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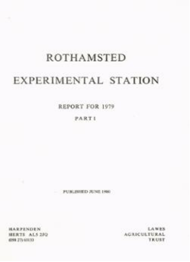

Soils and Plant Nutrition Department

P. B. Tinker

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Introduction

The structural changes in the Department have now been completed, with the appointment of Dr. R. Webster as the second organisational SPSO. A complete review and revision of the Department's projects is now almost complete.

Much of the Department's effort has been redeployed over the last 2 years, particularly into the priority areas of yield variation and soil-root relations. This has been done partly by transferring staff to new and existing projects on yield variation, partly by the filling of vacancies with staff who have biological training. Thus in the current year we have been joined by two physiologists, one to work on root studies and the other on plant nutrition, who fill existing gaps in the Department's ability to study all aspects of soil nutrients.

Some of the yield variation work is reported on here, but that dealing with the field experimental approach has been transferred to the multi-disciplinary section of the Report, including some results that are also relevant to our work on nitrogen. Additional sites, more intensive monitoring and detailed root-soil studies on these are now absorbing much of our effort. Collaboration with I.C.I. Ltd. has given access to their records of the 'Ten-Tonne Club' programme, and from these, very interesting results on the yielding capacity of different soil series and land capability classes are beginning to emerge. Our involvement with modelling has increased steadily, especially with regard to the yield variation modelling programme (in which a group of four Institutes has started work) and to studies with mycorrhizas. The modelling of nitrate leaching has continued, with the production of improved versions which predict nitrate distribution in a more complete way. Preliminary studies on the levels of trace metals in different soil series have been completed, and give some reason to believe that useful information could be obtained from total trace metal analysis of samples from selected soil series. In work on the calorimetry of cation exchange, it has been found possible to discriminate between the types of exchange sites on different clay minerals.

Much other work has either started or has received increased attention during the year, only some of which is briefly reported here. This includes the measurement of total N balances on cereal fields using ^{15}N, to determine the exact origin and mechanisms of loss of N; the investigation of the effects of subsoil tillage and deep placement of phosphorus and potassium; collaborative work with the Soil Survey on the factors controlling the regain of structure after drainage in different soils, and on the potassium-releasing characteristics of different soil series; work with the Plant Pathology Department and members of MAFF on investigating the soil properties which increase the likelihood of attack by take-all; and a fundamental study of the processes which control supply of trace metals from the soil to the root.

These changes have been greatly aided by the new equipment obtained during the year, including a mass spectrometer, a Pilcon drilling rig and an atomic absorption spectrophotometer with flameless source.

Yield variation

Work on this topic is now developing in several ways, though much of it is as yet at an early stage. The special interests of this department are to identify any interruption in or disturbance of nutrition of winter wheat crops on our experimental sites which are associated with differences in yield; to detect any differences in the development and function of root systems on different soils; and to determine whether there are intrinsic differences in the capacity of soil types to give high yields and if so, how far these differences interact with or can be reduced by management operations.

Field experimentation. A major interdisciplinary effort is now applied to Rothamsted's main winter wheat experiments, and this is reported on p. 17, including much of this Department's work. Here certain detailed aspects of crop nutrition are discussed.

The work started with a single experiment on winter wheat in 1978 (*Rothamsted Report for 1978*, Part 1, 36) on Rothamsted Farm, which aimed to test methods of running such multi-factor experiments, including irrigation, and to give detailed information on the nitrogen uptake rates.

Wheat var. Maris Huntsman was sampled on five occasions, and the nitrogen uptakes calculated. The crop contained on average 18·3 kg N ha^{-1} on 28 April, 87·5 kg ha^{-1} on 24 May, 102·7 kg ha^{-1} at anthesis on 28 June, a maximum of 170·3 kg ha^{-1} on 10 August, and 162·3 kg ha^{-1} on 29 August. There were no significant effects of sowing method, seed rate or irrigation on the uptake of nitrogen at any sampling. At the final sampling on 29 August treatments given 90, 120, 150 and 180 kg N ha^{-1} yielded 7·27, 7·70, 7·77 and 8·02 t ha^{-1} (SED ±0·239) of grain at 85% DM and the whole crop contained 136·9, 155·5, 165·8 and 190·9 kg N ha^{-1} (SED ±6·67). (Widdowson, Penny and Darby, with Taylor, Thorne and Welbank, Botany Department)

In 1979 this work expanded to the main experiment at Rothamsted, and a subsidiary test of six of the factors on Woburn farm. The crops on both farms took up similar mean amounts of N at all samplings, except that the N content of the Woburn crop decreased sharply between the last sampling and harvest, giving a difference in the N contents of the grain of 24 kg ha^{-1} between the sites. The reasons are not understood. The early sown crop contained three times as much N in December as the later sown, and in spring the % N and NO_3–N contents of the early sown crop were larger, but this had no significant effect on final yield; at Woburn the early sown crop contained 10 kg ha^{-1} more N at harvest than the later sown. The only outstanding difference in these measurements was that on 6 April wheat at Woburn not yet top dressed with N contained only 3 μg NO_3–N g^{-1}, whereas wheat given N in March (and all wheat at Rothamsted) contained several hundred μg g^{-1}. This was clearly due to the rapid leaching of nutrients in the wet spring from the Woburn soil; the total NO_3–N in the 90 cm profile decreased from 70 kg N ha^{-1} in February to 20 kg N ha^{-1} in early April. Comparable values at Rothamsted were 120 kg N ha^{-1} and 60 kg N ha^{-1}. These low levels of N at Woburn probably were responsible for the yield increase of 0·25 t ha^{-1} from dividing the N dressing there. In this year both plant nitrate concentrations and nitrate in the soil to 90 cm would have predicted the early lack of N at Woburn.

Three sites have been selected on farmers' fields within 20 miles of Rothamsted, where previous experience leads us to expect very large crops. Simple experimental treatments are being applied to the farmer's crop, and it will be monitored to give further comparisons with the main experiment at Rothamsted. (Widdowson, Penny, Hodgkinson, Hewitt and Williams, with Welbank, Taylor and Thorne, Botany Department)

The influence of rainfall distribution and drainage on yields of winter wheat and spring barley at Saxmundham. D. A. Boyd (Ph.D. Thesis, 1940) concluded, from an investigation of the influence of weather on crop yields on the Saxmundham Rotation One experiment, that above-average rainfall in the harvest year and two previous seasons, diminished yields. Examination of rainfall and losses of nitrate N in drainage from 1966 to 1978 indicated that yields of winter wheat were related to the length of the period of continuous winter drainage and the losses of nitrate N measured in them. During these years, the average amount of rain required to start continuous drainage was 230 mm after June, and at least 25 mm monthly was needed to maintain it. The average loss of nitrate N during the period of continuous drainage, when about 80% of the total annual loss occurred, was about 1 kg ha^{-1} for each 25 mm increment of rain.

This information was used to estimate the lengths of the annual periods of drainage, from rainfall records made at Saxmundham from 1930 to 1964, and these were related to the corresponding yields of winter wheat and spring barley on the NPK treatment of the Rotation One experiment. During this period yields and nitrogen dressings were low, and yields varied greatly (0·83–4·38 t ha^{-1}). The data were arranged in groups of increasing yield and compared with corresponding mean values of various rainfall parameters (Table 1). Rainfall in the previous September (reflecting poor cultivation or seed-bed conditions) and rainfall in July and August (reflecting harvest conditions) were not related to yield. Rainfall from July to 31 December in the previous year (reflecting winter leaching), and in April and May (reflecting later leaching of applied N) were inversely related to yield. The durations of continuous drainage, estimated by the principles given above were also negatively correlated with yield.

TABLE 1

Winter wheat grain yields, rainfall and estimated drainage at Saxmundham, 1930–64

Yield (t ha^{-1})		Years	Rainfall (mm)				Estimated continuous drainage (months)
Range	Mean		Sept.	July-Dec.	April+ May	July+ August	
0·50 – 0·99	0·84	2	52	512	38	91	8·5
1·00 – 1·49	1·09	1	151	543	157	145	9·0
1·50 – 1·99	1·71	3	52	340	118	79	7·0
2·00 – 2·49	2·26	7	53	377	87	130	5·9
2·50 – 2·99	2·65	8	59	356	85	114	5·1
3·00 – 3·49	3·24	9	52	318	80	106	5·6
3·50 – 3·99	3·73	4	48	324	72	121	5·3
4·00 – 4·49	4·38	1	10	236	62	110	4·0

Yields of spring barley were less clearly related to any of these quantities. (R. J. B. Williams)

Effects of soil type on 1978 yields of winter wheat. The I.C.I. 'Ten-Tonne Club' programme measures yields of wheat in fields where the farmers aim for high yield, and where management is therefore likely to be good. Details of the programme were made available to us by courtesy of Mr. M. J. Jones of I.C.I. Ltd. Soil series for 292 of the 1110 sites in the programme for 1978 were identified from Soil Survey maps or inferred from geological maps. Yields of winter wheat at these sites ranged from 3·0 to 11·0 t ha^{-1} (mean 7·30 ± 0·08). Thirty-two series were represented by three or more sites, and the mean yields of these ranged from 8·9 ± 0·3 t ha^{-1} for Coombe series, a typical calcareous brown earth on chalky solifluction deposits (four sites), to 6·1 ± 0·3 t ha^{-1} for Atrim series, a typical brown earth on Jurassic sands (three sites). Greater yields were generally obtained on freely drained soils, especially those with silty or fine loamy textures, such as series on deep loess (Wickmere 8·2, Hamble 7·9), silty alluvium (Teme 8·4) and the softer limestones (Sherborne 8·2, Icknield 8·1, Wantage 7·7). Eight of the 11 sites yielding 10 t ha^{-1} or more were on well drained soil.

The mean yield for soils of Land Capability Class 1 was 7·82 ± 0·22 t ha^{-1} (33 sites), for Class 2 soils was 7·10 ± 0·11 (145 sites), for Class 3 soils was 7·43 ± 0·14 (107 sites), and for Class 4 soils was 7·10 ± 0·54 (7 sites). The Class 2 soils probably performed worse than the Class 3 because many are sandy and hold too little water to assure maximum growth; in general mean differences are remarkably small.

The mean for seven sites on Batcombe series, the same soil type as much of Rothamsted Farm, was only 6·2 ± 0·2 t ha^{-1}, the second lowest of the 32 series. By comparison, the mean yield for 72 plots in the highest yielding winter wheat experiment on Batcombe series at Rothamsted in 1978 was 9·05 t ha^{-1}. As six of the seven selected 'Ten-Tonne Club' sites on Batcombe series were near to Rothamsted, and so had similar weather, the difference in yield is interesting. Because so many soil series are involved in the 'Ten-Tonne Club' Survey many more results are needed to evaluate and to distinguish clearly the effects of soil differences from those of variable management. (Catt and Weir)

Computer model for the growth of winter wheat. The four institutes collaborating in the project 'Causes of yield variation in winter wheat' have started to formulate a mathematical model for the growth of a winter wheat crop, to be programmed for the Rothamsted computer. To improve our understanding of the problems involved we obtained a similar model for spring wheat growing under Australian conditions designed by Dr. J. Morgan of MacQuarie University and ran it on the 4–70/72 computer. After several alterations it ran successfully and produced plausible figures for crop growth and grain yield. This experience has enabled us to make recommendations about the design of the computer programme for the new model, and the handling of data and output. (Rayner, Weir and Parry)

Investigations on nitrogen

Denitrification. The acetylene 'blocking' technique (inhibition of N_2O reduction to N_2 by acetylene) has been used in field studies to determine denitrification losses by measuring N_2O levels in or above the soil. If the technique is to be reliable, acetylene should only inhibit N_2O reduction and should not affect other metabolic pathways in the facultatively anaerobic bacteria capable of denitrification. Measurements of the total metabolic activity in three anaerobic soils, using triphenyltetrazolium chloride reduction to formazan to measure the production of reductant, showed that acetylene affected general soil metabolic activity, but the effects were difficult to reproduce, and varied between soils. There were no effects up to 24 h, but later low (0·5–1·0% v/v) acetylene concentrations depressed activity for at least 10 days. The technique is thus not reliable for other than very short-term experiments. (Rodgers)

Investigations on phosphate and potassium

Effects of phosphate and potassium manuring on take-all and yield of winter wheat. Two experiments were started in 1974 to investigate the effects of P fertilisers on take-all in successive crops of winter wheat (cv. Cappelle-Desprez). In the first experiment, in which winter wheat followed six barley crops, take-all was never severe, presumably because take-all decline had been established in the soil during the years in barley. 15 kg P ha^{-1} applied annually decreased take-all, but 60 kg P ha^{-1} each year had little further effect on it (Table 2); large single applications of phosphate over the 6 years had similar effects.

Unexpectedly, the large dressing of potassium (120 kg K ha^{-1}) increased take-all where nil or only 15 kg P ha^{-1} was given each year, but not where more P was applied, and over the whole period 1974–79, there was no significant correlation between the effects of extra K on take-all and on grain yield.

Annual applications of 15 or 60 kg P ha^{-1} increased average grain yields by 17 and 27% respectively, and equivalent amounts of phosphate applied once in autumn 1973 were equally effective.

In the second experiment four wheat crops were grown after barley on each of the three series of the Residual Phosphate Rotation, Rothamsted, which had previously grown swedes, potatoes and barley in a three-course rotation (*Rothamsted Report for 1973*, Part 1, 56).

On Series III, take-all was severe in crops grown in 1974 without P fertiliser but only

TABLE 2

Mean effects of phosphate and potassium fertilisers on take-all and yield of winter wheat (1974–79) and on NaHCO$_3$-soluble P in the soils from West Barnfield, Rothamsted

P applied (kg P ha^{-1})	K applied (kg K ha^{-1})	Take-all disease rating(c) (maximum 300)	Grain at 85% DM (t ha^{-1})	NaHCO$_3$-soluble P (mg P kg^{-1})	
				1974	1979
None	30	65	3·84	6	4
	120	98	4·01	6	4
15(a)	30	42	4·28	9	10
	120	64	4·85	9	9
60(a)	30	40	4·77	33	51
	120	44	5·21	32	53
90(b)	30	52	4·47	15	9
	120	60	4·91	14	8
360(b)	30	44	4·70	58	40
	120	40	5·13	67	43

(a)applied annually (b)applied in a single dressing in autumn 1973 (c)Take-all rating= % slightly infected roots +2(% moderately infected roots) +3(% severely infected roots).

slight where phosphate was applied (*Rothamsted Report for 1974*, Part 1, 223); in the following year it was severe with all treatments. In contrast, however, on Series II and I, where the first wheat crops were grown in 1975 and 1976 respectively, take-all did not become severe until the third successive wheat, when crops without P (6–8 mg NaHCO$_3$-soluble kg^{-1} soil) were most affected. These complicated differences in the development of take-all in the different series confirm (*Rothamsted Report for 1976*, Part 1, 261) the effects of the exceptionally dry summers of 1975 and 1976 on the disease. On average over the period 1974–79, P fertilisers decreased take-all and increased grain yields by more than 20% (Table 3). Large single applications of superphosphate every 3 or 6 years were generally as effective as the equivalent total amounts of P applied annually, except for the smallest 6-yearly dressing (150 kg P ha^{-1} in 1973).

TABLE 3

Mean effects of phosphate fertilisers on take-all and yield of winter wheat grown continuously for 4 years and on NaHCO$_3$-soluble P in soils from the Residual Phosphate Rotation, Rothamsted

P applied (kg P ha^{-1})	Take-all disease rating (d) (maximum 300)	Grain at 85% DM (t ha^{-1})	NaHCO$_3$-soluble P (mg P kg^{-1} soil)	
			1st year in wheat	4th year in wheat
None	123	3·66	9	6
12·5(a)	95	4·39	15	13
25(a)	78	4·59	20	23
50(a)	80	4·57	34	41
75(a)	67	4·80	56	68
75(b)	100	4·34	14	12
150(b)	80	4·57	20	21
150(c)	93	4·28	20	16
300(c)	76	4·66	41	31
450(c)	68	4·88	62	45

(a)applied annually (b)applied every 3rd year (c)applied every 6th year (d)see Table 2.

These experiments aimed to test early reports that P fertilisers controlled take-all. In the experiments summarised here P fertilisers consistently *decreased* take-all, but even so severe attacks occurred in some years in wheat given large amounts of phosphate, in agreement with our previous experience. On average there is little benefit from applying extra P because take-all is expected, but on P deficient soils (<10 mg $NaHCO_3$-soluble P ha^{-1}) even small dressings of P fertiliser (12·5 kg P ha^{-1}) greatly decreased take-all and increased yield when the disease first occurred in a sequence of wheat crops, so that the on-set of severe take-all was delayed by 1 year. (Mattingly, with Slope and Gutteridge, Plant Pathology Department)

Phosphate adsorption on allophanic soils. The kinetics and heats of phosphate adsorption in 10^{-2} M-NaCl were measured on the sodium-saturated <2 μm fraction of allophane, and of the whole soil from the surface (8% C) and subsoil (0·8% C) horizons of a field experiment site in Japan. Six amounts of P, as sodium phosphate, were tested at pH values 5 and 7 and at initial phosphate concentrations 5×10^{-4} M and 25×10^{-4} M. The latter were chosen to avoid the precipitation of aluminium phosphates.

A linear rate of adsorption was followed in succession by two exponential rates, believed to be due to, respectively, adsorption on external surfaces, adsorption on internal and freshly forming external surfaces, and the precipitation of aluminium phosphates. These effects are associated with the microstructure of allophane and, in the case of the soil samples, also with the desorption of organic matter adsorbed on allophane surfaces. This interpretation is strongly supported by parallel changes in the heats of adsorption with time, which show that when large amounts of phosphate are added, new and very phosphate-reactive surfaces are progressively exposed. It suggests that it is advisable to add small amounts of phosphate frequently for crop use to minimise the seemingly irreversible and rapid fixation of phosphate fertiliser in allophanic soils.

As is usual, more phosphate was adsorbed at more acid pH values and when smaller amounts of organic matter were present. (Imai, Goulding and Talibudeen)

Effects of mycorrhiza on plant growth and internal P concentration. Analysis of leek plants grown on irradiated soil in the glasshouse over a wide range of soil P levels (*Rothamsted Report for 1978*, Part 1, 284) showed that shoots of plants infected with the yellow-vacuolate (YV) mycorrhizal endophyte generally contained 2-3 times as much P as shoots of uninfected plants of equivalent dry weight. A similar effect was also shown by plants infected with E_3 endophyte, in another experiment.

A subsequent literature search has revealed that this effect appears to be characteristic of vesicular-arbuscular mycorrhizas, though as yet there are no reports that it occurs in the field. We believe the effect is caused by enhanced C loss by the roots as a result of infection, and are testing this idea through the development of a simulation model and by measurement of ^{14}C loss from roots of plants fed with $^{14}CO_2$. (Stribley, Tinker, Snellgrove and Rayner)

Models for the spread of mycorrhizal infection on roots. A model previously proposed (Tinker, *Symposia for the Society of Experimental Biology* (1975) **29**, 325–349) takes the rate of increase in length of infected root to be proportional to the product of the length so far infected and the remaining susceptible length, given that only a fraction of the root is potentially infectable. Experiment shows that there is a point in the growth of the root where the proportion of root infected increases rapidly, and the model fits this part of the behaviour well. However, if the model is applied to the earliest stages where the proportion of root to soil is small, then the predicted proportion of root infected may decrease, because the roots grow exponentially but infection fails to keep pace.

In an alternative model the spread of infection does not depend on the actual root density, but on the product of the proportion infected and the proportion still susceptible.

The observed behaviour again fits this model well in the region of rapid increase in infection. Data are being obtained at earlier stages in growth to discriminate between these models. (Rayner, Stribley, Goh and Tinker, with Ross, Statistics Department)

Heterogeneity of cation exchange sites in 'standard' clay minerals. Potassium-calcium exchange equilibria were investigated on the <2 μm fraction of clay minerals used as standards in the identification and quantitative mineral analysis of soils by other physical methods. Differential enthalpy measurements, $d(\Delta H_x)/dx$, where x is the fractional K saturation, show that groups of exchange sites with distinct $d(\Delta H_x)/dx$ values occur in each mineral except the mica (Table 4). It is most likely that the steps at $-6{\cdot}6$ and $-5{\cdot}6$ kJ eq^{-1} found in all the minerals except mica, are obtained from exchange on 'planar' surfaces. The proximity of the $-15{\cdot}9$ and $-14{\cdot}4$ kJ eq^{-1} values in vermiculite and kaolinite suggest the presence of weathered micaceous interleaves in the kaolinite. The presence of this impurity in the kaolinite is also supported by the standard free energy and enthalpy values, according to which kaolinite occupies anomalous positions in the sequence of clays. Likewise, the $-10{\cdot}5$ and $-10{\cdot}7$ kJ eq^{-1} steps in the mica and the montmorillonite indicate that 6% of the negative charge on the latter can be ascribed to mica layers interstratified with the montmorillonite layers. (Goulding and Talibudeen)

TABLE 4

Differential enthalpies of exchange and the fraction of the negative charge (in brackets) associated with each group of sites

Clay	CEC μeq g^{-1}	Differential enthalpies of exchange in kJ eq^{-1}					
Illite	210	$-20{\cdot}0$ (0·15)		$-10{\cdot}9$ (0·24)	$-7{\cdot}6$ (0·15)		$-6{\cdot}0$ (0·46)
Kaolinite	60		$-14{\cdot}4$ (0·32)			$-7{\cdot}1$ (0·68)	
Mica	60			$-10{\cdot}5$ ($>0{\cdot}9$)			
Montmorillonite	700			$-10{\cdot}7$ (0·06)		$-6{\cdot}5$ (0·23)	$-5{\cdot}2$ (0·71)
Vermiculite	1200		$-15{\cdot}9$ (0·13)			$-6{\cdot}3$ (0·87)	
Mean differential enthalpy		$-20{\cdot}0$	$-15{\cdot}2$	$-10{\cdot}7$	$-7{\cdot}6$	$-6{\cdot}6$	$-5{\cdot}6$

Critical potassium potentials for crop growth. Studies were continued on yield responses of crops, grown in a constant environment, to different levels of the chemical potential of soil potassium, averaged over the growth period ($\Delta G_{K,Ca+Mg} = RT\ln(a_K/a^{\frac{1}{2}}_{Ca+Mg})$; *Rothamsted Report for 1978*, Part 1, 285–6).

'Exhaustion' and 'optimum' potentials for perennial ryegrass and creeping red fescue were derived from second degree polynomials fitted to the response curves obtained on five soil series. These values varied more with soil type than with species or duration of growth (Table 5a), increasing with the corresponding %K saturation and with decreasing cation exchange capacity of the soils. This indicates that critical potassium potentials for crops depend partly upon soil properties. Alternatively 'exhaustion', 'optimum' and 'toxicity' potentials were derived by fitting three straight lines, for positive, zero and negative response, to the yield data by a numerical iterative method. This was done for the first 4 weeks' growth of maize, peas, sugar beet, wheat and field beans, grown on a

TABLE 5a

Ranges of 'exhaustion' and 'optimum' K potentials for perennial ryegrass and creeping red fescue on five soils

	Exhaustion	Optimum
	kJ mol^{-1}	
Perennial ryegrass	−28·2 to −17·5	−15·5 to −4·3
Creeping red fescue	−31·0 to −18·5	−14·7 to −3·3

TABLE 5b

'Exhaustion', 'optimum' and 'toxicity' K potentials for several crops, in the first 4 weeks' growth, on a sandy loam (Newport series)

	Exhaustion	Optimum	Toxicity
		kJ mol^{-1}	
Maize	−19·5	−10·8	+1·8
Peas	−19·1	−13·2	0·0
Wheat	−20·0	−10·6	+0·1
Beans	−40·3	−12·4	−1·3
Beet	−20·4	−7·3	+1·3
Ryegrass (after 6 weeks)	−22·9	−7·6	—
Fescue (after 6 weeks)	−20·6	−8·1	—

sandy loam of the Newport series (Table 5b). For the varieties used, the optimum K potential increases in the order legumes, cereals, grasses, beet. Exhaustion potentials do not vary greatly, except for ryegrass which is able to extract potassium at very low potentials. Only K potentials greater than −1·0 kJ mol^{-1} decrease yields. (Page and Talibudeen)

Micronutrients and heavy metals

The use of adsorption equations to describe copper complex formation by organic matter. Solutions of humified organic matter were obtained by extracting (with water and 0·2M–KOH) (a) a Batcombe series Rothamsted topsoil, and (b) plant material which had been aerobically incubated alone or mixed with a corresponding subsoil. Varying quantities of cupric nitrate were added to aliquots of the solutions, and the variation of the concentration of cupric ion with that of added copper (at a constant organic matter concentration, pH and ionic strength) was determined for each solution using a cupric ion-sensitive electrode. Attempts were made to fit five equations often used to describe adsorption of ions on soil surfaces to the results, using the computer programme GENSTAT.

Langmuir or Temkin equations did not fit the data very well, but double Langmuir, Gunary and Freundlich equations fitted almost equally well, leaving very small residual sums of squares. The Freundlich isotherm was preferred, because its parameter values were the only ones stable to changes in the range of copper or organic matter concentrations considered. This is probably because of the heterogeneity of all the forms of humified organic matter, each of which contains a variety of complex-forming sites of differing strength; similar measurements using a sample of polyacrylic acid, with a single type of site, gave results which fitted a Langmuir equation very well. (Sanders)

The behaviour of Cr(VI) in soil. In soil chromium of valency 3 (Cr(III)) is probably inert and harmless, whereas chromate (Cr(VI)) could be a much more harmful soil pollutant. It seems to be believed that Cr(VI) is reduced rapidly in soil, but this may be an artefact of the method of analysis used. Cr(VI) reduction was therefore investigated.

Cr(VI) is strongly sorbed by soil sesquioxides, the extent increasing with decreasing pH. To distinguish between losses of Cr(VI) from solution caused by reduction or sorption a method of quantitative desorption from soil is necessary. Sorbed Cr(VI) is readily desorbed from soil colloids at pH >9, but the usual alkaline reagents give too intensely coloured extracts. 0·2M-aqueous tris(hydroxymethyl)methylamine gave efficient extraction of Cr(VI) with only slight colour, which allowed colorimetric analysis.

Applying these methods to a set of topsoils with 0·8–1·0% organic carbon showed that their efficiency in reducing Cr(VI) increased regularly with decreasing pH. However, the corresponding subsoils with much less organic matter did not fit the same sequence as the topsoils, the former tending to reduce less and sorb more Cr(VI) than topsoils of the same pH.

Under anaerobic conditions a topsoil of pH 6·65 reduced about as much Cr(VI) as under aerobic conditions, *c.* 40 mg kg^{-1} soil, which is surprisingly little. However, in the presence of 0·5% dried plant material the initial 100 mg Cr(VI) kg^{-1} soil was completely reduced after 20 days' anaerobic incubation. Throughout this study we obtained no evidence for the formation of soluble Cr(III)—organic complexes. (Bloomfield and Pruden)

Trace elements in five soil series. To test the relationship between soil series classification and trace element content, in relation to the potential value of trace element analysis of the samples collected and stored by the Soil Survey of England and Wales, topsoil (A horizon) samples from ten profiles of each of the Newport, Hanslope, Highweek, Clifton and Denchworth series were analysed (Table 6). Their total contents of Cu, Pb, Ni, Zn, As and Mn were determined by X-ray fluorescence spectrometry, and extractable B, Mo, Co, Cd, Cu, Pb, Ni and Zn were determined by ADAS staff using their standard methods.

TABLE 6

Means and ranges of contents (mg kg^{-1}) of Cu, Pb, Ni, Zn, As, and Mn in five soil series

Element	Series	Newport	Hanslope	Highweek	Clifton	Denchworth
Cu	Mean	20	26	44	22	31
	Range	43–12	30–21	74–24	43–13	52–18
Pb	Mean	44	30	51	39	39
	Range	69*–24	46–19	94–28	58*–24	58–21
Ni	Mean	14	42	48	21	39
	Range	20–8	48–27	80–29	29–13	55–25
Zn	Mean	62	100	136	87	103
	Range	148–33	124–74	201–63	182–52	187–78
As	Mean	12	22	67	15	23
	Range	20–8	27–16	190–23	36–8	33–12
Mn	Mean	551	761	2459	485	695
	Range	1206–49	1059–491	5079–1318	841–320	1767–99

* One atypical and very large value omitted

The average total contents were smallest for soils with sandy parent materials (Newport and Clifton). The amounts of trace elements (excepting Pb) are related to the amount of the <2 μm e.s.d. clay fraction, except that the Highweek series had larger contents than would be expected because much of the >2 µm fraction consists of slate or shale fragments derived from clayey sediments. Some Highweek samples contain very large amounts of arsenic (>100 mg kg^{-1}), presumably because they occur on mineralised rocks or have been contaminated by mining.

The range of total contents within series differed markedly from Hanslope (average coefficient of variation over all six elements 18·5%) to Denchworth (36·6%), Highweek (45·8%), Newport (48·3%) and Clifton (63·2%). The large variability of the latter two series is largely due to two samples, one in each series, which may be artificially contaminated.

Correlation coefficients between total and extractable metals were 0·87 for Cu, 0·53 for Pb, 0·49 for Ni and 0·29 for Zn over all series. However within-series correlation coefficients between total and extractable amounts of these elements were much larger for all series, except Hanslope. Thus for Cu values of 0·98, 0·99, 0·92 and 0·97 were obtained with Newport, Highweek, Clifton and Denchworth series respectively, for Pb, 0·99 with Newport, 0·89 with Highweek and 0·81 with Denchworth, and for Ni, 0·87 with Highweek.

The results show that the total trace element contents are related to soil series, but that the ranges in different series overlap greatly. They also suggest that *accurate* determination of the total trace element contents of a sufficient sample of a soil series would increase our understanding of its geochemistry, and that within several series there are reasonably dependable relationships between extractable and total amounts of trace metals, especially for Cu and Pb. (Brown, with ADAS)

Soil organic matter

The effect of mechanical disturbance on organic matter changes in soil. Total organic matter, microbial biomass and ATP were measured in ploughed and direct drilled soils sampled from the Edinburgh School of Agriculture's 11-year-old experiment on cultivations for spring barley. As in previous work (*Rothamsted Report for 1978*, Part 1, 289), there was very little difference in the total C, total N, biomass C or ATP contents of the ploughed and direct drilled soils (Table 7), provided they were sampled on an equal soil weight basis to compensate for the difference in bulk density between cultivation treatments. The fact that little difference had emerged in the sensitive fractions (biomass C and ATP) after 11 years of direct drilling is strong evidence against there being a net accumulation of organic matter in direct drilled soil. In contrast, when 0–5 cm depth samples were taken from the same two plots of the Edinburgh experiment, the direct drilled sample contained considerably more organic matter, microbial biomass and ATP than the ploughed sample (Table 7). Direct drilling thus leads to an accumulation of

TABLE 7

Some properties of ploughed and direct drilled soils sampled on an equal weight or equal depth basis

Management	Sampling depth cm	Organic C %	Total N %	Biomass C	ATP
				µg g^{-1} oven dry soil	
Equal weight					
Ploughed	0–25	4·15	0·237	230	1·73
Directed drilled	0–23	4·27	0·241	246	1·85
Equal depth					
Ploughed	0–5	3·56	0·220	213	1·95
Direct drilled	0–5	4·66	0·346	297	2·67

organic matter near the soil surface, but does not influence the *overall* amount of organic matter in the profile.

It has been suggested that the results obtained by the fumigation method of measuring soil microbial biomass (Jenkinson & Powlson, *Soil Biology and Biochemistry* (1975) **8,** 209–213) depend on whether or not the soil is sieved. To test this, the effect of $CHCl_3$ on soil respiration was measured in soil cores that were either undisturbed or had been passed through a 6·35 mm sieve. Sieving increased the CO_2 evolution of unfumigated soil by 14%, but the increase in respiration caused by $CHCl_3$ fumigation, and hence the calculated biomass, was almost equal in undisturbed and sieved soil. The use of undisturbed cores is therefore not necessary. (Powlson and Jenkinson)

Improvements in techniques. In the method recently developed (Jenkinson & Oades, *Soil Biology and Biochemistry* (1979) **11,** 193–199) for measuring adenosine 5′-triphosphate (ATP) in soil, ATP in an extract is determined by adding luciferin and a crude firefly luciferase preparation, and measuring the light produced. This crude luciferase preparation contains nucleoside 5′-diphosphate kinase and is therefore capable of producing ATP through the reaction of guanine triphosphate (GTP) with ADP. GTP added to a soil extract gave a linear increase in light output, the output being half that of an equivalent amount of ATP. In contrast, a purified enzyme preparation (Sigma L-5256) responded to ATP alone, and when this was used, ATP measurements on extracts from four Rothamsted soils were, on average, 19·5% less than when measured with the crude enzyme. This indicates that the biomass C/ATP ratio for the soil microbial biomass should be 165, rather than the value of 138 proposed by Jenkinson, Davidson and Powlson (*Soil Biology and Biochemistry* (1979) **11,** 521–527.

When measuring soil microbial biomass by the $CHCl_3$ fumigation method (Jenkinson & Powlson, *Soil Biology and Biochemistry* (1975) **8,** 209–213), soils are usually incubated at 50% water holding capacity (w.h.c.). The effect of varying water content over the range 30–70% w.h.c. were examined on a grassland soil. Although respiration increased with water content, the effect was generally similar in both fumigated and unfumigated soil so that, over this range of water contents, biomass was within 10% of that measured at 50% w.h.c. The effect on the flush of mineral nitrogen was even less. (Jenkinson, Powlson and Rumley)

Effects of soil organic matter on cereal yields. From 1965 to 1977 various crops were grown in the Peat Experiment on sandy loam soil at Woburn (*Rothamsted Report for 1978*, Part 2, 83–98). Yields were always larger on soils with peat than without, except for total dry matter of winter wheat in 1974.

Spring barley was grown in 1978 and winter wheat in 1979 (Table 8). Yields of both

TABLE 8

Yield of spring barley and winter wheat, grain t ha⁻¹, given four amounts of N on soil containing two amounts of organic carbon

% C in soil	Fertiliser N applied, kg ha⁻¹: 0	50	100	150
		Spring barley 1978		
0·76	2·19	5·00	6·73	7·05
1·95	2·58	5·12	6·85	7·81
		Winter wheat 1979		
0·76	3·54	7·32	8·05	7·82
1·95	4·81	7·21	8·09	8·08

crops increased with N dressing, to 100 kg N ha^{-1} for wheat and 150 kg N ha^{-1} for barley. On average, there were small increases in yield where organic matter had been added, the greatest effects being with 0 or 150 kg N ha^{-1} for both crops. It is possible that the extra organic matter in some way increases nitrogen uptake by the crop, causing the increased yield with nil N, whereas additional water retention could explain the rest of the beneficial effect. Both wheat and barley yields were better than average for Woburn, probably because of the high April–July rainfall in both years. In the experiment on Yield Variation (p. 22) on a similar soil average wheat yield in 1979 without irrigation was 7·2 ha^{-1}, and with 120 mm irrigation yield increased to 8·4 t ha^{-1}. (Johnston and Poulton)

Investigations on soil structure

Soil structure formation. Compaction appears to be much more detrimental and permanent in some soils than in others, but the reasons are not understood. A project has been started in the Soil Structure Group to study the processes of structural regeneration in compacted soils, to identify soils where damage is persistent and to discover the basic reasons for soil differences. Preliminary work at Rothamsted on Batcombe series soil used a Land Rover to make deep ruts in autumn-ploughed land, after which the plot is only being worked by hand. Tensiometers and soil surface metering equipment have been installed, and undisturbed soils samples are being taken for laboratory examination from the wheeled and unwheeled areas of the plot. Water retention characteristics, shrinkage, image analysis of void structure, and the effects of cycles of wetting and drying, and freezing and thawing will be tested.

Both compaction and displacement of soil occurred during the wheeling, and during the reworking clay was dispersed from the soil in the wheel tracks. Compaction eliminated much of the void space larger than 60 μm, but there was no significant alteration to the water release characteristics between $-0{\cdot}05$ and -15 bar potential. By harvest the surface had subsided by $3{\cdot}5 \pm 0{\cdot}5$ cm, but there was no significant change in the profiles of the wheel tracks. Bulk shrinkage seems to be larger for the compacted than for the uncompacted soil. (Newman, with Bullock and Thomasson, Soil Survey)

The ability of fine-grained soils to form a structure which allows water and air transmission depends on the way that the potentially massive soil matrix differentiates into small units by cracking. A new study of soil cracking aims to develop techniques for describing and quantifying crack patterns, to use these techniques to compare soils with different cracking properties, and to discover the reasons for these differences.

The actual sequence of cracking of puddled soil as it dries has been studied using photographs taken at frequent intervals. The patterns of soil and cracks were then analysed on the Quantimet image analysing computer, and crack perimeter and area measured.

Crack patterns have also been simulated on the 4–70 computer by a stochastic mathematical model. This shows promise, but does not yet properly match the actual soil crack patterns recorded by photography. (Newman, Rayner, and Rees (vacation student))

Ion movement in soil

Nitrate leaching in soil. An earlier simulation model for the movement of solutes in soil was based on the 'layer' principle, and partitioned the soil solution into mobile and retained phases, of which only the mobile phase was displaced when rain occurred, the retained phase probably being found mainly within the aggregates (*Rothamsted Report for 1976*, Part 1, 87).

A new version of the model has been developed that differs from the original in the following ways. (a) The amounts of mobile and retained water in each layer are calculated from the aggregate size distribution, which determines their effectiveness in holding back solute. (b) Diffusion-controlled solute movement between the phases replaces immediate solute equilibration when movement ceases. The aggregates are treated as cubes rather than spheres, because peds are more commonly blocky than granular in structured agricultural soils, and because of the packing problems associated with spheres. Although there is no formal analytical treatment of diffusion in cubes, a simplified approach has been developed in which the cubes are divided into concentric volumes, and diffusion between these calculated by Fick's Law.

The amounts of mobile and retained water calculated with the new and old versions were similar for surface soils with small aggregates, which reach a state close to equilibrium in a short time. However, for the subsoil below 50 cm the new version calculated much larger ratios of retained to mobile water than the original, and which explain the arbitrary values found necessary for satisfactory simulation of chloride leaching in the Rothamsted 40-inch Drain Gauge (Addiscott, Rose & Bolton, *Journal of Soil Science* (1978) **29**, 305–314). Initial simulations of nitrate concentrations in cores taken by the Water Research Centre, Medmenham, (*Rothamsted Report for 1978*, Part 1, 287–288) to 20–30 m from the deep clay and chalk at Rothamsted suggested that the new version should be usable, with some modification, to these depths. (Addiscott)

Ion diffusion in structured soil. Movement of some major nutrients to roots is almost entirely by diffusion. The rate of movement is controlled by the diffusion coefficient and this work aims to measure the effect of soil structure and distribution of water within soil on the coefficient. Using bromide-chloride counter-diffusion and an ion exchange membrane as the ion sink, the diffusion coefficient in cores of field soil, and in the same samples after sieving and repacking, has been measured.

In a Hooke series topsoil all diffusion coefficients were in the range of $5–7 \times 10^{-6}$ cm^2 s^{-1}, which corresponds to values of f_c (the tortuosity factor) of 0·23–0·33. Neither the structure nor the method of wetting had much effect on diffusion coefficients, at the same values of water content and bulk density. If this is generally true, it will be relatively simple to measure diffusion coefficients of field soils. (Barraclough)

Soil and clay mineralogy

Allophane and ferrihydrite in field drains. Deposition of ochre in field drains is a local nuisance in agricultural land. At the Arthur Rickwood Experimental Husbandry Farm, in a field experiment testing drainage methods, drains that were used for back-irrigation contained ochre as a single layer (Deposit 1), whereas in the rest the deposit was stratified into an ochre and a pale buff layer (Deposits 2 and 3). Table 9 shows the estimated percentages of the principal constituents in typical samples.

It is believed that back-irrigation physically removed layer 3. The reason for the better crystallisation of ferrihydrite in deposit 1 is unknown, but may result from an alternation of oxidising and reducing conditions where back-irrigation is used.

TABLE 9

Constituents of drain deposits

Deposit	Protoferri-hydrite	Ferri-hydrite	Allophane	Organic matter	Gypsum	Clay and accessory minerals
1	—	68	6	19	5	2
2	65	—	8	14	4	9
3	20	—	52	16	5	7

The organic fraction was found, by infrared spectrophotometric analysis, to contain a large proportion of fulvic acid, possibly resulting from the subsoiling of this peaty soil, and electron microscopy showed numerous filaments from the oxidising bacterium *Gallionella ferruginea* Ehr. 1838. Some of the iron and most of the sulphate in the deposits are almost certainly derived from pyrite in the peaty sediments which has been oxidised by the oxidising bacterium *Thiobacillus thiooxidans*.

At this site sedimentation might be minimised by keeping the water level just above the drains with occasional back-flushing to remove solid material. (Ormerod)

Soil forming processes

Chalkland soils. The conclusions of earlier work at Rothamsted on the origin of chalkland soils in south-east England (*Earth Surface Processes* (1976) **1,** 181–193), have been tested in the Chilterns by a detailed examination of geological structures, surface drainage patterns and the composition of soil parent materials.

Computer mapping procedures were applied to height data from borehole records and geological maps to obtain contours of structural surfaces, such as the sub-Tertiary and sub-Senonian surfaces. These showed that the topographic features which Wooldridge and Linton (*Structure, surface and drainage in South-East England*, 2nd edition, 1955. London; G. Philip & Son Ltd.) attributed to Plio-Pleistocene marine bevelling of uniformly inclined strata, coincide with major NE-SW flexures, presumably of mid-Tertiary age. The Chiltern plateau surface therefore seems to be the warped sub-Tertiary surface, which was exhumed mainly by sub-aerial erosion during the late Tertiary or Quaternary, and has since been lowered only slightly by dissolution of chalk beneath a thin veneer of Reading Beds.

The main through valleys of the Chilterns are often located along the axes of minor transverse (NW–SE) synclines in the Chalk. Geological structure also controls distribution and type of minor dry valleys throughout the chalk dipslope. In terms of valley density and ordering, the networks on the three major facets proposed by Wooldridge and Linton are not significantly different; this supports the interpretation of the dipslope as a single geomorphological unit.

The particle size distribution and sand, silt and clay mineralogy of Reading Beds from the main Tertiary outcrop and outliers on the Chiltern dipslope plateau all proved more variable than was previously thought, and it is consequently difficult to distinguish them from undoubted Quaternary deposits. However, the composition of gravel fractions (>4 mm) proved more useful, and a few sites where marine Plio-Pleistocene deposits do occur (e.g. Little Heath near Berkhamsted) were identified largely on this basis. Attempts to find more of the Quaternary 'Red Crag' on West Barnfield (Rothamsted Farm) using various geophysical techniques all proved unsuccessful. We conclude that Plio-Pleistocene marine deposits do occur locally on the Chilterns, but that the sea merely trimmed a landscape of Lower Tertiary deposits, which were subsequently removed by renewed subaerial erosion. The influence of the marine deposits on present soils of the Chilterns is very small indeed. (Catt, with Moffat, Soil Survey)

Protein extractions

Protein extractability from, and polyphenol content of, leaves from *Helianthus annuus*, *Vicia faba*, *Atriplex hortensis*, *Chenopodium album*, *Medicago sativa*, *Amaranthus spp.* and *Rumex spp.*, were determined at different crop ages. High molecular weight polyphenols were estimated by the difference in the polyphenol content of a 0·02M-sodium carbonate extract and a 1M-sodium chloride extract made alkaline with sodium carbonate.

A weak negative correlation was found between the higher molecular weight polyphenol content and protein extractability as the crops aged with sunflower and amaranth, but not with the other crops.

Recent improvements to the juice extractor made it cheaper and easier to fabricate, and allow less fibre to be expressed with the juice. Other design changes prevent the auger becoming fouled by long fibrous material during processing, facilitate more efficient transfer of the charge to the cone section, and give a more even feed.

Leaf protein used for feeding infants in Coimbatore (India) is dried before being incorporated in the diet, because it is easily perishable, but this is expensive and reduces the nutritive value. A press-cake containing 55–58% DM was found to be less perishable, and cake containing only 40% DM can be preserved for 1–2 weeks at 27°C by adding acceptable amounts of acetic acid, salt or sugar. (Butler and Pirie)

Methods, apparatus and techniques

Trace metal analysis. A new atomic absorption spectrophotometer (Perkin Elmer 372) was bought with a graphite furnace for electrothermal atomisation to be used for trace metal analysis. The accuracy and precision of the instrument, and its sensitivity to matrix interference, have been assessed using acid ammonium oxalate extracts containing Cu, Co, Cr, Cd and Ni, all elements associated with sesquioxides in soil. Determination of copper seems most straightforward. Conditions for determining chromium, nickel and cadmium require much more careful control. (Newman and Branson)

Mercury porosimetry. A Micromeritics 915–1 porosimeter with a maximum working pressure of 50 000 psia (3·5 kbar) has been purchased to measure the volume of mercury intruded into porous soil as a function of applied pressure and so estimate pore size distribution. Pore sizes ranging from 100 to 0·002 μm are intruded. There have been problems associated with poor finish of the pressure chamber, insensitive pressure control and breakage of glass cells, but these are now thought to be rectified. Pore size distribution measurements are planned for several soil structure projects. (Newman and Patel)

Analysis of small samples by X-ray fluorescence spectrometry. The work on insect analysis methods in collaboration with the Entomology Department has continued. The main aims are to improve reproducibility in the position of the sample, and to allow analysis of samples smaller than 300 mg (see last year's *Report*), prior preparation of batches of samples for analysis, and storage of samples after analysis, so that optimum instrumental conditions can be used for each element, and additional elements in the sample may subsequently be determined.

A method is being developed using 13 mm diameter pressed discs, that appears to fulfil all the above requirements. The holders are relatively cheap and are normally considered as disposable, and samples as small as 50 mg can be used. The method will be applicable to any material from which coherent pressed pellets can be prepared, and will greatly increase the range of insect species that can be analysed. (Brown, with Stride, vacation worker in Entomology Department)

Prevention of the volatilisation of phosphorus during perchloric acid digestion of sodium bicarbonate soil extracts. About 10% of P was lost, mainly by volatilisation, during $HClO_4$ digestion of $NaHCO_3$ soil extracts for measurement of organic P. Addition of $MgCl_2$ prevented this loss, reduced variability of replicate determinations and ensured virtually 100% recovery of P added to $NaHCO_3$ solution and $NaHCO_3$ soil extracts before digestion. (Brookes and Powlson)

Soil solution extraction. Rapid and dependable methods for obtaining successive samples of soil solution could be of great value, because they could make much tedious soil sampling for nitrate unnecessary. Four kinds of samplers were developed for the extraction of soil solution under field conditions from depths down to 0·5 m, employing ceramic, phosphor-bronze and glass-fibre membranes. Some ceramic and all phosphor-bronze and glass-fibre membranes were useable at soil moisture suctions less than 0·3 bar. Finely porous ceramic units were effective to 0·6 bar suction. All units provided clear samples of soil solution immediately available for chemical analysis. Units are being developed for operation at depths >1 m and with facilities for transferring soil solution to sampling points outside experimental areas. A simple micro soil solution sampler has been developed using a glass-fibre membrane for use with a field spot test for nitrate N in investigations of leaching in the field. Values for soil nitrate obtained with these units are now being compared with those obtained by conventional soil sampling. (Williams)

Analytical section

Analyses. 95 000 digestions and analyses were done this year—7·8% less than last year. Of these, some 44 000 were for nitrogen, nitrate or ammonium. About 6·0% were for other departments. (Avery, Cosimini, Jasko and Messer)

New methods. A method (Hafiz, Brownell & Stout, *Communications in Soil Science and Plant Analysis* (1973) **4,** 333–341) for the determination of Rb and K by atomic absorption, each in the presence of the other, was successfully applied to plant and soil solutions.

A method involving the spectroscopic measurement of the chromic ion for the determination of organic carbon in soils in small Technicon digestion tubes, using a modified Tinsley method, gave good correlations with standard methods on a range of soils. (Cosimini, Jasko and Ramanjooloo)

Staff and Visiting Workers

R. Webster transferred to the Department from the Soil Survey to fill one of the organisational Senior Principal Scientific Officers posts, and J. S. Jenkinson was promoted to Senior Principal Scientific Officer by Special Merit. Iren Jasko resigned in August for family reasons, and Pat Bond left the Department in August for the Soil Survey on promotion to executive officer. R. Leigh joined the Department from Cambridge in October to work on root physiology, and S. McGrath came from Sheffield to study trace metal nutrition of plants. R. J. Darby arrived from the National Vegetable Research Station to join the team working on yield variation. In February R. A. Hodgkinson came to us on a 1 year appointment, to study soil nitrogen changes.

N. W. Pirie spent 2 weeks in Venezuela during January, at the invitation of the Ministry of Agriculture and the Fondo Nacional de Investigaciones Agropecurias, to discuss the prospects for making leaf protein, and also visited the Institute of Tropical Agriculture at Mayagüex, Puerto Rico. In April he visited Kuala Lumpur and Singapore for COSTED meetings, and Calcutta, Mysore and Bangalore to see and discuss leaf protein projects which exist or are being planned there. In October he was invited to Cairo and Alexandria by the Egyptian Academy and National Research Centre, to discuss their leaf protein projects. P. B. Tinker was elected to a Regent's Lecturership by the University of California and spent 4 weeks lecturing and visiting in the Riverside, Berkeley and Davies

Campuses. He also visited and lectured at Ames, Iowa and at Guelph. At the invitation of the Alberta Department of Agriculture, J. Ashworth worked in Edmonton, Canada, during 1979–80 on the effects and uses of xanthates and other inhibitors of nitrogen transformations in soil. During the year he visited and lectured at the Agricultural Research Centre at Lethbridge, the Research Council of Alberta, the International Fertiliser Development Centre at Muscle Shoals, and the Universities of Alberta, Manitoba, Kentucky, Iowa and Illinois. A. E. Johnston visited various research institutes near Hanover at the invitation of The Potassium Institute.

A. J. Moffat left to join the Soil Survey. A. Gildon completed his ARC scholarship period and left for post doctoral work at Newcastle University. A. B. McBratney who is working for his Ph.D. on a DAFS scholarship joined the Department with his supervisor, R. Webster. Mr. M. Zahari of The Malaysian Agricultural Research and Development Institute continued his studies on organic decomposition products in acid sulphate soil. Our Sandwich Course students were P. A. Grieve, Faith Hoare, M. J. Clements and A. K. Rumley. Blanche Benzian continued to work on nitrogen content in grain, as a member of the Department funded in part by the Phillips Price Trust, and A. Bromfield remained in Kenya working on the problems of sulphur in rain water.

Amongst our visiting workers, Dr. H. Imai, of the National Institute of Agricultural Sciences, Tokyo, completed his year with the Department, working on phosphate sorption, N. N. Ramanjooloo of the Ministry of Agriculture, Mauritius, spent 6 months working on analytical techniques; Dr. K. M. Goh of Lincoln College, New Zealand, worked on mycorrhizas for 5 months, Dr. C. C. Cerri of Centro de Energia Nuclear na Agricultura, Brazil, arrived to work for 6 months on carbon turnover in soils and A. R. B. M. Atan of the Malaysian Agricultural Research and Development Institute joined us to gain experience of techniques for studying sulphate soils.

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