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MACAULAY INSTITUTE  
FOR SOIL RESEARCH

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1941-1942

ANNUAL  
REPORT

# THE MACAULAY INSTITUTE FOR SOIL RESEARCH

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ADVISORY work and war-time problems continue to constitute the major part of the Institute's activities. A limited amount of soil survey work has again been carried out in conjunction with advisory sampling, and the survey of the peat resources of Scotland has been recommenced in collaboration with the Geological Survey of Great Britain. The spectrographic work has been further developed and Dr. D. M. C. Macewan has been appointed on a special grant from the Agricultural Research Council to undertake X-ray investigations.

As before, there has been co-operation with various other institutions, including the North of Scotland College of Agriculture, the Animal Diseases Research Association, the Forestry Commission and the Geological Survey. During the year the Institute has been represented on various committees, such as the Department of Agriculture's Scottish Lime Technical Committee and the Agricultural Research Council's conferences on mineral deficiencies of agricultural and horticultural crops and on the differences of feeding value for cattle of different pastures.

One of the main obstacles to increasing food production is lack of lime and, until adequate supplies are forthcoming from the ample resources in this country, farmers will be unable to benefit fully from the advice they receive.

It is already clear that detailed information regarding the soil resources of the country will be required at the end of the war by those dealing with land utilization and it is felt that a comprehensive soil survey programme should be drawn up and surveyors trained.

## SOIL FERTILITY AND ADVISORY WORK

### ADVISORY WORK

In view of the need for using to the best advantage the supplies of lime and fertilizers available, particular attention has again been given to advisory work and to problems of immediate practical importance. The bulk of the advisory work has been undertaken in connexion with general problems of liming and manuring on ordinary agricultural land, but a considerable amount of work has also been done on landing grounds on behalf of the Air Ministry, on Forestry Commission nurseries and on land under market garden crops, allotments, etc. Analyses have also been carried out on various materials such as by-product and waste limes, shell sands, wood ashes, flue dusts, sludges and other substances likely to be of value on the land.

During the year over 3,600 samples of soil have been tested and advice given on the treatment likely to be most suitable for the fields in question. On account of heavy snowfalls, field work had to be almost entirely abandoned for about two and a half months during the winter; but for this, a considerably greater number of samples would have been dealt with. As in previous years, most of the actual soil sampling work has been done by members of the staffs of the Institute and the North of Scotland College of Agriculture. A scheme of voluntary sampling with the aid mainly of rural school teachers, which was proving of great assistance to the Institute, has had to be largely abandoned on account of the calls made on these men by Home Guard and other defence duties.

Several short articles on problems of practical importance such as storage and methods and time of application of fertilizers and lime have been contributed to "Notes for Farmers," a Department of Agriculture for Scotland publication.

From results obtained on advisory samples during 1940 and 1941 a comparison has been made of the lime, phosphate and potash contents of soils from arable rotation land and old grassland in the North of Scotland. On the basis of their plant food contents the soils have been grouped as satisfactory, slightly low or low in relation to the needs of a rotation of crops of cereals, turnips, potatoes, hay and pasture which is commonly followed in the district. A separate grouping of the soils has also been made according to their parent rocks and some of the results are given in Table I.

The numbers of samples in the quartz-rich and peat groups are too small to permit of generalization, but have been included as giving some indication of the deficiencies to be expected in such soils. The results in Table I are in general agreement with those given for smaller numbers of samples in last year's report, and the main conclusions may be summarized as follows:

*Lime.*—Lime deficiency is very widespread in both arable rotation land and grassland and is most pronounced in soils derived from slates and shales and from quartz-rich rocks. As could be expected, the position is less unsatisfactory in soils of the basic igneous group than

TABLE I  
GROUPING OF ADVISORY SOIL SAMPLES ACCORDING TO THEIR CONTENTS OF LIME, PHOSPHATE AND POTASH

The figures under the various heads are percentages of the samples examined

Geological Origin.	No. of Samples Examined.				Lime.						Phosphate.						Potash.					
	† R.		G.		* S.		SL.		L.		S.		SL.		L.		S.		SL.		L.	
	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.	R.	G.
All formations excluding peat . . . . .	3882	1131	3	3	65	65	32	32	19	11	46	32	35	57	16	34	70	57	14	9		
Acid igneous rocks . . . . .	1755	541	3	2	64	65	33	33	16	7	54	33	30	60	18	34	67	58	15	8		
Basic igneous rocks . . . . .	805	197	1	2	81	77	18	21	39	28	44	36	17	36	14	25	71	61	15	14		
Slates and shales . . . . .	638	162	1	0	47	56	52	44	2	4	30	16	68	80	17	47	75	51	8	2		
Quartz-rich rocks . . . . .	149	53	7	4	54	58	39	38	9	6	36	26	55	68	12	45	74	47	14	8		
Peat . . . . .	71	35	10	6	68	80	22	14	1	3	1	3	98	94	4	14	25	46	71	40		

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

in the others, but even in this group the great majority of the soils would be improved by the application of lime.

*Phosphate.* Phosphate deficiency is much more pronounced in old grassland than in rotation land, but even in the latter there is a widespread need for phosphate. As with lime deficiency, the phosphate position is least unsatisfactory in soils of basic igneous origin. The peat soils examined are, practically without exception, very low in phosphate and the soils derived from slates and shales and quartz-rich rocks are likewise low in this plant food.

*Potash.* The general picture in regard to the potash contents of the soils is essentially the opposite of that obtaining for phosphate. Old grassland soils are generally richer in potash than are soils of rotation land, and in the mineral soils the risk of potash shortage is least in the slates and shales and greatest in the basic igneous group. Except in the peats, where most of the samples are deficient, the potash contents of the soils in both rotation land and grassland are relatively much more satisfactory than are the lime and phosphate contents.

The above general findings in regard to the lime, phosphate and potash contents of soils in the North of Scotland are well borne out in practice. In the majority of cases crops, other than priority ones such as potatoes, flax, etc., which have high potash requirements, are not likely to suffer unduly if for a few years little potash in artificial form should be available. The need for phosphate and for lime is widespread and, under the acid conditions obtaining in the vast majority of the soils, it is probable that nothing like full benefit is being derived from the plant food materials which are either present in the soil or added in manures. Under present conditions, the supplies of phosphate available are likely to be inadequate to meet the real needs of the soils, but there are in Scotland abundant reserves of limestone and calcareous sand which, if developed, could be used to great advantage on most of the agricultural land of the North of Scotland.

#### SOIL FERTILITY INVESTIGATIONS

*General Experiments with Lime and Phosphate.* Experimental work on the effects of lime and of phosphate on crop yields and soil properties has been continued during the year. In last year's report details were given of the yields of three successive crops in a series of experiments with lime and phosphate which had been undertaken in connexion with the Government Land Fertility Scheme. With one exception, these experimental areas were in 1942 under pasture which was being grazed and for which no yield data could be obtained. At one of the liming experimental centres (Aberdeenshire No. 2 in last year's report) a second hay crop has been harvested and the following relative yield figures obtained for the different treatments :

<i>Treatment</i>	<i>Relative yield figures for 2nd hay crop 1942</i>	<i>Soil pH value July 1942</i>
No lime . . . . .	100	5.50
Light lime . . . . .	117	5.95
Medium lime . . . . .	124	6.25
Heavy lime . . . . .	135	6.80



From these figures it is evident that the lime is continuing to have a beneficial effect in the fourth season after its application, a result which is borne out by observations made on the pasture of the other liming experimental areas. The residual effects of the phosphate dressings on the pasture appear to be less marked than those of the lime.

Other work undertaken during the year includes pot and field experiments for the comparison of the manurial value of different sources of phosphate and for the characterization of the phosphate status of several soils on which laboratory work on phosphate fixation is being carried out.

*Phosphate Fixation.* An account has been published<sup>1</sup> of the investigation on the colorimetric determination of phosphate with the aid of a Hilger "Spekker" photoelectric absorptiometer which, as mentioned in last year's report, was carried out as a preliminary to the work on phosphate fixation. Work on the latter problem, which is part of a long-term investigation, has been continued during the year. In particular, attention has been paid to possible complicating effects resulting from secondary reactions occurring during extraction with reagents commonly used to determine "available" phosphate. Results generally show that the reactions between the soil and added phosphate, resulting in fixation of the latter, are mainly inorganic in nature and take place rapidly. The replacement of phosphate by different anions under varying conditions is also being studied and it is hoped shortly to publish an account of the work to date.

Analysis of some 250 samples of soil from experimental plots at the North of Scotland College of Agriculture farm at Craibstone has been commenced. As a preliminary, hydrochloric acid and acetic acid extractions are being carried out with a view to obtaining some idea of the differences in the phosphate content of these soils as a result of the various treatments they have had. The results obtained so far indicate that where the soils have been receiving manurial dressings consistently over a period of years, distinct differences can be seen both in the readily soluble phosphate and in the total reserve of phosphate in the soil, due to the varying treatments. With the soils which have received only one or two applications of fertilizer, however, little or no significant difference can be noticed.

*Time of Application of Superphosphate and Conditioning of Fertilizer Mixtures.* In last year's report reference was made to experimental work which had been undertaken on the above problems. A general account of this investigation has now been published.<sup>2</sup> The results indicate that on average agricultural land superphosphate can be applied in autumn with little if any risk of its efficiency being reduced. It is noteworthy that with turnips, a crop which responds readily to phosphate and which could be expected to show up any serious loss in efficiency, autumn application of superphosphate proved just as effective as spring application. It would appear that more attention might well be given to the application of phosphates to the land in winter or at any time that is convenient, especially if there is difficulty in finding storage accommodation. In connexion with the general problem of storing fertilizers delivered out of season, attention is drawn to the good keeping qualities of a mixture containing as conditioning agent a peat litter of sphagnum-cottongrass origin.

*Crushed Biotite Schist as a Source of Potash.* An investigation of the manurial value of crushed biotite schist was commenced in 1940 and in the first two years of the experiment it was found that :

- (a) with turnips in the first season after the application of the experimental dressings to field plots the biotite schist had a certain manurial value, but in both unlimed and limed soil 100 lb. per acre  $K_2O$  from sulphate of potash was appreciably superior to  $2\frac{1}{2}$  times this amount of  $K_2O$  from the schist ;
- (b) with oats in the second season after application the biotite schist had a marked residual effect in both the unlimed and limed soil.

The investigation has been continued and from the results obtained in a series of pot experiments and in the field experimental area, where a hay crop has been grown in the third season following the application of the experimental dressings, it appears that the heavy biotite schist dressing (250 lb.  $K_2O$  per acre) is now supplying a considerable amount of potash to the soil.

*Study of Unusual Case of Soil Infertility.* In the course of advisory work attention was directed to portions of two fields in a district in East Aberdeenshire where all crops failed completely, although the remaining portions of the fields in question gave quite good yields. Spectrographic examination of the soil, which was found to be derived from basic igneous material, showed the presence of abnormally large amounts of nickel and copper in readily soluble form (about 10 mg. NiO and 12 mg. CuO per 100 gm. in one of the soils and a similar amount of nickel but less copper in the other, i.e. contents roughly 100 times those normally found). An experiment has been laid down in one of the infertile areas in order to obtain information on the effects of various dressings of lime and phosphate on the contents of readily soluble nickel and copper in the soil and at the same time to find out the treatment likely to be necessary to counteract the infertility. The application of lime appears to be having a very beneficial effect.

## PEAT SOILS AND SOIL ORGANIC MATTER

### PEAT SURVEY

On account of the considerable increase in enquiries regarding peat types and peat deposits, it was decided to resume the survey of peat deposits in Scotland. In collaboration with the Geological Survey for Scotland and the Geology Department of the University of Glasgow a scheme has been prepared and it is hoped to carry out a general survey of the country in a relatively short period. The methods and the publication of records of this survey will be similar to those adopted for the recent survey of the limestone resources of Scotland (Ann. Rep., 1940-41, p. 26). The introductory pamphlet is now being prepared. In the field the north-eastern region is being covered by the Institute, while the midland valley is being surveyed from Edinburgh and Glasgow.

### PEAT AND COMPOST INVESTIGATIONS

*The Water Relationships of Peat as a Soil or as a Constituent of Soil.* During the year an extended experiment has been in progress and is now completed. The data obtained still require careful analysis and no final conclusion has been reached. General examination of the data collected indicates that the results of the preliminary experiments reported last year have been confirmed, namely, that small amounts of some types of peat added to soil decrease its water retaining power, contrary to expectation.

*Growth Tests using Peat or Composts made up with Peat.* Because of the limited accommodation available under glass a considerable proportion of the experiments have had to be carried out in part at least in the open. Tomato plants have been found most generally useful as test plants in the past. Results this season have been badly affected by the abnormally bad weather. The tests made have been in continuation of the previous year's work. Most have not been finally assessed.

*The Effects of Degree of Fineness of Grinding of Peat.* In the past, commercial examples of finely ground peat have been used as seeding composts, or in them, and have not been found to be satisfactory. In addition some of the coarser commercial examples show variation in the size to which they are screened. It is generally accepted that material varying in size mainly between  $\frac{1}{2}$  in. and  $\frac{1}{4}$  in. diameter, with a lesser proportion of finer material, is most useful for seeding and potting composts. Earlier experiments on a lawn had indicated also that finely ground material does not produce results so satisfactory as materials of this size or even coarser. It was therefore decided to carry out some seeding tests to determine the effects of fineness of grist on germination and early growth of seeds in peat, peat and sand mixtures, and composts with peat, using the peats at different degrees of grist. The sizes used were :

- (a) coarse ground, i.e. passing a  $\frac{3}{4}$ -in. sieve but held on a  $\frac{1}{2}$ -in. sieve ;
- (b) medium size, i.e. passing the  $\frac{1}{2}$ -in. sieve but chiefly (up to 75 per cent.) held on the  $\frac{1}{4}$ -in. sieve ;
- (c) finely ground, i.e. passing a 1-mm. sieve (approximately  $\frac{1}{32}$  in.).

In the first experiments lettuce seeds were used. Three somewhat different types of sphagnum peat were ground to the above sizes (as far as coarser material was available). Each treatment was in triplicate. Stated shortly, it was found that with lettuce seeds, whether peat is used alone, in mixture with equal volumes of sand, or as a constituent of a compost (soil 7, sand 2, peat 3 parts), the best results were obtained with the medium ground material.

With coarser material used alone, germination was very irregular. Although there were a number of plants in the seed-boxes larger than the average size of those in the medium material, the general rate of germination was slower, and the final percentage of healthy plants very low (less than 50 per cent.) as compared with that shown by the corresponding medium ground peat. The results with peat and sand mixtures were similar if not quite so satisfactory; in the seeding composts the main effects of coarse material were (a) lower average percentage germination, and (b) the abnormally rapid growth of a few seedlings in each of the triplicate seed-boxes.

With the finely ground peat, the results were uniformly bad. Germination in its earliest stages was not unsatisfactory but many of the seedlings were unable to throw off the seed cases, or to develop their roots in the peat alone or mixed with sand. In the compost this phase was not so pronounced, but the general effect was that the young plants were checked in growth, having small dark coloured cotyledons, and tended to fall over because of weakly development at the collar. At the close of the experiment they were light in colour and affected by mould, besides being much poorer in growth than those in the medium grade of peat.

The general conclusion is that finely ground sphagnum peats are not satisfactory for making up composts, the main reason being that they tend to keep the soil in a waterlogged condition while the chief value of peat in composts is in keeping the soil in a moist but open condition. The experiment was repeated with tomato seeds on a somewhat reduced scale and the same general result was obtained. With black peats—consisting chiefly of sphagnum and cottongrass remains and of phragmites remains—the effects of very fine grinding were not so apparent in the composts, the final transplants from which were not inferior in appearance although mortality was higher in the germination stage.

*Finely Ground Peat as Top-dressing on a Tomato Crop.* A small bed of tomato plants in good growth was divided into six plots, each containing four plants of even growth. These plots were treated in pairs:

- (a) without top-dressing;
- (b) top-dressed with finely ground peat;
- (c) top-dressed with coarse ground peat.

The plots had been given identical watering for some weeks before the top-dressing was applied and showed even moisture contents at the time of top-dressing. They were heavily watered after the top-dressing was applied, and samples of the upper mineral soil were taken for moisture determinations at intervals until some of the plants showed signs of permanent wilting. Then the watering was repeated and sampling continued.

The details of this experiment are not complete but indicate that (i) either of the forms of top-dressing retain water better than soil alone;

(ii) the finely ground peat is much less satisfactory in practice because of its tendency to puddle when wetted even with a fine spray, shedding the water off the surface, and itself being washed away; (iii) penetration of the mineral soil by water is less even with finely ground peat than with bare soil; a top-dressing of coarse peat allows water to pass to the moist mineral surface below where it spreads still more evenly; (iv) when the mineral soil below is allowed to dry out too far, drenching does not spread the water through the soil so evenly as gentler watering over a few hours.

*The Relative Value of Slag and Superphosphate as a Source of Phosphate in Peat and Peat-containing Soil.* Previous experience has indicated that in certain circumstances basic slag when applied to peat gives better results than superphosphate of the same phosphate content. An experiment was carried out to determine whether this result followed the use of slag in place of superphosphate in potting composts.

Potting composts were prepared in the usual way, sphagnum-cottongrass peat being used with loam and sand. In addition to these, a second series was prepared but with peat and soil only in the proportion of 4:1. To each of these series in triplicate pots the following treatments were applied:

- (a) normal manuring (including superphosphate);
- (b) normal manuring but with basic slag in place of superphosphate;
- (c) as in (b) but with lime omitted.

The pots were watered throughout the season with nutrient solution from which phosphate was omitted.

In the earlier stages the rate of growth was uniformly better in the normal composts, and of the three treatments, the slag pots, (b), were distinctly better than those with superphosphate (a), but when lime was omitted (c), slag was somewhat inferior to the superphosphate. All the plants grown in the normal compost showed to a marked degree the purplish-blue colour associated with phosphate deficiency, while those in the peat + soil composts were on the whole a healthy green colour.

The position had altered, however, by the time the plants were at the "third truss" stage, at which the experiment may be considered to have reached a stable condition. Because of the bad summer no weight assessment was made, the set of fruit was very poor and most of the plants were damaged.

The tentative conclusions reached are: that (i) over the whole period the slag or superphosphate originally applied was insufficient for normal growth of plants so that differences in growth were a reasonable index to the relative efficiency of the phosphate used; (ii) maximum growth was made in both series where slag was used in place of superphosphate—there was little difference between the growth of the plants in compost and in peat + soil treated with slag; (iii) where, however, lime was omitted from the slag-treated pots, the growth was definitely less satisfactory than where lime was included, indicating that the use of slag did not compensate for omission of lime; (iv) the poorest growth in the peat + soil series was in the superphosphate treatment where, in addition to phosphate deficiency, another adverse factor was at work producing small brittle and sappy leaves—this was not high acidity as was at first suspected, and may have been a trace element deficiency.

*Biotite Schist as a Source of Potash in Horticultural Work.* It was thought that peat used as a constituent of a soil might serve to liberate the potash from biotite schist more rapidly than was experienced with ordinary agricultural soils either in the field or in pots. This experiment was carried out to obtain information on the point.

Tomato transplants were grown in boxes of soil consisting of loam 7 parts, moss meal 3 parts, coarse sand 2 parts, and manured with the normal amounts of manure, except that sulphate of potash was replaced wholly or partly with biotite schist in quantities equivalent to the sulphate of potash. The following are the variations in treatment used :

- (a) sulphate of potash at  $\frac{3}{4}$  oz. per bushel ;
- (b) with half of the potash replaced by biotite schist ;
- (c) with three-quarters of the potash replaced by biotite schist ;
- (d) with potash wholly replaced by biotite schist ;
- (e) with twice the potash equivalent as biotite schist.

The boxes in triplicate were watered with nutrient solution from which potash was omitted. The experiment was to be assessed when potash deficiencies became pronounced.

In the earlier stages the normally treated (a) plants were superior to the others, with treatment (e) not much inferior to (a). At the 3-flower stage there was no apparent difference between (a) and (e) but (d) was definitely poorest, and showed acute potash deficiency. At this stage the plants were transferred to the open and a short time afterwards were badly damaged by wind and rain so that any further assessment was of doubtful value. It was apparent, however, that the plants given treatment (d) were unable to recover, whilst the others recovered to some extent and produced one or two reasonable trusses. The best plants were those having treatments (a) and (e), but even here one of each of the triplicates was not in agreement with the others, so that the effect of the weather may have been greater than differences in treatment. As far as the experiment shows, the biotite schist must be used in very large quantities to give even the same response as sulphate of potash as an initial dressing ; no evidence is produced that potash was made available during the season as had been hoped. A laboratory experiment to determine whether peat liberates potash from schist is in progress but has not been concluded.

*The use of Coarse Carbonate of Lime for maintaining the pH of Soil under Horticultural Conditions of Heavy Watering.* When lime in the form of finely ground limestone is added to peat and peat-containing composts in the quantities shown to be necessary by the "lime requirement," it is found that in a short time the pH of peat may fall within a few weeks to lower levels than that of the original peat. The cause of this has not been ascertained but it may be due either to simple mechanical washing out of the limestone particles or to the development of mobile "lime + organic" compounds during the season. This experiment aims at finding out whether a cure for this lies in the use of coarse-grained limestone in place of, or in addition to, ground limestone. It is customary here to aim at a pH of 6.5 in horticultural composts.

After mechanical analysis of the coarse material used (poultry grit) it was estimated that 12 times the weight of ground limestone required

formed a first approximation to the quantity of grit required. Subsequent experience showed that this weight was much too high, since during the handling and mixing of the composts the grit was rubbed down to a very considerable extent, giving a much higher immediate effect than was expected. The experiment therefore suffers from this error in judgment. In order to compensate for the physical effect of the grit, the sand usually used in composts was replaced by a hard brick grit similar in size to the limestone grit. Since the problem is specially related to peat, the amount of peat used in the composts was higher than the normal quantity although a set of normal composts was included for comparison. The normal soil consists of soil 7, peat 3, grit 2 parts by volume. For this experiment the quantities used were soil 1, peat 4, grit 1. The major nutrient contents were made up by additions of "hoof and horn," superphosphate and sulphate of potash, and by watering with a strong solution at weekly intervals during the season. The treatments were triplicated in 9-in. pots in which tomatoes were grown. They consisted of incremental additions of lime and limestone grit from a low level to a high level.

It was found in the first assessment that the higher values were definitely harmful to the growth of the plants (lime additions equivalent to the "lime requirement" and grit additions above two-thirds of the estimated requirement showed poorer growth). The symptoms shown were over-deep colour and, in extreme cases, purpling corresponding to phosphate deficiency. The  $pH$  values of these soils were above 7.15 at this stage.

At a later stage it was found that the normal composts produced the best plants when treated with ground lime up to the "lime requirement" ( $7\frac{2}{3}$  oz. per bushel). The plants produced by the peat + soil composts with lower dressings of lime and grit were not much inferior (e.g.  $1\frac{1}{2}$  oz. limestone + 4.7 lb. grit per bushel). The experiment is not conclusive but affords a guide to more exact application of grit of this type for the purpose of maintaining  $pH$ . The  $pH$  values of all the soils to which grit had been applied had been over 7.1, showing that over-heavy dressings had been used.

In connexion with this investigation into the change in  $pH$  value during the growing season, and into the question of leaching of peat under horticultural conditions, a set of laboratory experiments has been carried out in order to throw light on the question of the amounts of nutrient which might be lost during heavy watering. Over a period of 10 weeks 52 litres of water were applied to 5 litres of limed peat in sufficient amount to give 1 litre of leachings at each application. The leachings were collected and the calcium content determined. At the end of this period it was found that less than 10 per cent. of the lime was lost by leaching and that the  $pH$  values of the peats had not altered by any considerable amount, a fall of 0.2  $pH$  being recorded as well as some increases. It appears, therefore, that direct leaching of lime is not the cause of changes in the  $pH$  values of peats and peaty composts. Similar tests were carried out with potash and phosphate when it was found that phosphate was rapidly and almost completely leached from peat with less than 5 litres of leachings; while potash, after the same volume of leachings had been collected, had been lost to the extent of 20 to 90 per cent. of the amount added, depending on the type of peat used. This work is being continued in the more accurate form of base-exchange investigations (see p. 17).

*Composting Experiments.* During the past season these have been carried out on a reduced scale, having been confined chiefly to the practical aspect of mixing peat into fresh composting materials so as to obtain a reasonably accurate idea as to the best volumes of various types of peat required to prevent drainage loss and at the same time maintain the necessary heat of composting.

As a result of field compost trials it appeared that, judged on the yields from a potato crop, a peat compost was little better than artificials alone, while composts from grass-cuttings, soft leaves and old tree litter composted with cyanamide were of about the same value as dung, provided the nutrient contents were brought to the same levels throughout. In pot work the value of composts for the growth of tomatoes was found to be similar to their nutrient content from whatever organic material they originated. A small scale laboratory experiment indicates that the use of sulphate of ammonia on grass refuse does not improve the rate of composting.

*Investigation into the Replacement of Farmyard Manure by Peat Fortified with Artificial Manures.* Owing to the growing scarcity of farmyard manure it is desirable to determine the suitability of other kinds of organic matter which might be drawn upon as substitute sources of soil organic matter. Of these, peat has already an established place in horticulture.

At the request of the Agricultural Research Council, an investigation has been commenced into the usefulness of peat as a source of organic matter in general horticultural and agricultural practice. This investigation aims at determining whether peat supplemented with artificials could take the place of farmyard manure; which of the more abundant types of peat are most suitable for the purpose; and whether, as a result of the use of peat and of the large additional amounts of artificial manures necessary, special soil conditions are likely to arise requiring special methods of soil management.

During the season several field experiments have been laid down on soils of lighter types, in which the growth of potato, turnip and cabbage crops are being compared after equivalent applications of dung, artificials and various types of peat. An experimental allotment has also been laid down on old pasture on the normal boulder clay soil at the Institute. The intention here is to compare over a number of years the effects in a vegetable garden of manuring with peat, with dung and with artificials alone, the organic additions being heavier than those commonly used in agricultural practice. The crops used were, generally speaking, those indicated in the Ministry of Agriculture "Growmore" leaflet No. 1. The results of the first season's growth in these experiments are not yet completed.

*Laboratory Work* has been in general closely linked up with field and experimental work. The principal sections are:

- (a) Routine analyses.
- (b) Study of methods of examination of soil organic matter (fractionation, etc.).
- (c) Routine analyses of survey samples.
- (d) Investigation of the physical and chemical properties of peat and organic soil types.



(a) The routine analyses carried out in connexion with experimental work are, where of particular importance, quoted in reports on the experiments concerned.

(b) Study of the methods of examination of soil organic matter has been limited through pressure of other more immediate work. During the year some work has been carried out on the phosphate content of the "Waksman" fractions, on the "non-cellulosic" portions of the acid hydrolysates and on methods of reducing the time required for the determination of total nitrogen.

(c) During peat survey, special samples are collected of types which seem to be of importance for specific purposes (e.g. wax content, iron content). These samples are examined from this aspect.

(d) Experimental work has continued on the water-holding properties of various typical peats, especially when used as constituents of made-up soils.

Investigations are in progress into the exchangeable bases and the ionic exchange properties of various peat types in relation to their use as soil and compost constituents.

## SOIL SURVEY

The work on soil surveys has been continued in the area of Aberdeenshire discussed in last year's report. Dr. Hart again assisted in this area. The Ardgartan survey reported last year is now completed and a beginning has been made in the correlation of choice of species and tree growth with the vegetation and soil types established. Other work carried out in conjunction with the Forestry Commission is described below.

The laboratory work on the soils collected during 1941 has been kept to the minimum necessary for the characterization of the soil series established. Soil sampling for advisory purposes has been continued in conjunction with the survey. Assistance has also been given the Advisory Department in connexion with special problems.

With regard to the method of soil classification used in the survey, further consideration and more extended use of it in the field has shown that the associate as previously defined (Ann. Rep., 1939-40) is the equivalent of the English and American term series (with somewhat narrower limits). The term association then covers a group of soils developed on a single parent material (e.g. till), while suite applies to those associations ultimately derived from what may be termed a parent rock (e.g. slate). The sequence of sub-groups then becomes—Zone, Suite, Association, Associate, or Series, Type, Phase. The first and last two are used in their accustomed senses.

### ABERDEENSHIRE

Soil survey work has been continued in central Aberdeenshire during the past year and an area extending from Old Meldrum to Udney Station, including part of the parishes of Udney, Tarves and Ellon, was covered. This comprises 24 square miles. Another area extending northwards from the line Ythan Wells to Woodhead, Fyvie, and including part of the parishes of Forgue, Auchterless, Turriff, Monquhitter, Fyvie, Methlick and Inverkeithny in Banffshire, was also surveyed. This area amounts to approximately 60 square miles, giving a total of 84 square miles surveyed this season. Representative soil profiles of the various soil associates established were collected for analysis.

*Topographical Description of the Area.* Old Meldrum to Udney. This is a relatively low-lying area, reaching a maximum height of about 600 ft. in the west, with 220 ft. being the lowest point. It is smooth, broadly-rolling topography with well rounded hilltops. The streams flow in an easterly direction joining the Bronie Burn. This area is mainly arable, and, apart from policy woods, there are few plantations.

Ythan Wells to Woodhead, Fyvie. This is a well diversified area topographically, consisting of relatively high ground in the north-west, reaching about 1,000 ft. near Ythan Wells. This high ground is succeeded to the north and east by a district about 500 ft. in general elevation, and is succeeded north-eastwards by a relatively low-lying area around the Howe of Auchterless. This area is diversified by a number of rounded hills about 600 ft. in height. The drainage of the higher land to the west runs north to join the Deveron at Inverkeithny, while the central part of the

area is drained by streams which unite to form the Ythan, running north-east through the Howe of Auchterless and then sharply north by Auchterless Station to Fyvie.

*Geology.* The following rock groups occur in the area :

Old Meldrum gneiss	Old Red Sandstone
Fyvie schists	? Pliocene gravel
Macduff schists	Granite.

Gneissic and granitic rocks are extensively developed in the Old Meldrum to Udney area but they are covered by a thick coating of a heavy glacial drift, which in the western part of the area has an admixture of basic igneous rock material. Only on the occasional high ground is the drift thin and the soils developed on shattered rock.

The Ythan Wells by Windyhills to Auchterless Station area is covered mainly by schists of the Highland Schist Series, by rocks of the Old Red Sandstone formation and by ? Pliocene gravels. The Highland Schist Series is represented by the Fyvie schists and the Macduff schists. The Fyvie schists consist of knotted and andalusite schists with pebbly grits and were seen in the Bartholchapel district. The Macduff group of schists, which consists of slates, argillaceous schists and pebbly grits, is very extensively developed in the area surveyed.

The Old Red Sandstone rocks, consisting of conglomerates and a small development of sandstone, are found in the Auchterless district and north of Fyvie. To the north-east of Fyvie round Windyhills is a spread of gravel consisting of quartzite pebbles of ? Pliocene age.

The whole of the area has been glaciated and, apart from the hilltops, an extensive deposit of boulder clay is found. This glacial drift is generally characterized by the underlying rock, especially in the extensive area underlain by argillaceous schist rocks. All the rock types have a strong influence on the local drift, but areas of mixed drift do occur. Some fluvioglacial deposits have been noted around the valley of the Ythan, and a coarse morainic drift occurs westwards from Balquholly. Alluvial deposits are found alongside the larger streams and especially in the Ythan valley. Deposits of peat, which have been extensively worked for fuel in the past, also occur, especially in the district west and north of Tifty, Fyvie, and at Burreldales Moss near Old Meldrum.

*Soil Associations.* Soil associations previously found to the south and described in the 1940-41 Report, also occur in this area. These are listed below with three new associations, Windyhills, Bartholchapel and Ordley. All the association names are provisional as yet.

<i>Association</i>	<i>Parent Material</i>	<i>P.M. Group</i>
Foudland	Till	Slate
Rothie	"	Argillaceous schist
Tulloch	"	Grit
Old Meldrum	"	Gneiss
Haddo	"	O.R.S. formation
Fyvie	Sand and gravel	Pebbly sands
Windyhills	Quartzite gravel	" "
Bartholchapel	Till	Andalusite schist
Ordley	"	Argillaceous schist + conglomerate

*Foudland Association.* This association has now been found to extend, on its western limit, from Wells of Ythan by Den of Largue to Fortrie, and on the east from Gordonstown by Pitglassie to the Burn of Tollo on the north. No essential differences have been found in the profile characteristics of this association.

*Rothie Association.* This association has now been found to extend westwards of the line Wells of Ythan, Den of Largue, Fortrie. It is also found in a narrow belt eastwards of Kirkton of Auchterless and stretching to Badenscoth. There is also an area about two miles wide running north-east from Fyvie. No appreciable change was noted in this association.

*Tulloch Association.* Within the area generally characterized by the Foudland and Rothie associations, soils largely developed on grit have been found. They are best seen around Bush near Fisherford and have been provisionally linked with the Tulloch association. The previously described soils of this association are two associates of poor drainage. The Bush soils are freely drained and under woodland are podzolized, while the cultivated soil has a thin A horizon with a bright brown B horizon of a silty loam texture on a khaki coloured stony, fine sandy till. This association is not extensively developed, but in the Rothie association an admixture of grit rocks does occasionally occur in the argillaceous rock drift. It is now considered advisable to include the Tulloch association as a sub-group.

*Old Meldrum Association.* This has been examined in the district stretching from Old Meldrum and Whiterashes in the west to Pettymuck and Pitmedden in the east. The soils are developed mainly on a heavy stony clay drift formed from gneissic and granitic rocks. In the western part of the area an admixture of basic igneous rocks has been found in the drift. A typical soil has an A horizon of a brown, heavy loam to fine loam, friable and crumbly; the B horizon is a khaki, fine sandy loam, friable, which passes into a stiff stony clay which is generally mottled. The wet soil has a cloddy grey-brown A horizon on a grey clay with iron mottled gley horizon. A characteristic feature of the association is the depth of the cultivated layer, which is seldom less than 12 inches.

*Haddo Association.* This is now found to extend north and east of the Ythan valley from Tifty, north of Fyvie. The soils of the main body of this area are developed on a red-brown cobbly gritty clay till of conglomerate origin, and are very pebbly at the surface and throughout the profile. The freely drained or slightly impeded soils have a brown to red-brown A horizon, but extensive areas occur of a wet associate with a cobbly black to very dark brown A horizon on a strongly gleyed horizon which becomes red-brown at a depth of approximately 60 cm. This associate is found on moderate to steep slopes, and its poor drainage appears to be largely due to the relatively heavy nature of the drift.

On the eastern side of this area, about Blachrie, the conglomerate drift changes into a bright red heavy clay relatively stone-free and derived largely from sandstone. Soils developed on this drift are generally of a reddish-brown clay loam A horizon on a bright red clay drift, which is slightly mottled with iron staining. The hilltop areas in this district are exceedingly cobbly.

*Fyvie Association.* Bordering both sides of the Ythan valley from Fyvie to Auchterless Station, there occurs spreads of fluvioglacial sands and

gravels. They are more extensive on the eastern side of the valley. Soils developed on these are very light textured and stony with excessive drainage.

*Windyhills Association.* North of Woodhead, Fyvie, at an elevation of about 350 ft. there is a spread of ? Pliocene gravel forming the Windyhills. This deposit consists of bands of white quartzite pebbles and micaceous quartz sands. The uncultivated portion is now under calluna and cut-over woodland. A strongly developed iron pan with a root mat above is a marked feature of the soils which are podzolized. The cultivated soils are pebbly loams, sometimes highly organic, and both freely drained and poorly drained associates occur.

*Bartholchapel Association.* The rock underlying the drift here is an andalusite schist, and the soils so far seen resemble the Rothie association. The extent of this association requires further investigation.

*Ordley Association.* An area of mixed Old Red and argillaceous schist drift occurs, bordered on the north by the Burn of Balquholly and on the west by Uppermill and Cushnie and on the east by the Howe of Auchterless. The freely drained soils are red-brown in the A horizon, overlying a reddish-brown drift which contains a high proportion of argillaceous schist with an admixture of conglomerate pebbles. The proportions of these rock types in the drift vary considerably so that in this area soil types closely resembling the Haddo and the Rothie associations are found.

#### ROSS-SHIRE

In connexion with the study of sheep pining being made by the Institute a soil survey of healthy and unhealthy areas in Easter Ross has been carried out. While these areas were of limited extent, they appear to be typical of considerable stretches of the district and it was found possible to establish a number of soil associations which appear to be of widespread occurrence.

*Topography and Geology.* The most westerly of the selected areas lies on the slope of the hills bordering the north side of the Cromarty Firth, the others lie within or just above the various stretches of raised beach formations which lie to the east of Alness.

The whole of Easter Ross, except for the Hill of Nigg, is underlain by rocks of the Old Red Sandstone formation (Upper and Middle groups). The principal rock is a yellow sandstone but there also occur conglomerates and pebbly grits, and locally narrow bands of greenish and purplish shales, and limestone. The ground has all been glaciated and the bulk of the area bears a mantle of till, with drumlins a feature of the eastern part. A broad stretch of fluvio-glacial gravels forms a prominent feature north of Alness. Subsequent to the last glaciation, there has been a considerable amount of raised beach formation round the coast. The position is further complicated by erosion, both submarine and sub-aerial, so that in some cases the beaches have been completely denuded, while in others indeterminate relics still remain. The result is that there is a great variety of soil parent materials, often within a very small area. Shingle bars and blown sand are locally important.

The area of ground in which rock comes near to the surface is not great and it is probably in most cases covered with a very thin skin of drift. The deposits of till can be divided into two main groups—red till and dun-brown-grey till. The dun-brown-grey till is only found within the raised beach

area and the colour possibly results from strongly reducing conditions. The red till is mainly above the raised beach level although it occurs locally as a border to the 85-ft. beach margin.

The sand and gravel deposits are of a variable degree of stoniness, and one variety (shingle bar) has been taken out as a special type, since the soils occurring on it are very distinctive. Areas of almost stoneless sand are found both in the raised beaches where they are sometimes intermixed with silt, and as blown sand along the margin of the 85 ft. and present-day beaches.

*The Soils.* These have been grouped according to parent material and drainage conditions as described in the report on Aberdeenshire (Ann. Rep., 1940-41). The list of associations is given below. It is probable that others will be found as the survey is extended. The association names are provisional.

<i>Association</i>	<i>Parent Material</i>
Achandunie . . . .	Sandstone ( $\pm$ conglomerate)
Cadboll . . . . .	Till—red
Saltburn . . . . .	Till—grey
Kincraig . . . . .	Sand and gravel
Balintore . . . . .	Sand and gravel (phase)
Delny . . . . .	Sand
Allan . . . . .	Silty clay (carse)

*Achandunie Association.* In this association the shattered rock lies very near the surface so that, although the soil may be derived from a very thin "scruff" of drift, the influence of the rock on drainage is sufficiently strong to warrant the separation of a soil association. The soils are all shallow, being rarely deeper than 30 cm. and averaging 20 cm. In texture they are lightish loams of easy working consistence. The sub-soil is definitely a relic podzol B horizon, varies from a yellowish fawn to warm coffee-brown colour and is occasionally somewhat indurated. A distinct iron pan is only rarely encountered. The shattered rock follows the B horizon and is either sandstone or conglomerate.

The oromorph associate is confined to the steeper, the phytomorph to the gentler slopes, and the former is somewhat lighter in texture. The area of these soils appears to be of limited extent, and no ill-drained associates were seen, although an associate at present referred to the Cadboll association may, on further investigation, be found to belong here.

*Cadboll Association.* This probably occupies the largest area in Easter Ross and has also been found in Sutherland. The till which forms the parent material varies from a pale reddish-brown to a bright red. It is invariably stony and compact and often, especially in the redder varieties, tough and tenacious, being used locally as a thatching clay. Sometimes there is a thin scruff of a lighter textured drift on the surface.

The oromorph associate is found on the tops of the drumlins. The surface soil is red, stony and very arid. The phytomorph associate is rarely red in colour when wet, but may assume a reddish tint when dry. The soil is nearly always deep (up to 75 cm., average 40 cm.), loamy in texture, with a crumbly structure and mellow consistence. A marked plough pan is occasionally encountered at about 25 cm. At the base of

the A horizon lies an extremely hard, cemented B horizon which can be pierced only with difficulty. This hard layer is usually about 10 cm. thick. Earthworms apparently can penetrate it and through their channels carry down surface soil. The red till below sometimes shows large grey vertical tapering bands which are suggestive of former root channels.

The less well-drained associates are not so common, but locally occupy quite large areas. Two phases can be distinguished, depending on the stoniness of the profile. The stony phase appears to be associated with the light coloured drift overlying conglomerate and sandstone of the lower Old Red. These associates are mostly of the deep type.

*Saltburn Association.* This appears to be of limited extent. At Saltburn it occurs in the 50-ft. beach area and is often in a complex with what seems to be a marine or lacustrine clay. The soils are of medium depth and light loam texture, and still show relics of their original podzolic character in the marked coffee-brown B horizon. Below the B horizon gleying is often intense.

*Kincraig Association.* This is associated with the less stony areas of sand and gravel. Such areas are common although of limited extent. The soils are deep light loams with a typical podzol B horizon.

*Balintore Association.* Although also occurring on sand and gravel this association has been separated as something more than a phase of the lower Kincraig association. The Balintore soils are formed on shingle bars which consist more often than not of little else but pebbles. They have been strongly podzolized with a massive B horizon and are cultivated only to a small extent.

*Delny Association.* The parent material of this group is a fine sand virtually stone-free. It occurs wholly within the raised beach level and is evidently of marine origin and contains beds of shells. The associates are predominantly of the ill-drained type and occur extensively in the long hollow behind Invergordon. In texture they vary from almost pure sand to a silty sand, with locally a peaty cover. In the central part of the Lower Kincraig-Delny hollow the surface soils are somewhat humose, while towards the margins the colour is light grey.

The soils of areas of blown sand have also been included provisionally in this association. The range of associates on such ground is from oromorphie to hydromorphie. Locally, as at Cadboll, a two-story profile occurs with the A and B horizons of blown sand overlying red till. In depth the soils range from extremely shallow types, as on recent blown sand, to deep, where the sand has long been cultivated.

*Allan Association.* This is best developed in the stretch of carse land between the Bay of Nigg and Fearn, although it occurs in small areas elsewhere within the raised beach area. The texture is a silty clay, extremely tenacious when wet and baking hard when dry. The associates seem to be invariably of the ill-drained type.

#### MECHANICAL ANALYSIS OF SOILS

For a rapid check on field texture determinations over a fairly wide range of soils the Bouyoucos hydrometer method has been found very suitable. In order to avoid the need for removal of organic matter an approximate relation between loss on ignition and organic matter (from

carbon) has been established and the sand fraction, which in the Bouyoucos method carries the greater error due to non-removal of organic matter, can then be corrected. It has been found that dispersal of the soils with soda is quite satisfactory. The results of the analyses agree very well with those from the pipette method.

#### SOIL CONDITIONS AND TREE GROWTH

*Unsatisfactory Growth in Japanese Larch.* Plantations of Japanese larch in the Carron Valley Forest have not been successful and a preliminary soil examination, carried out at the request of the Forestry Commission, suggests that mineral deficiency together with poor drainage may be the cause, although exposure to strong north-west winds and smoke damage may be complicating factors.

The soils are formed from till overlying basalts and seem to be derived entirely from this basic igneous material. In spite of the high lime content of the parent material the surface soil is extremely low in exchangeable Ca, and the readily soluble  $P_2O_5$  content is also very small. In fact the values obtained for Ca are the lowest so far recorded for forest soils. The acidity is not abnormal. Anaerobic conditions prevail in the upper layers, due in part to the very dense grass mat and peaty covering. Further work is in progress on this problem.

*Die-back in Pines.* Scots and Corsican pines planted in soils derived from calcareous rock have shown severe die-back in a Forestry Commission area. Analyses of the needles from such trees compared with those for healthy specimens on adjoining non-calcareous soils show that the chief difference is in the manganese content. In the unhealthy needles it may amount to only a tenth of that in the healthy needles. Further work is in progress.

#### SOIL MINERALOGY

In order to assist in the classification of the soil parent materials in the field study of the soils, investigations of the mineralogical composition of soil types from the surveyed areas have been carried out.

The soils studied have come mainly from Aberdeenshire, and the fine sand fractions have been investigated. It has been found possible by this means to characterize the glacial drifts from which most of the soils have been derived, and the method is especially helpful in the case of drifts of mixed rock origin. A limited number of soils developed on the Old Red Sandstone formation in various parts of Scotland are also being investigated.



## SPECTROGRAPHIC INVESTIGATIONS

Some 7,000 samples have been examined during the year by the Lundegardh flame emission spectrographic method, which involves the spraying of a solution of the cations it is desired to determine into an air-acetylene flame. It is particularly suited to routine determinations of the alkalis and alkaline earths and gives an accuracy of some  $\pm 5$  per cent. The majority of the determinations made have been of potassium, with occasionally in addition magnesium and manganese, for advisory purposes. A considerable number of base determinations on composts and like materials at different stages of maturity have been carried out as well as exchangeable cation determinations on forest soils. This method has also found application in the estimation of the contents of potassium, sodium, magnesium and manganese in hydrochloric acid extracts of plant ashes. The results obtained in these various investigations are discussed more appropriately in the sections dealing with the problems with which they are concerned, as the Lundegardh method is being employed as a routine method for such determinations.

Applications of the arc methods of spectrographic analysis described in previous reports (1939-40, 1940-41) have been concerned chiefly with investigations into the problems of the relation of cobalt deficiency to the incidence of sheep pining in Ross-shire, and with a study of the soils and pastures of reputedly good and poor feeding farms in Aberdeenshire, which are discussed elsewhere.

The quantitative method for the determination of trace constituents after 8-hydroxyquinoline concentration has been extended to include determinations of copper and zinc. A full account of the technique is at present in the press.<sup>12</sup> At the same time investigations have been in progress with other organic reagents in order to include further trace constituents, and these investigations are being continued. In the course of various investigations by this method, interesting facts regarding the distribution of trace elements in soils and the crops which they produce have been brought to light. A general summary of our present knowledge of this subject has been given in a paper to the Nutrition Society which it is hoped will later be published.<sup>13</sup>

Associated with the question of the occurrence of trace constituents in soils is their distribution in igneous rocks. A series of related igneous rocks from the Skaergaard Intrusion in Greenland, surveyed by Dr. L. R. Wager of the University of Reading, have been analysed by the semi-quantitative cathode layer method. In these rocks, which vary from ultra-basic to acidic in character, and which crystallized from the same original magma, it was possible to follow the relative distribution of each trace constituent and to correlate the results obtained with our knowledge of their geochemical behaviour. An account of the results has been presented to the Mineralogical Society and is awaiting publication.<sup>14</sup>

The determination of fluorine and boron in materials of agricultural interest has been studied. It has not so far been possible to evolve a

straightforward method for fluorine, using the well-known calcium fluoride band, as this band appears to be particularly sensitive to the phosphate content of the material. In the determination of boron, which must be carried out in electrodes other than carbon as these cannot generally be obtained in a boron-free condition, a search is being made for the most suitable internal standard element. The possibility of using an internal standard other than iron for such easily volatile elements as zinc in the general cathode layer method mentioned above, is also receiving attention.

## SPECIAL INVESTIGATIONS

### COBALT MANURING AND PINING IN STOCK

This investigation, which is being done in collaboration with the Animal Diseases Research Association, has been continued and extended during the year and two papers on the subject have been published.<sup>3, 4</sup> In the first, details are given of a confirmatory experiment showing that pining in lambs due to cobalt deficiency can be cured and prevented by the application to the soil of a manurial dressing of 2 lb. cobalt chloride per acre. It is also shown that the beneficial effects of such a dressing persist for more than one season. In the second publication, attention is drawn to the fact that in one soil with a relatively high molybdenum content, the application of a cobalt-rich fertilizer has caused a marked increase in the molybdenum content of the herbage.

Further work, which has been undertaken on this problem during the year, includes :

- (a) The study of soils and pastures on over 30 farms in the northern counties of Scotland where there is a possibility of pining due to cobalt deficiency. As a result of this work several farmers in the area have themselves undertaken cobalt manuring with very beneficial results ; cobalt sulphate has been used as a source of cobalt in this further work and appears to be just as effective as the chloride, which is relatively more costly.
- (b) The study of the residual effects of manurial dressings of cobalt and the investigation of the inter-relationships of cobalt, molybdenum, copper and other trace constituents which may enter into the nutritional balance of the plant and the animal. This is being made the subject of special study by spectrographic methods and experimental material is being obtained from (i) a series of field experiment plots with varying dressings of cobalt, copper, iron and lime, and (ii) a series of pot experiments with different pasture species and with varying trace element additions.

### DIFFERENCES OF FEEDING VALUE FOR CATTLE OF DIFFERENT PASTURES

At the request of the Agricultural Research Council, the Institute is co-operating in a joint investigation of the differences of feeding value for cattle of the produce from different farms, where there is no obvious soil or other factor to account for such differences. In this investigation the Institute is concerned with the complete examination of the soils and the determination of the mineral, particularly trace element, contents of the produce.

A start has been made with this investigation and a preliminary examination is being made of samples of soil and produce from a number of farms in Aberdeenshire where differences in feeding quality have been reported.

## SURVEY OF SCOTTISH LIMESTONE RESOURCES

Some 230 specimens of limestone have now been analysed and the work is nearing completion. The pamphlet on Area III, East Central Scotland, has been published,<sup>7</sup> while that on Area VII, Caithness and North-western Highlands, is at the printers.<sup>16</sup> The account of Area II, West Central Scotland,<sup>16</sup> is in the course of preparation and should soon appear. A set of summary tables of the results of the survey arranged by counties has also been prepared.<sup>8</sup>

In connexion with the limestone survey it was found possible by a series of experiments to distinguish between the terms *hardburnt* and *overburnt* which appear to be somewhat loosely applied to burnt limes. In the case of *hardburnt* lime it was found that the time of slaking was longer than that of the softburnt product, while the solubility in sucrose solution was the same. X-ray analysis shows that as the lime is heated to the *hardburnt* stage the CaO crystallites become progressively larger and an approximate estimate of the crystal size can be made from the photographs. *Overburnt* lime, on the other hand, slakes more slowly and also shows a lower sucrose solubility. This decrease was shown by X-ray and chemical analysis to be due to the presence of tricalcium silicate,  $\beta$ -dicalcium silicate, tricalcium aluminate and magnesium oxide, the first three being characteristic of portland cement.

The X-ray examination of a softburnt lime from a close grained limestone showed that the CaO crystallites were of larger size than normal for such a lime and it appears that grain size in the initial stone has some influence on that of the burnt product.

## X-RAY WORK

During the past year, the X-ray apparatus has been considerably developed, and has been used in a number of investigations. The X-ray tube is a Hilger self-rectifying all-steel gas tube evacuated by a mercury diffusion pump, backed by a Hyvac rotary oil pump. The high tension supply is from a single-phase transformer capable of supplying 10 m.A. at 60 K.V. The tube was originally fitted with a needle valve opening to the atmosphere, but this has now been replaced by a fixed leak (made by drawing out capillary tubing) opening to a space, the pressure in which can be controlled by a filter pump. This arrangement allows of a very accurate adjustment of the pressure in the tube and the setting once made is maintained.

The tube has been further modified to make the targets and windows readily interchangeable; the windows are secured to a brass frame which is sealed in position with Apiezon Q compound, while the targets can be simply screwed into position, the joint being made airtight with a well greased rubber washer. With this arrangement, the targets and windows can be replaced in a few minutes, with the certainty of getting an airtight joint.

The 9 cm. Metropolitan Vickers powder camera has been modified, so that it can be evacuated by a filter pump to a pressure of a few cm. of Hg. In addition, the collimating system has been modified. This gives photographs which have a clear background right up to the centre, a feature

which is particularly important in investigations of soil colloids where many of the minerals have very large characteristic spacings. Considerable attention has been given to the problem of reducing exposure times, which tend to be inordinately long. The elimination of the aluminium windows and the evacuation of the camera contribute to this, while it has been found possible to double the normal output of the tube. A fully exposed photograph of a soil colloid can now be obtained in 6 hours with Fe—K $\alpha$  or Cu—K $\alpha$  radiation (filtered). It is hoped to improve on this result still further.

As a preliminary to investigation of actual soil colloids, a number of photographs of soil mineral samples have been made. As a development of this work, photographs have been made of montmorillonite (from bentonite) saturated with various bases, and it has been found that these photographs provide a clue to the position of the exchangeable bases in the colloid; these appear to enter between the layers of the crystal lattice, and not to any marked extent on the surface of the particles. This conclusion had already been arrived at by American workers on the basis of differential thermal curves.

#### STUDIES ON SOIL DRAINAGE WATER

The study of the drainage waters from the soils of the Craibstone lysimeters has been continued during the year.

Rape, sown at the rate of 12 lb. per acre on 16th July, 1941, to take the place of oats that failed to germinate, was cut to about 1 in. above ground level on 8th December, 1941, and weighed. The weights, calculated per acre, are shown in Table II. While lysimeter No. 1 received no manurial

TABLE II

CROP—1941—RAPE

*Weights per acre*

	1.	2.	3.
As cut . . . . .	4 cwt. 50 lb.	73 cwt. 91 lb.	74 cwt. 90 lb.
Dry matter . . . . .	84 lb.	10 cwt. 77 lb.	12 cwt. 43 lb.
Per cent. dry matter . . . . .	16.8	14.5	16.5

treatment, Nos. 2 and 3 each received, per acre,  $\frac{3}{4}$  cwt. sulphate of ammonia,  $2\frac{1}{2}$  cwt. superphosphate and  $\frac{1}{2}$  cwt. muriate of potash; this was given when the oats were sown at the end of April, 1941. When cut, the plants on No. 1 were very small and stunted but appeared quite healthy; they were from 2 to 3 in. high. On Nos. 2 and 3 the plants were from 4 to 10 in. high and were strong and healthy.

After the crop was removed the lysimeters were dug over, the roots of the rape being turned under. On 12th April, 1942, the soil was dug over again and "Onward" oats sown at the rate of 5 bushels (200 lb.) per acre, Nos. 2 and 3 each receiving per acre,  $\frac{3}{4}$  cwt. sulphate of ammonia,  $2\frac{1}{2}$  cwt. superphosphate and  $\frac{1}{2}$  cwt. muriate of potash. At this time the soil was very dry and only traces of rain were recorded till the middle of May. No germination occurred and a second sowing was made on 20th May. In

TABLE III  
SUMMARY OF LYSIMETER RESULTS

1st October, 1940, to 30th September, 1941						
	Lysimeter 1.		Lysimeter 2.		Lysimeter 3.	
Rainfall— <i>inches</i> . . . . .	43·36					
Drainage— <i>inches</i> . . . . .	28·63		29·25		26·37	
<i>% of rainfall</i> . . . . .	66·0		67·5		60·8	
	Parts per 100,000.	Pounds per acre.	Parts per 100,000.	Pounds per acre.	Parts per 100,000.	Pounds per acre.
Soluble solids . . . . .	11·59	776	12·79	844	11·07	664
Loss on ignition of soluble solids . . . . .	3·35	216	3·12	208	3·14	188
SiO <sub>2</sub> . . . . .	0·79	52	0·82	54	0·88	53
SO <sub>3</sub> . . . . .	0·59	39	1·67	111	1·88	111
CaO . . . . .	1·65	107	2·06	137	1·89	114
MgO . . . . .	0·60	39	0·62	41	0·59	35
K <sub>2</sub> O . . . . .	0·08	6	0·07	5	0·08	5
Na <sub>2</sub> O . . . . .	1·64	107	1·73	115	1·40	84
Cl . . . . .	1·30	85	1·39	92	1·25	75
N . . . . .	0·03	2	0·04	3	0·05	3
1st October, 1941, to 30th September, 1942						
Rainfall— <i>inches</i> . . . . .	38·07					
Drainage— <i>inches</i> . . . . .	22·74		20·02		17·80	
<i>% of rainfall</i> . . . . .	59·7		52·6		46·7	
	Parts per 100,000.	Pounds per acre.	Parts per 100,000.	Pounds per acre.	Parts per 100,000.	Pounds per acre.
Soluble solids . . . . .	20·99	1083	17·87	812	18·30	739
Loss on ignition of soluble solids . . . . .	2·69	139	3·73	170	4·06	164
SiO <sub>2</sub> . . . . .	1·20	62	1·24	56	1·08	44
SO <sub>3</sub> . . . . .	1·08	56	2·34	106	3·14	127
CaO . . . . .	3·98	205	3·34	152	3·76	152
MgO . . . . .	1·12	58	0·97	44	0·91	37
K <sub>2</sub> O . . . . .	0·12	6	0·13	6	0·11	4
Na <sub>2</sub> O . . . . .	2·07	107	1·86	85	1·75	71
Cl . . . . .	1·71	88	1·98	90	2·31	93
N . . . . .	0·04	2	0·05	2	0·05	2

spite of abundant rainfall and higher temperature germination was very poor and only a few plants appeared. The soil was dug over again and on 19th June rape was sown at the rate of 12 lb. per acre, without further manurial treatment. Growth on all three lysimeters appears to be somewhat similar though the plants are not so high as those during 1941. This crop has not yet been taken off.

*Rainfall and Drainage.* Rainfall during October and November, 1941, was very heavy over 6 in. being recorded in each month, while December was exceptionally dry just over 1 in. being registered. Snow fell during the last week of December and further falls from January to March accumulated to depths up to 20 in. on the lysimeters. During the whole period from October to September 38.07 in. of rainfall, including snow, were recorded, of which from 47 to 60 per cent. appeared as drainage.

*Colloidal Suspended Material.* Contrary to previous experience the rapid copious flow of drainage in March, caused by the melting of the snow, did not carry with it any material in suspension. Nothing came through up to the end of September, 1942.

*Soluble Constituents in the Drainage.* During the previous year an unexplained abnormal increase occurred in the amount of total dissolved solids in the drainage waters, even from the unmanured lysimeter, during the summer and autumn months. From October, 1940, to April, 1941, the total soluble solids from the unmanured No. 1 was, on the average, about 7.5 parts per 100,000. In May it increased to 11.3, in July to 26.6 and in August to 43.5 parts per 100,000 with a drop to 31.3 in September. The drainage from the other two lysimeters also showed somewhat similar increases. Analysis of the monthly collections indicated a rise from May in the concentrations of bases, with increases to some extent in sulphates and chlorides: nitrogen compounds did not appear to be different in amount from previous estimations. No explanation has been arrived at to account for these increases, and the failure of the oats.

During the year October, 1941, to September, 1942, the proportions of total dissolved solids continued high, and again, from May to July the concentrations were greater than in the preceding three months. In this period the drainage flow was so reduced that the collections of April and May were combined, as were those of June and July. Traces only came through in August and small amounts during September.

A summary of the results for the two years is presented in Table III.

## PUBLICATIONS

### *Issued during the year—*

1. "The Colorimetric Determination of Readily Soluble Phosphate in Soils." By E. G. Williams and A. B. Stewart. (*J. Soc. Chem. Ind.*, LX, 291-7, 1941.)
2. "Time of Application of Fertilizers, with special reference to Superphosphate." By A. B. Stewart and E. G. Williams. (*Scot. J. Agric.*, XXIV, 52-6, 1942.)
3. "Pining in Sheep: II. Confirmatory Experiments on its Control by Cobalt-rich Fertilizers." By J. Stewart (Animal Diseases Research Association), R. L. Mitchell and A. B. Stewart. (*Emp. J. Expt. Agric.*, X, 57-60, 1942.)
4. "Cobalt Manuring and Pining in Stock." By R. L. Mitchell, R. O. Scott, A. B. Stewart and J. Stewart (Animal Diseases Research Association). (*Nature*, 148, 725, 1941.)
5. "The Revival of Liming." By W. G. Ogg. (*Scot. J. Agric.*, XXIII, 355-66, 1942.)
6. "Soils and Plant Nutrition." By W. G. Ogg. (*Farming Handbook*, Jarrold & Sons, Norwich, 1942, pp. 50-72.)
7. "Limestones of Scotland. Area III. East Central Scotland." By D. Haldane and J. B. Simpson (Geological Survey); and A. Muir and H. G. M. Hardie. (Geological Survey of Great Britain War-time Pamphlet No. 13.)
8. "Limestones of Scotland. Summary Tables." By A. Muir. (Department of Agriculture for Scotland. Mimeographed.)

### *In preparation—*

9. "The Fractionation of the Organic Matter, including Nitrogen, of Certain Soils and its Relation to their Quality." By M. R. F. Ashworth. (To appear in *J. Agric. Sci.*)
10. "Changes Occurring in the Organic Matter during the Decomposition of Compost Heaps." By M. R. F. Ashworth. (To appear in *J. Agric. Sci.*)
11. "Soil Studies in relation to Geology in an Area in N.E. Scotland. Part II. The Soils and their Development." By R. Hart. (To appear in *J. Agric. Sci.*)
12. "Concentration Methods in Spectrographic Analysis. I. Recovery of Co, Ni, Mo, Cu and Zn from Plant Materials and Soil Extracts by 8-hydroxyquinoline." By R. O. Scott and R. L. Mitchell. (To appear in *J. Soc. Chem. Ind.*)
13. "The Distribution of Trace Elements in Soils and Grasses." By R. L. Mitchell. (Paper presented to the Nutrition Society.)
14. "Preliminary Observations on the Distribution of the Trace Elements in the Rocks of the Skaergaard Intrusion." By L. R. Wager (University of Reading) and R. L. Mitchell. (To appear in *Mineralogical Magazine*.)
15. "Limestones of Scotland. Area VII. Caithness and North-western Highlands." By T. Robertson, J. Knox and J. G. C. Anderson (Geological Survey); A. Muir and H. G. M. Hardie. (Geological Survey War-time Pamphlet No. 13.)
16. "Limestones of Scotland. Area II. West Central Scotland." By J. B. Simpson (Geological Survey); A. Muir and H. G. M. Hardie. (Geological Survey War-time Pamphlet No. 13.)