 m.e. per 100 g. soil, and exchangeable calcium may be present in only trace amounts. Similarly, while the H horizon of the Dod series has relatively satisfactory levels of both total and extractable phosphorus, much lower amounts are found in the mineral soil, the fall being most marked in the extractable fraction.

The strong morphological contrast between the brightly coloured yellow brown B_2 horizon and the other horizons of the profile is not reflected in the analytical data discussed above, although the silica: sesquioxide ratio may be expected to show wide variation down the profile.

On the Merrick, Kells and Lamachan Hills a type of mountain or alpine soil has been mapped at elevations of 2,000 feet and over as the Merrick series of the Ettrick Association. The soil consists of a loose mixture of black raw humus and mineral matter, overlying a light brown (10YR5/3) fine sandy loam parent material. The looseness of the upper horizons is thought to be due to frost-heaving during winter. The black raw humus/mineral horizon appears to consist of two layers, in the upper of which the sand grains are clean and bleached, and in the lower the sand and grit particles have greasy black coatings, so that some translocation appears to be taking place.

The reaction of these soils is generally slightly above pH 4 in the surface (rather higher than in the peaty podzol Dod series) rising to near pH 5 in the C horizon. The base exchange capacity generally lies between 25 and 50 m.e. per 100 g. soil and remains fairly constant down the profile until the C horizon where it falls below 20 m.e. per 100 g. soil. The degree of saturation of the exchange complex is however extremely low, being usually below 5 per cent., so that the soil is very impoverished of exchangeable nutrient bases. The organo-mineral horizons contain between 20 and 30 per cent. organic matter, having carbon: nitrogen ratios which range widely, between

12 and 24. Clay content is low, being less than 10 per cent. throughout the profile, while the phosphorus status is similar to that of the peaty podzol.

Some of the most productive farms in the area are situated on brown forest soils which show some gleying in the B and C horizons. They occur mainly in the west and north-west of the area, on middle and lower valley slopes, where the till is of clay loam or sandy clay loam texture. The Kedslie and Dunlop series are typical of this group, while the Altimeg series differs somewhat in being of medium texture and generally having an indurated layer. Analytical data concerning the Kedslie series are not yet available, but results for the Dunlop and Glenalmond series indicate that these soils are less strongly leached than the freely drained soils of the area, the surface horizons having a pH between 5·0 and 5·5, which may rise down the profile to pH 6·5 or 7. The base exchange capacities lie mainly between 15 and 30 m.e. per 100 g. soil and the percentage saturation, usually well over 50 per cent., rises down the profile to near 100 per cent. The surface horizon usually has an organic content between 5 and 10 per cent., with the low carbon:nitrogen ratio of about 10, reflecting the higher base status of the soils. The phosphate status of the Dunlop series is moderate, but values for extractable phosphorus are fairly high and rise down the profile. The exchangeable magnesium of this soil is high throughout, and locally, where concentrations of ultrabasic material occur in the till, may exceed that of exchangeable calcium, but apparently not to such an extent as to affect plant growth.

The Altimeg series is more strongly leached than the Dunlop series or the Kedslie series, and in many chemical features it resembles the Linhope series.

The widespread development of peat over low-lying areas has led to relatively restricted occurrence of non-calcareous gley soils, despite the high rainfall to which the region is subject. The Greensides series of the Ettrick Association occurs locally throughout the area, often in 'flush' sites. The profile is strongly gleyed throughout, although ochreous mottling is less intense than in the Amlaird series or the Ettrick series. The soil is rather more strongly leached than is usual in gley soils, having an acid reaction of between pH 4·5 and 5·5, which rises somewhat down the profile. The base exchange capacity is usually between 15 and 30 m.e. per 100 g. soil in the surface and falls with depth, while the exchange complex becomes more saturated down the profile, values rising from 15 to 30 per cent. in the surface to 60 to 80 per cent. in the parent material.

The Ag horizon has a high organic content which varies between 12 and 25 per cent., the carbon: nitrogen ratios of which also show wide variation. The phosphate status is variable, but usually lies between 200 and 400 mg. P_2O_5 per 100 g. soil in the surface and falls down the profile; conversely the amounts of extractable phosphorus usually rise with depth.

The peaty gley soils, like their counterparts the non-calcareous or low humic gleys, are rather restricted in extent due to the development of peat on the lower and more gentle hill slopes where they might have been

expected to occur. The Dochroyle series of the Ettrick Association, although not typical of the peaty gley soils of Scotland as a whole, occurs widely in the present area. It is usually of medium texture, although the clay content may rise to 30 per cent in the lower horizons, which may also be indurated. Grey colours predominate throughout the mineral soil with only small amounts of ochreous mottling; this is primarily due to the very poor drainage status of the soils, but may also be conditioned by their strongly leached nature having led to the removal of free iron.

The peaty surface horizon closely resembles that of the organic horizon of the Dod series, already described. The pH values are similarly low, between pH 3·6 and 4·3, with a base exchange capacity between 70 and 90 m.e. per 100 g., generally less than 10 per cent. saturated. Down the profile the pH rises somewhat but rarely exceeds 5·5, while base exchange capacity falls markedly in the mineral soil. The degree of saturation of the exchange complex varies irregularly with depth. The carbon : nitrogen ratios are generally near or above 20 but are less uniform than in the peaty podzol Dod series. Total phosphorus generally exceeds 200 mg. P_2O_5 per 100 g. soil in the humus horizon, but values appear to be irregular in the mineral soil, as does the acetic soluble phosphorus.

Besides soil series, a considerable number of soil complexes have been mapped. These units consist of assemblages of different soil profiles, occurring individually in areas too small to be represented adequately on the scale of 1 inch to 1 mile. They are grouped, where possible, with the soil series into associations according to the lithology of their parent materials, most of the units being placed in the Ettrick, Dalbeattie and Darleith Associations.

The underlying cause of these rapid changes of soil type is usually topographic, frequent changes in degree of slope, occurring in rugged or mounds country. The Minnoch and Stroan Complexes, for example, have been mapped on moraine fields in the Minnoch Valley and around Carsphairn. The former is a pattern of peaty podzol profiles developed on greywacke- and shale-derived moraine mounds with intervening areas of peat; in the latter complex the brown forest soil Linhope series occurs on the moraines, which are similarly separated by peat. The Trool and Finlas Complexes are somewhat analogous in that they are also areas of peat with a pattern of protruding knolls, in this case of rock. The Trool Complex has been mapped where the knolls carry mineral soils, the Finlas Complex where the soils have a peaty surface horizon. The Trool Complex is strikingly seen in the valley of the Trool Water, while the Finlas Complex occurs around Loch Finlas and is widespread on the moors behind Knockville.

The major agricultural enterprises are concerned with the utilization of the rough grazings and moorland which cover the larger part of the area. These are mainly grazed by Blackface sheep on an extensive pattern of management. Some cattle are also kept on the moorland, generally of the Galloway breed. Dairy farming, which accounts for the bulk of the remaining agriculture, is concentrated in the west and north-west of the area and along the valley of the River Stinchar and its tributary the Duisk. Ley

grassland as part of a long rotation makes up most of the grazing on these farms, on which some oats and turnips are also grown. Along the coast a specialized type of arable farming is possible; the light soils and freedom from spring frosts have in the past made the growing of early potatoes a profitable enterprise. These are generally harvested in June and early July, following which grass is sown on which lambs are fattened in late summer and autumn.

Since 1945 the Forestry Commission has been very active in the district and large areas around the eastern hills have been afforested. There are now large plantations established in the Minnoch Valley, around Tairlaw, and at Dendeugh. Planting has been carried out up to about 1,500 feet, and the common species are Sitka and Norway spruce, with some pines, and Japanese or Hybrid larch on some of the better soils, such as the Linhope series.

SPECTROCHEMISTRY

The ultimate object of the investigations carried out in this department is to obtain information on the occurrence, properties and behaviour of the constituents of soils and plant materials which can be assessed by spectrochemical and related physicochemical techniques. While considerable emphasis has been laid on trace element investigations, equally important is the work on major inorganic plant nutrients and on the examination by infrared and ultraviolet adsorption methods of soil constituents.

In all trace element investigations, here and elsewhere, there has inevitably been a tendency to concentrate on soil or plant materials associated with disorders in plants or animals suspected to arise from deficiencies or excesses. There is therefore still a lack of information on the normal contents of many types of plants and of their seasonal variations, although a reasonable amount of information is available regarding the normal total and extractable contents of Scottish soils, particularly in the areas which have been surveyed. Several long-term investigations into the uptake of trace elements by plants, and of their distribution within them, have therefore been initiated, to follow up the work on pasture herbage and leaves of deciduous trees which is now approaching completion.

During the past year, visiting workers included Dr F. J. Coetzer of the Stellenbosch-Elsenburg Agricultural College, South Africa, and Miss E. J. Mackenzie of the Edinburgh School of Agriculture.

Dr R. L. Mitchell attended the Eighth International Congress of Soil Science in Bucharest, Rumania, and took part in a 10-day tour following the Congress. Many useful contacts with workers interested in trace element problems were made and a number of promising lines of work were suggested by several of the papers presented, particularly those dealing with the occurrence of sesquioxides and clay minerals in soils and with the nature of the humic acid complexes in soil organic matter. After the Congress, Dr Mitchell visited the Pushkarov Institute of Soil Science in Sofia, Bulgaria, where he presented a paper on the spectrochemical and trace element work at the Macaulay Institute. Dr Mitchell also presented, by invitation, an account[51] of soil research in Scotland to the Naturforschende Gesellschaft in Bern, Switzerland.

Dr V. C. Farmer was granted three months leave of absence to take up a temporary appointment as Research Associate in the Soil Science Department of Michigan State University, on the invitation of Professor M. M. Mortland. The research project, which was supported by the National Science Foundation, concerned complexes of clay minerals with simple nitrogenous compounds, a field which overlaps work in progress at the Macaulay Institute. Although the visit was short, the excellent facilities, which were made freely available, and close collaboration with Professor Mortland resulted in considerable progress in infrared studies of the mechanism of adsorption of ethylamine and pyridine on montmorillonite and an account

of the work has been prepared[52]. The visit, by providing an opportunity for frequent discussion of subjects of common interest, proved valuable and intensely stimulating.

Members of staff again attended numerous meetings of scientific and official organizations in Great Britain. Dr R. L. Mitchell served on the Technical Organizing Committee of the Twelfth International Spectroscopy Colloquium to be held in Exeter in July 1965. Dr A. M. Ure has been responsible for sections dealing with fundamental physical and physico-chemical measurements in a recently published laboratory handbook[11].

Trace Elements in Soils, Plants and Biological Materials

Soils and Soil Parent Materials. Determinations have been made of the total and extractable trace element contents in selected profiles from the area covered by the Soil Survey Memoir for Sheets 33 and 34 (East Lothian), which is now in preparation. The most extensive soil association, Ettrick, derived from greywackes and shales, has one or two interesting features. It occasionally provides surface soils with relatively high extractable lead (>3 p.p.m.) and zinc (>30 p.p.m.) contents. Exceptionally, some of these soils may be deficient in extractable cobalt, copper and manganese, but in this area such deficiencies are more probable, but not inevitable, in soils of the Lauder and Eckford associations on conglomerates and fluvioglacial sands and gravels respectively. The sands of the Fraserburgh Association are the most likely to show cobalt, copper and manganese deficiencies unless remedial measures are taken. None of the soils examined appear liable to give rise to toxicity problems. It is however interesting to record the appearance of a few parts per million of germanium in some organic surface horizons on the Ettrick Association.

The factors involved in the mobilization of trace elements and their location following soil development are discussed in the chapter on *Trace Elements* in American Chemical Society Monograph No. 160 now published[12]. Work on several of the aspects of trace element availability discussed therein is at present in progress. The findings regarding the trace element contents of Swiss granites have now been published[13].

Soil Status and Plant Uptake. Results of several long-term investigations are now approaching completion following the delays brought about by the transfer to the new laboratories some years ago. The work on the seasonal variation in leaves of deciduous trees has been prepared for publication[53, 54], and the analytical work on the mineral composition of a 30-year-old Scots pine is now almost completed. Further attention is being given to the variations in composition of herbage plants, cereals and vegetables at different stages of growth and in different plant parts. The investigation into the factors affecting the lead content of herbage and vegetables has been continued, in collaboration with National Agricultural Advisory Service workers in the south and east of England.

Various investigations on soil-plant relationships following trace elements and other fertilizer treatment are in progress, in collaboration with the department of Soil Fertility, and an attempt is being made to clear off some of the samples from this type of experiment which have been delayed for

several years because of pressure of other work. A recent increase in the staff concerned with this type of work should assist in this respect.

A comprehensive examination is being made of 40 representative samples of sewage sludges from different areas of England, in collaboration with the National Agricultural Advisory Service, who are investigating possible toxic effects in pot experiments. High contents of zinc, nickel and other trace elements have been observed in some instances. The possibility of toxicity from such materials has also led to the examination on behalf of the Forestry Commission of a number of composts derived from town refuse.

Collaboration with other organizations has included the analysis of a number of animal organs for the Rowett Research Institute and the examination of various types of samples from University and other sources both at home and overseas.

A general discussion of the soil factors which can affect the trace element status of plants and animals, referred to in last year's report, has now been published[14], but a further paper[55] reporting some results of trace element and fertilizer trials has not yet appeared.

Spectrochemical Methods of Analysis

The descriptions of the emission methods of spectrochemical analysis employed in the department have been brought up to date, as at February 1963, by the recent publication[15] of the Commonwealth Bureau of Soils Technical Communication No. 44A containing an addendum covering the developments between 1948 and 1963. Any changes or modifications described below refer to the methods detailed therein.

Arc Emission. Work on the extension of the lower limits of determination of biologically important trace elements has continued. The object has been to use a technique compatible with the concentration method for the simultaneous determination of a number of elements, and, as previously reported, the use of a recording microphotometer for low levels of some elements has proved valuable. Accuracy has been improved by the use of iron as variable internal standard in place of the empirical line height measurement initially tried. With the Leeds Northrup Recording Microphotometer, using the plates obtained by standard cathode layer arc excitation of chemical concentrates from plant materials or soil extracts, it has proved feasible to determine 10 p.p.m. Pb (using Pb 2833·0 : Fe 2828·8), 1 p.p.m. Co (using Co 3453·5 : Fe 3451·9) and 1 p.p.m. Mo (using Mo 3170·3 : Fe 3175·4). These limits correspond to 0·02 p.p.m. Pb and 0·002 p.p.m. Co and Mo in an original 20 g. sample concentrated to 40 mg., a reduction of 10 times in the limit of determination obtainable with a non-recording microphotometer. Similar improvements should be obtainable, if required, with a number of other elements.

Following the demonstration of the advantage of recording microphotometry for reduction of limit of determination, progress has been made towards the completion of the display microphotometer previously described. This instrument should be of value in this type of work, and has now been almost completely redesigned and rebuilt with this in view.

The increased sensitivity has been applied to the work on the trace element content of Scots pine, now approaching completion, and to numerous other research projects, including that on factors affecting the lead content of soils and plant materials.

A motorized plate transport for the Large Quartz Spectrograph used for semi-quantitative trace element estimations in soils has now been brought into use and has proved useful in ensuring greater reproducibility between spectrograms and also between operators.

A slight modification in the determination of molybdenum in concentrates is the use of Mo 2871·5, with Fe 2838·18 as internal standard, for contents of molybdenum above 300 p.p.m. The molybdenum line at 3170·3 is not satisfactory at contents above 1000 p.p.m. because of self-absorption, and previously samples were diluted and re-arced if high molybdenum contents were found. Similarly, in the plant ash method, contents of manganese in the range 1000-30,000 p.p.m. in ash are being determined, without dilution, using Mn 3607·5, with Cr 3593·4 as internal standard.

Flame Emission. An E.E.L. flame photometer has been added to the equipment available for flame emission work. This is employed for the analysis of extracts of plant materials in which potassium alone is required, thereby increasing the availability of the two three-channel instruments for samples in which calcium or sodium are also required, and helping to eliminate the bottleneck which arises when one flame photometer is out of commission for servicing. Good agreement between potassium results obtained by the E.E.L. and the three-channel instruments has been found.

Direct Photometry. No significant changes in the employment of the small and medium direct readers have been made during the year. Upwards of 10,000 magnesium determinations are made annually on the small direct reader on behalf of the Soil Fertility and several other departments. Demands for EDTA-extractable copper in soils, determined on the medium instrument, are also considerable.

Atomic Absorption. Several modifications have been made to the atomic absorption equipment built for the determination of cobalt in acetic acid extracts of soils. The signal to noise ratio has been improved by a factor of two by the incorporation of a 100 c/s tuned stage in the Box and Walsh amplifier. The output stage has been modified to supply a Honeywell-Brown recorder as an alternative to the microammeter previously used. This modification includes the incorporation of a scale expansion circuit suitable for use with the recorder. Flowmeters and accurate pressure gauges have been introduced into the flame gas supplies.

Improved dissolution of the evaporated soil extract has been obtained by adding 5 ml. ethanol to the 5 ml. 0·06N HCl, containing 1·0 per cent. Al as chloride, employed previously. No loss of sensitivity results, as the dilution effect is almost exactly counterbalanced by an enhancement of sensitivity following the introduction of ethanol. As a result of these changes, the precision and the accuracy of the method have been considerably improved. Replicate analyses at a concentration of 1 p.p.m. Co (0·5 p.p.m. Co extracted

from the soil) show a standard deviation of around ±2 per cent. and complete replicate analyses of soils, including sampling, extraction, etc., at a similar concentration, show a standard deviation of ±4 per cent. with a recovery of added cobalt indicating an analytical accuracy of a similar order. Over 1000 soil samples are being analysed annually by this method.

Absorption Spectrometry of Soil Constituents

Considerable progress has been made towards establishing a sound theoretical basis for the interpretation of the infrared spectra of layer silicates[16, 17], which form the principal crystalline component of the clay fraction of soils, and often an important part of the silt fraction. Variations in the spectra of pure minerals can now be related to variations in their structure and composition. Vibrations of the lattice hydroxyl groups, as observed under the high resolution of a diffraction grating, have proved to be a valuable diagnostic feature. It seems likely that further useful information could be obtained from studies at wavelengths longer than 16μ, the limit of the infrared spectrometer presently in use, as all silicates have strong absorption bands at longer wavelengths. In addition to the crystalline clay minerals, amorphous and ill-ordered material form an important component of many soil clays. A section on the application of infrared studies to their characterization has been contributed to a review article[10] on amorphous inorganic materials in soils. These amorphous components probably retain much of the oxalate, derived from soil organic matter, found in some soil clays after treatment with hydrogen peroxide[4]. A review of infrared investigations in a wider field of minerals has now been published[18].

The surface properties and reactivity of clay minerals, rather than their underlying structures, are their most important contribution to the physical and chemical properties of soils as a whole. In this field, studies of water sorbed on montmorillonite and saponite[5,6] and on reyerite[19] have been completed. This work has provided a basis for distinguishing adsorbed water from the structural hydroxyl groups of amorphous aluminosilicates. It also provided a sound foundation for an infrared investigation of the adsorption of ammonia by montmorillonite and saponite. As anhydrous ammonia is the cheapest and most widely used nitrogenous fertilizer in the U.S.A., there is considerable interest in the mechanism of adsorption. These studies have resolved a long-standing discussion of the relative importance of physical and chemical adsorption. When in the exchange complex, the polyvalent cations, magnesium, calcium and aluminium are largely or entirely converted to hydroxides by ammonia, and their place on the exchange sites is taken by ammonium ions, but copper and the monovalent cations, lithium and sodium, form principally co-ordination complexes which are stable in vacuum but decomposed by water. Nearly a hundred ammonia analyses made by the department of Pedology have made an important contribution to this work, and thermal gravimetric facilities contributed valuable information in the study of adsorbed water.

Infrared studies have continued to contribute to work in progress in the departments of Microbiology and Biochemistry. A study of polysaccharides

produced by organisms in the root region of grasses has been accepted for publication[57]. A collaborative study with the department of Biochemistry on the role of lignin in the humic acids of sphagnum and phragmites peat, now published[20], involved both infrared and ultraviolet spectrometry, and these techniques assisted in the characterization of the glycoside catalpol. Infrared spectra are also assisting in the characterization of soil and peat waxes.

BIOCHEMISTRY

The department suffered its second tragic loss within twelve months by the sudden death of Dr M. J. Palmer on May 19th 1964.

Dr Palmer received his university education at Hull; after post-graduate work under Dr B. T. Cromwell he was called up for a full period of National Service in the army, and when demobilised joined the department early in 1959 at the age of 26. His basic training was in botany, but both as an undergraduate and as a research student he had been strongly influenced in the direction of biochemistry.

His Ph.D. work at Hull, on transaminase systems in plants, had made him familiar with biochemical manipulations of plant tissue, and he quickly came to grips with the problems that were to occupy him during his five years at the Macaulay. These all concerned the transformation and accumulation of organic acids, which have a special position in the metabolism of plants.

A spectrophotometric method for the assay of aconitase had been adapted for use with small samples of leaves (Bacon, Palmer and DeKock, *Biochem. J.*, **78,** 198, 1961). Aconitase is the enzyme which catalyses the interconversion of citric, *cis*-aconitic and isocitric acids. When applied to leaves of mustard plants this method, which measures the conversion of isocitric acid to aconitic acid, indicated that the enzyme activity was depressed in iron-deficiency. Measurements based on the conversion of citric acid to aconitic, and on the disappearance of *cis*-aconitic acid confirmed this result (Bacon, DeKock and Palmer, *Biochem. J.*, **80,** 64, 1961), but an attempt to measure citric acid production failed because the citric acid content of the leaf extracts was too high. However, it directed attention to the possibility of using micro-analysis to study the effects of variations in mineral nutrition on the organic acids of the mustard leaf (chiefly citric and malic acids).

Simultaneous measurements of these two acids and of four mineral cations (sodium, potassium, magnesium and calcium) suggested a close correlation between calcium and malic acid in the normal plant. Factors influencing calcium uptake (K/Ca ratio) or malic acid synthesis (nitrate as opposed to ammonium nutrition) produced corresponding changes in the other constituent. Iron-deficiency disturbed the relationship (calcium exceeding malic acid), and curative treatment restored the balance (Palmer, DeKock and Bacon, *Biochem. J.*, **86,** 484, 1963).

More drastic means were sought by which the balance might be upset, and were found in control of illumination. Plants grown in an 18-hour day with about 1200 foot-candles of mixed fluorescent and incandescent light accumulated both calcium and malic acid rapidly; in a 6-hour day there was little accumulation of either. Plants transferred from 18-hour days to 6-hour days showed a sharp fall in malic acid content (sometimes as much as 150-200 m.e./kg. fresh weight of leaf), but little change in calcium, suggesting that the plant has no means of disposing of calcium once it has entered

the leaf, and showing quite clearly that malic acid is not an excretory product, but quickly responds to changes in the pattern of metabolism.

The disappearance of the acid might be expected to create an excess of cations over anions, but since the pH of the sap does not alter appreciably there is evidently a compensatory increase in the other anions. Much of the last year of Dr Palmer's research was spent in trying to decide which anions were concerned. Nitrate was the most important, and there were smaller increases in citrate and sulphate. A satisfactory balance sheet could be written for the leaf sap, but analyses of the whole tissue still showed a discrepancy.

Closer examination of the phenomenon revealed diurnal changes in the malic acid content, not previously detected. The content increased during the first few hours of illumination, declined a little during the last few hours and fell more markedly during the dark period; nevertheless the malic acid content increased from day to day.

These more recent findings were the subject of a paper which Dr Palmer was to have given to the Sixth International Congress of Biochemistry in New York in August 1964; they will be prepared for publication in due course.

A rather different line of research, which also originated in the studies of iron-deficient plants, was the purification of aconitase from mustard leaves (*see* Ann. Rep. 1961/62). A full description of the work has now appeared[21]. It confirms the impression received at an earlier stage that this enzyme does not contain iron, nor does it depend upon iron for its action. The depression of aconitase activity in iron-deficiency would therefore seem to be a secondary effect.

Most of this research was essentially quantitative, and many of the analytical procedures used were far from simple. There were the usual difficulties which arise from the labile nature of the substances handled, whether substrates or enzymes. Aconitase itself is particularly unstable, so that the purification procedure had to be carried through as quickly as possible, and repeated many times in order to study various aspects of the purified enzyme. Michael Palmer brought to bear on these problems ingenuity and skill and a capacity for hard and careful work. Apart from the sense of personal loss which was felt throughout the Institute, we are conscious also of a loss of talent and experience which still had much to contribute to the development of plant biochemistry.

Publications. Accounts, mentioned in the last Annual Report, of the decomposition of powdered legume roots in moist sand[22, 23], and a study of the lignin of sphagnum and phragmites and peats derived from them[20], have now been published.

Accounts of several researches in which the late Dr R. B. Duff participated have been accepted for publication. These include the identification of apiose as a major constituent of duckweed, and a minor constituent of many higher plants[58] and collaborative work with Dr D. M. Webley on poly-

saccharide-producing bacteria from grass roots[57] and 2-ketogluconic acid-producing organisms in soil[59].

A paper describing the formation of invertase in discs of beet root tissue prepared and washed under aseptic conditions has been accepted for publication[60]; it was the outcome of joint work with the departments of Plant Physiology and Microbiology.

Conferences. Dr Bacon attended a meeting in Paris on March 7th at the invitation of the Société Française de Physiologie Végétale and presented a review of recent work on invertase in plant tissues, which will be published in the Bulletin of the Society[61]. He was also invited to contribute a paper on carbohydrates to a symposium on *Biosynthesis in Higher Plants* arranged by the Plant Phenolics Group at Leeds in April. Two members of the department attended the International Botanical Congress in Edinburgh in August.

PLANT PHYSIOLOGY

The emphasis in the work on mineral nutrition has now shifted to the organic constituents. The balance between cations in plant leaves and organic anions has been further studied, particularly the alteration in the balance caused by different forms of nitrogen nutrition.

Dr Linna Bentley of Bedford College, London, spent seven months in the department working on the changes in organic acids in leaves in relation to mineral metabolism. Techniques of organic acid estimation, using paper chromatography, have been introduced into the department by her. Mr E. A. Kirkby of the department of Agriculture, University of Leeds, continued collaborative work on the nitrate and ammonium nutrition of plants. Mrs Alison Innes completed a second year of research towards a Ph.D. degree. A survey of her work was presented at a conference of the Society for Experimental Biology in Nottingham in March. During November 1963, Dr P. C. DeKock gave a course of lectures on the use of radioactive isotopes in plant physiological research at the Department of Agriculture of the University of Ankara under the sponsorship of the International Atomic Energy Authority. Mr A. H. Knight spent six months at the American University of Beirut, Lebanon, as an International Atomic Energy Authority adviser to the Government of Lebanon on the application of radioactive isotopes in agriculture. Mr M. V. Cheshire completed his thesis on the copper nutrition of oat plants grown in peat and has received the degree of Doctor of Philosophy from the University of Bangor.

Ion Transport and Electrical Potentials in Plant Cells. ^{36}Cl and ^{32}P have been used in studying the kinetics of active and passive anion transport in slices of red beet tissue. Earlier studies on the inhibition of the development of anion uptake capacity in disks by chloramphenicol have been extended using puromycin which is a more powerful and a more specific protein synthesis inhibitor.

Results obtained from previous experiments investigating the rate of ion uptake from a range of potassium chloride solutions indicated that at 0°C uptake of chloride by potato tuber slices followed closely the passive influx predicted on the basis of theoretically derived values for electrical potential difference across the cell membrane. An apparatus has now been constructed for the measurement of trans-membrane potentials in single cells, and the theoretical values assumed in the above ion transport studies have been confirmed by direct observation. With increasing external potassium chloride concentration the potential becomes more positive, but when chloride concentration alone is increased, with potassium concentration held constant, the potential is little altered. These initial measurements were carried out at room temperature, but the apparatus has now been modified to allow the tissue to be maintained at a temperature near 0°C. Electrical potentials across excised root systems have also been measured, with a view to an assessment of the electro-chemical forces operative in the transport of ions into whole plants.

Cell Water Relations. The relationships between water potential, osmotic potential and water content of leaf tissue have been the subjects of collaborative work with the Department of Botany of the University of Aberdeen. Using an empirical vapour pressure method, measurement of water potential is followed by a measure of osmotic potential (OP) on the same sample after freezing and thawing to remove the wall pressure component. Relative turgidity is measured on a parallel sample. Such a measurement of OP relates to the effective concentration of total cell solutes, including those of the cytoplasm, in the total cell water (including that of the cell wall), and therefore as a measure of vacuolar OP involves certain systematic errors. The outcome of this work will have an important bearing on the interpretation of OP data obtained in connection with the osmo-regulation studies initiated last year.

Cation Exchange Capacity of Plant Materials. An account of the study of cation exchange capacity and mineral composition on a range of species of conifers has been accepted for publication[47]. This is collaborative work with the department of Soil Fertility and the sections of Peat and Forest Soils.

Radioactivity

In addition to the work on ion uptake mentioned above, there has been a continuation of the studies with the department of Biochemistry on the transformations of isotopically labelled compounds when incubated with soil.

MICROBIOLOGY

Dr Moira E. K. Willox (nee Henderson) who has been a member of the staff for over eleven years left the department in June. During her period of service she made notable contributions to the study of fungi involved in the decomposition of lignin and related compounds. She showed, for the first time, that the sub-units of lignin, e.g. vanillic and syringic acids, could be released from wood lignin by certain basidomycetes. She also demonstrated that many of the common soil microfungi could utilize these aromatic compounds for growth. In collaboration with the department of Spectrochemistry she worked out the metabolic pathway by which these aromatic compounds were further broken down. Her work has thrown considerable light on the manner in which the microbiological decay of lignin could take place in soil. Full details of these studies and also her investigations on the role of fungi in the solubilization of silicate minerals have been published in fourteen papers.

Up to the present the department has concerned itself with the principal groups of the soil microflora (bacteria, fungi and actinomycetes) and their role in (a) the decomposition of organic matter and (b) physiological activity in the root region of plants. This year a start has been made on the soil microfauna and a new member of staff was appointed to study soil protozoa, with particular reference to their activity in the root region of plants.

The other lines of work reported on last year have continued and details of the progress made are given below.

Organic Phosphates

The study of the breakdown of organic phosphates by micro-organisms from the root region of pasture grasses has been continued. The plate methods introduced for the detection of the hydrolysis of specific organic phosphates (*see* Ann. Rep. 1962/63) have been supplemented in some instances, by more critical analytical methods. A technique for determining phytase activity in soil micro-organisms[26] has been published. In collaboration with the department of Soil Fertility the hydrolysis of phytic acid in buffered solution by micro-organisms has been studied using chromatographic methods. Preliminary results seem to indicate that there is a stepwise removal of inorganic phosphate from the hexaphosphate resulting in the appearance of intermediate lower esters. Paper chromatographic techniques have also been used in an attempt to demonstrate the course of breakdown of lecithin, ribonucleic and deoxyribonucleic acids.

A study of the effect of clay minerals on the hydrolysis of organic phosphates by soil micro-organisms has been started.

Polysaccharide-producing Bacteria

The results of a systematic study of the incidence and nature of the polysaccharides produced by the predominant organisms in the root region of Ryegrass S23, Timothy S50 and Cocksfoot S143 have been accepted for

publication[57]. It was found that the root surfaces of the grasses had the highest percentage of bacteria producing capsules and/or slime (particularly the latter) when compared with rhizosphere and non-rhizosphere soil. Infrared and paper chromatographic analyses of the extracellular material, carried out by the departments of Spectrochemistry and Biochemistry respectively, showed that the ability to produce fructosans was commoner in isolates from the root surface.

The non-fruiting myxobacterium found on the root surfaces of the pasture grasses (*see* Ann. Rep. 1962/63) has been identified as *Cytophaga johnsonii*. A preliminary account[1] of the electron microscopic study of the surface structure and slime layer of this interesting organism has been published.

Protozoa

Various methods for estimating the protozoan population of the rhizosphere are being investigated. The most satisfactory method so far tested consists of the detection of protozoa in small aliquots (0·5 ml) from 15 two-fold dilutions of a known weight of soil. A concentrated cell mass of the eubacterium *Aerobacter aerogens* (partially disrupted) acts as a food source for the protozoa.

Although a survey of the protozoan population of the rhizosphere soil of the perennial Ryegrass (S23) obtained from the North of Scotland Grassland Centre, Muchalls, is in its preliminary stages, certain features seem clear; (1) rhizopods and flagellates form the bulk of the population, with ciliates present only in small numbers, and (2) significantly larger numbers of protozoa can occur in the rhizosphere soil compared with non-rhizosphere soil, although so far no qualitative differences between them can be detected. This work is continuing.

Incidence of Bacteria Capable of Producing 2-Ketogluconic Acid in Soils

A paper[59] containing full details of a 'most probable number' (MPN) method for enumerating bacteria which produce 2-ketogluconic acid in soils and other habitats has been accepted for publication. The technique, which involves paper chromatography, depends on the ease with which the acid or its calcium salt can be detected on chromatograms. A number of agricultural soils, organic debris from rock crevices and fly ash, which had had no organic manures applied for over twelve years, were examined by the method. The results clearly showed that the highest numbers of this group of bacteria were associated with the habitats rich in organic matter. An enchancement of 2-ketogluconic acid-producing bacteria was also demonstrated in the rhizosphere of barley and around pellets containing starch which had been buried in soil.

Lignin Decomposition

The work reported last year on the use of pellets, consisting of aromatic compounds and a kaolinite base, in a study of soil fungi which could attack the aromatic compounds, has been completed and a paper[63] has been accepted for publication. When the pellets were buried in soil a rapid development of fungi occurred on the surface of, and in the soil surrounding,

pellets containing α-conidenrin, α-conidendrol, syringic and vanillic acids. Species of *Acrostalagmus*, *Cylindrocarpon*, *Cylindrocephalum*, *Fusarium*, *Gliocladium*, *Monocillium*, *Penicillium* and *Volutella* and a number of mycelial yeasts grew in increased numbers. Their growth on the aromatic compounds in pure culture was studied and a correlation was found between the pellet substrates from which they were obtained and the compounds on which they would grow. It was also found that those aromatic compounds which were most rapidly metabolized by fungi in pure culture disappeared most rapidly when buried in soil in pellet form.

The paper on the fungal metabolism of certain aromatic compounds[27] has been published.

SOIL FERTILITY

The research programme continues to be directed towards clarification of the significance of pedological factors, soil properties and environmental conditions in relation to crop production, manurial practices, and the development and calibration of laboratory methods for evaluating soil nutrient status. The experimental approach therefore remains the concurrent development and integration of field, pot and laboratory studies covering different plant nutrients, selected soil types mapped in the Soil Survey of Scotland, and the main agricultural crops.

Advisory soil testing in collaboration with the North of Scotland College of Agriculture, supplemented with contributions to the agricultural press[28] and lectures and demonstrations to various agricultural and horticultural groups, continues to provide the main channel for translating research findings into practice. Collaboration 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 with a number of other research organizations and technical bodies, especially the Hill Farming Research Organization and the Rowett Research Institute. The department also continued to be represented 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 relevant Working Parties organized by the Agricultural Research Council.

Drs E. G. Williams, J. W. S. Reith and G. Anderson took part in the Eighth International Congress of Soil Science in Bucharest, and Dr W. M. Crooke attended the Tenth International Botanical Congress in Edinburgh. Dr Reith also attended a meeting held by the Organization for Economic Co-operation and Development in Paris on the use of black peat in the production of slow acting nitrogen fertilizers, and took part in the conference on availability of soil potassium and magnesium organized by the National Agricultural Advisory Service in London, while Dr Anderson attended the joint meeting of the British Society of Soil Science and the Agriculture Group of the Society of Chemical Industry on soil fertility and nutrient turnover, also in London. Papers on magnesium and organic phosphorus presented at these meetings are mentioned under the appropriate sections below.

Dr J. B. Passioura, School of Agriculture, University of Melbourne, joined the department in November 1963 for one year, with the aid of a studentship from the Commonwealth Scientific and Industrial Research Organization, to work on inorganic soil phosphate. Mr J. K. Powrie, Senior Lecturer in Agronomy, Waite Agricultural Research Institute, University of Adelaide, also came during the year, for five months, to gain experience in this field. In August 1964, Dr R. L. Halstead, Soil Research Institute, Ottawa, arrived to spend a year studying organic phosphates in soils, under the transfer of work arrangement operated by the Research Branch of the Canadian Department of Agriculture.

Mr R. B. McKercher and Mr N. M. Scott have completed the first year of their studies on soil phosphate and soil sulphur relationships respectively, in candidature for the degree of Doctor of Philosophy from the University of Aberdeen.

Effects of Fertilizers on Crop Yields and Composition. A paper[64] summarizing the main effects of N, P and K on the botanical and chemical composition of herbage cut five times per annum for conservation has been accepted for publication. These results are from a series of six collaborative experiments carried out under the auspices of the Grassland Committee of the Scottish Agricultural Improvement Council. No clover survived with dressings of 35 and 70 lb. N per acre per cut, with consequent increases in the proportions of certain grasses, especially ryegrass and cocksfoot. Superphosphate dressings had no effect on botanical composition, while K increased the clover content of the sward only in the absence of N. The percentages of crude protein, Ca, Mg and Na showed a clear increase from the first cut in May to the fifth cut in October. The percentage of crude protein was not normally increased by dressings of 17·5 or 35 lb. N per cut but was always raised by the 70 lb. rate. With adequate K, 350 lb. N per annum at least doubled the total yield of crude protein. The only effect of superphosphate was to give a small but very consistent increase in the percentage of P in the dried herbage. Application of K produced a large increase in the content in the herbage, the effect being very similar in the absence and presence of N. The Na percentage was always reduced by K treatment, but was increased by N. The Ca percentage showed a variable effect of applying N and K separately but was usually reduced when they were applied together. Applying N tended to increase rather than decrease the Mg percentage but K treatment generally depressed it slightly. This effect of K was appreciably less in the presence than in the absence of applied N. The influence of selected treatments on a range of trace elements was measured at one centre. The 350 lb. N per acre per annum treatment reduced the cobalt, manganese and strontium contents of the dried herbage, but there were no other large effects of the N, P and K dressings. Grass treated with heavy dressings of N and regularly cut for conservation removes large quantities of nutrients from the soil and the results emphasize the need for adequate supplementary manuring.

At the invitation of the International Potash Institute, a paper[65] was prepared for its Regional Conference on *Potassium and Crop Quality*, held in Switzerland in June 1964. This summarized some of the main effects of fertilizer dressings, especially K, on the mineral composition of crops grown in Scotland. Except, as outlined above, in the case of herbage, normal dressings of fertilizers generally have very little effect on the contents of N, P, K, Ca and Mg. The variation in mineral composition of crops grown on different fields and in different years is much greater than the effect of fertilizer treatment required to produce optimal yields.

Field experiments of factorial design are being continued on the common agricultural crops on different soil types.

Methods and Times of Applying Fertilizers. The paper[29] containing the main results from a series of experiments testing various times of applying N for barley mentioned in last year's report has now appeared. Field experiments have been continued on swedes and oats to compare broadcast and band applications of various phosphatic compounds.

Calcium and Magnesium. The main findings on the relationship between readily-soluble soil Mg and Mg content of herbage, and on the variation in Mg content of crops treated with various rates and sources of Mg and with other fertilizers, especially N and K, have been reviewed in two papers, one presented at the N.A.A.S. Conference[66] already mentioned and the other at the Eighth International Congress of Soil Science[67]. Single dressings of about 30 lb. Mg per acre have very little effect on crop content but heavy applications supplying about 500 lb. Mg can produce substantial increases, especially in herbage. No large differences have been detected in the effectiveness of magnesium sulphate, kieserite, magnesite, calcined magnesite and magnesian limestone applied at equivalent Mg rates. The tentative conclusion is that, on slightly acid mineral soils in northern Scotland, the exchangeable Mg should not be less than about 20 mg. Mg per 100 g. soil and that the ratio of exchangeable Ca to Mg (mg. per 100 g.) should be less than 10 in order to ensure a reasonably high content of Mg in crops and herbage.

Field and laboratory studies are being continued to measure the long-term effects of various Mg supplements and of fertilizer dressings, especially of K, on the Mg content of crops.

Nitrogen and Potassium. Field experiments have been continued on the effects of various N treatments on mixed grass and clover swards. In one experiment the residual effects of this treatment are being measured with potatoes. A preliminary experiment has also been carried out to compare the influence of ammonium sulphate, ammonium nitrate, and sodium nitrate on the mineral composition of barley at various stages of growth. Further measurements are being made of the effects of K, applied as chloride, sulphate and bicarbonate on the yield and dry matter content of potatoes. It is already clear that high rates of K encourage production of tubers of ware size, and that to obtain a high proportion of seed size only moderate K dressings should be used.

Trace Elements. Field and laboratory studies on the need for trace element applications, on methods and quantities required to correct deficiencies, and on the effects of liming and manuring on the trace element content of crops, especially pasture herbage, are being continued in collaboration with the department of Spectrochemistry. The joint paper[55], mentioned in the last two reports, should appear before the end of 1964. Field work is being continued to measure the duration of the residual effects of soil applications of copper sulphate, and new experiments have been started to compare the effectiveness of solid and liquid dressings.

Organic Phosphorus. Further investigations have been carried out on the nature and quantity of the soil phosphorus compounds occurring in organic

forms. The lipid fraction has been characterized by an examination of its hydrolysis products, and an account of this work[30] has been published.

Next to orthophosphate, the most abundant phosphate compound so far identified in soils is inositol hexaphosphate. Its chemical and physical properties are in several respects similar to those of orthophosphate as it forms iron and aluminium salts insoluble in acid media, and calcium salts insoluble in alkaline media. It is also adsorbed strongly by clay minerals and sesquioxides, and reactions such as these have been cited as the reason for its remarkable stability in soil and for the difficulty with which it can be extracted. However, it has now been shown that some of the soil inositol hexaphosphate is associated with other components of the organic matter from which it is difficult to separate and a paper[31] describing this investigation has been published. The only suitable method of releasing it which has been found so far is by a prolonged hot alkaline hydrolysis. Inositol hexaphosphate bound in this way does not behave like the free ester during chromatography or electrophoresis, and would escape detection in some methods which have been used to measure the ester in soil. Modified methods have therefore been developed so that the total amount of the ester may be more accurately determined. Two contrasting techniques have been used in the extraction of inositol hexaphosphate from British soils. Both methods involved a treatment with hot 3N sodium hydroxide to release bound inositol hexaphosphate, and after extraction, the ester in both cases was precipitated in a crude form, redissolved, and purified by an ion-exchange technique which separated it from other phosphate esters. Phosphate in the appropriate fraction was then measured. In each case the nature of the fraction was confirmed by paper chromatography. A more detailed examination which was carried out in a few cases confirmed the presence of the hexaphosphates of myo-, DL-, and scyllo-inositol. In 17 British surface soils, inositol hexaphosphate was found to account for 24 to 58 per cent. of the total organic phosphate, with an average of 40 per cent. One soil contained 2,000 lb. of P_2O_5 per acre in this form, while the average was 1,000 lb. A paper describing the above methods[68] was presented at the Eighth International Congress of Soil Science in Bucharest.

Inorganic Phosphorus. Long-term experiments measuring residual values of superphosphate and ground mineral phosphate are being continued. Otherwise, the main effort in both the field and pot experiment programme has centred on the relative effectiveness, placement reactions, and residual effects of various types of condensed phosphates compared with orthophosphates, in continuation and extension of a major study initiated two years ago. Further pot work has also been done on the availability of organic phosphates, and the possibility of positive interactions between inositol hexaphosphate and inorganic orthophosphate.

On the laboratory side attention continues to be given to fractionation of the residues of phosphate applications in different soil types and examination of methods for evaluating soil phosphate status, including studies by Dr J. B. Passioura on the use of anion exchange resin to extract water-soluble phosphate and examine phosphate mobility.

Sulphur. Good progress has been made in studies on the sulphur relationships of a range of contrasting Scottish soils, covering the influences of parent material, drainage conditions and soil properties on various aspects of sulphate sorption and retention, and on the distribution and interrelationships of different categories of organic and inorganic sulphur. Field work is continuing to examine the long-term effects of the use of sulphur-free fertilizers.

Cation-exchange Properties and Mineral Composition of Plants. Studies on the lines outlined in last year's Annual Report have continued in collaboration with the department of Plant Physiology. A paper covering the results for conifer species[47] has been accepted for publication. Some attention has also been paid to the effects of soil pH on values of cation-exchange capacity found for roots and leaves of agricultural crops, and to the effects of age on cation-exchange properties, either by periodic sampling of plants or by measurements on a suite of leaves from the same plant.

A paper reviewing methods for measuring the exchange capacity of plant roots, and dealing with the procedure developed in this laboratory, has now been published[32] and an abstract has appeared (*Fert. Feed. St. J.*, **59**, 263-264, 1963) of a lecture on the implications of this property of roots, given to the Agriculture Section of the British Association for the Advancement of Science at its Aberdeen meeting in 1963.

Advisory Work. During the year about 14,500 soil samples were analysed to assess lime and nutrient requirements. Most of these were taken from agricultural or horticultural land by the staff of the North of Scotland College of Agriculture, but they included also a number of soils from forest nurseries which were examined in collaboration with the department of Pedology. Assessment of the trace element status of soil and crop samples from areas with suspected deficiencies or excesses liable to affect either plant growth or animal health continue to be undertaken in collaboration with the department of Spectrochemistry.

The general pattern of the advisory results for lime, phosphorus, potassium and magnesium shows little change over the past two to three years. On nearly 70 per cent. of the fields examined there is still a need for applying lime to correct outstanding deficiencies. The remainder are at a satisfactory level but require a maintenance dressing every six to eight years. In contrast, only about 2 per cent. of the soils have low contents of potassium, nearly half being at a satisfactory level and requiring only maintenance dressings, while the remainder are only slightly low and can be expected to give only small to moderate yield responses to potassium. Thus, except for potatoes grown for ware, the need for applying fertilizer mixtures with high potassium contents to crops grown in the northern half of Scotland is very small. The phosphate position remains the least satisfactory, with about 30 per cent. still in the low category and only about 20 per cent. at an adequate level.

STATISTICS

In addition to collaboration with major experimental projects, advice is also given on such matters as sampling of material, accuracy of an experimenter's own calculations and techniques, and presentation of results in tabular form. These are all matters which contribute to the improvement in the quality of research work.

A considerable proportion of the work of the section continues to arise from the field experiment programme of the department of Soil Fertility. This programme contains almost equal numbers of experiments continued from previous years and commenced in 1964. One series of long-term experiments concerning the residual effects of phosphate fertilizer and its interaction with fresh dressings makes use of fractional replicates of a confounded factorial design. Other series dealing with the effectiveness, on different crops, of a range of phosphate fertilizers and with the method of application of phosphate fertilizers are being continued and extended. The experimental designs used include randomized blocks, triple lattices and lattice squares. Other experimental designs used in the current programme are split-plot randomized blocks, latin squares and factorial designs with and without confounding.

The examination of measurements of the botanical and chemical composition of herbage has been completed for a series of grassland regional manurial experiments of factorial design co-ordinated by the Grassland Committee of the Scottish Agricultural Improvement Council. An account of the results[64], prepared in collaboration with the department of Soil Fertility, has been accepted for publication.

By using the Mitscherlich response equation, the precision of estimates of the soil content of P_2O_5 has been examined[69] in a number of cases of equally and unequally spaced fertilizer levels.

In collaboration with the department of Soil Fertility a number of correlation studies have been carried out to investigate (i) the dependence of the yield and the response to potash of swedes and potatoes on the percentage of clay and the soil content of K_2O as measured by different extraction methods, (ii) the dependence of crop-yield and uptake of P_2O_5 on the resin elution P_2O_5 value for the soil, and (iii) the correlation between the resin elution P_2O_5 value and values of the P_2O_5 content of the soil as measured by a number of extraction methods.

Experiments of factorial design have been planned in collaboration with the department of Plant Physiology to investigate further the phosphorus-iron balance in plant tissue and the effect of form of nitrogen additions on copper deficiency in oats. The examination of an extensive range of measurements on chemical composition of plants has been completed for two series of experiments, mostly of factorial design.

An example of a study of the accuracy of a technique has been on the dilution method of estimating the number of organisms of a given type

present in a medium. On behalf of the department of Microbiology comparisons have been made for series of different steps, lengths and numbers of replications.

Plans have been drawn up for a number of sampling investigations on behalf of the department of Pedology (Peat and Forest Soils) and sampling schemes have been based on the results of completed pilot surveys. The majority of these are concerned with the sampling of peat and the containers and instruments used. Random and stratified-random sampling schemes, and randomized block and latin square designs have been employed. Two randomized block experiments have been designed to study the nitrogen response curve of value increment in Corsican pine of different ages. A computer programme has proved of immense value in processing 2-hourly measurements of the head of water obtained for the whole of 1962 from a catchment area. Results in terms of daily and weekly run-off in cubic feet per acre and equivalent weekly inches of rainfall were produced by the computer in little more than one hour.

The section has co-operated with the North of Scotland College of Agriculture in the combined analysis of barley variety trials from two series extending over a number of sites and a number of years.

Collaboration with the Crop Husbandry Department of the West of Scotland Agricultural College continues. Further series of NPK experiments, based on the 3^3 factorial design, have been planned for swede and potato crops and reports have been submitted on the examination of the results from the 1963 series.

Contact is being maintained with the Agricultural Research Council Unit of Statistics and with the Department of Statistics of the University of Aberdeen, where a course of statistical technique lectures on biometric practice in forestry was given to Honours degree students.

LIBRARY

Despite the difficulties occasioned by the sharp rise in the cost of books and journals in recent years, the Institute library provides good general coverage of the literature on soil science and related subjects. One hundred and nine books were bought during the year and subscriptions taken out to six additional journals. Publications not available in the library are generally obtainable through the inter-library lending schemes, and in the provision of a satisfactory library service the facilities offered by the National Lending Library for Science and Technology are of particular value. This year 516 requests for loans were made to other libraries.

Subject to the requirements of the staff, material is lent to individuals and institutions either on direct application or through the inter-lending services. A list of about 200 periodical holdings is available on request.

Reprints of papers published by members of the Institute staff are obtainable free of charge, and anyone interested in the work of the Institute and wishing to receive regular notification of available reprints can be placed on the mailing list. This year 955 requests were dealt with.

The sixth volume of *Collected Papers* (1958-1960) was issued during the year and Volume 7, covering the years 1961 to 1963, is now in the hands of the binder.

PUBLICATIONS

(A) *Published—*

1. The slime layer of a non-fruiting myxobacterium. By E. A. C. Follett and D. M. Webley. (*Proc. III Europ. Reg. Conf. Electron Microsc., Prague, 1964*, 529-530, 1964.)

   A method is described for demonstrating, by means of electron microscopy, the presence of an outer slime layer on a non-fruiting soil myxobacterium (*Cytophaga johnsonii*) isolated from the root surface of grasses.

2. Differential thermal analysis. By R. C. Mackenzie. (Chap. 22 of *The Chemistry of Cements.* Edited by H. F. W. Taylor. Vol. 2. London: Academic Press, 1964.) *No reprints.*

   A brief review of the theory, apparatus, technique and application of differential thermal anaylsis, with particular reference to calcium silicates.

3. "Scifax" differential thermal data index. Compiled by R. C. Mackenzie. First supplement. (London: Cleaver-Hume Press Ltd., 1964. *Price*: £25. *Enquiries should be addressed to the publisher.*)

   694 punched cards.

4. Occurrence of oxalates in soil clays following hydrogen peroxide treatment. By V. C. Farmer and B. D. Mitchell. (*Soil Sci.*, **96**, 221-229, 1963.)

   The oxidation of organic matter in soil clays with hydrogen peroxide leads to the formation of three types of oxalate: soluble oxalato-aluminates and -ferrates, insoluble oxalate ions chelated to aluminium and iron on the clay surfaces, and insoluble calcium oxalate. These oxalates give undesirable effects in the infrared spectra and differential thermal curves of peroxidized soil clays. The results suggest that hydrogen peroxide treatment may cause significant changes in the composition and properties of the clay.

5. The red glacial drift deposits of north-east Scotland. By R. Glentworth, W. A. Mitchell and B. D. Mitchell. (*Clay Miner. Bull.*, **5**, 373-381, 1964.)

   Extensive deposits of red glacial till and lacustrine clay occur along the Aberdeenshire coastal plain and constitute the parent materials of an important group of agricultural soils. The mineralogy of these red superficial deposits is discussed in relation to the glaciology of the region. The theory that these red glacial drifts were transported from Strathmore is not supported.

6. The mineralogy of some Ceylon soils. By F. S. C. P. Kalpagé, B. D. Mitchell and W. A. Mitchell. (*Clay Miner. Bull.*, **5**, 308-318, 1963.)

   The mineralogical composition of the clay, silt and sand fractions from soil profiles representative of four of Ceylon's major soil groups have been determined using X-ray, differential thermal, optical and chemical methods. The results show that the mineral assemblages in these fractions can be correlated with the pedogenesis and the degree of maturity of the profile.

7. Peat: its origin, properties and use in horticulture. By R. A. Robertson. (*Sci. Hort.*, **16**, 42-51, 1962/3.)

   The term "peat" covers a range of widely different materials not all of which are suitable for horticultural purposes. Factors which influence the origin and development of peat lands in Britain are summarized and the nature of certain common types

of peat is described. Chemical and physical properties of importance to the horticulturist are discussed and attention is drawn to the general need for specifications without which considerable irregularities in marketing procedure and price can be expected.

8. Nutrient deficiencies in conifers. By J. Keay. (*Scot. For.*, **18**, 22-28, 1964.)

An outline of the elements essential for tree growth is given. The technique of foliar analysis for the diagnosis of nutrient deficiencies is described, and the prospects of economic forest fertilization are discussed.

9. Soils of the ultra-basic rocks of the Island of Rhum. By J. M. Ragg and D. F. Ball (Nature Conservancy). (*J. Soil Sci.*, **15**, 124-133, 1964.)

Soils developed on the ultra-basic and basic igneous rocks of Rhum consist of rankers, podzols and braunerden. The braunerden and rankers have normal profiles, but the podzols differ from typical podzols in having no A_2 horizon. All three soil groups have relatively high pH and exchangeable cations, especially magnesium.

10. The soils of the country round Aberdeen, Inverurie and Fraserburgh (Sheets 77, 76 and 87/97). By R. Glentworth and J. W. Muir. (*Mem. Soil Surv. Gt. Brit.*: *Scot.* 1963. pp. 371. London: H.M.S.O. *Price*: £4 4s.)

The country described, comprising approximately 1,000 square miles, covers the eastern part, or Buchan area, of Aberdeenshire, together with an area lying to the west of Aberdeen and generally north of the River Dee. Two types of terrain are represented: (i) the northern lowland region, including the Buchan Platform, the Upper Buchan Platform, and the Skene Lowlands, including the lower Dee and Don Valleys, and (ii) a foothill region including the Grampian foothills, the Insch Valley, the Bogie and Upper Don Valleys and the Alford and Tarland Basins. Following the introductory chapters dealing with the land form regions, climate, and geology, the soils are described in 21 soil associations comprising some 71 named soil series. The generalized accounts of the series are supplemented by chemical analytical data on all of them. Peat deposits, vegetation, agriculture and forestry, and methods and definitions are comprehensively covered. As well as text figures there are 56 plates illustrating landscape and land use and four coloured plates of soil series. From the keys to the three soil maps accompanying the memoir the major soil group, parent material and drainage class of the soils can be determined.

11. Fundamental measurements: Light—measurement of intensity, refractive index and wavelength: Physical chemistry—methods of measurement: Electrical measurements: Temperature measurements. By A. M. Ure. (Chaps. 7-11 of *Laboratory Handbook*. Edited by N. L. Parr. London: Newnes. 1963.) *No reprints.*

12. Trace elements in soils. By R. L. Mitchell. (Chap. 8 of *Chemistry of the Soil.* Edited by F. E. Bear. Second edition. 1964. New York: Reinhold.) *No reprints.*

A general discussion of the source and mode of occurrence of trace elements in soils.

13. The geochemistry of some Swiss granites. By T. Hügi (University of Bern) and D. J. Swaine. (*J. roy. Soc. N.S.W.*, **96**, 65-71, 1963.)

The trace element content of 20 granites from the Aarmassif, Switzerland, are reported. The results support the hypothesis that in the older granites intensive mixing of granitic and metamorphic material occurred.

14. Soil aspects of trace element problems in plants and animals. By R. L. Mitchell. (*J. R. agric. Soc.*, **124**, 75-86, 1963.)

A non-technical discussion of some of the factors affecting the occurrence of trace elements in soils and their uptake by plants.

15. The spectrochemical analysis of soils, plants and related materials. By R. L. Mitchell. (*Tech. Commun. Commonw. Bur. Soils*, No. 44A, 1964. Farnham Royal, Bucks.: Commonwealth Agricultural Bureaux. *Price*: £2.)

An Appendix bringing up to date the descriptions of the methods in use at the Macaulay Institute.

16. The infra-red spectra of layer silicates. By V. C. Farmer and J. D. Russell. (*Spectrochim. Acta*, **20**, 1149-1173, 1964.)

The clay fraction of soils, because of its high surface area and consequent reactivity, plays an important part in determining the physical and chemical properties of soils. Infrared spectroscopy is making an increasing contribution to the characterization of this fraction, limited largely by the lack of background information on the characteristics of its separate components. This paper is concerned with the layer silicates, which constitute the principal crystalline components of the clay fraction. Differences in the infrared absorption pattern which arises from vibrations of the hydroxyl groups and silicon-oxygen framework of these minerals, are correlated with differences in their structure and composition. Minerals examined include pyrophyllite, beidellite, rectorite, muscovite, margarite, montmorillonite, nontronite, celadonite, lepidolite, and kaolins in the dioctahedral series, and talc, hectorite, saponite, phlogopite and biotite in the trioctahedral series.

17. Infrared absorption of hydroxyl groups in kaolinite. By V. C. Farmer. (*Science*, **145**, 1189-1190, 1964.)

An interpretation of the hydroxyl absorption pattern of kaolinite given in the preceding paper (No. 16) is shown to be consistent with new published information.

18. Infrared spectroscopy of silicates and related compounds. By V. C. Farmer. (Chap. 23 of *The Chemistry of Cements*. Edited by H. F. W. Taylor. Vol. 2. 1964 London: Academic Press.) *No reprints.*

The applications of infrared spectroscopy to the study of minerals is reviewed. (141 references).

19. Reyerite. By R. A. Chalmers (University of Aberdeen), V. C. Farmer, R. I. Harker (The Johns-Manville Research Center, New Jersey) and S. Kelly and H. F. W. Taylor (University of Aberdeen). (*Miner. Mag.*, **33**, 821-840, 1964.)

As part of the programme of research into the characterization and differentiation of structural hydroxyl groups and water in soil clays and layer silicates by infrared techniques, the calcium layer silicates, reyerite, truscottite and related synthetic preparations, have been investigated. Ionic hydroxyl groups were found in all specimens, and zeolitic water in reyerite. Chemical analyses, X-ray powder and single-crystal diffraction patterns, and thermal weightloss curves are also reported. The structure of the minerals is discussed in the light of these results.

20. Lignin in sphagnum and phragmites, and in peats derived from these plants. By V. C. Farmer and R. I. Morrison. (*Geochim. et cosmoch. Acta*, **28**, 1537-1546, 1964.)

Organic matter in soils and peats consists either of modified plant constituents or of synthetic products of animals and other organisms participating in the decomposition of the plants. Lignin is the most resistant of the plant constituents and is most likely to accumulate. This paper is concerned with changes in plant materials during peat formation, and in particular with the fate of the lignin fraction, which is followed by nitrobenzene oxidation and infrared spectrophotometric studies. The lignin of sphagnum moss, which differs markedly from that of higher plants, persists apparently unchanged in sphagnum peats of low humification, from which it is not extracted with alkali. In contrast to this, little-altered lignin residues in phragmites peat are concentrated in the alkali-soluble humic acid and account for 25-40 per cent. of the alcohol/benzene-soluble fraction of the humic acid.

21. The relationship between iron and the activity of aconitase purified from the leaves of mustard (*Sinapis alba*). By M. J. Palmer. (*Biochem. J.*, **92**, 404-410, 1964.)

It was shown in previous work that the activity of aconitase (an enzyme directly concerned in the metabolism of organic acids and in the respiration of plants) was lower in iron-deficient than in normal mustard plants. It was suggested in this work that the lower activity was due to a lack of the whole enzyme and not just iron. In order to study this further, the aconitase of mustard leaves has been purified. The results have shown that the purified enzyme has a high activity which is not affected by the addition of iron. Similarly the amount of iron in the enzyme protein is considered to be too low for it to be implicated in the action of the enzyme. It is concluded that iron does not play a direct role in the activity of aconitase and that the lower activity found in iron-deficient tissue is a secondary effect on the production of the enzyme.

22. Decomposition of leguminous plant roots in sand. I. Transformation of nitrogen compounds. By W. Mysków and R. I. Morrison. (*J. Sci. Fd. Agric.*, **14**, 813-821, 1963.)

In view of the imp rtance of yellow lupin (*Lupinus luteus*) and white melilot (*Melilotus alba*) as gree manure plants, a study has been made of the biological decomposition of the root material of these plants in sand culture, and in order to obtain information about the fate of organic nitrogen of plant residues in sandy soils, special attention has been paid to the changes which take place in the amino acids, free and combined, during the decomposition. It was found that most of the amino acid in the root materials was destroyed fairly rapidly, but temporary increases in the amount of certain amino acids and also of glucosamine did take place. After three months the relative levels of amino acids in the acid hydrolysate of the melilot root material were distinctly different from the original; the differences were less in the lupin material. The proportion of the nitrogen in water-insoluble organic compounds in the melilot root mixture decreased rapidly, but in the lupin root mixture it changed only slightly. The mineralization of organic nitrogen compounds was accompanied by the liberation of ammonia and a loss of nitrogen; at the end of the incubation period this loss amounted to 69 per cent. for the melilot material but only 9 per cent. for the lupin material.

23. Decomposition of leguminous plant roots in sand. II. Humus formation. By W. Mysków and R. I. Morrison. (*J. Sci. Fd. Agric.*, **15**, 162-168, 1964.)

The humus substances formed during the decomposition of the root material of yellow lupin and white melilot were fractionated, and the fractions compared with corresponding preparations from a garden soil. Differences were found in the composition, including the content of carbohydrates, amino acids, aromatic substances and methoxyl groups. It is suggested that in the practice of green manuring the choice of plant and the age at which it is ploughed in may have an important influence on soil fertility.

24. Influence of the counter-ion on the absorption isotherm for chloride at low temperature. By G. G. Laties (University of California), I. R. MacDonald, and J. Dainty (University of Edinburgh). (*Plant Physiol.*, **39**, 254-262, 1964.)

Plant nutrition begins with the uptake of nutrients from the environment and ion absorption is therefore essential to the economy of the higher plant. In this study the influence of potassium and calcium on the absorption of chloride at 0°C has been investigated by the use of an isotopic method. The results are shown to be consistent with a straightforward electrochemical theory of ion transport across cell membranes.

25. The physiological significance of the potassium-calcium relationship in plant growth. By P. C. DeKock. (*Outlook on Agriculture*, **4**, 93-98, 1964.)

The relationship which exists between potassium and calcium in plant leaves is discussed. Factors which cause disturbances of this ratio, such as trace element

deficiencies, progressive dilution of the medium and genetical variation, are compared, and it is shown that the potassium and calcium ions may be related to changes in the organic acid composition of leaves in particular in the quantitative changes between citric and malic acid. Such a relationship does not necessarily exclude the many other theories proposed to account for changes in these ions.

26. A rapid method of determining phytase activity of soil micro-organisms. By M. P. Greaves, G. Anderson and D. M. Webley. (*Nature*, **200**, 1231-1232, 1963.)

Phytin is the major constituent of the organo-phosphorus fraction of soils, yet very few studies have been made of its breakdown by pure cultures of micro-organisms. This note describes a rapid method for detecting the presence of phytase in large numbers of organisms isolated from soils, etc. It is hoped that the method will prove useful for studies of the incidence of phytin-splitting micro-organisms in soils and in the root region of plants.

27. Fungal metabolism of certain aromatic compounds related to lignin. By Moira E. K. Henderson. (*Pure appl. Chem.*, **7**, 589-602, 1963.)

The composition, structure and occurrence of lignin and previous work on its decomposition by fungi are described briefly. Different techniques, using soil and wood-rotting fungi, to study the metabolism of lignin-related aromatic compounds are outlined and the results are considered in relation to the decomposition of lignin in soil.

28. Soil fertility on hill farms. By J. W. S. Reith. (*J. Blackface Sheep Breeders' Assoc.*, **17**, 53-55, 1964). *No reprints.*)

The paper considers briefly the main soil conditions affecting growth on both the arable and uncultivated land on hill farms where the soils are usually acid and deficient in plant nutrients, especially lime and phosphate. The general methods of improving the productivity of the soils are outlined, with particular reference to the need for adequate liming and manuring.

29. Seed time and late nitrogen for barley. By J. W. S. Reith. (*Scot. Agric.*, **43**, 214-216, 1964.)

This paper reports briefly the results of experiments carried out to test the effectiveness of nitrogen applied at the following times: (1) all on seed bed immediately before sowing, (2) all four to six weeks after sowing, (3) all eight to ten weeks after sowing, and (4) half on seed bed and half eight to ten weeks later. The yields of grain and straw show no consistent superiority of the split treatment, but applying all the nitrogen eight to ten weeks after seeding is undesirable because of the risk of delaying the ripening of a proportion of the crop. Nitrogen can be applied at any time during the early development of the crop and normally is best given along with phosphate and potash at seeding time.

30. Identification of hydrolysis products of soil phospholipids. By R. J. Hance and G. Anderson. (*Soil Sci.*, **96**, 157-161, 1963.)

In an earlier study on the organic phosphorus fraction in soils an estimation was made of the phospholipid content, involving the measurement of phosphate dissolved by a variety of organic solvents after acid pretreatment. Examination of the extracted material has now confirmed the presence of the lipid components glycerophosphate, choline and ethanolamine. Serine and inositol could not be detected. It seems likely that phosphatidyl choline is one of the predominant phospholipids in the soil.

31. Investigation of an organic phosphorus component of fulvic acid. By G. Anderson and R. J. Hance. (*Plant & Soil*, **19**, 296-303, 1963.)

Further investigations on the nature of the organic phosphate in soils have shown that some of the inositol hexaphosphate, the most abundant constituent of this

fraction, is present in a bound form which has not been previously taken into account during estimation of the ester. Similar materials containing bound inositol hexaphosphate were isolated from six agricultural soils, and their components analysed. The nature of the binding is discussed.

32. The measurement of the cation-exchange capacity of plant roots. By W. M. Crooke. (*Plant & Soil*, **21**, 43-49, 1964.)

The ability of plant roots to exchange cations with the surrounding medium and the fact that different plant species possess this ability in differing degree have led to suggestions that such properties may influence the cation content of plants. Methods designed to measure the cation-exchange properties of plant tissues have been reviewed. They depend on the replacement of the exchangeable cations of the tissues by H+, which is then determined directly, or indirectly by exchange for another cation, usually calcium. A rapid and reproducible method using dried milled plant material has been developed which employs acid-washing followed by titration to pH 7 using a glass electrode. This method has been used successfully for measuring the cation-exchange capacity of different tissues of a wide range of higher and lower plants, and gives values which correlate well with their related uronic acid content.

(B) *Awaiting Publication at 30th September, 1964—*

33. Methods of mineralogical analysis of soils. By W. A. Mitchell. (Submitted to *Proc. N.A.T.O. Int. Study Grp. on Soils, Cambridge Meeting, 1964.*)

34. Hydratationseigenschaften von Montmorillonit. By R. C. Mackenzie. (*Ber. dtsch. keram Ges.*, **41**, 696-708, 1964.)

35. The thermal investigation of soil clays. By R. C. Mackenzie. (pp. 200-244 of *Soil Clay Mineralogy*. Edited by C. I. Rich and G. W. Kunze. Chapel Hill: University of North Carolina Press.)

36. Chemical analysis in the quantitative mineralogical examination of clays. By M. L. Jackson (University of Wisconsin) and R. C. Mackenzie. (pp. 313-325 of *Soil Clay Mineralogy*. Edited by C. I. Rich and G. W. Kunze. Chapel Hill: University of North Carolina Press.)

37. The retention of amorphous, colloidal ferric hydroxide by kaolinites. By E. A. C. Follett. (Submitted to *J. Soil Sci.*)

38. The clay minerals in Scottish soils. By R. C. Mackenzie. (Submitted to *Pochvovedenie.*)

39. An occurrence of phlogopite and its transformation to vermiculite by weathering. By Wilma W. Aitken. (Submitted to *Miner. Mag.*)

40. Amorphous inorganic material in soil. By B. D. Mitchell, V. C. Farmer and W. J. McHardy. (*Adv. Agron.*, **16**, 327-383, 1964.)

41. The application of differential thermal analysis to plant materials. By B. D. Mitchell and A. H. Knight. (Submitted to *J. exp. Bot.*)

42. The mobilization of iron by aqueous extracts of plants. I. Composition of the amino-acid and organic acid fractions of the extract. By J. W. Muir, R. I. Morrison, C. J. Bown and J. Logan. (*J. Soil Sci.*, **15**, 220-225, 1964.)

43. The mobilization of iron by aqueous extracts of plants. II. Mobilization by the amino-acid and organic acid fractions of a pine needle extract. By J. W. Muir, G. Logan and C. J. Bown. (*J. Soil Sci.*, **15**, 226-237, 1964.)

44. Scottish peat resources. By R. A. Robertson. (Submitted to *Trans. Int. Peat Congr. Leningrad, 1963.*)

45. Run-off studies on a peat catchment. By R. A. Robertson and I. A. Nicholson and R. Hughes (Hill Farming Research Organization). (Submitted to *Trans. Int. Peat Congr., Leningrad, 1963.*)

46. Magnitude of the nutrient fund in heather ecosystems. By R. A. Robertson and G. E. Davies (Hill Farm Research Organization). (Submitted to *J. appl. Ecol.*)

47. Mineral composition, cation-exchange properties and uronic acid content of various tissues of conifers. By W. M. Crooke, A. H. Knight and J. Keay. (*For. Sci.*, **10**, 415-427, 1964.)

48. Quantity potential relationships in nutrient studies. By J. B. Craig. (*Scot. For.*, **18**, 318-319, 1964.)

49. A method for measuring the iron-mobilizing capacity of aqueous extracts of plants. By J. W. Muir. (Submitted to *Trans. VIII Int. Congr. Soil Sci., Bucharest, 1964.*)

50. Soil survey of Great Britain: application to problems of engineering. By R. Glentworth. (Submitted to *Proc. N.A.T.O. Int. Study Grp. on Soils, Cambridge Meeting, 1964.*)

51. Soil research in Scotland. By R. L. Mitchell. (Submitted to *Mitt. naturf. Ges. Bern.*)

52. An infrared study of complexes of ethylamine with ethylammonium and copper ions in montmorillonite. By V. C. Farmer and M. M. Mortland (University of Michigan). (Submitted to *J. phys. Chem.*)

53. The trace and major element composition of the leaves of some deciduous trees. I. Sampling technique. By M. M. Guha and R. L. Mitchell. (Submitted to *Plant & Soil.*)

54. The trace and major element composition of the leaves of some deciduous trees. II. Seasonal changes. By M. M. Guha and R. L. Mitchell. (Submitted to *Plant & Soil.*)

55. The effect of soil treatment on trace element uptake by plants. By J. W. S. Reith and R. L. Mitchell. (Submitted to *Proc. IV Int. Colloq. Plant Anal. Fert. Problems, 1962.*)

56. An infrared spectroscopic study of the dehydration of montmorillonite and saponite. By J. D. Russell and V. C. Farmer. (Submitted to *Clay Miner. Bull.*)

57. A study of polysaccharide-producing organisms occurring in the root region of certain pasture grasses. By D. M. Webley, R. B. Duff, J. S. D. Bacon and V. C. Farmer. (Submitted to *J. Soil Sci.*)

58. The occurrence of apiose in *Lemna* (duckweed) and other angiosperms. By R. B. Duff. (Submitted to *Biochem. J.*)

59. The incidence, in soils and other habitats, of micro-organisms producing 2-keto-gluconic acid. By D. M. Webley and R. B. Duff. (Submitted to *Plant & Soil.*)

60. The development of invertase activity in slices of the root of *Beta vulgaris* L. washed under aseptic conditions. By J. S. D. Bacon, I. R. MacDonald and A. H. Knight. (*Biochem. J.*, **94**, 175-182, 1965.)

61. Quelques speculations sur le role de l'invertase dans les tissues vegetaux. By J. S. D. Bacon. (Submitted to *Bull. Soc. franc. Physiol. veg.*)

62. A comparative study of the influence of salt type and concentration on $^{14}CO_2$ fixation in potato slices at 25°C and 0°C. By I. R. MacDonald and G. G. Laties (University of California). (*J. exp. Bot.*, **15**, 530-537, 1964.)

63. Enrichment in soil of fungi which utilize aromatic compounds. By Moira E. K. Henderson. (Submitted to *Plant & Soil.*)

64. The effect of fertilizer on herbage production. II. The effect of nitrogen, phosphorus and potassium on botanical and chemical composition. By J. W. S. Reith and R. H. E. Inkson *and collaborators.* (*J. agric. Sci.*, **63**, 209-219, 1964.)

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66. Effects of soil magnesium levels and of magnesium dressings on crop yield and composition. By J. W. S. Reith. (Submitted to *Proc. N.A.A.S. Conf. on Availability of Soil Potassium and Magnesium, London, 1963.*)

67. Effect of magnesium dressings on soils and crops. By J. W. S. Reith. (Submitted to *Trans. VIII Int. Congr. Soil Sci., Bucharest, 1964.*)

68. Investigations on the analysis of inositol hexaphosphate in soils. By G. Anderson. (Submitted to *Trans. VIII Int. Congr. Soil Sci., Bucharest, 1964.*)

69. The precision of estimates of the soil content of phosphate using the Mitscherlich response equation. By R. H. E. Inkson. (*Biometrics*, **20**, 873-882, 1964.)