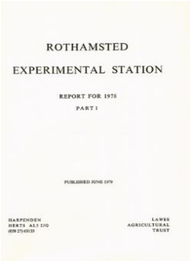
Report for 1978 - Part 1

Full Table of Content


ROTHAMSTED
EXPERIMENTAL STATION

Entomology Department

T. Lewis

T. Lewis (1979) *Entomology Department ;* Report For 1978 - Part 1, pp 85 - 107 **- DOI: https://doi.org/10.23637/ERADOC-1-135**

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Introduction

The work of the Department is presented in four sections covering pesticide use, pest detection and surveying, cultural and biological control and honeybees.

A 'typical' season, entomologically speaking, seems to be a thing of the past; once again unusual weather, this year a cold spring and early summer, delayed the appearance of many pests, and restricted some experimental programmes. When the weather eventually improved to give a long and unusually mild autumn many species, especially aphids, became abundant, and entered the winter with populations at a high level.

It has been a year of initiation and steady progress on many topics. We were gratified to see the joint work of the Entomology and the Insecticides and Fungicides Departments on pheromone monitoring of pea moth reach commercial practice. New work within the Department included the beginnings of a broad collaborative approach to the integrated control of cereal pests, the start of work on mechanisms of insecticide resistance in field

https://doi.org/10.23637/ERADOC-1-135

populations of some important pest aphids, and a preliminary assessment of elemental analysis of insects as a technique for studying their dispersal.

A link of great potential value for the surveying and population dynamics studies in the Department was established with Professor G. W. Schaefer of the Cranfield Institute of Technology, with ARC support.

The Department was pleased to be host to two meetings in September sponsored by the International Organisation for Biological Control (OIBC)/WPRS, the Working Group on Soil Pests, and the inaugural meeting of a sub-group studying the use of pathogens in the integrated control of soil pests.

Pest detection and surveying

The sampling of aerial populations of insects using a national network of suction traps and light traps continued. The suction traps provide the material for the weekly bulletin of the incidence of pest aphids at 20 sites in Great Britain and two in Holland, as well as the data for longer term studies on the use of suction traps for forecasting aphid abundance. The four-weekly total catches are listed in Table 1 (a–h) *Rothamsted Report for 1978*, Part 2, 138–153.

Since May 1978 seven identical suction traps have been in operation in France and information is regularly exchanged between the British and French networks.

The entirely different approach to local pest monitoring, using sex attractants, continued successfully, and the system was developed for pea moth monitoring on a commercial scale.

Aphid surveying

Aphid occurrence. Aphid migration was again delayed and numbers caught were below average until late in the season. Exceptionally large catches occurred during the prolonged mild autumn. Trap catches for 31 species are summarised in Appendix Tables 1 and 2, pp. 103–104. The first appearance of these species was latest in the southern regions, and in the South-West eight of the listed species were more than 3 weeks later than the annual mean date. However, with the exception of a very few species including *Sitobion avenae* and *Rhopalosiphum padi*, migrations were earlier than in 1977. Total catches during the season were below average for most species, the most important exceptions being the cereal aphids *Metopolophium dirhodum*, *R. insertum*, *R. padi* and *S. fragariae*, which were more than twice as abundant as usual.

The peach-potato aphid, *Myzus persicae*, arrived about 3 weeks late in the South-East, South-West and North. The apparently early migration in the Midlands was attributable to a single early specimen caught at Preston. Numbers of *M. persicae* remained considerably below average in all regions, especially in the North.

The potato aphid, *Macrosiphum euphorbiae*, was a few days early in most regions. The total number trapped was well below the annual mean in the South-East. Only in the North did numbers exceed the annual mean and this was due to large catches at Dundee in the first half of August.

The rose-grain aphid, *M. dirhodum*, arrived more than 3 weeks early in the South-East but this was the only region where numbers stayed below the annual mean. Over the rest of the country this aphid was 1–2 weeks early and total numbers were well above normal especially in the North. Exceptionally large migrations were recorded from mid-July to mid-August.

The grain aphid, *S. avenae*, arrived later and was less common than in 1977 in all regions. After the slow start, numbers remained small throughout the early summer and

https://doi.org/10.23637/ERADOC-1-135

rose to a late peak, dispersing at the end of July-early August. Total numbers nowhere exceeded a third of the annual mean.

The bird-cherry aphid, *R. padi*, was late in all regions especially in the South but was on average twice as common as other years. However, it was abundant only in the latter part of the season, numbers remaining well below normal at most sites until the end of July. A large autumn migration occurred in many areas particularly at Wye and Shardlow, and on the basis of this ADAS (Wye) warned farmers to be alert for aphid infestations in early sown cereal crops. Since the mild, dry autumn allowed southern farmers to sow many crops early in 1978, it seems likely that barley yellow dwarf virus, of which *R. padi* is the main autumn vector, will be a serious problem in winter sown cereals in 1979.

The oat-apple aphid, *R. insertum*, was also unusually abundant especially in the Midlands. It occurred in larger numbers than *R. padi* at Rothamsted (Tower), Rosewarne and Hereford. In contrast to *R. padi*, *R. insertum* arrived generally a few days early except in the Midlands. *R. maidis* also arrived early this year but was less common than usual except in the South-West.

Cereal aphids were surveyed on crops at Rothamsted for the tenth successive year and at North Farm, Sussex, for the second year. At Rothamsted, peak populations on winter wheat were smaller and later than usual, reaching a maximum of only 200 *M. dirhodum* and 60 *S. avenae* per 100 tillers; *S. fragariae* was slightly more abundant than usual. At North Farm the scarcity of aphids in the suction traps was reflected in the crops nearby with *M. dirhodum* being dominant among the few species present. Field populations which reached a maximum of 1–2 per ear in winter wheat fields, were estimated by taking plant samples and by using a vacuum sampler based on a 'D-vac' design. This proved useful in detecting early immigration into the crop, long before they were found in plant samples.

The black-bean aphid, *Aphis fabae*, arrived late in the South-East where fewer than usual were caught. In other regions it was early, and as many or slightly more than average were recorded. The hop aphid, *Phorodon humuli*, was late only in the South-East. It had an unusual regional distribution with four times the annual mean number in the North while in other areas it was scarce. (Taylor, French, Woiwod, Cole, Dupuch, Cameron, Dean and Dewar)

Analysis of suction trap records. Programs have been written to provide a preliminary analysis of the bulletin data as soon as it is available, making the suction trap records more immediately useful. Comparisons can now be made between the size and timing of the current migrations of some species and the average situation from previous years. As a further aid to forecasting, methods of putting the data into the computer quickly and efficiently for subsequent graphic display, are being studied. (Taylor, French, Woiwod, with Gledhill and Bicknell, Computer Department)

Overwintering of potato aphids. From January to May 1978 the survival of aphid populations was studied in two fields of brassicas at Rainham, Essex. Both fields contained a range of weeds which were host plants for the potato aphids, *M. persicae* and *M. euphorbiae*. *M. persicae* was recorded on all plant species examined at these sites but samples were taken from only five host-plant species on all eight sampling dates. *M. persicae* is normally thought to occur at barely detectable densities during the winter on a wide range of host plants. However, at the sites used in this study numbers of *M. persicae* in mid-January exceeded 100 per stem on both the small nettle (*Urtica urens*) and shepherd's purse (*Capsella bursa-pastoris*). The major cause of aphid mortality at these sites was the indirect result of frost damage to the host plants. *Capsella* was particularly frost

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susceptible; larger leaves of *U. urens* suffered some damage but most axillary branches were unaffected. Chickweed (*Stellaria media*) survived the frost but died back after flowering so did not support its aphid population right through the winter. (Cameron)

Suppression of potato aphid populations. The use of short wavelength light to repel potato aphids was investigated in 1977 and 1978 by growing potatoes under an extensible polythene film. Aphids not repelled by sky reflection and landing on the polythene would be able to crawl through the 9-mm long slits in the sheet on to the potato plants below. In 1977 too few *M. persicae* were recorded on uncovered plots for results to be conclusive. This year, six plots (15 × 15 m) of Pentland Crown were covered with film for comparison with six uncovered plots. Half the plots were not planted until the end of June to ensure that the crop would be in the early stages of development and thus susceptible to aphids at the time of the large summer migrations. As in 1977, covered plants were generally free of aphids, the exceptions being mostly along the edges of the plots. There were 75% fewer winged aphids of all species under the film. The greatest protection achieved this year was from winged *M. persicae* whose numbers on covered plots were reduced by over 99%, while winged *Macrosiphum euphorbiae* were decreased by 98%. (Cameron)

Monitoring for pea moth

Field trials. The commercial version of the pea moth monitoring system and the original experimental traps were compared in field trials. No differences in performance were found between the two types but it has been suggested that the original experimental rubber carrier for the attractant should be used to ensure even more persistent attractiveness in the field.

Early in the season large numbers of flies, confused with moths by some growers, were caught in the commercial traps after having been attracted to the sticky white card insert. This problem was reduced by using cards with a brown sticky surface uppermost. These modifications are to be incorporated in the commercial system for the 1979 season.

A long-term spray trial, occupying approximately 1 ha, started in 1977, continued to give satisfactory results. In both years the previously determined threshold catch of ten moths present in any one of a pair of traps on two consecutive 2-day periods gave a satisfactory indication of the pests' presence in a crop, but in both years the suggested 10-day interval before application of insecticide would have been too short because of unusually cold weather. However, by taking daily maximum and minimum temperature measurements after the date on which the threshold occurred and converting these to percent development, it would have been possible to predict an accurate spraying date. In 1977 this would have been 14 days after threshold, and in the exceptional weather of 1978, 23 days. A nomogram and simple circular calculators have been devised to simplify the calculation of development times for growers.

Similar trials by ADAS and PGRO using smaller plots and hand sprayers gave similar results. (Macaulay, with Etheridge and Goodchild, Insecticides and Fungicides Department)

Pheromone trap spacing. Work on the interactions between adjacent pheromone traps, which was started in 1977 (*Rothamsted Report for 1977*, Part 1, 94), was continued and expanded. The interactions reported in 1977 were between traps placed in lines of three with an inter-trap distance of up to 100 m. In 1978 interactions between pairs of traps up to 200 m apart, and lines of five traps up to 100 m apart, were investigated.

Results confirmed that pheromone traps for the pea moth, containing 100 μg of (E,E)-8,10-dodecadienyl acetate (*Rothamsted Report for 1975*, Part 1, 123–124), placed

https://doi.org/10.23637/ERADOC-1-135

in lines along the mean wind direction, do mutually interfere at trap spacings up to 100 m. This interference results in trap catch distortions, whose magnitude depends on the position of the trap in the line and on meteorological conditions. The interference can be demonstrated clearly in lines of three or five traps, but not in pairs of traps.

The results from 1977 and 1978 are being used as the basis for a simple model to describe the field behaviour of male pea moths responding to continuously emitting pheromone traps. (Wall, with Perry, Statistics Department)

Population dynamics of moths

Movement and diversity. Investigations into the spatial dynamics of single and multi-species populations of moths sampled by light traps are now producing results suitable for some types of large scale analysis. In 1961 a general hypothesis of population redistribution was proposed which suggested that single-species populations could be regarded as dynamic density surfaces with characteristic parameters of mean population density and surface roughness, measured by variance (*Rothamsted Report for 1961*, 152, *for 1965*, 185, *for 1969*, 243). Recent analyses confirm that these expectations are universal among all organisms and show the surface parameters to be species specific in time and space. They also present a new approach to species diversity, linking it with the fluctuations of single-species populations in space and time, and have produced a new interpretation of the statistics commonly used in both single- and multi-species dynamics. These fundamental studies provide an essential basis for field work in applied entomology by bridging the gap between theoretical mathematical models and advisory practice. (Taylor, French, Woiwod and Nicklen, with Perry, Statistics Department and Mr. R. A. Kempton, Plant Breeding Institute, Cambridge)

Cutworm biology and migration. Catches from four Insect Survey light traps at Rothamsted, and one at Gleadthorpe Experimental Husbandry Station, Notts., were examined daily in attempts to provide warnings of probable oviposition dates of *Agrotis segetum*, for a large area of carrots near Worksop. It is now apparent that the Rothamsted type light trap does not catch enough of the less common species such as *A. segetum* and *Euxoa nigricans* to provide adequate data for warnings.

A Robinson type trap has been used to provide fresh stock for laboratory cultures of *A. segetum* and *Noctua pronuba*, and material for chemoprinting studies of *N. pronuba*, and it will be necessary to use this type of trap for general studies.

Compared with 1977, only about half as many adults of the main pest species caught in the Rothamsted traps (*A. segetum*, *A. exclamationis*, *E. nigricans*, *N. pronuba* and *Plusia gamma*) were recorded in 1978. Sex ratios were again strongly biased towards males, though, as in 1977, that of *Plusia gamma* was nearer unity than the other species (Table 1). In *A. exclamationis* and *N. pronuba* there was a linear decline in the ratio of females from the start of the flight season, but in *A. segetum* relatively more females were caught 3 weeks after the flight season began, than at other times.

TABLE 1

Sex ratios of cutworm moths in light traps at Rothamsted and Gleadthorpe

Species	Sex ratio, ♂ : ♀	
	Rothamsted	Gleadthorpe
Agrotis segetum	1 : 0·20	1 : 0·70
Agrotis exclamationis	1 : 0·21	1 : 0·19
Euxoa nigricans	1 : 0·33	—
Noctua pronuba	1 : 0·15	—
Plusia gamma	1 : 0·70	—

https://doi.org/10.23637/ERADOC-1-135

TABLE 2

Frequency distribution of numbers of spermatophores in females of cutworm moths

Species	Numbers of spermatophores					
	0	1	2	3	4	5
Rothamsted						
Agrotis segetum	–	2	1	–	–	–
Agrotis exclamationis	–	6	9	3	2	
Euxoa nigricans	1	3	1	–	–	–
Noctua pronuba	24	4	3	2	4	
Plusia gamma	10	–	1	–	1	1
Gleadthorpe						
Agrotis segetum	1	2	1	–	–	–
Agrotis exclamationis	3	8	7	1	–	–

The numbers of spermatophores present in females, Table 2, in association with estimates of ovarian and fat-body development, provides a means of estimating the ages of females trapped. Dissections again showed most early females to be immature. The striking exception was *P. gamma*, in which the first three females caught, in July, were all mature. No more females of *P. gamma* were caught until the end of August; from then until flight ceased in mid-October, all were immature.

There were large catches of *N. pronuba* in the Robinson trap on 3 and 4 August. Dissection of a sample of females from each night revealed two distinct age groups; a small number of mature females each with several spermatophores, the rest unmated immatures. Previously, all females had been unmated immatures, the condition expected at Rothamsted early in the flight season of this species, which has a long period of immaturity. The catches on 3 and 4 August coincided with a meterological change which suggested that immigration had occurred.

As a possible means of tracing the source of migrants a feasibility study was made on chemoprinting individual moths using the X-ray fluorescence technique (*Rothamsted Report for 1978*, Part 1, 295). Analyses of these and later samples of wild and laboratory bred material have been confined to the elements Al, Si, P, S, Cl, K, Ca, Ti, Fe, Cu and Zn; quantities were measured and expressed as ppm dry weight, $\pm$SD where appropriate. The most striking difference between two mature females of 3 August and the rest of the sample on that date (as well as bulked samples of females) was in respect of Ti. The mature females each contained 10·1 ppm, compared with $5{\cdot}8 \pm 2{\cdot}9$ for the others. Males on 3 August and bulk male samples did not differ from each other, their Ti content being $3{\cdot}5 \pm 0{\cdot}5$ ppm. There were no differences of comparable magnitude among other elements. Females were, in general, much more variable in their elemental content than males, though averages were similar except for Ca, for which females average 2100 ± 340 ppm compared with 640 ± 70 for males.

This promising preliminary study has justified the start of a comprehensive programme to establish basic 'fingerprints' for populations of *A. segetum* and *N. pronuba* reared on artificial diets, and on various combinations of plants and soil types. (Bowden and Sherlock)

Pesticide use

Medium to long-term assessment of the effects of pesticides on pests of peas and beans, grassland and forage crops, and the soil fauna, continued. A new departure for the Department was the initiation of studies into aspects of the variability in aphid populations that may influence the development and spread of resistance to pesticides.

https://doi.org/10.23637/ERADOC-1-135

Control of pea and bean weevils. Populations of *Sitona* weevil larvae attacking the roots of field beans were moderate and comparable with 1977, varying between 4·8 and 11·8 per untreated root in mid-July, when larvae were most abundant. Growing conditions for beans were the best for several years, and yields were high. In departmental experiments most insecticide treatments against *Sitona* increased yields, but these differences were only significant in the 'Factors affecting bean yields' experiment (see Field Experiments Section, p. 117).

Efforts were continued to develop practical and economic methods of controlling *Sitona* infestation on spring-sown field beans. With permethrin sprays applied at 0·15 kg ha^{-1} the most effective treatments were those applied in mid-May when *Sitona* adults became noticeably abundant in bean fields. This treatment halved subsequent larval populations, but sprays applied in early June or early July had comparatively little effect.

A further small-scale experiment was done to compare the efficiency of various insecticides applied in the drill furrow, or to the seed (Table 3). These confirmed that

TABLE 3

Insecticides and the control of Sitona *larvae*

	Number of larvae per root 20 July 1978
Untreated	4·75
Aldicarb to seed furrow (2·24 kg a.i. ha^{-1})	1·88
Carbofuran to seed furrow (2·24 kg a.i. ha^{-1})	0·00
Fonofos to seed furrow (2·24 kg a.i. ha^{-1})	2·50
Phorate to seed furrow (2·24 kg a.i. ha^{-1})	0·25
Fonofos broadcast before cultivation (4·48 kg a.i. ha^{-1})	5·44
Phorate seed treatment (0·25 kg a.i. ha^{-1})	3·87
Phorate seed treatment (0·75 kg a.i. ha^{-1})	0·75
SED between treatments	1·920
SED between treatments and control	1·662

phorate at 0·75 kg a.i. ha^{-1} was an effective seed treatment. Phorate and other insecticides applied as furrow treatments at 2·24 kg a.i. ha^{-1} also gave excellent control of larvae. These are realistic commercial rates, although there may be application difficulties. Larger scale experiments are planned to investigate yield effects and application methods.

More speculative control methods tried included a barrier treatment intended to prevent ovipositing adults moving into bean fields from their over-wintering sites, and an attempt to infect *Sitona* larvae with the entomophagous fungus *Metarhizium anisopliae*. The barrier treatment consisted of aldicarb granules applied to the seed bed at 10 kg a.i. ha^{-1} in a band 5 m wide at the edge of the field. It was ineffective, perhaps because the band was too narrow. The pathogen (provided by N. Wilding) was applied as a formulation on chipped rice grains at 80 g m^{-2}, cultivated into the top 2–3 cm of the soil in late May. This, too, proved ineffective, perhaps because the pathogen was not placed deep enough.

The control of *Sitona* on winter bean was also investigated. Aldicarb and fonofos drilled with the seed had little effect on larval populations which reached a maximum of five per root on untreated plots. Permethrin sprayed at 0·15 kg a.i. ha^{-1} in mid-May halved larval populations but did not increase yields. (Bardner and Fletcher, with Griffiths, Insecticides and Fungicides Department)

Pests of leafless peas. Two separate experiments at Rothamsted and Woburn were repeated as in 1977, using the cv. Filby.

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All combinations of the following treatments against a control were tested on each site: (i) aldicarb at 10 kg ha^{-1} rotavated into the soil before sowing; (ii) triazophos at 0·34 litre ha^{-1} applied as a foliar spray at the time of pea moth abundance; (iii) benomyl at 0·56 kg + zineb at 1·6 kg ha^{-1} applied as a foliar spray.

Untreated plots at Rothamsted and Woburn yielded 4·8 t ha^{-1} and 3·4 t ha^{-1} of grain respectively, whereas plots receiving the full combination of chemical treatments yielded 5·1 t ha^{-1} and 4·4 t ha^{-1} of grain.

Yield increases on aldicarb treated plots were associated with an 80–90% decrease in the numbers of *Sitona lineatus* larvae attacking the roots. Pea-moth, aphid, and nematode numbers were at levels unlikely to cause yield losses. (Fletcher and Macaulay, with McEwen, Field Experiments Section, Cockbain and Salt, Plant Pathology Department, and Whitehead, Nematology Department)

Variability of pest aphid populations and insecticide resistance. Excessive use of insecticides encourages resistance in some species of pest aphid. Little is known about the rate at which resistant mutants spread within populations or throughout the countryside, or their persistence in field populations when spraying has ceased. A knowledge of the genetic structure of populations is essential before changes in the distribution and persistence of resistant strains can be interpreted.

Work has begun on three agriculturally important aphid species (*M. persicae*, *S. avenae* and *R. padi*), each suspected of parthenogenetic reproduction during mild winters instead of the normal pattern of sexual reproduction (holocycly). Populations in spring display limited genetic variability due to selection for and persistence of a relatively few 'fit' strains which later disperse and dominate populations over large areas. Overall variability is thus much reduced.

Investigations have started on the genetic structure of widely separated greenhouse and field populations of these species. Using polyacrylamide gel electrophoresis the relative mobilities of 18 enzymes that occur in field and greenhouse populations have been assessed. At the same time, some chromosome karyotyping has also been done to see whether enzyme variants are correlated with chromosomal changes.

In a number of greenhouse strains of *M. persicae* no polymorphism was detected at several genetic loci examined. This suggests that greenhouse populations of *M. persicae*, at least, have arisen from limited clonal sources.

A similar investigation of two greenhouse colour forms of *S. avenae* has shown that both strains possess an identical normal karyotype ($2n = 18$), whilst displaying distinct electromorphs of Est-3. Thus, by contrast with *M. persicae*, electromorphic variation in these clones does not appear to be associated with an observable chromosomal change. (Loxdale and Dean)

Symbiotes of aphids. Studies in Germany have suggested that insecticide resistance in *M. persicae* is associated with the number and type of gut symbiotes. However, the lengths of individual symbiotes (intercellular micro-organisms) and the numbers of these per unit area in ultrathin sections of the mycetomes (specific abdominal organs) did not differ between strains of *M. persicae* that were resistant or susceptible to demeton-S-methyl in Britain. This is contrary to the German observations although it does not exclude the possibility that symbiotes play an active part in resistance to insecticides. (Ball and Bailey)

Pests of grass and forage crops. Studies on invertebrates and pasture productivity continued in collaboration with the Grassland Research Institute, Hurley.

Field studies to date have shown that the activities of the normal invertebrate occurring

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at endemic densities in perennial ryegrass swards or ryegrass-dominant pasture, annually cause losses of up to 30% of dry matter output. Italian ryegrass is generally even more severely affected, yielding less and persisting a shorter time under pest attack. Emphasis has therefore moved from assessing effects on grassland to developing control measures, while at the same time examining the possibility of similar losses in herbage legumes.

The long-term effects of drastically suppressing virtually all soil and foliage invertebrates in a ryegrass sward by continued severe pesticide treatment were followed for another year (the tenth), in an experiment laid out at Hurley in 1968. The consistent improvement in annual yield on treated plots recorded in previous years was not repeated: small improvements in output at individual cuts had been recorded during 1977, but during 1978 no significant differences were detected in either individual cuts or annual yield. This implies that broad-spectrum, persistent treatments which have undesirable side effects, such as increasing soil compaction and surface litter, cannot form a basis for chemical control measures; more specific and less persistent treatments are required.

Attempts to select more suitable chemicals that will give comparable pest control on perennial ryegrass without undesirable side effects were disappointing: of 14 materials tested none improved yield as much as the chosen standard, the insecticide/nematicide phorate, although small improvements were noted using the synthetic pyrethroids cypermethrin and decamethrin.

The benefit of controlling pests of Italian ryegrass, especially stem-boring larvae of the Chloropidae and Geomyzidae, was confirmed in field experiments at both Institutes and elsewhere. Yields of most of the current NIAB-recommended varieties were improved by pesticide treatment, some as much as twofold in individual cuts, especially later in the season, with total annual DM output increased by over 50% depending on variety.

In Italian ryegrass (cv. RvP) sown at Rothamsted in mid-April 14% of tillers on control plots were infested by stem-boring dipterous larvae by mid-August, while grass on plots treated with phorate at 5 kg a.i. ha^{-1} at sowing had only 8% of tillers infested by this time. By mid-October the figures were 9 and 4% respectively as the pesticide degraded. Control plots yielded 8·2 kg DM ha^{-1} in four cuts over the period, while treated plots gave 9·3 kg ha^{-1}. (Henderson and Welch, with Mr. R. O. Clements, The Grassland Research Institute)

Pesticides and the soil fauna. The long-term studies into the effects of pesticides on soil-inhabiting invertebrates continued. In 1978, six pesticides were tested in field plots which were ploughed, treated with pesticide, thoroughly cultivated, and reseeded to grass. Effects on arthropods were assessed from soil samples taken at two-monthly intervals; earthworms were sampled by applying dilute-formalin to 0·5 m^2 quadrats. Six pesticides were tested including two fungicides, benomyl (10 kg ha^{-1}) and carbendazim (10 kg ha^{-1}), a molluscicide, oxamyl (10 kg ha^{-1}) and three insecticides, permethrin (0·1 kg ha^{-1}), phorate (1·5 kg ha^{-1}) and pirimicarb (0·5 kg ha^{-1}).

Of these, only phorate was toxic to a wide range of invertebrates. The others were only moderately toxic to arthropods at the recommended doses tested. Benomyl, carbendazim and phorate were extremely toxic to earthworms.

Studies continued on the factors that affect the uptake of the aldicarb into the tissues of earthworms (see *Rothamsted Report for 1977*, Part 1, 99). Large amounts of aldicarb were absorbed rapidly by earthworms from flooded soil treated with recommended doses, concentrations reaching a peak of 160 ppm within 24 h. Most worms came to the surface in response to stimulation by the chemical and if ten worms containing such large residues were eaten by a bird it would probably be fatal, which could account for the numerous bird deaths reported in 1975 when aldicarb was applied to flooded soil after prolonged

https://doi.org/10.23637/ERADOC-1-135

wet weather in spring. By contrast, another insecticide, phorate, applied under similar conditions, accumulated in earthworms much less rapidly, reaching a concentration of only 20 ppm in 2–3 weeks. Aldicarb was rather less toxic than phorate under dry conditions. (Edwards and Lofty, with Briggs, Insecticides and Fungicides Department and Mr. P. Brown, Pest Infestation Control Laboratory, Slough)

Cultural and biological control

Considerable effort continued to be put into exploring ways of limiting pest populations by non-insecticidal means. Wide-ranging programmes included studies on how invertebrates encourage root growth in direct drilled plots, the effects of several pathogens on pest populations, and speculative investigations on pest behaviour that might eventually be exploited for control purposes.

A start was made to draw many of these studies together into an investigation of how cultural and biological methods can best be combined with traditional chemical methods to control pests in cereals.

Cultural control

Direct drilling and the soil fauna. Populations of small invertebrates, surface-living arthropods, slugs, earthworms and stem borers were compared in ploughed and direct drilled plots of rotational experiments at Englefield, Northfield and Compton Beauchamp organised by the Letcombe Laboratory. Similar assessments were made on the continuous cereal experiments of the National Institute of Agricultural Engineering at Rothamsted and Boxworth, and on an ADAS experiment at Hundon. Results confirmed the trends reported previously.

The effects of direct drilling on populations of soil invertebrates were confirmed on a commercial farm scale by assessing populations of all invertebrates in April 1978 in seven ploughed and seven direct drilled cereal fields on Lee Farm, Sussex. Shoot-borers were more abundant in ploughed fields than direct drilled; conversely, slugs were more common in direct drilled fields. There were more earthworms in direct drilled fields although numbers were very variable. The most significant difference was for carabids and staphylinids which were much more abundant in ploughed fields than in direct drilled ones.

Experiments on the influence of the soil fauna on root growth of cereals in direct drilled soil continued. For the second year, intact soil profiles were taken from the direct drilled plots at Silsoe and Boxworth and placed in boxes with transparent plastic sides. They were fumigated with ('D-D') to kill all soil arimals, then known populations of arthropods and selected earthworm species were introduced into the boxes in numbers similar to those normally inhabiting the soil under normal arable conditions. Spring barley was planted and its growth recorded for 2 months. The profiles were then taken from the boxes and impaled on a bed of large nails to retain the roots in their normal position, before the soil was carefully washed away. Root growth in the boxes with no animals was much poorer than in all the boxes with soil animals, and the distributions of roots in the profiles closely resembled the zones of activity of the animals. In boxes with only arthropods and also those with *Allolobophora chlorotica* and *A. caliginosa* which move near the surface, root growth was shallow. By contrast, in boxes inoculated with earthworms that have permanent and deep burrows, root growth was dense to the bottom of the profiles. Thus, in certain soil types and in the absence of ploughing the soil fauna is clearly necessary to open up the soil and to provide channels for root growth.

Other experiments showed that it was not only the physical activity of earthworms that favours root growth. By comparing the growth of roots through earthworm and

https://doi.org/10.23637/ERADOC-1-135

similar artificial burrows it seems that cast material on the walls of the burrows helps to promote root growth.

These experiments were extended to the field at Boxworth by adding earthworms to 9 m^2 plots on land that had been direct drilled for 6 years, after the existing fauna had been killed by injecting the soil with 'D-D'. Some plots were inoculated with 30 adult *Lumbricus terrestris* or *Allolobophora longa* per m^2, others with 45 *A. caliginosa* or *A. chlorotica* per m^2.

All plots were planted to winter wheat. The weight and depth of roots, number and height of plants, numbers of tillers and yield were all much greater in the plots to which *L. terrestris* and *A. longa* had been added than in those not inoculated with earthworms. There was also a lesser, but significant, effect on these characteristics caused by the activities of *A. caliginosa* and *A. chlorotica*. Large quantities of straw remained on the surface throughout the season on the plots without earthworms, and on those inoculated with shallow burrowing earthworms (Table 4). (Edwards and Lofty)

TABLE 4

Weight of roots and straw disappearance resulting from inoculation of earthworms into direct drilled plots (June 1978)

	Inoculated with *L. terrestris* and *A. longa* (after 'D-D' treatment)	Inoculated with *A. caliginosa* and *A. chlorotica* (after 'D-D' treatment)	Worms killed with 'D-D'	Normal field population of worms
Weight of roots/plant (gm)	7·17	3·48	1·92	1·83
Weight of surface straw dm^{-2} remaining	38·5	88·6	96·6	102·9

Effects of fertilisers on the soil fauna. Studies on the Park Grass experiment showed that large doses of nitrogen adversely affect populations of some soil invertebrates (see *Rothamsted Reports for 1975* and *for 1976*, Part 2).

This work has been followed up by examining the fauna on other long term experiments on fertilisers at Rothamsted. The effects of nitrogen on invertebrates at 2–6 times the recommended dose were greatest on Symphyla, some Collembola, Chilopoda, Hemiptera and coleopterous larvae (particularly wireworms). This confirmed the findings on the Park Grass experiments.

An experiment designed to study the effect of organic fertilisers, especially sewage sludge, on earthworms and soil arthropods was initiated in the spring of 1978 as part of a collaborative programme under the auspices of the International Organization for Biological Control (IOBC). The work will concentrate on the effects on pests and predators of the nitrogen content of organic fertilisers. On a field site later sown to spring barley, sewage sludge (as fragmented cake) and farmyard manure were applied at 200 kg N ha^{-1}. Earthworm and arthropods were sampled in the autumn and spring but are not yet counted. (Edwards and Lofty)

Biological and behavioural control

Predators of cereal aphids. Assessment of the importance of carabid and staphylinid beetles as predators of cereal aphids continued. In the 3 previous years, experiments in which populations of carabid beetles were manipulated in wheat plots by using metal

https://doi.org/10.23637/ERADOC-1-135

or polythene barriers, and pitfall traps, showed an inverse relationship between the numbers of cereal aphids and carabids, particularly *Agonum dorsale*, *Pterostichus melanarius* and *Harpalus rufipes*.

In 1978, barriers were set up around plots with five replicates of three treatments at monthly intervals in early March, April or May. One treatment allowed all beetles access to cereal aphids, in another carabids were removed by trapping, and in a third carabids, staphylinids and all surface-living arthropods were eliminated by trapping and surface treatments with fonofos (4·4 kg ha^{-1}).

The sequential exclusion of beetles demonstrated clearly that early predation by carabids, especially in March, greatly restricts cereal aphid infestations in summer. This was reflected in yields which were much higher in plots to which beetles were allowed access in March.

A duplicate experiment at North Farm (in collaboration with Dr. K. Sunderland, Glasshouse Crops Research Institute, Littlehampton) confirmed these results. (Edwards and Steed, with Mr. K. S. George, MAFF, Plant Pathology Laboratory)

Very few other predators (coccinellids, syrphids, *Chrysopa carnea*) were found on wheat at Rothamsted. There was more parasitism (mainly *Aphidius* spp.) than in 1977, with a peak (20–40%) after mid-July, especially of *S. avenae* on the ears when aphid populations were largest and about to decrease. Laboratory observation of field-collected mummies showed that there was little hyperparasitism of the primary parasites. Similarly, infection by fungus (*Entomophthora* spp.) exceeded 17% only after mid-July. (Dean, Dewar and Wilding)

Slug behaviour. Work continued on the identification of host plant components influencing behaviour of the grey field slug, *Deroceras reticulatum* (Mull.) (*Rothamsted Report for 1977*, Part 1, 100, 147). Since this slug is polyphagous, constituents common to many plants are probably attractive to it. Components of lettuce thought to merit further tests were selected from compounds present in major gas-chromatographic peaks common to the volatiles from both lettuce and dandelion.

A number of C_6 unsaturated alcohols and related compounds were identified by gas chromatography and mass spectrometry and tested using a trail-following bioassay. (E)-2-hexen-1-ol and 1-hexen-3-ol induced significant responses in slugs, similar to those produced by lettuce, dandelion and carrot volatiles. The prospects of incorporating these materials into toxic baits are being considered. (Stephenson, with Pickett, Insecticides and Fungicides Department)

The copulatory and aggregation behaviour of *D. reticulatum* has also been studied. This slug locates a mate by following its mucus trail. When the slugs meet they either soon separate again or crawl head-to-tail in a clockwise circular 'dance' until the genitalia meet and copulation occurs. Experiments have shown that the trail-laying slug does not secrete sex pheromones, because a trail-following slug will follow trails of both sexually active and inactive individuals. A sexually active follower will follow any mucus trail until it locates the trail layer, but it is not known how the follower detects that the leader is sexually active.

The role of mucus in aggregation behaviour has also been studied. In field experiments *D. reticulatum* did not aggregate in traps smeared with fresh mucus. Laboratory experiments with choice chambers indicated that slugs preferred to settle in sites contaminated with faeces containing green plant material. In the wild this would ensure that they stay near to a food source. (Burke)

Entomophthora *species controlling bean aphis*. Experiments begun in 1975 on the effect of distributing aphid pathogenic fungi of the genus *Entomophthora* in populations

https://doi.org/10.23637/ERADOC-1-135

of *Aphis fabae* were continued following the finding in 1977 (*Rothamsted Report for 1977*, Part 1, 102–103) that an application of the fungus decreased aphid damage.

In 1978, the natural population of aphids was small and as in previous years was supplemented, in early June, with aphids reared in a glasshouse. Living aphids infected with *E. aphidis*, *E. fresenii* and *E. planchoniana* were distributed in a bean crop of the 21 June. The cool, moist weather favoured the spread of the fungi, which infected 31, 61, 76 and 85% of samples of adult apterae from treated plots, and 1, 11, 31 and 62% of adult apterae from untreated plots on 3, 10, 17 and 25 July respectively. Aphid numbers in plots treated with *Entomophthora* remained similar to those in untreated plots until 11 July when populations were $0{\cdot}8 \times 10^3$ aphids per plant. Thereafter, numbers in untreated plots increased to a maximum of $1{\cdot}7 \times 10^3$ per plant on 25 July, whereas those in *Entomophthora*-treated plots had declined to $0{\cdot}17 \times 10^3$ per plant. Adjacent plots were treated each week with carbaryl which kills aphid predators but is relatively harmless to aphids. In these plots, aphid numbers increased to 3×10^3 per plant on 25 July but the proportion infected with *Entomophthora* remained the same as in the untreated plots, showing that the greater host density did not increase the rate of spread of the fungi.

The differences in yields between the plots were small, even between the untreated ones and those kept free of aphids with pirimicarb. However, bean aphid populations of the sizes recorded here have been shown, elsewhere, to cause important effects on yield. This supports the conclusion reached by others that the effects of aphids on the yield of beans vary greatly according to the growing conditions.

These results confirm that *Entomophthora* species distributed in an aphid population can arrest the multiplication of the aphids but it still is not known whether the fungi can decrease aphid damage at low aphid host densities in years when the crop is less able to resist aphid attack.

***The effect of fungicides on* Entomophthora.** The fungicides benomyl, captan, ethirimol, fentin acetate, maneb, tridemorph, thiram and zineb, in addition to captafol and mancozeb discussed previously (*Rothamsted Report for 1977*, Part 1, 103), at concentrations corresponding to those usually applied in the field, decreased or prevented germination of conidia of *E. aphidis* on agar containing the chemicals. Correspondingly, the infection of *Acyrthosiphon pisum* inoculated topically with conidia and dipped 6 h later, into suspensions of the fungicides, was inhibited. However, many more became infected when they were dipped in the fungicide 24 h after exposure to the conidia, probably because by that time the fungus had invaded the host and the fungicides were not transmitted to the site of fungal development within the aphid. When aphids were dipped into the fungicides 6 h before inoculation, all except zineb and captafol decreased the proportion of aphids that became infected. Further, the effect of the chemicals persisted, at least partly, when the aphids were dipped in them 48 h before inoculation.

However, irrespective of these laboratory demonstrations of how the chemicals affect *Entomophthora*, those tested in the field—benomyl, captafol, mancozeb and tridemorph—had no effect on the proportion of *A. fabae* that became infected even though they were applied far more frequently than would be appropriate commercially. (Wilding, Brobyn and Best)

The natural incidence of cutworm diseases. In 1975, 1976 and 1977 cutworms, mostly *Agrotis segetum*, were collected from various crops at 41 sites; 1237 individuals were reared in the laboratory and 32% died before moths emerged. However, pathogens were detected in less than 8% of the dead cutworms, confirming the low natural incidence of disease indicated by the preliminary results (*Rothamsted Report for 1977*, Part 1, 102). Most infections were either viral or fungal, and the incidence of each was about 4%. The

https://doi.org/10.23637/ERADOC-1-135

commonest fungus, isolated from more than 2% of the cutworms, was provisionally identified as *Entomophthora megasperma*. Two types of Baculovirus were detected, granulosis virus (GV) and nuclear polyhedrosis virus (NPV): each infected about 2% of the cutworms. Mixed virus infections were found in five cutworms: three were infected with both a GV and an NPV and two others with an NPV and a non-occluded virus with particles 40 nm in diameter. NPVs were the most widespread type of pathogen detected at 11 sites, whereas the other pathogens were found at five (*E. megasperma*), or fewer sites.

Such low natural incidence of diseases suggests that populations of cutworms could be decreased by the planned introduction of a suitable pathogen. (Sherlock)

Integrated control in cereals. Members of the Department have long been concerned with cereal pests such as aphids, stem borers, gall midges, wheat bulb fly and slugs, and have also investigated the other fauna of cereals, including soil microarthropods, parasites and predators. Efforts are now being made to develop integrated pest management systems for cereals, and in this connection, two new cereal experiments have been started.

In the first, untreated plots of winter wheat were compared with plots treated with fonofos at 5 kg a.i. ha^{-1} cultivated into the soil before sowing in October, and with others where chlorpyrifos at 5 kg a.i. ha^{-1} was sprayed on the soil in mid-April. The fonofos treatment was designed to restrict predator activity in the soil during the winter, and the chlorpyrifos was intended to control predator activity on the soil surface during the spring and early summer.

In the second experiment, untreated plots of spring-sown wheat were compared with (i) a combination of soil and foliage insecticides designed to control soil pests, stem-borers and foliage pests, (ii) an aphicide spray of pirimicarb and (iii) biological control using entomophagous fungi applied to the soil. These treatments were designed to compare the effects of maximum chemical control with commercial practice, and with biological control.

In both experiments pest numbers, especially aphids, were low and although all treatments had higher yields than untreated plots, these differences were not significant. Examination of the many samples is not yet complete, but a soil treatment of dyfonate before sowing decreased winter populations of carabids and also the predators of wheat midge larvae in the soil; populations of thrips in the following summer were larger than in untreated plots. The spring applications of chlorpyrifos decreased the subsequent infestations of midges and thrips and also the numbers of carabids in the spring and early summer. Useful experience of techniques was gained which will be utilised in future experiments. (Bardner, Dean, Dewar, Edwards, Fletcher, Lofty, Stephenson and Wilding)

As part of this programme, the efficiency of plant and suction sampling methods for estimating populations of cereal aphids was compared with direct counts of aphids on the growing crop. Plant sampling revealed only 70–90% of aphids known to be present from field counts, and the suction sampler collected only 50–65%. Plant sampling gave a reasonably realistic estimate of the earlier aphid instars, but many adults fell from the plants as samples were taken; the suction sampler collected the alates and later instars efficiently, but not those first and second instars that were firmly attached to their feeding sites. Neither method proved as accurate as field counts made during the development of aphid populations, but field counts are too time consuming to be feasible on a large scale during the growing season. (Dewar and Dean)

Integrated control of pests of sugar-beet seedlings. The collaborative experiment of the Integrated Control of Soil Pests Working Group of the IOBC/WPRS continued for a

https://doi.org/10.23637/ERADOC-1-135

third year in seven countries (Ireland, Belgium, France, West Germany, Switzerland, The Netherlands and UK). Results confirmed those of the previous year but attacks by all pests were much less than in 1977 except for attack by *Atomaria* in successive sugar-beet crops. It is gradually becoming apparent that the increase in attacks by marginal pests such as *Onychiurus* and millipedes is related more to seed-spacing and herbicide use than to the destruction of the predators of these pests by insecticides. There was some evidence that increased Collembola populations were inversely correlated with nematode (*Heterodera schactii*) populations.

The application of the entomophilic nematode, *Neoaplectana*, to small plots to control seedling pests of sugar beet was much less effective than in 1977 indicating that this biological control agent acts most efficiently in dense pest populations. (Edwards and Lofty, with Oswald, Nematology Department and Dunning and Thornhill, Broom's Barn)

Honeybees

The work on honeybee pathogens continued, but the emphasis of other studies was on the pheromones which may be used as an aid to colony management and perhaps to improve crop pollination.

Viruses of bees

Cloudy wing virus. Bees that died unexpectedly early in laboratory experiments and that had developed opaque-white or cloudy wings, contained many isometric virus-like particles about 17 nm across. Many of the same particles were found in bees, showing the same symptoms, from a local moribund colony unconnected with the laboratory bees, and they have been identified in samples of sick and dead bees from elsewhere. However, the cloudy wings may not be a specific sign of the infection.

Tests showed that the particles are pathogenic and observations suggest that air-borne infection is the natural means of transmission. However, artificial infection of bees by a variety of methods has so far proved unreliable.

The particles are physically indistinguishable from those associated with chronic bee-paralysis virus (*Rothamsted Report for 1975*, Part 2, 133), but they are serologically unrelated to them and require different conditions of purification to be kept in solution. (Bailey and Ball)

Bee virus Y. Isometric virus-like particles, 35 nm across, were frequently detected in samples of dead bees from local field sites and in similar bees from elsewhere in Britain. Serologically the particles are distantly related to those of bee virus X but appear to be much more common. Like black queen-cell virus (*Rothamsted Report for 1977*, Part 1, 104), they were associated with severe infection by *Nosema apis*. This probably means they are similarly transmitted, i.e. by ingestion of faecal material, but are independent. They were detected when all samples were routinely examined by electron microscopy in addition to the serological methods previously employed, being numerous in samples that failed to react with antisera to any of the known bee viruses. (Bailey and Ball)

Kashmir bee virus. Three viruses closely related to each other and to Kashmir bee virus were isolated from dead adults, larvae and prepupae of *Apis mellifera* L. from Australia (S. Australia, New South Wales and Queensland). All four strains of the virus are physically indistinguishable and each contain three proteins, although two proteins of the Australian strains differ in molecular weight and stability from those of Kashmir bee virus. All the virus strains are very pathogenic for adult individuals of *A. mellifera*

https://doi.org/10.23637/ERADOC-1-135

either by injection or by contact with the cuticle where setae have been freshly broken. (Bailey, with Carpenter and Woods, Plant Pathology Department)

Other viruses from abroad. Viruses found in amounts sufficient to be detected directly by serology in extracts of sick or dead individuals of *A. mellifera* sent from abroad were black queen-cell and sacbrood viruses from Australia and New Guinea, and black queen-cell and acute bee-paralysis virus from Belize. Kashmir bee virus was detected in several samples of sick adult individuals of *Apis cerana* from Mahableshwar, India.

This is the first evidence of these viruses in the parts of the world mentioned. (Bailey)

Honeybee pheromones

Forage marking pheromones. The secretion of the Nasonov gland of the honeybee contains a volatile pheromone which is attractive for foraging honeybees. The components have been identified as (Z)-citral, (E)-citral, nerol, geraniol, nerolic acid, geranic acid and (E,E)-farnesol, and quantified (*Rothamsted Reports for 1977*, Part 1, 146 and *for 1978*, Part 1, 136, Insecticides and Fungicides Department).

The individual compounds were bioassayed for their attractiveness to foraging honeybees. Each compound, except geraniol, was attractive. A mixture, containing compounds in proportions found in the honeybee, was almost as attractive as the natural secretion. Thus a synthetic mixture containing the same amounts of individual compounds present in 20 glands was as attractive as five excised glands. Each component contributed to the activity of the mixture.

The components in the Nasonov secretion were analysed throughout the year and remained qualitatively similar. Estimation of the absolute amounts of geraniol and (E,E)-farnesol, showed that the compounds were not detected in newly emerged bees but after 7 days the amounts of both increased to reach a maximum at 28 days of 1·88 μg per bee of geraniol and 0·62 μg per bee of farnesol, and thereafter remained similar throughout the summer. In mid-winter, glands contained only 0·25 μg of geraniol and 0·08 μg of farnesol but in spring increased amounts were again present. Therefore production of the secretion appears to be related to foraging behaviour; it increases when young honeybees and overwintered honeybees begin to forage but diminishes during the winter when foraging ceases. (Williams, with Pickett, Insecticides and Fungicides Department)

Use of a forage-marking pheromone. When *A. mellifera* foragers have made several consecutive trips for water many of them expose their Nasonov glands at the source of supply, especially when it lacks an odour of its own. By contrast, foraging *Apis florea* L. in Oman were observed to expose their Nasonov glands at their nest, but not at sources of odourless sugar syrup. However, an apparently volatile pheromone left at the food source by foragers induced others to alight. (Free and Williams)

A similar type of communication between *A. mellifera* foragers has now been observed. Pheromones from heads, thoraces and abdomens of foragers present *in situ* or on filter paper wipes elicited the alighting response of would-be foragers, but wipes from the dorsal surface of the abdomen were more effective than from the head and thorax. When extracted from the substrate with dichloromethane the forage-marking pheromone retains its biological activity. Its chemical composition is being investigated.

The response of bees to a food source with a floral or a non-floral scent was increased by the addition of the forage-marking pheromone, which seems always to be deposited when a bee forages, irrespective of whether or not the food source has an odour. It is therefore a less specific and probably a more primitive form of communication than the Nasonov pheromone. (Ferguson and Free)

https://doi.org/10.23637/ERADOC-1-135

Although the forage-marking pheromone is very effective in releasing an alighting response it is not known at what distance it is perceived and responded to by bees seeking forage. If foragers are attracted from a long distance the possibility of using a synthetic preparation of this pheromone to apply to crops needing insect pollination, alone or with synthetic Nasonov secretions is worth exploring.

Affect of brood pheromones and pollen-gathering. On most crops, honeybees collecting pollen are more efficient pollinators than those collecting nectar only, because they carry more pollen in their bodies and are more likely to transfer it to the stigmas. Therefore, increasing the number of pollen-gatherers in a colony should enhance its value for pollinating agricultural and horticultural crops. Brood of all stages of development, but especially larvae, stimulate pollen collection, probably because of a pheromone they produce. The amount of pollen a colony collects increases with the amount of brood it is rearing.

Experiments have now shown that even when the amount of brood in a colony remains unchanged, the amount of pollen collected can be influenced merely by altering the accessibility of the brood area to foragers. When the hive entrance of a colony led directly into the brood area, the foragers collected much more pollen, and so were more valuable pollinators, than when it led into the storage area only. To stimulate maximum pollen collection, and so increase a colony's pollinating efficiency, the brood should be located near to the hive entrance. (Free)

Mechanism of queen influence in colonies. The pheromone 9-oxo-(E)-2-decenoic acid (9-O-2), which occurs abundantly in the mandibular-gland secretion of queen honeybees, was discovered in 1960 as the result of attempts to identify the substances responsible for a queen's power to inhibit queen rearing. It was subsequently found to attract drones, and swarms that had lost their queens. Nineteen other substances were later identified in ether extracts of queens' heads but proved inactive in simple tests.

A reliable difference in visible response to materials from queens' and workers' heads has been demonstrated by presenting the materials in a Latin-square arrangement on the top of an almost undisturbed colony. This test has shown that some, at least, of the queen substances involved are stable, of low volatility and probably acid. A quantity of ethanol in which laying queens had once been kept has apparently lost little activity during 16 years' storage at room temperature. In contrast, all the identified queen substances so far tested, including 9-O-2, gave little or no response in this test. Some active material was shown to be present in queens' abdomens and much was obtained from ethanol extracts of workers from a colony with a queen and brood. The source of the latter, however, proved to be the brood and not the queen. (Simpson)

Some progress has been made towards identifying the active substances. Total activity remained with the residue from queens' heads that had been subjected to distillation at $<10^{-3}$ torr and *c.* 20°C for 20 h, demonstrating the low volatility of the substance. The active material was also shown to be much less soluble in paraffins than in ethanol. Tests of six chromatographically separated fractions, singly and in combinations of five, indicated that the pheromone consists of at least two mutually synergic components. (Simpson, with Pickett, Insecticides and Fungicides Department)

Staff

J. Simpson retired after more than 30 years' loyal service and many valuable contributions to studies on honeybees.

https://doi.org/10.23637/ERADOC-1-135

L. R. Taylor was appointed Visiting Professor in Entomology at Queen Elizabeth College, London University.

We welcomed Dr. P. Benedeck, Head of Forecasting Department, Hungarian Ministry of Agriculture and Food, who spent some time in the Department as a Visiting Scientist.

R. Bardner presented a paper, under joint authorship with K. E. Fletcher, to the Association of Applied Biologists and another to the Society of Chemistry and Industry Pesticides Group Symposium.

C. A. Edwards presented two papers to the Association of Applied Biologists, one in collaboration with Dr. C. G. Butler and J. R. Lofty. He attended the Fourth International Congress of Pesticide Chemistry in Zurich, and EEC meetings on Ecotoxicological testing of Chemicals. He organised two meetings for the IOBC Working Group on Soil Pests at Rothamsted in September; one of the Seedling Pest sub-group, and the other, with P. L. Sherlock, of the sub-group studying the use of pathogens in the integrated control of soil pests. He spoke to the British Association for the Advancement of Science, Lackham College of Agriculture, the Royal Entomological Society of London, the National Farmers' Union and an ADAS Conference.

The 29th Annual General Meeting of the International Bee Research Association was held at Rothamsted in May. In the morning members were shown current research by L. Bailey, A. W. Ferguson, J. B. Free, J. Simpson, J. H. Stevenson (Insecticides and Fungicides Department) and I. H. Williams on honeybee pheromones, bee diseases and poisoning. In the afternoon J. B. Free chaired the AGM. He also lectured to the Central Association of Bee-keepers and was elected President of the Association.

L. R. Taylor gave an invitation paper at the British Ecological Society Symposium on Population Dynamics and was joint author of an invitation paper on Contemporary Quantitative Ecology at the 2nd International Congress of Ecology.

C. Wall presented a paper to the Society of Experimental Biology (with J. N. Perry) and was appointed Convenor of the Entomology Group, Association of Applied Biologists.

Janice Cole, Brenda Cox, P. Hugo, J. Laband, Adrienne Smith and J. R. G. Turner resigned. Mark Allen and Adrian Riley were appointed as assistant scientific officers and Julia Keitch as secretary. Hilary Steeds, R. Bennell, A. Castree and S. Wainwright worked as sandwich course students, and O. Ajayi joined the Department to follow a post-graduate course leading to a Ph.D. on 'Interactions between barley yellow dwarf virus cereal aphids and *Cladosporium* fungus'.

L. Bailey attended the Fourth International Congress for Virology at The Hague and was chairman of the Workshop on non-occluded viruses of insects. J. B. Free gave the opening lecture at the Fourth International Pollination Symposium at Maryland, USA.

C. A. Edwards visited Sri Lanka and India as a consultant for UNESCO and FAO respectively. J. Bowden also visited India to advise on the establishment of a pest monitoring and forecasting system.

G. J. W. Dean went to Niger on an ODM sponsored study of grasshoppers harmful to millet.

C. Wall visited Max-Planck Institute for Behavioural Physiology, Seewiesen, W. Germany to discuss the use of electro-physiological techniques in work on insect behaviour.

N. Wilding visited colleagues at the Station de Zoologie Appliquée de l'État, Gembloux, Belgium and the Institut Pasteur, Paris to discuss work on fungal pathogens of aphids.

https://doi.org/10.23637/ERADOC-1-135

APPENDIX TABLE 1

Time of arrival of first aphid in 1978 compared with mean dates for the previous 9 years' catches, by regions

	Annual mean date of arrival					1978 days earlier (+) or later (−) than mean				
	All traps	SE	Mid-lands	N	SW	All traps	SE	Mid-lands	N	SW
A. pisum	4/6	18/5	31/5	21/6	5/6	−14	−13	−11	−19	−18
A. fabae grp.	11/6	28/5	11/6	29/6	7/6	+6	−2	+14	+12	+4
Aphis spp.	5/6	27/5	23/5	22/6	30/5	−2	−5	−4	+3	−10
A. rubi	15/6	8/6	15/6	6/7	22/5	−7	0	+2	+11	−64
A. solani	31/5	22/5	24/5	29/6	18/5	−16	−11	−14	+13	−57
B. helichrysi	19/5	13/5	19/5	3/6	11/5	−1	−1	+4	+1	−3
B. brassicae	5/7	20/6	26/6	12/8	20/6	0	−22	−29	None	+11
C. aegopodii	22/5	17/5	19/5	4/6	16/5	−9	−10	−8	−8	−11
Cinara spp.	21/6	9/6	23/6	4/7	23/6	−4	−15	−2	+3	+24
D. platanoidis	19/5	16/5	15/5	21/5	18/5	−1	−6	−2	0	0
D. plantaginea	17/7	16/6	1/7	28/8	19/7	−1	−20	−34	+14	+8
E. abietinum	16/5	14/5	16/5	20/5	10/5	+2	+3	+2	−1	+1
E. ulmi	16/6	11/6	11/6	22/6	18/6	+3	0	+1	+5	+5
H. pruni	17/6	10/6	16/6	25/6	16/6	−3	−5	+10	+1	−16
H. lactucae	5/6	25/5	1/6	25/6	29/5	−5	−11	+1	+3	−12
M. euphorbiae	30/5	19/5	26/5	17/6	20/5	+5	0	+2	+5	+6
M. dirhodum	27/5	17/5	24/5	17/6	14/5	+14	+23	+5	+6	+14
M. festucae	21/5	6/5	18/5	11/6	9/5	−10	−19	−20	−6	−5
M. ascalonicus	4/5	22/4	25/4	18/5	2/5	−6	−11	−7	−9	−3
M. certus	3/6	21/5	4/6	25/6	25/5	−26	−28	−32	−13	−33
M. ornatus	23/5	17/5	24/5	22/6	26/4	−30	−8	−37	+14	−64
M. persicae	2/6	19/5	28/5	30/6	19/5	−19	−22	+16	−29	−32
N. ribisnigri	7/6	27/5	4/6	26/6	2/6	−11	−15	+7	−1	−29
Pemphigus spp.	30/6	23/6	29/6	9/7	1/7	−5	+12	−6	−19	−11
P. humuli	9/6	26/5	31/5	2/7	7/6	+5	−4	+1	+18	+4
P. fagi	5/6	30/5	6/6	5/6	12/6	+5	−3	+10	+3	+14
R. insertum	30/5	30/5	20/5	9/6	27/5	+3	+3	−3	+8	+2
R. maidis	15/7	4/7	2/8	27/7	10/7	+8	+6	+11	−5	+26
R. padi	10/5	4/5	15/5	31/5	25/4	−18	−22	−18	−3	−25
S. avenae	25/5	15/5	21/5	13/6	13/5	−13	−14	−12	−10	−20
S. fragariae	2/6	22/5	26/5	27/6	22/5	+1	−11	−5	+18	−1

SE = ADAS South-eastern and Eastern Regions
Midlands = ADAS East and West Midland Regions and Lancashire
N = Yorkshire, the ADAS Northern Region and Scotland
SW = ADAS Wales and South-western Regions
'None' in the table means no record
'0' means no difference from the mean data

https://doi.org/10.23637/ERADOC-1-135

APPENDIX TABLE 2

Level of pest aphid populations in 1978 compared with mean values for the previous 9 years' catches, by regions

	Annual mean per trap					1978 as % of annual mean				
	All traps	SE	Mid-lands	N	SW	All traps	SE	Mid-lands	N	SW
A. pisum	104	237	66	39	28	111	69	272	216	117
A. fabae grp.	460	786	504	323	184	102	68	129	155	92
Aphis spp.	175	242	205	151	105	48	53	39	25	77
A. rubi	9	11	8	5	14	44	64	57	60	7
A. solani	19	20	42	8	19	72	130	34	13	37
B. helichrysi	686	1092	1113	201	625	102	96	73	111	116
B. brassicae	162	295	221	21	151	63	30	39	0	190
C. aegopodii	400	678	789	127	221	41	38	40	42	30
Cinara spp.	13	16	11	11	10	31	100	30	82	17
D. platanoidis	667	467	1121	871	429	128	55	64	220	96
D. plantaginea	28	52	24	1	34	86	89	40	100	93
E. abietinum	239	91	58	435	244	49	225	111	8	53
E. ulmi	74	94	142	68	27	100	71	102	129	44
H. pruni	600	1062	509	442	230	26	28	41	9	27
H. lactucae	46	70	60	18	44	56	55	64	44	45
M. euphorbiae	100	113	157	76	84	95	68	83	150	87
M. dirhodum	927	1364	1076	909	278	255	82	252	562	226
M. festucae	118	169	272	73	43	28	30	14	18	64
M. ascalonicus	64	102	117	36	31	47	47	37	22	60
M. certus	19	27	50	6	13	26	26	5	100	40
M. ornatus	11	12	8	4	15	27	22	16	25	42
M. persicae	215	301	459	126	108	36	43	21	13	61
N. ribisnigri	19	22	18	9	26	74	93	59	7	74
Pemphigus spp.	409	305	244	286	810	165	382	262	12	83
P. humuli	656	1435	1269	6	228	39	24	59	417	33
P. fagi	85	80	39	155	14	18	11	71	13	59
R. insertum	1662	1266	1333	1847	2098	279	371	664	115	246
R. maidis	19	24	7	20	18	37	36	76	20	44
R. padi	5729	5228	5623	6281	5676	210	220	278	257	140
S. avenae	2139	3529	3191	1058	1276	25	21	27	22	31
S. fragariae	118	182	147	50	120	235	251	272	108	172

SE = ADAS South-eastern and Eastern Regions
Midlands = ADAS East and West Midland Regions and Lancashire
N = Yorkshire, the ADAS Northern Region and Scotland
SW = ADAS Wales and South-western Regions

https://doi.org/10.23637/ERADOC-1-135

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