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Report for 1961

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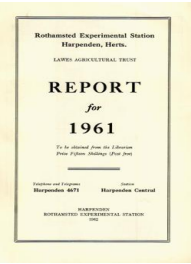
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Plant Pathology Department

P. H. Gregory

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PLANT PATHOLOGY DEPARTMENT

P. H. Gregory

E. W. Buxton returned from secondment to the Central Research Laboratories of the United Fruit Company, Norwood, Mass., and G. A. Salt from secondment as Plant Pathologist to the Sudan Government Service.

The following joined as temporary workers: Dr. Jeanne Dijkstra (Wageningen), Miss R. H. Gregory (Harpenden), Mr. O. Khalifa (Khartoum), Dr. J. B. Kendrick (Riverside, California). A. J. Gibbs and A. C. Hastie were awarded the Ph.D. degree of London University.

G. D. Heathcote visited British North Borneo on behalf of the Colonial Development Corporation to investigate a virus disease in abaca plantations at Tawau. B. Kassanis visited Paris and Versailles to discuss plant tissue-culture techniques. D. H. Lapwood visited institutes in Wageningen and the Max-Planck Institute, Cologne, in connection with work on blight-resistant potatoes. I. Macfarlane was awarded a W. K. Kellogg Foundation Fellowship and spent four months at the University of California, Berkeley.

Viruses and Virus Diseases

Properties of reaggregated tobacco mosaic virus protein

Intact tobacco mosaic virus resists proteolytic enzymes such as pepsin, trypsin and papain, but these hydrolyse the disaggregated protein produced when the virus is disrupted by alkali. This is now shown to happen because the different walls of the protein sub-units of the virus differ in their susceptibility to attack: the walls normally exposed to the environment are resistant, whereas those concealed within the virus particle are susceptible but inaccessible to the enzymes. When the pH of protein solution is lowered the protein sub-units aggregate by a process comparable to crystallisation. The protein sub-units fit into a regular pattern similar to that in intact virus particles or in reconstituted virus containing nucleic acid. All such particles resist attack by the proteolytic enzymes. (A. Kleczkowski.)

Tobacco necrosis viruses

Five isolates of tobacco necrosis virus (TNV) were studied; they were serologically related but differed in their antigenic composition and several physical and biological properties. Two obtained from the " Rothamsted culture " had many antigenic groups in common with bean stipple streak and cucumber TNV, and these four all induced the multiplication of the satellite virus of the " Rothamsted culture " of TNV, which alone does not multiply detectably. The fifth virus, isolated from the roots of a *Datura stramonium* plant,

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had only a few antigenic groups in common with the others and does not induce the multiplication of the satellite virus. Bean stipple streak became systemic in French bean and cucumber TNV in cucumber, but the others remained localised in all the species of plants tested.

Studies of inactivation *in vitro* at different temperatures showed that preparations of TNV contained two fractions, which inactivated according to first-order kinetics but at greatly different rates. The ratio of the two fractions differed at different temperatures. The more resistant fraction was about 10% of the preparation at 50° C., and the proportion decreased with increasing temperature.

An unstable variant was isolated from one of the TNV strains. Sap from leaves infected with it gave fewer lesions when inoculated to bean or tobacco plants than did leaf extracts made with water-saturated phenol, in contrast to its parent virus, with which sap gave more lesions than extracts made in water-saturated phenol. The results suggest that the unstable variant may occur in leaves mainly in the form of nucleic acid, which loses its infectivity when the leaves are macerated.

All the isolates except cucumber TNV were often found in considerable amounts in the roots of normal-looking plants grown in the glasshouse. In some species of plants virus was also detected in the leaves. Natural infection of roots by TNV was prevented by adding a fungicide to the soil during the winter but not during summer. (Kassanis and Babos.)

Potato virus X

The multiplication of potato virus X (PVX) in tobacco (White Burley) is considerably influenced by changes of temperature. The relative concentrations in inoculated leaves, measured serologically by precipitation tests, were 512 at 25° C., 64 at 28° C., 16 at 31° C., and the virus was not detected at 34° C. In systemically infected leaves the relative concentrations were 1,024 at 25° C., 128 at 28° C. and virus was not detected at 31° C. or 34° C. However, in plants inoculated simultaneously with potato virus Y (PVY), the relative concentrations of PVX in the systemically infected leaves were 4,096 at 25° C., 1,024 at 28° C., 128 at 31° C. and the virus was not detected at 34° C. The effect of PVY in increasing the concentration of PVX at 25° C., 28° C. and 31° C. was confirmed by infectivity tests. Some other viruses than PVY made virus X multiply detectably at 31° C.; in systemically infected leaves the relative concentration of PVX was 64 with tobacco mosaic virus and 256 with henbane mosaic virus and with yellow cucumber mosaic virus. These viruses multiply at 31° C., and inoculation with tobacco severe-etch virus, a strain of cucumber mosaic virus or potato aucuba mosaic virus, which do not multiply at 31° C., failed to stimulate the multiplication of PVX. (R. Close.)

Potato aucuba mosaic virus (PAMV)

In summer and autumn this virus reached a high concentration (precipitin end point $\frac{1}{256}$) 14 days after inoculation to a White Burley tobacco leaf, and the concentration was the same whether

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treatments, a result only 5% below the mean of a recent 20-year period.

Broadbalk has been sown in spring on two previous occasions, in 1845, the second year of the experiment, and in 1853, the second year after the present system of manuring was adopted. In both years winter varieties were sown. Some of these yields and those recently obtained from the only other sowings made in the New Year are given below.

Year	Variety	Sown	Grain (cwt./acre) No manure	Grain (cwt./acre) Dung 14 tons
1845	Old Red Lammas	March	12·9	17·6
1853	Red Rostock	March	3·2	10·0
1959	Squarehead's Master	5 January	—	18·8 *
1961	Squarehead's Master	18 January	11·4	17·0 *
1844–55	Mean of 10 autumn-sown crops		9·6	17·3
1950–60	Mean of 10 autumn-sown crops		10·4	21·8 †

* Plot 2B, section Ia, continuous wheat.
† Plot 2B 4th crop after fallow till 1954 then section Ia.

The March sowing in 1853 was a failure, but the other three late-sown crops were only slightly inferior in grain yield to autumn-sown wheat of about the same period. Apart from these exceptional seasons, three-quarters of the Broadbalk crops have been sown in the 3 weeks between 16 October and 8 November.

Broadbalk was very weedy in 1961, for the plant was thin and the bare places soon filled up with weed. Section V near the drain was especially bad, but even the plots bare fallowed in 1960 were far from clean.

Section Ia carrying the 10th crop of continuous wheat was sprayed with MCPA/TBA, and broad-leaved weeds were well controlled, though some appeared later in the season. Slender foxtail (*Alopecurus myosuroides*) was very prevalent. This weed had been kept in check in recent years by sowing the wheat rather late, usually about 1st or 2nd week in November, after the grass had germinated and the seedlings had been destroyed by cultivation. In 1961, however, *Alopecurus* was more plentiful than for many years, not only in the continuous wheat but also on the remainder of the field, including the first crop after fallow. The abnormally wet autumn and winter may have delayed germination till the spring. Experiments on the dormancy of *Alopecurus* seeds will be started in the Botany Department.

Hoosfield

The combined effect of the liming programme (*Rep. Rothamst. exp. Sta.* for 1954, p. 148) and a long and sustained attack on weeds, has been greatly to improve the appearance of this field and increase its demonstration value. Wild oats (*Avena fatua*), annual weeds, coltsfoot (*Tussilago farfara*) and couch (*Agropyron repens*) have all been much decreased, as have the irregularities on some of the formerly acid plots. The crop in 1961, although late-sown, yielded well. The plots with complete fertiliser gave 24·4 cwt. grain/acre, about 20% above their long-period means. Farmyard manure,

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FIELD EXPERIMENTS SECTION

G. V. Dyke

The field experiments at Rothamsted and Woburn are controlled by the Field Plots Committee: F. Yates (Chairman), G. V. Dyke (Secretary), F. C. Bawden, G. W. Cooke, H. V. Garner, P. H. Gregory, J. R. Moffatt, C. A. Thorold, R. G. Warren and D. J. Watson.

G. V. Dyke was seconded for six months to Hunting Technical Services Ltd. to start experiments on land recently reclaimed from salinity and waterlogging in the Indus Valley, West Pakistan. J. McEwen joined the section.

In 1961 the farm staff laid out and harvested 3,115 full-scale plots on the two farms. Table 1 shows how they were divided according to crops and type of experiment.

Table 1

Number of full-scale plots harvested 1961

	Grain	Roots	Hay	Grazing	Total
Classical experiments:					
Rothamsted ...	227	—	126	—	353
Woburn	50	—	—	—	50
Long-period rotation experiments:					
Rothamsted ...	613	407	184	96	1,300
Woburn	136	326	40	12	514
Short-period experiments:					
Rothamsted ...	535	127	—	—	662
Woburn	76	136	24	—	236
Total ...	1,637	996	374	108	3,115

There were another 148 full-scale plots for which yields were not required, and 78 that were laid out and harvested by other staff. There were 897 microplots, bringing the total to 4,238.

Broadbalk

The land was ploughed in October 1960, but the unusually wet autumn and winter delayed drilling until 18 January 1961. The usual wheat variety, Squarehead's Master, was sown. There had been very little frost to mellow the seedbed, but the land was caught in reasonably good order, though the tilth was rather fine. The seed went in fairly well, and to roughen the seedbed it was covered by spring-tine harrows, which exposed some seed. Early growth was very slow and uneven, and in May many of the plots, including the dunged strips, looked yellow and backward. At this stage the prospects were bad and there was some doubt whether the plants would come into ear. Later there was a remarkable recovery, the crop thickened out and, though straggled before harvest, it was not lodged. The section immediately after fallow looked quite well, and in fact yielded over a ton of grain per acre on the average of all

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8. Analysis of extensive data on age at menarche in Bantu girls, for the South African Institute for Medical Research (Healy (12.4)).

9. Tabulations and regressions for the Institute of Criminology, Cambridge (Rees and Hills).

10. Advice to the Ministry of Transport (at the request of the Treasury Organisation and Methods Division) on the use of computers for the analysis of origin and destination surveys of road traffic, for the planning of motorways. It is intended to make a pilot analysis on the 401, using the General Survey Programme, but data are still awaited. Full-scale analysis will require a larger machine (Yates, Rees and Healy).

Smaller problems were tackled for many individuals and organisations; these include the Imperial Cancer Research Fund, the Royal Veterinary College, the Animal Breeding Research Organisation, the Agricultural Research Council Pest Infestation Laboratory, the National Institute for Agricultural Engineering, the British Sugar Corporation, the Glasshouse Crops Research Institute, St. Albans College of Further Education and the Medical Research Council Social Medicine Research Unit. This is in addition to the regular statistical consulting service provided to other Rothamsted departments.

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twins and singles in growth and conformation. He also collaborated with Mr. J. A. Nelder (National Vegetable Research Station) and members of the Genetics Department, University of Birmingham, in applying improved statistical techniques to estimate genetical parameters in experiments on *Drosophila* and tomatoes (12.5). Ross worked with Dr. E. C. R. Reeve of the Department of Animal Genetics, Edinburgh University, on a model for the inheritance of mu-particles in *Paramecium Aurelia*.

The statistical technique known as discriminant analysis, introduced in the 1930s, has been little used in practice because it requires much computation. In essence, it provides a means of studying the relationships between groups of individuals when several measurements have been made on each. We recently applied this technique to data from many different sources. During 1961, for example, it was used on botanical measurements from clover varieties for Miss V. Lofthouse, National Institute of Agricultural Botany (Gower), and on psychological results from groups of maladjusted children (Simpson). This last investigation was made in connection with the National Survey of the Health and Development of Children, and is part of a continuing collaboration with Dr. J. W. B. Douglas, Director of the Survey; other studies dealt with relationships between social class, family size, puberty and growth, and with the influence of home and school conditions on performance in intelligence tests. Intelligence test results from children tested at 8 and 11 years of age were also analysed for the National Foundation for Educational Research, and a large survey of methods of teaching arithmetic by the same organisation is at present being analysed (Simpson).

Other investigations include:

1. Capture–recapture studies on bats for the Earl of Cranbrook, Chairman of The Mammal Society of the British Isles (Yates and Simpson).
2. Analysis of nitrification studies by Mr. H. Barkworth, National Agricultural Advisory Service (Gower).
3. Analysis of sets of non-orthogonal data on pig growth for the National Institute for Research in Dairying and the Agricultural Research Council Statistics Unit, Cambridge (Rees).
4. Problems involving continuous recording of data, etc., for the Glasshouse Crops Research Institute (Rees and J. R. Davis).
5. Monte Carlo studies of theoretical models for competing species, with Dr. P. H. Leslie, Bureau of Animal Population, Oxford (Gower and Martin).
6. Classification problems, using methods devised by Dr. P. H. A. Sneath; several bodies of data were analysed, for the Low Temperature Research Station, the National Institute for Research in Dairying, the Commonwealth Bureau of Mycology and the London University Institute of Psychiatry (Gower).
7. Assessment of physical maturity in children from X-ray ratings of bones in the wrist and hand, for Dr. J. M. Tanner, London University Institute of Child Health (Healy).

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A large survey of dairy farms was analysed for the Milk Marketing Board (Vessey). The Board's Production Division is preparing the results for publication.

We advised on the planning or analysis of surveys of oestrus in cows (in Scotland), calf husbandry (Northern Ireland), cattle fertility (Devon and Somerset) and cattle disease (France).

Commonwealth and Overseas Work

Work continued on a large collection of data relating to control of capsids on cocoa from the West African Cocoa Research Institute, Ghana. Preliminary conclusions were communicated to the Institute and to the chemical firms engaged in capsid control research (12.2), and a paper is being prepared in collaboration with C. G. Johnson (Entomology Department) and Mr. G. Burge, formerly of the Department of Agriculture, Ghana. This work showed that there was a need for research into the conduct of experiments on cocoa. Various points relating particularly to capsid control were followed up on the Institute data, but these proved inadequate for studies on yield. With the assistance of the Institute, C. A. Thorold (Woburn) and Dr. S. C. Pearce (East Malling Research Station), complete yield records for a 6,000-tree farm extending over 15 years were assembled on punched cards. Various preliminary investigations of these figures were made, and their study is continuing in collaboration with Dr. Pearce (Vernon and Morris).

Vernon also continued his work with Mr. J. L. Gregory (Federal Agricultural Research Organisation, Nigeria) on yam beetles and collaborated with H. Greene in the design of a long-term rotation experiment to be laid down at Ibadan, Nigeria. In connection with these and other projects, he visited Nigeria during December.

A computer programme was written for Miss N. Tanburn (Department of Agriculture, Ghana) to assist with the forecasting of cocoa yields during the next decade. This involved studying the results of varying assumptions concerning rates of planting and of senescence since 1900 (Healy).

Dr. T. Eden completed a report on the analysis of the long-term experiment on coconuts for the Coconut Research Institute, Ceylon. Church visited Ethiopia for the second time on behalf of the Food and Agriculture Organisation of the United Nations to advise on agricultural surveys. Four rotation experiments from Larissa, Greece, were analysed (Gower and Ross). Bonsall is analysing a large collection of data from dairy cattle in Israel; this involves fitting parameters to the results from each animal to describe its lactation yields and subsequent analysis of the fitted values. (These last two pieces of work came to us *via* the Food and Agriculture Organisation of the United Nations.)

Other Work

Several studies with a genetical background were made, some of which have already been mentioned. Bonsall is analysing the results of ram progeny tests for the Department of Agriculture, University College of North Wales, to study the differences between

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Experimental Husbandry Farms was completed (Patterson and Dr. Rice Williams (12.10)).

Theoretical work on long-term experiments continued, and a general method of analysis for experiments comparing rotations of different length is being developed (Patterson). Healy and Gower prepared a paper on aliasing in partially confounded experiments (12.8).

The errors of some 500 cereal experiments done by the National Institute for Agricultural Botany between 1956 and 1960 were examined. All the experiments used long, narrow plots and were harvested by combine. The most important conclusion is that the need for small blocks in cereal experiments is as great now as it was before combine-harvesting and long, narrow plots were introduced. An empirical rule is that the variance per plot is roughly proportional to $n^{\frac{1}{4}}$, where n is the number of plots per block. (Patterson, Ross and Mr. D. Harrington of the Agricultural Institute, Dublin.)

At the request of the Soil Fertility Committee of the National Agricultural Advisory Service Soil Chemists' Conference, reports were prepared (Lessells) on the use of gypsum on land unaffected by sea-water (12.6), on an investigation into methods of measuring stability of soil structure and on the effect of nitrogen on cereal yield (two reports). The results of case-studies on the effects of drainage on restored opencast coal sites were reported (Lessells). A paper on weight loss and sprouting in bulk-stored maincrop potatoes was completed (Dr. A. R. Wilson, Mr. P. T. G. Twiss and Lessells (12.12)).

Surveys

Surveys of fertiliser practice were done in 1961 in eighteen districts in England and Wales and five districts in Scotland; these are being analysed. Arrangements were made for a much larger survey in England and Wales in 1962. A paper is being prepared on the use of fertilisers on grassland, based on surveys done in England and Wales in the period 1957–60 (Boyd, Church and Hills). A report on a survey of fertiliser practice on fruit-growing farms in Kent was completed (Hills).

A survey done by the National Agricultural Advisory Service Crop Husbandry Officers and their staffs on the use of herbicides in four English arable-farming districts was reported (Church).

We have been concerned with five surveys for the Ministry of Agriculture's Animal Health Division. The field and laboratory records of the *Brucellosis* survey began to arrive towards the end of the year. This survey should be ready for analysis in the spring of 1962. A survey of mastitis on all farms within 10 miles of Reading was analysed (Vessey and Leech). Some further work is required before this can be written up. The Ministry also surveyed during October and November the incidence of turkey reactors to the haemagglutination inhibition test for Newcastle Disease virus. The results were reported to the Ministry (Leech). The survey of sheep losses in England and Wales during 1959/60 was analysed (Vessey). Plans were prepared for a survey of calf husbandry and losses during 1962/3 (Leech).

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confidently expect that outside users, both full-time statisticians and others, will take advantage of our computing facilities much more than has been feasible so far. For this to happen, we shall have to insist on these users handling as much as possible of their problems themselves. They cannot be asked to learn the Orion machine code, and only fairly regular users will become proficient in the general autocodes that will be available. As we shall not have enough staff to write or adapt programmes for the wide variety of problems that will arise, we propose to write what will amount to several very specialised autocodes simple enough for their use to be learnt quickly.

It is interesting that the general programmes for surveys and experiments, both of which in large part consist of operations on multi-way tables, have large sections in common, and it now appears probable that one programme will suffice for both the analysis of experiments and for the analysis of the results of surveys, once the basic tables have been constructed from the original survey data. This has clearly many advantages, both to the writers of the programmes and to the users.

Bonsall completed a programme that enables programmes written in the Orion symbolic input language to be tested on the 401. Not all the Orion facilities are included, and the size of the simulated programme is limited, but this simulation programme should be a considerable asset when we start writing Orion programmes during 1962. If it is found that the programme makes excessive demands on machine time it may be re-written for the 402. A small amount of work has been done on the inverse problem of running 401 programmes on the Orion (Bonsall and Rees). An Orion programme which would enable the Orion to accept 401 programmes, and run them at reasonable speed, would certainly ease the formidable problems of the change-over period after the Orion is installed.

Gower wrote a programme for covariance analysis of data organised in a hierarchical or nested classification with up to eight levels. In connection with this, he devised an algorithm for calculating the coefficients needed to estimate components of variance in unbalanced data, and an auxiliary programme embodying this has been written (Martin). These programmes were applied to a large collection of data relating to the inheritance of milking characteristics in Friesian cattle (with Dr. J. S. F. Barker, Milk Marketing Board).

Experimental Design and Analysis

As in previous years, the Department analysed the results of many experiments for the National Agricultural Advisory Service and for other research stations and institutes (Dunwoody, E. P. Simpson and Holgate). Requests for the design and analysis of livestock experiments, mainly from the National Agricultural Advisory Service, increased (Frater). A report was produced on Beef Carcase Assessment, based on the data from the Beef Progeny and Performance Tests at Rosemaund and High Mowthorpe Experimental Husbandry Farms (Boyd and Frater). A paper on the residual effects of phosphate fertilisers in experiments on the

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Programming Developments

The General Survey Programme completed in 1960 was used extensively throughout 1961 and proved an extremely powerful tool for processing large bodies of data. The machine time devoted to the analysis of surveys and similar types of analysis has increased by 67% in 1961. Although some similar programmes have been written for other, and larger, machines, ours is, I believe, still the most powerful programme in existence for the types of analysis required in survey research work.

Preliminary work on the construction of a similar General Survey Programme for the Orion has started (Simpson and Gower). Gower prepared a paper on the methods we have adopted for handling multi-way tables on the computer, and made suggestions for autocode instructions covering these operations for inclusion in the Mercury Autocode (12.7). Simpson has extended the General Survey Programme to deal with sampling on successive occasions, but this extension is not yet fully tested.

As mentioned in last year's report, the development of the General Survey Programme suggested that a similar approach might solve the general problem of the analysis of replicated experiments of varied design on computers (see also (12.13) and (12.14)). Other commitments delayed this work early in the year, but it was resumed in the autumn. A General Experiments Programme is now almost complete, and large parts of it have been tested (Yates, Simpson and Gower).

The basic principles of this programme are similar to those of the General Survey Programme. The particular analysis required is specified by a series of instructions which control the whole sequence, often very complex, of operations which require to be performed. It would, of course, be intolerable to have to write and punch a new set of instructions for the analysis of each experiment, and it is therefore intended to provide standard sets of instructions for the commoner designs. Provisions have been made in the programme which permit groups of designs of a given type (e.g., $3 \times 3 \times 3$ designs in blocks of 9 with two or more replicates) to be covered by a single set of instructions, and which allow minor variations in the analysis.

The General Experiments Programme requires a considerably more elaborate repertoire of instructions than is needed for survey analysis, and its implementation taxes the capacity of the 401 (including the newly enlarged store) to its limits. It has not been possible to incorporate many refinements which would make it more convenient to use. The programme will also undoubtedly be slow compared with our existing ones for the analysis of standard designs, so we do not intend that it should replace such programmes where these exist. It will, however, fill many gaps in our present set of programmes, notably in the directions of covariance analysis, complex factorial designs, incomplete blocks and long-term experiments. It will also serve as a prototype which will give us the necessary experience to construct a more powerful and sophisticated programme for the Orion.

These two general programmes typify our present ideas on the way in which our much larger future computer will be used. We

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TABLE 2

Numbers of replicated experiments analysed in the department

	Number of experiments:— By hand	On computer	Total	Number of variates on computer
1934	115	—	115	—
1951	437	—	437	—
1955	384	419	803	834
1956	181	683	864	1,701
1957	98	1,253	1,351	5,041
1958	182	1,664	1,846	6,260
1959	67	2,649	2,716	11,102
1960	85	3,687	3,772	11,147
1961	89	2,862	2,951	15,184

the analysis of experiments and an almost equal amount on the analysis of surveys. Almost all the survey analysis was done by the General Survey Programme developed in 1960.

GIFT OF A 402 COMPUTER

Late in 1961 we were generously offered a gift of a 402 computer by Elliott Brothers. This machine, which is about 5 years old, has been in use in the Elliott Computing Service Bureau. The 402 is essentially a production version of the 401, with almost identical electronics but with a different order code.

The machine has now been installed and commissioned. We propose to use the 401 card-reader for the 402, and this is now being fitted; as the machines are so similar, we do not anticipate any difficulty in this. The machine has been placed in the same room as the 401, so that the same operator can tend both machines. It is intended to use the 402 almost wholly for survey analysis, thereby freeing time on the 401 for other work. The General Survey Programme written for the 401 has already been transcribed for the 402 (Simpson), but has still to be tested. It may also be possible to link the magnetic tape unit to the 402. This will further increase its power for survey analysis.

THE ORION COMPUTER

Final decisions were reached on the peripheral equipment for the Orion. Three Ampex magnetic tape units were ordered. Input will be by five- and seven-hole paper tape and punched cards; output will be wholly by seven-hole paper tape. After further consideration it was decided not to install punched-card output or line-printer output at present.

The manufacturers are regrettably behind schedule, and it is not now expected that the machine will be delivered before the spring of 1963. Because of the delay in delivery, and because also final particulars on autocodes, etc., are still awaited, we have not yet organised any formal courses on the Orion for statisticians at other Agricultural Research Institutes, but it is hoped to do this during 1962.

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eers, who undertook late working in addition to "on call" duty. Fearne, who supervised the arrangements, is especially to be commended for the smooth working of the system.

The machine itself continues to give reliable service. The trouble mentioned in the 1960 Rothamsted Report, due to interference from the motor driving the new drum, continued into 1961, but was cured, with the assistance of the manufacturers, by replacing the drum motor by the old motor used to drive the disk. Since then no further trouble has been experienced.

The new drum store has more tracks than the original disk store. We have now designed, built and installed a unit which enables eight of these additional tracks to be used, thus making available 31 tracks (3,968 words) instead of 23 tracks (2,944 words) (Rees). This increase in storage capacity enables us to tackle certain problems previously impossible. In particular, the construction of the General Experiments Programme referred to below would have been impracticable without this increase.

TABLE 1

Record of machine operation for 1957–61

	1957	1958	1959	1960 *	1961
Total hours worked	2,622	2,869	2,993	2,757	3,688
Productive work, hours ...	1,305	1,676	2,211	1,853	2,666
Percentage overtime ...	32·6	45·1	50·8	55·9	86·5
Percentage of time for					
Productive work	49·8	58·4	73·9	67·2	72·3
Programme development, etc.	22·6	16·8	10·3	17·4	11·8
Idle time	4·4	1·7	0·7	0·4	0·3
Maintenance, etc.	23·3	23·2	15·1	15·1	15·6
Total	100·1	100·1	100·0	100·1	100·0

* 46 weeks. The machine was out of commission for 6 weeks in 1960 because of the failure of the magnetic disc.

Table 1 records machine operation for the years 1957–61 in the same form as in previous reports, except that time required for maintenance, both scheduled and unscheduled, and time wasted by machine faults, are grouped together; the subdivision between these items is very similar to that of earlier years. The productive computing time increased from 1,853 hours in 1960 to 2,666 hours in 1961 (an increase of 44%). This is attributable in part to the increase in hours worked, in part to less time being required for programme development and in part to the loss of 6 weeks in 1960 from the magnetic disk failure.

Table 2 shows the number of experiments analysed in 1961 and in earlier years and also the number of variates (which is a rough measure of the amount of computer work). Fewer experiments were analysed than in 1960, when there were over 2,000 simple experiments from Bihar and Pakistan, but 36% more variates. Excluding Bihar and Pakistan, the number of variates analysed per experiment was 5·5 in 1960 and 5·3 in 1961.

The time spent on different classes of work was recorded. Slightly under 30% of the productive computing time was spent on

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STATISTICS DEPARTMENT

F. YATES

The following members of the Department left during the year: Beryl Turner on marriage, D. J. Knight to take a post with De Havillands Aircraft and J. R. Davis to take a teaching post in mathematics with the Universities Mission to Central Africa. Appointments were: G. J. S. Ross from Cambridge University and M. L. Hill from Ferguson Radio Corporation.

Yates acted as consultant to the Seminar on Sample Surveys of Road Transport organised in Geneva by the Inland Transport Committee of the United Nations Economic Commission for Europe. Yates, Healy and Patterson attended the 33rd Session of the International Statistical Institute held in Paris, at which Yates and Healy gave a paper on the application of electronic computers to research statistics (12.14). Healy attended the General Assembly of the International Union of Biological Sciences in Amsterdam on behalf of the Biometric Society, of which he is Secretary. Leech attended the Fourth International Congress on Animal Reproduction held at The Hague and gave a paper on the construction of an index of herd fertility (12.9). B. M. Church spent three months in Ethiopia on behalf of the United Nations Economic Commission for Africa to report on problems and techniques for livestock surveys in Africa, to draw up a programme for a livestock survey in Southern Ethiopia and to organise the initial stages of the fieldwork for this survey. Earlier, at the invitation of the Foreign Office, he attended a Central Treaty Organisation seminar on sampling methods in Lahore. Vernon spent a month in Nigeria with the Federal Department of Agricultural Research, Ibadan, advising on agricultural experiments.

F. B. Leech was awarded the D.Sc. degree of the University of Belfast. S. F. Buck was awarded the Ph.D. degree of the University of London, for his work, while an Agricultural Research Council Scholar, on the relation between rainfall, temperature and actual transpiration and the yields of wheat, sugar beet and potatoes (12.3).

The additional building for the Department was completed and occupied in January 1962. This has relieved the very serious overcrowding, which became particularly acute in 1961 because of associated alterations in Rivers Lodge and the Hut.

Four temporary workers spent varying periods in the department during the year, three from overseas.

THE 401 COMPUTER

The 401 computer was very intensively used throughout the year. The regular system of overtime, introduced at the beginning of 1961, enabled more hours to be worked with less strain on the scientific staff (86% over laboratory hours, compared with 56% in 1960). This would have been impossible without the willing co-operation of the machine operators, who volunteered for late duty, and the engin-

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dine is ineffective, therefore, at preventing either spore germination or the multiplication of the parasite; the results confirm those of controlled field experiments made elsewhere years ago. (Bailey.)

Paralysis

Many adult bees became paralysed about 8 days after they had been sprayed with aqueous extracts of naturally paralysed bees and incubated at 30°. This confirmed previous workers. Bees sprayed with extracts of healthy bees were unaffected. Aqueous extracts of naturally or artificially paralysed bees shaken with carbon tetrachloride and centrifuged at 8,000 g. for 10 minutes were bacteria-free but still infective. Bees injected through an abdominal intersegmental membrane with such extracts made from paralysed bees became paralysed after about 4 days, but they also did so when injected with similar, although more concentrated, extracts of most bees from several apparently healthy colonies. Bees injected with water similarly treated with carbon tetrachloride remained healthy.

Infective extracts contain isometric particles resembling those of many viruses. They are 28 mμ in diameter and have the characteristic ultra-violet absorption spectrum of a nucleoprotein. The particles occurred not only in naturally and artificially paralysed bees but also in some bees that seemed healthy. Artificially infected bees contained at least 100 times as many particles as apparently healthy individuals.

A whole healthy colony, sprayed on different occasions with extracts of paralysed bees, produced crops of paralysed individuals at about 8-day intervals after each spraying, whereas naturally affected colonies produce paralysed bees more continuously. These and other observations suggest that hereditary differences between bees determine whether the paralysis virus increases to lethal numbers. Artificially infected bees, which are usually resistant to the spread of their own virus, presumably became diseased because they received an overwhelming dose of virus by unusual routes of infection. (Bailey and Lee, with Gibbs, Plant Pathology Department.)

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Bee Diseases

European Foul Brood disease

Strains of *Streptococcus pluton* isolated from diseased larvae from North and South America, Britain and Switzerland were all of the same serological type and quite unrelated to any strain of *Streptococcus faecalis* ("*Streptococcus apis*") isolated from diseased larvae from the same places. (Bailey, with Gibbs, Plant Pathology Department.)

Cultures of *S. pluton*, various strains of *S. faecalis* and of *Bacillus alvei*, all derived from diseased larvae, were tested for pathogenicity in field experiments by inoculating them into the food surrounding individually identified larvae. Only *S. pluton* and one strain of *S. faecalis* caused nurse bees to eject the larvae (very few larvae were found diseased or dead, even when inoculated with natural disease material: most were ejected from the colony within a few days). Laboratory and field tests showed that those larvae that successfully reached the propupal stage after they had been infected with *S. pluton* were lighter in weight than usual and voided many live bacteria in their faeces, whereas those infected with *S. faecalis* were of normal weight and voided few or no live bacteria. Although some strains of *S. faecalis* may be pathogenic, therefore, they seem unable to survive long in larval intestines and seem unlikely causes of endemic disease. (Bailey and Lee.)

S. pluton, isolated and propagated on media containing the extract of one larva/10 ml. of medium, was significantly more effective or virulent than bacteria isolated and propagated on plain medium. Controlled field tests showed that dry smears of the contents of midguts of diseased larvae became non-infective after fumigation with acetic acid in the way recommended for combs contaminated with *Nosema apis*. (Bailey.)

Nosema apis

Some spores of *Nosema apis* in dried faecal deposits kept at 20° and 50% R.H. were alive after 12 months, but most had died. All were dead after the same time in honey.

In endemically infected colonies the percentage of infected drones was about one-quarter that of infected worker bees. That drones have less infection is not surprising if infection comes mainly from faecal contamination on combs and not from stored food, because drones do not clean combs. The percentage of drones infected was nevertheless high (14% in one colony), so they may be infected by receiving contaminated food from workers engaged in both comb-cleaning and brood-feeding.

Because many beekeepers claim recently that sodium sulphapyridine controls infection, tests were made by infecting caged bees with spores in syrup containing 0·5 g. sodium sulphapyridine per 100 ml. (The drug was previously found non-toxic to bees at this concentration, which was about the dose recommended.) The bees were incubated at 30° for 10 days and supplied with the drugged syrup *ad lib*. After this time the number of spores that developed in the ventriculi of drugged bees was the same as in control bees similarly infected and then fed with ordinary syrup. Sulphapyri-

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ficial cup used was its widest part. Colonies given artificial cups made with the internal dimensions of natural ones did not mutilate them; a few eggs were laid in those in the colony whose queen had been laying in natural cups, and queens were reared from these eggs. However, no method has yet been found for getting a queen to lay eggs in many cups, whether artificial or natural.

When twelve empty natural queen-cell cups were left overnight in a queenless colony five had eggs in them next morning. These eggs were removed, but 24 hours later another egg was found in a cup. The worker bees must, therefore, either have transferred the eggs from worker or drone cells or laid them themselves. This result was not repeated when the experiment was repeated with another colony. (Simpson.)

Pollination and Field Behaviour

Some tree-fruit varieties need to be pollinated from other varieties. A suggestion from previous work (see *Rep. Rothamsted exp. Sta.* for 1960), that main variety trees next to pollinisers are better pollinated than those farther away, was tested. In an apple orchard where four rows of a variety needing cross-pollination were planted together the row nearest the pollinisers had about twice the fruit set of the other rows. A plum orchard with only two rows of a polliniser variety bisecting it showed an even greater contrast; about 7% of the flowers of the main variety trees adjacent to the polliniser rows set fruit, but four or more rows away the average set was less than 1%. In the row beside the polliniser row there was even a difference in set between the sides of the trees facing and away from the pollinisers. Similarly, where cut branches of the polliniser variety were placed in the main variety trees, the set was greatest closest to these branches. This suggests that the methods currently recommended for arranging polliniser varieties among main variety trees will not always give maximum pollination.

Bees foraging on a crop of field beans were selected at random and observed for as long as possible, and the behaviour of distinctively marked individuals was recorded from day to day. Three types of visit were distinguished: to the extra-floral nectaries, for nectar; to holes bitten by bumblebees at the bases of the flowers, for nectar; to the mouths of the flowers, for nectar and pollen. Most individuals persisted in one or other type of visit, and instead of changing their type of visit tended to desert the crop for part of the day when their type of visit became unprofitable. Because bees visit the extra-floral nectaries of field beans before the flowers open and tend to persist in this behaviour, it is probably best to delay taking colonies to the crop until the flowers themselves are open.

Previous work (see *Rep. Rothamsted exp. Sta.* for 1960) showed that feeding syrup to colonies increases their pollen-collecting activities, so it might be worthwhile to feed colonies used to pollinate beans, as all pollen-gatherers are efficient pollinators. (Free.)

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cluster could be prevented, however, when its queen was caged and suspended among the workers, even when the cage had double wire-gauze walls preventing the workers from touching their queen. When the queen was removed from such a cage the workers persistently gathered on its wire-gauze walls, but never on its wooden parts, though these contained the entrance where any contamination from the queen would occur when she was put into and removed from the cage. Once, when a cluster dispersed, leaving its caged queen behind, the bees flew about 50 m. in a straight line, then circled for a time before eventually returning to their caged queen. These observations show that the workers of a colony can detect the presence or absence of their queen without touching her, and suggest that they can even do so when flying as a swarm towards a new site. It is difficult to understand how chemical perception can operate in a moving swarm, unless the queen flies at its head. (Simpson.)

Observations by Gary (*Science*, **133**, 1479–1480, 1961) indicate that most of the queen scent that attracts worker bees is produced in the mandibular glands, but olfactometer experiments showed that it is not the 9-oxodecenoic acid (" queen substance ") produced in these glands. A scent that queens produce does, like 9-oxodecenoic acid, partly inhibit queen rearing by worker honeybees; it acts synergistically with 9-oxodecenoic acid to inhibit queen rearing completely. Removing a queen's mandibular glands seems not to decrease the inhibitory scent, which, like 9-oxodecenoic acid, is present on all parts of her body. When different parts of living queens, whose mandibular glands had been removed several weeks previously, were tested the inhibitory scent was always found on all parts, so it is probably produced in glands widely distributed over her body. The evidence suggests, therefore, that a queen's inhibitory scent is probably distinct from her attractive scent, but this cannot be demonstrated until one or other of these scents has been obtained pure. Whereas virgin queens produce very little 9-oxodecenoic acid until they are about 10 days old, even newly emerged virgin queens produce some inhibitory scent, but old, mated, laying queens produce more. The scent alone presumably explains the fact that young virgin queens can partially inhibit queen rearing by their colonies. (Butler.)

Queen rearing

In commercial queen rearing female larvae are transferred from worker cell cups and given to queenless colonies to rear as queens. Much labour could be saved if the transfer could be avoided by getting eggs laid in the cups. When a queenright colony is given empty artificial cups of the usual pattern, however, it invariably mutilates them, even though its queen may be laying in natural queen-cell cups. When natural cups (removed from colonies) and artificial cups, mounted in a frame used for queen rearing, were presented simultaneously to a queenright colony, all the artificial cups but none of the natural ones were mutilated. Plaster-of-paris moulding showed that the internal shapes of the two differed; in particular, the mouth of a natural cup is constricted and only about the width of a worker cell, whereas the mouth of the type of arti-

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BEE DEPARTMENT

C. G. Butler

In January C. G. Butler lectured in the U.S.A. at the invitation of the American Institute of Biological Sciences. In September J. Simpson attended the International Union for the Study of Social Insects Congress in Italy, L. Bailey took part in a Conference in Madrid organised by the International Office of Epizootiology, and J. B. Free and C. G. Butler attended a Conference of Bee Research Workers, followed by the International Beekeeping Congress, in Madrid.

Behaviour and Physiology

Swarming

A colony of bees deprived of its hive and combs behaves like a swarm, first clustering on the nearest convenient support, then suddenly dispersing into the air either to cluster again near by or to fly in a body across country to a new nest site. When several colonies were simultaneously deprived, and the first cluster started to disperse the others could be induced to do so by holding them close to the first one. Bees from the first cluster alighted on the other clusters and performed the " schwirrlauf " movements described by Lindauer (*Z. vergl. Physiol.* **37**, 263–324, 1955). A colony deprived of its hive and combs only ½ hour earlier was " triggered off " in this way. Bees on combs did not respond, however, though they became somewhat excited. The nature of the stimulus is not certain. Recordings of the sounds made by the bees of a dispersing cluster had no effect when played to a combless cluster. As all the bees of the colonies that could fly took part in the dispersals, the behaviour induced in these experiments is analogous to the " absconding " of whole colonies rather than to a reproductive swarming in which only part of a colony goes off in a swarm. However, absconding bees, once they have left their hive, behave like a reproductive swarm; the behaviour of a swarm seems intrinsic to bees at all times and not to depend on any physiological changes resulting from swarming out of a hive or any lengthy preparation for swarming or supersedure.

Further evidence that individual bees can be induced to swarm without lengthy preparation was provided by an experiment in which the bees of a colony that was swarming were diverted through the hive of a colony that was not even preparing to swarm. The swarm, when collected, contained as high a proportion of the bees of the second colony as of the first. (Simpson.)

Queen pheromones

When colonies whose hives and combs had been removed had their queens taken away the clusters of workers tended gradually to disperse and join colonies in nearby hives. Such dispersal of a

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afternoon. Clearly, frit fly, like aphids and many other insects too, are adapted to migrate at high altitudes, and this allows the population to disperse over an immense area when acquiring new habitats. It now has to be discovered whether the generation emerging from tillers in the oats behaves in the same way. (Johnson and Taylor, with Dr. T. R. E. Southwood of the Imperial College of Science and Technology.)

Spiders

The effect of food and temperature on Zygiella x-notata (Clerck).

Spiders were fed with different numbers of adult *Drosophila melanogaster* at temperatures from 15° to 30°. Partial starvation and excessive food increased the number of instars, but partial starvation lengthened the instars. The number of instars also increased with rising temperature. *Z. x-notata* is well adapted to withstand starvation, and adult males have been reared on as little as one *Drosophila* a week, when they may be only $\frac{1}{12}$ the weight of a well-fed one.

Gall Midges

Populations of Swede Midge (*Contarinia nasturtii*), assessed by daily emergence rates and bi-weekly counts on plants, were much smaller in 1961 than in 1960. There were only two, late, generations in 1960 compared with three and a partial fourth in 1961. The late attacks produced only slight symptoms, and "swollen petiole" was very rare. Several National Agricultural Advisory Service Centres recorded slight attacks, but the infestation was large at Newcastle. (Edwards with H. Bardner, née Twigg, Ministry of Agriculture, Plant Pathology Laboratory.)