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ROTHAMSTED RESEARCH

Report for 1981 - Part 1

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General Report

L. Fowden

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GENERAL REPORT

L. FOWDEN

Lawes Agricultural Trust. Lord De Ramsey retired from membership of the Trust Committee at the end of the year. He had been a member since 1964 and Committee Chairman since 1978. His long period of service and his deep interest and involvement in the work of the Experimental Station has been appreciated greatly by his colleagues on the Committee and by all members of staff at Rothamsted. We are pleased that he will retain a close association with the Station in his continuing role as a Trustee. Mr John S. Martin, an East Anglian arable farmer, has been nominated by the Royal Agricultural Society of England to fill the vacancy on the Trust Committee.

Staff. J. McEwen assumed the Headship of the Field Experiments Section at the beginning of the year. G. V. Dyke, who had been Head of the Section from 1959 to December 1980, and a member of Rothamsted staff since 1947, retired in November. Other members of staff retiring after more than 20 years' service (department and year of appointment in parentheses) included: G. Berneye (Engineering and Maintenance, 1958), M. Kay Boutwood (Administration, 1953), E. J. Burgess (Engineering and Maintenance, 1953), Doris Court (Statistics, 1948), C. C. Doncaster (Nematology, 1950), J. H. A. Dunwoody (Statistics, 1947), R. A. French (Entomology, 1948), D. W. King (Soil Survey, 1947), G. A. Salt (Plant Pathology, 1948), O. Talibudeen (Soils and Plant Nutrition, 1951) and R. J. B. Williams (Soils and Plant Nutrition, 1956).

The deaths of two members of staff are reported with sadness: V. C. Gullick had operated an efficient printing service for the Station, and E. Thomas had provided enthusiastic leadership of a group in Biochemistry engaged in plant cell and tissue culture and regeneration forming part of our genetic manipulation programme.

Honours and awards. The Knight Grand Cross of Royal Victorian Order was conferred on our senior Trustee, His Grace the Duke of Northumberland, in the Queen's Birthday Honours List. A. W. Neill, a member of the Farm staff since 1941 and bailiff at Woburn Experimental Station since 1948, was awarded the British Empire Medal in the same List. M. Elliott was made a Commander of the Order of the British Empire in the New Year's Honours List, 1982.

J. A. Nelder was elected a Fellow of the Royal Society in recognition of his distinguished contributions to statistical theory and computer-based statistical programs, and awarded an Honorary Doctorate of the Paul Sabatier University of Toulouse for his statistical work. M. Elliott, N. F. Janes and D. A. Pulman received jointly the Mullard Award of the Royal Society for their work leading to the development of synthetic pyrethroid insecticides: this award is given to individuals who have made an outstanding contribution to the advancement of science or technology leading directly to national prosperity in the United Kingdom.

L. Fowden was elected a Corresponding Member of the American Society of Plant Physiologists.

Buildings. The first phase of a new glasshouse development on Ninnings field was completed in the spring, and work on the second stage should begin early next year. Other building work was limited to small programmes of refurbishing and improvement of existing facilities.

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Visits and visitors. During the year Rothamsted received a Visiting Group, on the regular 6-yearly basis, to conduct an independent review of the effectiveness of the research programme having regard to the resources of staff, buildings and equipment available to the Station. In practice the Group consisted of four coordinated subgroups, and each spent 3 full days at Rothamsted. Much additional time was required for the preparation of research reports and other documentation needed by the Group, and for these reasons it was decided to forgo, for 1981 only, the annual Subject Days that have become a welcome part of our visitor programme. However, we arranged a special day in July for about 60 senior members of the Royal Agricultural Society of England; during the morning some possibilities for developing new agricultural technologies from current research were reviewed, whilst the afternoon was devoted to visits to both the classical and the modern multidisciplinary field experiments. Aspects of our research were presented also to large groups of participants in post-conference tours after the Fourth International Barley Genetics Symposium and the International Soil Micro-morphology Meeting held respectively in Edinburgh and London. Rothamsted was host to a 2-day training meeting for about 45 soil science specialists from the Agricultural Development and Advisory Service (ADAS) when soil structure and its regeneration following adverse treatment, subsoil cultivation, soil organic matter and nitrogen balances, and drought and tillage experiments were among topics examined. Another 2-day workshop, organised by the Plant Pathology Department and attended by scientists from universities, research institutes and industry, reviewed techniques in plant disease epidemiology, and through practical sessions offered participants direct experience of modern research techniques.

Visitors again came individually or in small groups from many countries for research discussions. Among these were the Hon. T. L. Austin, Minister of Agriculture of the Government of Victoria, Australia, the President and other officers of the Sociedad Rural Argentina, members of a study group concerned with the development of a pesticides research institute in the People's Republic of China, and a group of leading soya-bean researchers from the USA. Rothamsted was also host to the Biennial Meeting of the Working Group of the International Organisation for Biological Control specialising in Pesticides and Beneficial Arthropods.

The number of overseas visitors undertaking research for periods of 1 month or more in our scientific departments exceeded all previous levels. A total of 76 visitors came from 39 different countries; Brazil, China and New Zealand were represented most significantly.

During the year members of Rothamsted travelled to more than 30 countries to act as advisers on agricultural problems, to participate in research programmes, to attend international conferences, or to engage in scientific research discussions or lecture tours. B. R. Kerry and D. W. Lawlor each spent about 4 months collaborating in research in Australia, D. H. Crump and J. Lacey shared their expertise with researchers in the USA, and D. Hornby undertook a 3-month consultancy on cereal root diseases in South America, based in Brazil. We maintained contact with institutes under the aegis of the Consultative Group on International Agricultural Research by visits by J. E. Beringer to the Centro Internacional de Agricultura Tropical (CIAT) in Colombia, by G. A. Salt to the International Centre for Agricultural Research in the Dry Areas (ICARDA) in Syria and Egypt, and by J. M. Day to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. Five members of staff represented Rothamsted at the 13th International Botanical Congress in Sydney, Australia, whilst B. Clayden travelled to New Zealand to attend meetings of Commissions of the International Society of Soil Science and to participate in pre- and post-congress field excursions. L. Fowden and T. Lewis visited China, as members of delegations, within the provisions of the Royal Society—Chinese Academy of Sciences exchange agreement, and J. A. Pickett was a

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member of a group presenting seminars on Analytical Instrumentation in Agricultural Research and Practice at different centres in China.

Research exhibits at outside sites. The Agricultural Research Council (ARC) celebrated its fiftieth jubilee during the year in a number of ways, including a scientific soirée held in June in the premises of the Royal Society. Rothamsted contributed material to three of the exhibits: the synthetic pyrethroids; the increased efficiency of cereal cultivation systems; and genetic manipulation for the improvement of crop plants. The collection of exhibits was on display during the following week at the Royal Agricultural Show at the National Agricultural Centre, Stoneleigh. At the annual soirées of the Royal Society, Rothamsted collaborated with the National Institute of Agricultural Engineering in an exhibit illustrating electrostatic spraying of crops; demonstrations showed the advantages of this technique over conventional spraying systems, allowing pesticides to be applied more efficiently and with greater efficacy against insect pests on crop foliage. An enlarged and updated exhibit of electrostatic crop spraying equipment attracted very considerable attention from agricultural machinery manufacturers and spraying contractors at the British Crop Protection Conference held at Brighton in November.

The technique developed at Rothamsted for incorporating granular nematicides into soil for the control of cyst nematodes in potato crops was demonstrated at the East of England Agricultural Show at Peterborough in July, and again at a Potato Marketing Board demonstration at Sutton Bridge, Lincolnshire, in September. The Station also contributed to the ICI Cereal Fair held at Ropsley, Lincolnshire; our exhibit described how the nutrient elements, nitrogen, phosphorus and sulphur affect the protein content and protein yield of cereal grain.

Weather and crops. January and particularly February were drier than average, making land work possible and allowing early sowing of some spring barley and beans. Although mean maximum and minimum temperatures in March were significantly higher than long-term averages, the month was particularly wet with rain falling on 28 days and total rainfall approaching three times the monthly mean; sowing, halted towards the end of February, was not restarted until the first week in April. Rainfall in April was average, but May was another wet month with 20 rain days. Under these conditions, some potatoes were planted rather late and crop spraying was often difficult. The main growing season was cool, mean maximum temperatures for the 4 months April to July inclusive being lower than the respective long-term means. Harvesting of winter barleys began in the last days of July, but field work was interrupted by unsettled weather in early August: an unbroken spell of dry, sunny weather followed and cereals were combined in good order with little need for drying. Sunshine totals in August, September and October were higher than average and this brighter weather sustained dry matter production in the sugar-beet crop. November was warmer and drier than average and facilitated late sowings and other field operations, but snow in early December brought an end to land work and marked the beginning of a long cold period which included the lowest temperature (−17·0°C) ever recorded at Rothamsted.

Wheat. Flanders still formed the main winter wheat variety, but Hustler was also grown, and some Avalon and Brigand were introduced. Herbicides applied in the previous autumn were generally effective in controlling weeds, but disease was prevalent, especially mildew, and one field at Woburn was infected badly by barley yellow dwarf virus. Few aphids infested cereal crops. Generally yields were a little lower than in 1980, although some very high yields were recorded for individual plots. The mean yield of 8·3 t ha^{-1} from plots within the multidisciplinary winter wheat experiment at Rothamsted was

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lower than the corresponding values for the 2 previous years (*see* p. 19). The smaller companion experiment on light land at Woburn outyielded that at Rothamsted for the first time with the best combination of treatments giving 11·4 and 10·4 t ha^{-1}. Diseases were the major limiting factor, and fungicide application increased yields by up to 2·7 t ha^{-1}. In experiments comparing eight winter wheat varieties at Rothamsted, Norman performed best on both healthy and diseased (soil-borne pathogens) sites; the highest yield on the healthy site (10·6 t ha^{-1}) was obtained from a plot receiving high nitrogen, fungicide and growth regulator treatments.

Barley. The area sown to winter barley again increased slightly, Igri being the main variety grown. Field yields were less than in 1980 (about 6·3 t ha^{-1} compared with over 7 t ha^{-1}). Most spring barleys, either Triumph or Georgie, were not sown until early April, and since there was sufficient moisture to sustain growth, yields were better than last year and some yields exceeding 7 t ha^{-1} were recorded. Mildew was widespread and all crops were sprayed once, and some twice, with fungicides. All barleys were harvested in good condition, later sown spring crops being combined after the wheats.

Potatoes. Planting was late and protracted by unfavourable weather, but in general crops established and grew well: little irrigation was required, but regular sprays of mancozeb and pirimicarb were applied against blight and aphids. Lifting was done under satisfactory conditions; although yields were generally less than in 1980, some yields over 70 t ha^{-1} were recorded.

Beans. An increased interest at Rothamsted in winter beans resulted in a larger experimental programme but some experiments were lost as a result of severe chocolate spot in the February/March period. Damage was greatly lessened by seed treatment with benomyl but even when this was combined with later benomyl sprays and control of weevils, yields were a little less than 5 t ha^{-1}.

Spring bean sowing was timely but yields were generally less than in 1980 with only a few exceeding 5 t ha^{-1} (*see* Multidisciplinary Activities, p. 32).

Sugar beet. Drilling of the crop was delayed by the wet March, but the current practice of 'drilling-to-a-stand' permitted very rapid progress to be made in the first half of April. Although the heavy rains of late March leached nitrogen from the surface soils, analyses indicated that most remained in the subsoil and in experiments the crops did not respond to additional nitrogen supplied in May. Heavy rain in late April and a wetter than average May encouraged the ectoparasitic nematodes causing Docking disorder, and some damage resulted nationally; undoubtedly, this would have been more widespread had not granular pesticides been applied to 40% of the crop. Following the mild winter, virus yellows was expected to be more prevalent than in any year since 1976. The average level of infection at the end of August was 8%, but marked variation occurred between different areas; indeed, field to field variation within a small area was very marked, affirming the importance of Broom's Barn's research seeking to make decisions regarding aphid control at the field level more precise. Weather and other factors combined to make the final dry matter production of the Broom's Barn crop at the end of October 2·45 t ha^{-1} more than in a comparable crop in 1980.

Selected examples of current research

The Station's programme of research seeks new knowledge in many scientific disciplines essential for the future advancement of agricultural technology and crop production.

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Our activities include both fundamental and applied research supportive of our main objectives, and are in the broad areas of soils research, plant science especially the physiology, biochemistry and pathology of the major arable crop species, and the biology of crop pests and measures for minimising the damage they cause: a smaller but important area of research concerns beneficial insects and other invertebrates.

Soils research

The soils of England and Wales. The Soil Survey of England and Wales commenced a programme in 1979 that would lead to a national soil map at a scale of 1:250 000. The field surveying necessary for the project is virtually completed, ahead of schedule, and the map will be published in six sheets in the spring of 1983. Each map will carry an informative legend, and will be supplemented by records, to be published by summer 1984, providing fuller descriptions of the soils of different regions. Future mapping requirements have been agreed with the Ministry of Agriculture, Fisheries and Food (MAFF), and include a national objective to complete a 1:50 000 scale map for England and Wales; more detailed surveys for specific local purposes will form an important element of this programme. Fieldwork will be initiated in July 1982. The Survey now devotes more effort to special local objectives and to contract surveys. Recently a 1:50 000 scale map of peat thicknesses in the Somerset Moors was produced, a valuable addition to information concerning an area subject to major land use conflicts. Contracts include surveys for the National Coal Board at sites where opencast workings for coal are proposed, and for Water Authorities to evaluate the benefit of improved arterial drainage, the agricultural effects of ground-water abstraction and recharge, and run-off and flood risk.

Soil drainage. Soil physicists have continued the study of mole-drain performance in association with the National College of Agricultural Engineering. Mole ploughing creates both a drain channel and a zone of loosened soil around, and mainly above, the channel. Water flow through the loosened soil and into the channel has been examined further by the application of potential theory. The results establish that the drain is increasingly effective as the zone of loosened soil becomes more exactly rectangular, and so scientific theory supports current trends in the design of mole-plough blades.

Fertiliser requirements for winter wheat. The field experiments forming part of our yield variation programme with winter wheat are being used to develop a system for predicting the best amount of fertiliser N needed as a spring top dressing. Ideally, N present in the soil profile to 90 cm is determined in autumn and spring, and the latter value is used to estimate the required amount of N for maximum yield using a 'nitrogen balance' system. The measurement of profile mineral N in spring, however, is impractical in a working system, and the leaching model for movement of N through soil profiles developed in the Soils and Plant Nutrition Department has been extended to include mineralisation and crop uptake, so that on the basis of autumn soil N measurements it is now possible to estimate mineral N in the profile in spring from simple soil and weather data. The system has worked promisingly when tested on six sites in each of the last 2 years, although there is still uncertainty about the most practical method of defining the amount of mineral N in the profile in autumn, and some of the changes in soil N occurring during the growing season. A program to model the whole N cycle, now beginning, should help to resolve these problems.

Mycorrhizal studies. There is an increasing interest worldwide in the benefits that can accrue to crop plants following infection of their root systems by vesicular–arbuscular

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(VA) mycorrhizal fungi. Recent research in the Soils and Plant Nutrition Department suggests that in many soils natural infection is important and is responsible for significant increases in cereal crop dry matter production. The host crop–VA mycorrhizal relationship is a symbiotic one, the fungi deriving carbon sources from their hosts and, in return, transferring P to the root systems. New experiments employing ^{14}C have shown that an additional 8% of the total carbon fixed photosynthetically by leeks is directed to the roots when they are mycorrhizal, but this drain on the host is compensated by an apparent increase in the rate of C fixation per unit of dry matter, but the underlying control mechanism remains uncertain.

In the past, the potential for using mycorrhizal inoculation at the field level has been limited by the small quantities of inoculum available. A new method for inoculum production developed by members of the Soil Microbiology Department has adopted the nutrient film culture technique widely used for glasshouse crops. Host plants are grown in peat blocks placed in the culture channels; after introduction of a small amount of inoculant, the host roots which proliferate extensively within the blocks rapidly become mycorrhizal. The blocks can be comminuted into small pieces of peat containing root fragments and be used for inoculation in almost the same way as a *Rhizobium* peat inoculant. Cooperation with a commercial horticulturalist enables batches of several hundred kilograms of inoculum to be produced, if needed.

Crop plant research

Models describing crop growth and photosynthesis. As part of an inter-Institute collaborative programme on factors responsible for yield variation in winter wheat, a computer modelling group was formed in 1979 and set out to simulate the growth and development of the crop (*Rothamsted Report for 1979*, Part 1, 13). Good progress has been achieved and submodels for tiller and leaf growth, root growth and assimilate partitioning are now available as working computer programs. The submodels are being linked to provide a model simulating dry matter accumulation and grain weight in disease-free crops receiving ample water and nutrients. Predictions are being tested with data from crops grown at Rothamsted under what are regarded as optimal conditions. Constraints to growth such as shortage or excess of water or lack of nutrients will be introduced into the model in the near future.

Various models describing the relationship between net photosynthesis of leaves of C_3 crop plants, light intensity and CO_2 concentration in substomatal cavities have been adapted by members of the Physics Department and examined for goodness of fit to data obtained in the field and in controlled environments. The most suitable model, based on a resistance analogue for gaseous diffusion and the known physiology and biochemistry of photosynthesis, involves four parameters: quantum yield, mesophyll resistance for CO_2 transfer, and the rates of basal respiration and of photorespiration. Using the model, it has been possible to describe and quantify the effects of water stress and temperature on the parameters determining net leaf photosynthesis.

Mechanistic studies of CO_2 fixation. This year the photosynthesis group in the Botany Department has given increased emphasis to the investigation of the kinetic properties, structure and function of ribulose bisphosphate (RuBP) carboxylase/oxygenase, the enzyme that both catalyses CO_2 fixation in chloroplasts and initiates photorespiration by effecting an oxidative splitting of the RuBP molecule. Procedures have been developed for the preparation from wheat of RuBP carboxylase of consistently high specific activity, and the intact enzyme was shown to be a protein, typical of higher plant carboxylases, composed of eight large and eight small subunits. In the

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catalytically active state, the protein exists as an enzyme/CO_2/Mg^{2+} ternary complex for both carboxylase and oxygenase activities, and the activating CO_2 and Mg^{2+} probably are bound within the RuBP-binding site on the enzyme. Preliminary studies indicate that sulphite affects the activation of the enzyme, an observation of considerable interest in view of the effects of sulphur pollutants on photosynthesis in crop plants.

Cereal storage proteins. The grains of barley, wheat and rye contain prolamins as their major storage protein, and prolamins form the main type of protein in crops harvested in Britain; the 1981 cereal harvest provided almost 10^6 t of these proteins. The chemical and genetic relationships characterising the prolamin complex are the subject of detailed study within the Biochemistry Department, in conjunction with other research institutes, because they are of prime importance in determining grain quality both in regard to baking properties and nutritional value. Superficially, the polymorphic series of prolamin proteins appear complex, but recent analyses of the amino acid compositions and N terminal sequences of purified components indicate that three principal groups of prolamins occur in all three cereals. The groups are homologous in the three species and probably are coded for by complex multigenic loci derived from single ancestral genes. Differences in the relative amounts of the three types occur between species and these probably affect their suitability for use in bread making or in food technology more generally. We hope to define the homology further by attempting cross-hybridisation of mRNAs coding for the prolamins to cloned cDNA known to contain sequences specifying sulphur-rich barley prolamins. The present and future studies should provide a fuller understanding of these most important components of the cereal grain.

Mildew disease of cereals. Following the introduction of systemic fungicides active against mildew, farmers have placed increased reliance on chemical control of this disease. In years such as 1981 when mildew was prevalent, high performance of widely grown mildew-susceptible barley varieties such as Golden Promise is very dependent on the continued effectiveness of the chosen fungicide. The Insecticides and Fungicides Department started to monitor levels of mildew sensitivity to triazole fungicides in 1978, and data now available establish the existence of some triadimenol-insensitive strains in the field and highlight the need to define strategies, using particularly cross-sensitivity data, that will maintain fungicide effectiveness. A potentially promising finding is that the strains less sensitive to triadimenol, and other fungicides with similar modes of action, are more sensitive to ethirimol, which acts differently.

Predictions of levels of virus infection of crops. In last year's *Report* (Part 1, 182) the Plant Pathology Department introduced the concept of an Infectivity Index, which would indicate the likely need for treatment of cereal crops against the insect vector of barley yellow dwarf virus. This year the Infectivity Index has been available nationally for the first time as a guide to the need for an autumn aphicide treatment. The Infectivity Index for crops sown in autumn 1981 was less than one-tenth of that for the previous year, and so few of these crops are likely to have benefited from prophylactic aphicide treatment. We have refined the Infectivity Index by providing a cumulative value calculated weekly, that should be more useful because it recognises the overriding importance of sowing date on the incidence of the virus.

New investigations on the yellowing viruses of sugar beet may lead eventually to better prediction and thereby more effective control of infection. Beet mild yellowing virus has been purified successfully and antiserum prepared. With the antiserum, identification of single viruliferous aphids is now possible using either the highly sensitive immunosorbent

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electron microscopy (ISEM) or the established enzyme-linked immunosorbent assay (ELISA) techniques. This advance may facilitate the determination of the proportion of aphids arriving on the crop that are carrying virus and thereby the improvement of the spray warning scheme, with the qualification that virus content of an aphid and its ability to transmit virus to the crop are not necessarily related.

Research on insect pests and beneficial invertebrates

A mosquito pheromone. Pheromones normally possess high intrinsic activity, but since many are volatile and rather unstable, it is often difficult to devise ways in which they can be used successfully to manage populations of insect pests in the field. Members of the Insecticides and Fungicides Department now have identified the oviposition attractant pheromone of the mosquito genus *Culex* as the lactone of *erythro*-6-acetoxy-5-hexadecanolide, a compound that is both stable and relatively involatile. Since *Culex* species are not controlled efficiently by conventional means, the new compound, which has been synthesised, has a potential application in attracting gravid females to insecticides, thereby reducing their effectiveness as vectors of damaging human diseases such as elephantiasis.

Electrically charged spray application. Last year's *Report* (Part 1, 15) described the results of early trials with electrically charged spraying systems developed in the Insecticides and Fungicides Department. During 1981, the performance of the tractor-mounted APE 80 electrostatic sprayer was evaluated in field trials using oil- and water-based formulations of several pesticides and a microencapsulated form of permethrin. The results relating to the control of pea and bean weevils, bean aphids and barley mildew suggest that the advantages of electrostatic spraying can be exploited most clearly in open canopy crops, or where the pest is mobile, or when a systemic material is used. In favourable circumstances, pesticide doses can be reduced to half those now applied by conventional spraying techniques and volumes of carrier fluid decreased 100-fold without loss of biological effectiveness.

Earthworm protein production. Our studies aiming to establish earthworms as a new source of protein for animal feeding were extended during the year and now the Entomology Department is engaged in collaborative work with other Rothamsted departments, ARC institutes, university departments and commercial organisations. Analyses of four species of earthworm have indicated compositions on a dry-weight basis of about 11% N (about 70% protein); the worms contain more of the nutritionally essential amino acids than either fish or meat meal, and adequate amounts of several fatty acids that cannot be synthesised by non-ruminant farm animals. For three species, feeding trials with trout conducted with Stirling University showed better growth over 10-week periods when dietary protein was provided as freeze-dried worms rather than as fish meal; the fourth species, *Eisenia foetida*, supported good growth if it was mixed with an equal weight of commercial meal. Pig- and chicken-feeding trials will begin soon.

Methods for the progressive scaling-up of worm production on various pig and cattle wastes, including material previously used for methane generation, are under active investigation with the National Institute of Agricultural Engineering, Birmingham University and Commonwork Enterprises, Kent. Poultry wastes have been adapted as a growth medium after removal of excess ammonia, and trials are in progress to determine the optimum depths of rearing beds and stocking rates for the various organic wastes, and the most economic methods for separating and preserving worms.

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The study has the combined objective of developing an integrated system combining waste disposal with the production of feed protein and a residual material suitable as plant growth medium. The possibility that the spent waste may be very suitable for mushroom production is being evaluated in conjunction with Aston University.

Computing services

The ARC Computing Committee have reviewed the options for the provision of computing services to Institutes within the Agricultural Research Service (ARS) after early 1984 when the present ICL system-4 mainframe based at Rothamsted will become obsolete. It has been decided to strengthen the computing resources of individual institutes by the provision of a modern computing network and to create a new independent ARC Computing Centre located at the Rothamsted campus. The Centre will exercise a coordinating and advisory role in the continual development and updating of the computer network, and manage and operate any central computer facilities required in support of the hardware and software based at institutes.

The Prime computer at Rothamsted has been upgraded to provide a 'user-friendly' system for crystallographic computing that replaces the previous dedicated computer operated by the Molecular Structures Department.

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