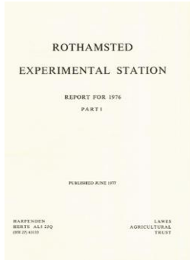
ROTHAMSTED RESEARCH

Report for 1976 - Part 1

Full Table of Content



Entomology Department

T. Lewis

T. Lewis (1977) *Entomology Department ;* Report For 1976 - Part 1, pp 119 - 140 **- DOI: https://doi.org/10.23637/ERADOC-1-133**

ENTOMOLOGY DEPARTMENT

T. LEWIS

Staff

Head of Department T. Lewis, PH.D.

Senior Principal Scientific Officer
L. Bailey, SC.D.

Principal Scientific Officers
R. Bardner, B.SC.
J. Bowden, PH.D.
G. J. W. Dean, PH.D.
C. A. Edwards, PH.D.
J. B. Free, D.SC.
R. A. French, J.P., B.SC.
J. Simpson, PH.D.
L. R. Taylor, D.SC.

Senior Scientific Officers
I. F. Henderson, PH.D.
J. R. Lofty
E. D. M. Macaulay, B.SC.
J. W. Stephenson, M.SC.
C. Wall, PH.D.
N. Wilding, PH.D.

Higher Scientific Officers
Mrs. Janice B. Cole, B.SC.
A. M. Dewar, B.SC.
K. E. Fletcher, PH.D.
P. L. Sherlock, PH.D.
R. A. Welch
Mrs. Ingrid H. Williams, B.SC.
I. P. Woiwod, B.SC.

Scientific Officers
Brenda V. Ball, B.SC.
Patricia J. Brobyn, B.SC.
Mrs. Rita K. Chambers
Maureen J. Dupuch
Susan Greenwood, B.SC.
A. R. W. Griffin, N.D.B.
Mrs. Joan Nicklen
Dolores M. Sturgeon, M.SC.
P. W. Tomkins
A. E. Whiting
B. G. Withers, B.SC.

Assistant Scientific Officers
J. Ashby
J. E. Bater
M. P. Bentley
Mrs. Susan K. Best
C. P. Brookes
Janice Cook
J. L. Doran
D. G. Garthwaite
Barbara Goult
R. P. Hadley
Carole A. Horne
P. D. J. Hugo
Barbara A. Jones
Susan M. Jones
J. I. Laband
R. Moore
Jane Oliver
Theresa Onufryk
Mrs. Susan J. Parker
Adrienne K. Smith

Temporary Workers
Anne Cameron, B.SC.
D. D. Burke, B.SC.
Mrs. Margaret G. Jones, PH.D.
K. A. Nicholson

Secretary
Mrs. Brenda I. Cox

Clerical and other Staff
Mrs. Marjorie Bellingham
R. C. Coulter
Mrs. Doris E. Jolly
Mrs. Patricia Roberts

Introduction

The year was notable for the mild winter, the long summer drought and the unusually wet autumn, weather that was clearly reflected in the atypical presence, early appearance, and exceptional abundance of many invertebrates.

Encouraged by the warm dry spring, aphid migrations started early and populations increased rapidly in June while crops remained succulent. Many species far exceeded their usual densities and then numbers declined sharply as host plants ripened and predators increased. Perhaps the most widely noticed insects were ladybirds which were common in late June and early July, and from mid-July remarkably large populations built up, especially in eastern England. Their larvae and pupae on potatoes led to many false reports of infestations by Colorado beetles! Large populations of adult ladybirds persisted through August and September, seemingly aggregating wherever moisture was available.

Towards the end of summer and early autumn unusually large populations of several species of cutworms caused serious spoilage and losses to vegetable crops, and as the wet

https://doi.org/10.23637/ERADOC-1-133

autumn progressed, slugs, which had apparently been absent from the upper soil layers throughout the summer, reappeared in great numbers to intensify the damage to root crops and attack autumn-sown cereals.

The change of Head of Department in April and the imminent completion of new laboratories in the South Building has inevitably stimulated a reappraisal of priorities and a period of forward planning. In broad terms, the Department will continue long-term research on fundamental biological and ecological topics, maintain an adaptable response to current pest problems, and try to anticipate new ones that may arise as a result of changing cultural practices. Over the years, the fund of knowledge built up in the Department on cereal insects, the soil fauna, honeybees, insect pathogens and airborne populations will be used as a basis for the gradual introduction of new studies appropriate to modern agriculture. Several changes are already planned.

Sporadic outbreaks of pests as, for example, occurred this year with cutworms, present a problem for the continuity of research. Unless interest in the factors that cause populations to fluctuate is maintained long enough for research to be productive, the next time an 'outbreak' occurs no improved measures will be available to combat it. Thus, a commitment to long-term studies of population changes is essential, and to those already established will be added studies on cutworms and leatherjackets based on the wide background of surveying knowledge and insect pathology in the Department.

The solution of many pest problems requires a multidisciplinary effort, and this approach will be pursued vigorously. The highly successful work on aphid surveying in the Department, and the new methods for detecting and categorising resistance to insecticides in aphids developed in the Insecticides and Fungicides Department, provide an opportunity to link these projects in a common effort to counter the increase in resistance to pesticides. We look forward to a geneticist joining the staff to work on the immediate problem in aphids, and to start long-term studies on the mechanisms of spread of acquired characters within local and regional populations of pests. Links with the Insecticides and Fungicides Department will also be extended through more joint work on behaviour-controlling chemicals to include studies on moths, wheat bulb fly, honeybees and slugs.

Assessment of the effects of pests on yields will continue as part of the Station's wider multidisciplinary studies on maximum yield already in progress on field beans and contemplated for cereals. The growing awareness of the need for nitrogen economy in agriculture will be reflected in further studies, with the Grassland Research Institute, on the role of insects in the establishment and persistence of clover in grass/legume swards, and on the persistence of high yielding varieties of ryegrass.

Changing cultural methods are always likely to produce unexpected pest problems. To anticipate these, work on the effects of direct drilling and minimum cultivation on the whole spectrum of the soil fauna will be intensified, alongside a completely new involvement with the Glasshouse Crops Research Institute and the Game Conservancy in a study of the entomology of the farming systems on the Sussex Downs centred on North Farm.

The economic implications directly underlying many of the Department's projects will be assessed frequently to ensure that its work remains relevant to agricultural needs and to assist research findings to be implemented.

This year, some of the senior staff's time has been taken up with planning the internal fitments and equipment for the new Entomology quarters in the South Building. Its completion in Spring 1977 will enable the whole Department to be housed in one building and provide improved facilities.

Basic biology and behaviour

An understanding of the biology and responses of individual animals is usually a necessary basis for more applied work. At present, the responses of slugs to plant extracts and the

https://doi.org/10.23637/ERADOC-1-133

physiology of mucus production are being studied in the expectation that they will eventually lead to more effective methods of control. Similarly, successful screening of insect pheromones for monitoring pest populations is enhanced by an appreciation of the sensory receptors involved, and the use of male moth sex attractants to time applications of pesticides requires detailed information on rates of egg development.

The responses of slugs to aqueous plant extracts. The responses of *Agriolimax reticulatus* to aqueous extracts of the leaves of plants occurring in their natural habitat continued to be assessed. The attractiveness of leaf extracts of three plants that were not eaten by the slugs were each compared with water as an alternative in a modified Y maze (*Rothamsted Report for 1975*, Part 1, 130). Extracts were prepared by macerating the equivalent of 20 g dry weight of leaves in 100 ml of water to give a 20% aqueous extract. *Plantago lanceolata* extract was barely less acceptable than water, but *Convolvulus sepium* extract was considerably less acceptable ($P = 0{\cdot}05$) and *Hedera helix* much less so ($P = 0{\cdot}001$). In the field, these plants may be avoided because water-soluble constituents are detected by the slugs in the moisture film that covers the leaves when slugs are active.

The acceptability to slugs of aqueous maize meal extract has been demonstrated (*Rothamsted Report for 1975*, Part 1, 130) and extracts using three different organic solvents have now been tested. Dichloromethane and hexane extracts were slightly more acceptable than water alone; ethanol extract was less acceptable than water. Maize meal remains the most acceptable plant material to *A. reticulatus* so far tested and the greatest response is elicited by the water-soluble constituents in it. Generally, the investigations have shown that aqueous extracts of the leaves of most of the plants present in the slug habitat are acceptable to them. (Stephenson)

Antennal morphology of pea moths. The morphology, histology and distribution of the sensilla on the antennae of both male and female pea moths have been studied using light and electron microscopy. Six main types of sensillum have been identified, four of which are probably olfactory (*Sensilla trichodea*, *S. basiconica*, *S. auricillica* and *S. coeloconica*). The *S. trichodea* have been shown to be the sex pheromone receptors in other Lepidoptera (e.g. silk moth) and in male pea moth these sensilla are both more numerous and much larger than in females; electroantennographic work indicates that females cannot smell their own pheromone with their antennae. Sensilla were measured using a Quantimet 720 Image Analyser which provided accurate measurements of these curved hair-like structures.

The distribution of some sensilla is surprising, particularly of the clearly olfactory *S. auricillica* which occur abundantly underneath scales on the dorsal surface of the antennal segments. The effect of the scales on the air-flow and movement of odour molecules around the antennae needs investigation. (Wall, with Jones and Turner, Plant Pathology Department)

Rate of egg development in pea moth. If pheromone traps are to be used successfully to time pesticide applications against pea moth, knowledge of the rate of egg development is needed to predict hatching dates following meaningful catches of adults in crops.

In the laboratory eggs were incubated at a range of constant temperatures between 10 and 34°C, and at different fluctuating regimes approximating field conditions in June and July. Development at constant temperatures over the range 10–28°C was 51–54 days and was 16–6% slower than at fluctuating temperatures with the same mean over a similar range.

Several thousand eggs were kept in well-ventilated cages in a pea field and hatching dates were predicted by relating local climate to laboratory-derived development curves.

https://doi.org/10.23637/ERADOC-1-133

Comparisons of the accuracy of the predictions were made when the temperatures in the field were measured on site, and at distances of 150 m and 8 km away. These proved correct, at best, to within −1 day (i.e. 1 day early) and to within −3 days in unusually cold weather. These relatively small discrepancies in estimating the duration of the 6–24 day incubation period suggest that hatching can be predicted from daily mean temperatures with acceptable accuracy. (Lewis and Sturgeon)

Pest detection and surveying

Information on the presence and size of pest populations is vital for planned pest control, so much of the Department's effort is devoted to devising methods of detecting, and, where possible, giving early warning of the arrival of pests. On a regional scale the Rothamsted Insect Survey continues to monitor aphids and a few other airborne pests and beneficial insects with suction traps. On a more localised scale, pheromones now provide promising prospects for very early detection of single species.

The long-term studies on the population dynamics of moths using light traps have continued, with particular emphasis on the effects of changing agricultural practices and land use reflected so sensitively by these insects.

Suction trap surveying

Sampling sites. The increasing reliance of the Advisory Services on information on aphid occurrence provided by the system of suction traps has enhanced prospects for a more comprehensive coverage. With the current need for more information on potato virus epidemiology, the Department of Agriculture and Fisheries for Scotland have established their own aphid survey unit by adding sites, at Stirling, in the Central Lowlands, and at Musselburgh, in East Lothian, to the existing site at East Craigs. Although identification will be done at East Craigs, Rothamsted will help maintain present standards. These new sites will improve the east–west projection of aphid maps in the area and the definition of the distribution of the peach–potato aphid (*Myzus persicae*) and other potato aphids. Similar interest in new seed growing areas in Cumbria, Wales and Lincolnshire demands more detailed information than Rothamsted can provide without additional staff. A new trap is now operating at Belfast but is not included in this year's records.

Interest in aerial aphid sampling is increasing also in Western Europe. There is one trap in Denmark and three in Sweden; a second trap may soon be running in Holland, France is interested in a programme for six sites and Norway has been trying to finance a trap for some time. The increase in insecticide resistance in aphids is undoubtedly responsible for much of this concern to increase the knowledge and understanding of aphid distributions. (Taylor, French, Woiwod and Cole)

Aphids. During 1976, 30 Bulletins were issued. Details of the catches for 33 species are listed in Tables 1 and 2, and in *Rothamsted Report for 1976*, Part 2, 196).

After another mild winter, aphid migration increased rapidly at the beginning of May. The first individuals of most species arrived early, and the summer migration, encouraged by the hot, dry weather, was, in general, three to four weeks early. (Table 1, see p. 137.) Numbers declined sharply at the beginning of July when crops ripened and predators increased. Autumn migrations were smaller than average, but larger than in 1975. (Table 2, p. 138.)

The peach–potato aphid (*Myzus persicae*) appeared in the southern traps at the end of April, three to four weeks early. It increased rapidly in the Midlands and south, more

https://doi.org/10.23637/ERADOC-1-133

slowly in East Anglia and the north, and reached a maximum at the end of June in England, two to four weeks early. The peak in Scotland came two weeks later. The Midland region overall had more than six times, and Shardlow twelve times, as many as usual. In the north, fewer than usual were caught, though they were very early.

The potato aphid (*Macrosiphum euphorbiae*) was slightly more common than average, except in the north, and early everywhere except in the Midlands. It reached a peak in early June in the south, at the end of June in East Anglia and at the beginning of July further north, becoming abruptly less common in the second week of July.

The rose-grain aphid (*Metopolophium dirhodum*) was also abundant, especially in the Midlands and south-west, reaching a peak three to four weeks early, in mid-June in the south, at the end of June in the Midlands, and two weeks later in the north.

The grain aphid (*Sitobion avenae*) was even more common than *M. dirhodum*. It was most abundant in the Midlands, where catches at Shardlow and Preston were eight times above average. As with *M. dirhodum*, the south-east had fewer than elsewhere. It reached a peak at the end of June in England, and two weeks later in Scotland.

None of the other cereal aphids were abundant. The total number of *Rhopalosiphum padi* caught was average for the year, except in the south-west, but the summer migration was atypically large whereas the autumn migration was small.

The cabbage aphid *Brevicoryne brassicae* was common and early everywhere, particularly in the Midlands and north.

Survey samples of the beech leaf aphid (*Phyllaphis fagi*) and elm leaf aphid (*Schizoneura ulmi*), the sycamore aphid (*Drepanosiphum platanoidis*) and the green spruce aphid (*Elatobium abietinum*) have been used in the Forestry Commission publication *Towards integrated control of tree aphids* (HMSO) by C. I. Carter.

Bean aphid (*Aphis fabae*) migration was well below average, although slightly larger than 1975, and early in the south-east. The small autumn migration, similar to 1975 despite suitable weather for flight, suggests that bean aphids will not be a serious problem in 1977. (Taylor, French, Woiwod, Cole and Dupuch)

A forecast for *A. fabae* infestations on field beans made annually from egg counts and numbers of aphids on spindle trees, also indicated that this pest would not be serious in 1977. (Fletcher, with Mr. M. J. Way, Imperial College, London)

During the year some other groups of insects have been sorted retrospectively from suction trap catches to provide an insight into the many uses to which the survey catches could be put were staff available to examine them.

Diptera. Flies were abundant. Bibionidae were common, particularly in southern traps, and catches were dominated by *Dilophus febrilis* and *D. femoratus*, *Bibio* spp. being uncommon everywhere. Other grassland and cereal pests well represented where Chloropidae, including many of the frit fly (*Oscinella frit*) complex and a few Opomyzidae. Agromyzidae were common. By contrast, Tipulidae occurred rarely; even during the 1974 outbreak of *Tipula paludosa*, only occasional males were trapped showing that these high-level traps are unsuitable for tipulid studies. Similarly, no wheat bulb fly were found, although adults are caught in ground-level traps and occur in traps as high as 3 m.

The common blowfly, *Calliphora vicina* (better known as *C. erythrocephala*) occurred regularly. It has two peaks of abundance, one small in spring, the other much larger in September and October. Catches are entirely of females in a uniform reproductive state, apparently just prior to oviposition. Blowflies of the genus *Lucilia* (whose larvae cause sheep myiasis) are rare and high-level traps provided little information on their phenology or population dynamics. Information on the distribution and phenology of Ceratopogonidae, Simuliidae, Culicidae and Chironomidae is also available. (Bowden)

https://doi.org/10.23637/ERADOC-1-133

Delphacidae and Cicadellidae. Leafhoppers are frequent and catches include *Javesella pellucida*, vector of European wheat striate mosaic virus, and *Macrosteles* spp., vector of aster yellows mycoplasma. (Bowden)

Scolytidae. Bark beetles, including *Scolytus multistriatus*, vector of Dutch Elm Disease, occurred often enough to suggest that further examination of catches would provide information on their phenology and the weather associated with high-level flight and dispersal. (Bowden)

Ladybirds. In 1976, over 2000 ladybirds (Coccinellidae) were caught in the Survey suction traps. About 63% were 7-spot (*Coccinella 7-punctata*) and 32% 11-spot (*C. 11-punctata*). Other species, such as 2-spot (*Adalia bipunctata*) and 16-spot (*Halyzia 16-guttata*) were no more abundant than usual. The unusually large numbers occurred mainly in eastern England as far north as Newcastle (mostly 7-spot) and of the western traps only Long Ashton caught many, mostly 7-spot. Very few were caught in Scotland.

Regular catches of the two main species began in late June and early July, and rose to peaks, for both species, in mid-July over most of southern England. At Long Ashton there was a distinct peak in the first week of July, ten to fourteen days earlier than in other southern traps. In north-east England, maximum catches of 11-spot occurred in late July, of 7-spot in early August. In half the traps 7-spots dominated and were exceptionally abundant at Writtle, Silwood and Long Ashton; 11-spots were more common in the other traps, notably at Wye, Shardlow and High Mowthorpe. (Bowden)

Light trap surveying

Moths. Following the exceptional autumn and warm winter of 1975 and the unusual spring and summer weather in 1976, the year's light trap catches are atypical in many respects, with many species appearing early. For example, the common quaker moth (*Orthosia stabilis*), normally expected in March and April, appeared in Devon on 25 December. Several records of second generations were noted, when in more normal years, only one occurs (see also *Rothamsted Report for 1976*, Part 2, 212).

Numbers were generally much larger than usual, and an exceptional emergence of many species occurred in south west England around the end of June and beginning of July. Great increases in numbers of the heart and dart moth, *Agrotis exclamationis* were reported in traps in the area. Rosewarne (Cornwall) catches for this species in 1975 were no higher than 15 on any one night, but exceeded 400 on one occasion this year. Yarner Wood (Devon) reported similar increases, from usually no more than 44 to over 1300.

Reports of other cutworm pests, from East Anglia particularly, indicate that counts will be high when sorting is completed. (Taylor, French, Woiwod and Nicklen)

Leatherjackets. Catches of adult *Tipula paludosa* in two light traps at Rothamsted showed a slight decrease in numbers to 1117 in 1976, compared with 1384 in 1975 and 1152 in 1974. The very dry summer delayed first appearance of adults in traps until early August, compared with mid-June in previous years, and numbers remained small until late September. Following rain, there was a large emergence in the last two weeks of September, when 80% of the total catch occurred. In the last week of the month 40% of the catch were females; most had normal, fully developed ovaries or had already laid. Soil conditions were favourable for oviposition, survival of eggs and larval development, so large winter populations of leatherjackets are expected. (Bowden)

Presentation and analysis of Survey data. The SYMAP V contour mapping program (Laboratory of Computer Graphics, Harvard) is still used extensively for visual represen-

https://doi.org/10.23637/ERADOC-1-133

tation of the data, so program sequences were devised to improve the routine production of distribution maps, to make mean and difference maps, and to measure map areas and values along transects.

Mean and difference maps have been produced for the migrations of *Aphis fabae*, *Myzus persicae* and most of the cereal aphids to provide an insight into the spatial redistribution and overwintering success in these species. Annual and seven-year mean density distribution maps are available for analysis for over one hundred species of moths caught in light traps. (Taylor, French and Woiwod)

Pheromonal monitoring for moths

Sex attractants. Following the discovery of two synthetic sex attractants for male pea moth (*Rothamsted Report for 1975*, Part 1, 123–124), trapping experiments were done during 1976 to examine the effect on catches of dose and formulation, weathering of the lure, and the addition of possible synergists and inhibitors.

(E,E)-8,10-dodecadienyl acetate proved a much better attractant (when fresh) than (E)-10-dodecenyl acetate ($P < 0{\cdot}001$); even lures containing only 0·1 μg of the former on rubber caught as many moths as the best lure containing (E)-10-dodecenyl acetate (1000 μg on rubber). There was no distinction between formulations on fresh rubber and polythene of either attractant, except (E,E)-8,10-dodecadienyl acetate at 0·1 μg.

The effectiveness of (E,E)-8,10-dodecadienyl acetate as an attractant decreases with time, and deterioration is more rapid on polythene than on rubber; even one week old doses on polythene are less effective than fresh ones. Weathering for up to three weeks has no effect on the activity of (E)-10-dodecenyl acetate, whether formulated on rubber or polythene; however, the 100 μg dose on rubber (used in the experimental monitoring scheme this year) was much less effective than the other lures tested ($P < 0{\cdot}01$ to $P < 0{\cdot}001$) (viz. 1000 μg on rubber, 1000 and 10 000 μg on polythene). Rubber lures with 1000 μg of (E)-10-dodecenyl acetate are recommended for future use in monitoring traps.

A wide range of compounds, most of which had elicited electro-antennographic responses in male antennae, were tested for synergistic or inhibitory properties when placed in traps containing one or other of the attractants. Only (Z) and (E)-8-dodecenol were significantly synergistic, but several strong inhibitors were found, notably (Z) and (E)-8-dodecenyl acetate which virtually eliminated any attraction to traps containing either attractant. (Wall, with Greenway, Insecticides and Fungicides Department)

Pheromone trap design. Six modifications of the triangular trap (*Rothamsted Report for 1975*, Part 1, 124) were compared in the field against the standard model in an effort to improve its effectiveness. The traps were used with either clear or opaque inserts mounted normally or inverted, or with water trays replacing the sticky plate, or with an attached polystyrene vane to keep the long axis of the trap aligned with the wind. Lures were also suspended over sticky plates protected from the weather by a flat aluminium roof.

The two versions with the sticky surface above the lure caught a total of only seven moths. Catches in the other variants were all much larger (200–300) and no significant differences were found between them during a period of three weeks. The water trap, as expected from previous experience, caught the greatest number and the lure suspended over the sticky plate caught many insects other than pea moths, which might confuse an untrained operator.

The effect of trap size on catch was also tested. Traps were scaled, retaining the original proportions but having sticky areas of 45 cm^2, 90 cm^2, 180 cm^2 (standard), 360 cm^2, 540 cm^2 and 720 cm^2. Increasing the trap size above that in current use did not produce

https://doi.org/10.23637/ERADOC-1-133

an increased catch, although on the basis of catch per unit area the trap of half standard size caught most moths.

Three dispenser sizes, of surface area of 30, 790 and 3160 mm², and each made of the same material and bearing the same amount of attractant, were compared. Within this size range, catch was unaffected by the area of the dispenser.

On the evidence of these experiments the design of the original simple triangular trap seems adequate for monitoring pea moth. (Macaulay and Lewis)

Monitoring trials for pea moth. In co-operation with the Agricultural Development and Advisory Service (ADAS), the Processors and Growers Research Organisation and farmers, 24 pairs of traps baited with (E)-10-dodecenyl acetate were operated in pea fields throughout eastern and southern England. At three of these sites an additional pair of traps was placed in fields of wheat after peas.

At seven sites pea plots were treated with single sprays of 'Gusathion MS' (azinphos methyl plus demeton-S-methyl sulphone) at four-day intervals on a pre-arranged schedule of calendar dates. It was hoped that this trial would demonstrate a 'best control date' which would be linked retrospectively to a level of moth numbers in traps to establish a threshold catch from which to time spraying in future years.

Moths appeared in traps a fortnight earlier than expected from the experience of previous years and the spray trial gave little useful information. The extraordinarily hot weather undoubtedly accounted for the early emergence and may have been responsible for the ineffectiveness of the insecticide. Nevertheless, the monitoring trial demonstrated that there was no advantage to be gained from siting traps in emergence sites rather than pea fields, and that by using the traps it was possible to predict an infestation more positively, earlier, and with a great deal less effort, than by the existing method based on egg counts. (Macaulay)

Pest populations and damage assessment

The presence of a pest in a crop does not necessarily mean that control is worthwhile. Often the damage done is unimportant and the eventual loss in yield is so small that the expense of treatments with pesticide is unjustified. Thus, considerable effort is made in the Department to assess the effect of pests on growth of plants and crop losses. At present, three crops (oilseed rape, field beans and winter wheat) are being studied in the field from this point of view, supported by growth room studies on the inter-relationships between infestation by leaf-feeders and yields of root crops.

Oilseed rape. A survey has been made of the damage caused by pollen beetles (*Meligethes aeneus*) and seed weevils (*Ceuthorhynchus assimilis*) to 19 crops of winter rape and 22 crops of spring rape in south-central England.

Rape buds and flowers that fail to set fall from the plant leaving podless stalks. This damage has been attributed to pollen beetles. Although up to 23 and 20% podless stalks were found in winter and spring crops, respectively, the percentage present was not correlated with the seed or pod yield of plants, the farmer's yield, the number of years rape had been grown on the farm, or the location of the crop. The percentage of podless stalks is unlikely to be correlated with pollen beetle abundance, because the mean percentage was similar on winter and spring rape, although pollen beetles are relatively more abundant on the latter. The percentages of podless stalks at the edge and centre of crops were also similar, although pollen beetles are usually more abundant at the edge. Probably, some podless stalks develop for reasons not associated with pollen beetles. The

https://doi.org/10.23637/ERADOC-1-133

presence of podless stalks did not diminish yield, and plants can probably compensate for more damage to buds and flowers than was seen in the present survey.

In lightly infested crops usually more seed weevils were present at the edges than at the centres, but the opposite tended to occur in heavily infested crops, probably because adult populations spreading from the edges converged at the centre of fields. Benefits from insecticide treatment of the borders may therefore be relatively greater in lightly infested crops.

In winter rape crops infestation of pods by the seed weevil increased with the number of years rape had been grown on the farm, but this was not so for spring rape. No correlation was found between the frequency of insecticide applications and crop yield, but the number of applications made to spring rape crops was positively correlated with the number of years rape had been grown on a farm. (Free and Williams)

Populations and life history of *Sitona lineatus* at Rothamsted. Preliminary studies were made on Stackyard sown to winter beans, and Little Hoos, sown to spring beans. Populations of adults were monitored using water, pitfall and tile traps placed between rows of beans. The overwintering adults became active early in April, and although catches decreased temporarily in rainy, cold weather, numbers increased gradually until late May, after which there was a sharp decline until the new generation of adult beetles emerged in early July. Counts of feeding-notches in the leaves showed a similar pattern. All the measurements depended on both the number of the beetles present and their activity, so cannot be used to estimate population size. The increasing catches in the early part of the season were probably caused by rising temperatures, and the subsequent rapid decline, by mortality.

Adult females captured in the field were laying eggs freely on 15 May, when observation began, but had ceased by 7 June.

Only roots of the spring-sown crop were examined for larvae and pupae. The first injured root nodules were found on 18 May, and the first larvae on 24 May. Numbers of larvae increased rapidly to a peak of 13 per plant on 2 June, but then declined. None were found in root nodules after 17 June and none in surrounding soil after 28 June. Pupae were found on all sampling dates between 17 June and 5 July. Newly-emerged adults were found near roots on 24 June and the peak emergence occurred about the 12 July.

The results suggest there were about 5×10^6 larvae ha^{-1} on the Little Hoos site, but that fewer survived to the pupal stage, when there were only about 6×10^5 ha^{-1}. (Bardner, Fletcher and K. Ewen)

Wheat bulb fly

Egg counts. Populations of eggs in fields on Rothamsted farm in the winter of 1975–76 were generally low. Stackyard fallow had 0·75 million ha^{-1}, Great Harpenden fallow 0·25 million ha^{-1} but Broadbalk fallow had a larger population of 4·27 million ha^{-1}. Larval populations in the spring were all less than 0·5 million ha^{-1} so further detailed studies of survival rates ceased. (Fletcher)

Phenology and egg maturation. Adult wheat bulb flies started to emerge on 18 June on Stackyard field; peak emergence occurred between 30 June and 3 July. More flies emerged than in 1975; the mean density was equivalent to 318 000 ha^{-1}. For the first time for several years *Phygadeuon* sp. (Ichneumonidae) a parasite of wheat bulb fly pupae was common (9000 ha^{-1}).

Wheat bulb flies were collected by sweeping winter wheat at Whittlesey on 8 July and a few laid eggs during the following days in the laboratory. By the next week, more flies were mature, and of those collected at Earith on 22 July, 50% were mature and 48% had

https://doi.org/10.23637/ERADOC-1-133

already laid their eggs. At Rothamsted, flies caught in the light traps on 16, 17 and 18 July had already laid their first batch of eggs and by 6 August the second batch was ready for laying. During the hot summer, therefore, most eggs were laid before the end of July, one to two weeks earlier than usual. (M. Jones)

Effects of leaf-eating insects on the growth and yield of root crops. Growth room studies have been resumed, using larvae of the Diamond-back moth, *Plutella maculipennis*, feeding on turnip. There are four instars of approximately equal length, but it was found that over half the total amount of food required is eaten during the last instar, which lasts three to four days at 20–25°C. There is a linear relationship between the age of the larvae and the logarithm of food consumption. Studies are continuing on the time spent feeding under various conditions, and on the effects on yield of altering the competitive relationship between plant growth and the rate of destruction of leaf tissue by insects. (Bardner and Fletcher)

Pesticide use

Two main aspects of pesticides investigated in the Department are their direct use for the control of pests with the resulting effects on yields and, in the long-term, their effect on the environment in general, and on soil organisms in particular.

Control of soil pests

Effects on yields of field beans of controlling* Sitona *larvae. Since 1969, 16 field experiments have been done with soil insecticides controlling *Sitona* larvae at Saxmundham, Woburn and Rothamsted. The insecticides and rates used varied from year to year, but included gamma-HCH (gamma-BHC) at 2·24–4·48 kg a.i. ha^{-1}, dieldrin at 1·12–4·48 kg a.i. ha^{-1}, and aldicarb at 4·48–10 kg a.i. ha^{-1}. Percentage yield increases compared with untreated plots were: HCH 4·0–41·1 (mean 9%), dieldrin 0·35–12·30 (mean 6%) and aldicarb 0·3–127·1 (mean 32%). Yields of untreated plots varied from 0·63–3·73 t ha^{-1} (mean 2·46 t ha^{-1}), while larval numbers per root on the untreated plots varied from 3·3 to 29·0 (mean 12·3 larvae per root). Aldicarb was more effective in controlling larvae than either HCH or dieldrin, but it also affected nematodes and foliage-feeding insects; however, the results of treatment with HCH and dieldrin, show that controlling *Sitona* larvae gives a useful increase in yield. Residue problems make the commercial use of these two materials unacceptable and aldicarb is too expensive, so work is continuing to find a satisfactory and economic insecticide to control this pest. (Bardner and Fletcher)

Control of* Sitona *larvae attacking roots of field beans. A method for the selective control of *Sitona* larvae is needed to replace dieldrin in the multidisciplinary experiment on factors affecting the yield of field beans (*Rothamsted Report for 1976*, Part 1, 150). Both dieldrin and HCH (BHC) applied to the soil control *Sitona* larvae, without affecting foliage pests; but they leave undesirable residues. A range of moderately persistent soil insecticides were therefore compared with dieldrin, and chlormephos and fonofos applied at 2·24 and 4·48 kg a.i. ha^{-1} were the only ones comparable in effect with it. (Bardner and Fletcher)

Control of seedling pests of sugar beet. The main seedling pests of sugar beet are pigmy mangold beetle (*Atomaria lineatus*), springtails (*Onychiurus armatus*), millipedes and symphylids. As part of the co-operative experiment of the International Organization for Biological Control of Noxious Pests and Diseases (IOBC), Integrated Control of Soil Pests Group, two experiments were laid out with the following treatments: 1, no insecticide, no herbicide; 2, aldicarb (1 kg ha^{-1}), no herbicide; 3, BHC (1 kg ha^{-1}), no herbicide; 4, no insecticide, herbicide; 5, aldicarb, herbicide; 6, HCH (BHC), herbicide.

https://doi.org/10.23637/ERADOC-1-133

The aim was to investigate the impact of commonly used pesticides on the whole crop/soil system. At the treated sites, populations of as many organisms as possible were assessed throughout the seedling stage of the sugar beet. Observations and assessments were made on seedling emergence, loss or damage, disease infection, populations of nematodes, micro-arthropods, slugs, millipedes, symphylids, spiders, *Atomaria* and carabid and staphylinid beetles. Attack by virus yellows and yields were also recorded. The insecticides almost invariably increased yields and the extensive nature of the experiments enabled the components of yield loss to be assessed. (Edwards and Lofty, with Dunning, Broom's Barn)

Invertebrates and pasture productivity. Investigations into the effects of insects and other invertebrates on grassland productivity were continued in collaboration with the Grassland Research Institute, Hurley.

Pest damage and annual grass growth pattern. Weekly measurements of the growth rates of a sward of S24 perennial ryegrass treated with the insecticides aldrin and phorate were compared with measurements made on untreated parts of the same sward. The growth rate of the treated sward exceeded that of the untreated at all times, the difference being greatest at the beginning and at the end of the season, when grass was growing slowly. There was an apparent correlation between the difference in rates of growth of the two swards and the density of stem-boring fly larvae in the untreated sward. (Henderson, Welch and Withers, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Varietal responses to pest damage. Swards of cocksfoot, timothy and nine varieties of ryegrass were sown in Spring 1974, and part of each sward treated with pesticide from that time. Annual dry matter (DM) yield of cocksfoot was only slightly affected by treatment, being increased by 12%, but the yield of timothy was increased by 23%. All six varieties of perennial ryegrass yielded more when treated with pesticide, the improvement ranging from 18 (cv. Barlenna) to 33% (cv. S23). A more marked effect was noted with the Italian, hybrid and Westerwolds ryegrass varieties. By the end of this (third) year the treated plots had produced amounts of DM similar to the previous year, while the untreated plots had hardly any surviving plants of the sown variety. (Henderson, Welch and Withers, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Long-term effect of pesticide use on perennial ryegrass. Continued application of pesticides to a sward of S24 perennial ryegrass, sown at Hurley in 1968, increased the annual DM output for the seventh consecutive year, although prolonged drought reduced annual yields to between 50 and 70% of the average value for the previous seven years, the greater reduction occurring at the higher levels of N application. The trend of the previous two years for yield response to pesticide application to diminish was reversed, the increased output of treated plots over untreated plots exceeding that of the previous two years both relatively and absolutely. The accumulation of a layer of undecomposed surface litter with associated fall in soil organic matter content, and a decrease in soil bulk density on the pesticide-treated plots has continued, but has not yet had a detrimental effect on the growth of established plants. (Henderson, Welch and Withers, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Effects of pesticides on soil organisms

Pesticides and the soil fauna. The work on diflubenzuron ('Dimilin') reported in *Rothamsted Report for 1975*, Part 1, 128 was completed. This pesticide had no effect on

https://doi.org/10.23637/ERADOC-1-133

earthworm populations, or soil respiration and little effect on the breakdown of organic matter in soils.

Three new treatments were applied to the long-term reference experiment on Appletrees field, namely fonofos ('Dyfonate') and two unregistered compounds, 'Duphar-Midox PH60-41' and 'PH60-42'. None of these insecticides affected earthworms and had little influence on the breakdown of organic matter. Fonofos was much more toxic to most soil animals than the other two insecticides. All three chemicals decreased numbers of surface-living beetles. (Edwards, Lofty and Le Brun)

Pesticides and soil respiration. Laboratory studies of the influence of a range of pesticides on the respiration of soil were made using soil respirometers. All insecticides tested increased soil respiration for the period of the experiments (21 days). 'Duphar-Midox PH60-41' and 'PH60-42' caused only very small increases, aldrin, dieldrin and benomyl moderate increases, and chlorfenvinphos, parathion, thionazin and diazinon greater increases. The effects were dosage-dependent and occurred even when excessively high doses were applied (up to 10 000 ppm). The evidence from fumigation tests suggested that micro-organisms were using the insecticides as substrates. (Edwards, with Jenkinson, Pedology Department)

Cultural and biological control

Many pests problems can be prevented and the harmful effects of others lessened by paying careful attention to cultural methods that encourage rapid plant growth, or that maintain populations of beneficial insects and pathogens. Though crop protection will continue to depend largely on conventional pesticides for many years, other approaches to control that can be developed to limit their use would be extremely valuable. Much effort is directed, therefore, to investigations in field and laboratory of methods that could supplement, or perhaps occasionally replace, chemical control.

Cultural control

Strawburning. The investigations into the effects of burning cereal straw on the surface and soil-living fauna were continued. Because of the dry autumn conditions straw residues were much slower to break down than in previous years, so many more surface-living animals remained on the burnt plots for a longer period than usual. (Edwards, Lofty and B. Jones)

Effects of direct-drilling on the soil fauna. The long-term investigations on the effects of direct-drilling of cereals on soil animals were continued. Previous seasons' results were confirmed, particularly the greatly reduced susceptibility of direct-drilled crops to stem borers. Tests are under way to establish the cause. Experiments sponsored by the Letcombe Laboratory at Englefield, Northfield and Compton Beauchamp and other field trials organised by National Institute of Agricultural Engineering at Rothamsted, Boxworth and Silsoe were monitored for microfauna, surface-living arthropods, slugs, earthworms and stem borers. Results were consistent with those reported in 1974 and 1975.

The work has extended into studies of the influence of the soil fauna on root growth in direct-drilled crops. Measurements of roots at intervals through the season showed that growth was much slower than in ploughed soil early in the season but later caught up. Spring wheat was grown in boxes containing intact soil profiles from sites that had been direct-drilled for five years. Before sowing the seed by a simulated direct-drilling method, the profiles were fumigated to kill all soil animals present and known populations of arthropods and selected earthworm species were introduced in numbers representative of typical populations. The growth of aerial parts of the plants was monitored regularly.

https://doi.org/10.23637/ERADOC-1-133

After two months, the boxes were dismantled; some replicates were embedded and sectioned and others were carefully washed to remove all soil from the roots. The soil animals, especially earthworms, greatly encouraged root growth in unploughed soil by providing cracks and crevices in the soil. (Edwards and Lofty)

Biological control

Carabids and cereal aphids. A simpler version of the experiment described in 1975 (*Rothamsted Report for 1975*, Part 1, 120) was done in 1976. Plots 10 × 10 m were surrounded by polythene barriers (0·4 m high and 10 cm below soil) in late May. There were four replicates of each treatment. In half the plots carabid beetles were trapped in dry pitfall traps, counted and released; in the other half they were trapped and removed. Cereal aphid populations were assessed at weekly intervals. As in 1975, strong negative correlations were recorded between numbers of cereal aphids present and beetles trapped, especially for *Pterostichus melanarius*, *Harpalus rufipes* and *Agonum dorsale*. (Edwards, with K. George, MAFF Plant Pathology Laboratory)

Maturation of carabid eggs. Female beetles caught in winter wheat on Stackyard Field in April after recent emergence from the pupa, were sexually immature, with the exception of *Notiophilus biguttatus*. In May, *Harpalus aeneus* females were ready to lay but most *Pterostichus melanarius* were old individuals that had laid the previous year. In July *Agonum dorsale* and *Bembidion lampros* laid. During August, some *Pterostichus melanarius* and *P. madidus* also laid, but many *H. rufipes* were still immature. Most *P. melanarius*, *H. rufipes*, *Trechus quadristriatus* and *Clivina fossor* had laid by September. As in 1975, many mature male and female *Nebria brevicollis* migrated into the field and by the end of September a few of these had also laid. (M. Jones)

Other predators and parasites of cereal aphids. The cereal aphids *Sitobion avenae*, *Sitobion fragaria* and *Metopolophium dirhodum* appeared on winter wheat late in May, and numbers increased rapidly during the hot, dry June. As soon as the ears appeared, *S. avenae* colonised them, and ears, leaves and stems were heavily infested with aphids until the last week in June. The plants were rapidly cleared of aphids between 26 June and 6 July, probably largely due to predation by ladybirds (*C. 7-punctata* and *Propylea 14-punctata*) assisted by a few syrphid (*Episyrphus balteatus*, *Metasyrphus corollae*, *Dasysyrphus lunulatus*) and lacewing (*Chrysopa carnea*) larvae and parasites. Because of the many aphids available early in the season, percentage parasitism did not rise above 1% until the end of June but by 6 July only parasitised mummies remained. Aphid mummies collected in the field yielded mainly *Aphidius picipes* plus hyperparasites. Among these, there were fewer *Asaphes vulgaris* and more *Phaenoglyphis picipes* (67% of total) compared with other years; *Dendrocerus* spp., and *Alloxysta* sp. were also present. (M. Jones)

Entomophthora *species attacking bean aphids.* Fungi of the genus *Entomophthora* often kill many bean aphids infesting field beans, though usually too late to prevent the aphids from damaging the crop. In 1975, an attempt to introduce the fungi into the population before it occurred there naturally, failed to increase the proportion of aphids subsequently infected. This may have been because the fungi were distributed too late or too sparsely, or conditions may have been too dry (*Rothamsted Report for 1975*, Part 1, 120). A similar experiment was done in 1976. The aphid population was sparse, as in 1975, and was supplemented on 7 June with aphids reared in a glasshouse. By 15 June, 27% of the plants were infested with aphids. *Entomophthora aphidis*, *E. fresenii*, *E. thaxteriana* and *E. virulenta*, in infected aphids that were about to die and disseminate fungal conidia, were distributed on 17 June, earlier in relation to the development of the aphid population,

https://doi.org/10.23637/ERADOC-1-133

and more densely than in 1975. Each of the distributed species of *Entomophthora* was recovered from the treated plots in live aphids collected on 21 June. These aphids must have become infected in the field because those providing the inoculum would have died by then. However, on 28 June aphids were found infected only with *E. fresenii* and no more than 10% of individuals were attacked on any plot. On 5 July no infected aphids were found. Only four of 2500 aphids sampled from control plots between 14 June and 5 July were infected and three of these were infected with *E. planchoniana*, a species that had not been distributed in treated plots. The results confirmed the findings in 1975 that *Entomophthora* spp. can be artificially introduced into an aphid population in the way described. However, in 1976, they failed to spread further after starting to do so following heavy rain on 19 and 20 June, probably because the weather became unusually dry, and also because the aphid population diminished earlier than usual when large populations of ladybirds arrived. (Wilding, Brobyn and Best)

The effect of fungicides on the development of insect pathogenic fungi. Fungicides used to control plant pathogenic fungi may also affect fungi that kill insects. If so, the application of a fungicide to a crop may allow an insect pest to multiply more than usual. A series of experiments were started to determine the effects of fungicides on the development, *in vitro* and *in vivo*, of certain *Entomophthora* species that are pathogenic for aphids.

Germination of conidia of *E. aphidis* and *E. thaxteriana* decreased greatly on slides treated with 1 and 10% suspensions of maneb in water and 10% captan but not with lower concentrations. Captan at concentrations of 0·1% or more and maneb at 1% or more prevented growth, and maneb at 0·01 and 0·1%, retarded growth of *E. thaxteriana* on Sabouraud dextrose agar. The mortality of *Acyrthosiphon pisum* was not affected when inoculated experimentally with conidia of *E. aphidis* and *E. thaxteriana* and dipped 36 h later into 10% suspensions of captan and maneb. However, spore discharge of *E. aphidis* from infected aphids was prevented by dipping the dead individuals in 10% suspensions of captan and maneb, and decreased by dipping them in 1% suspensions.

Evidently these fungicides are active against *E. aphidis* and *E. thaxteriana* and may well diminish their effect on aphid populations in the field, although they are unlikely to eliminate fungi that remain protected in the bodies of infected aphids. (Wilding and Brobyn)

Honeybees and pollination

The authoritative position held by the Department on bee diseases and pollination of field crops has been maintained with further studies on causes of winter mortality, virus transmission, bacterial characterisation, pollination efficiency of honeybee colonies and field experiments on pollination of runner and field beans.

Honeybee diseases and disorders

Virus diseases. Preliminary surveys have shown that bees falling dead from the winter clusters of at least half the local live colonies contained much black queen-cell virus and chronic bee-paralysis virus. Some colonies contained both viruses. Black queen-cell virus was also detected in live adult bees from all seemingly healthy colonies sampled in spring, and much of the same virus occurred in individual dead worker and queen pupae occurring sporadically about the same time. This latest virus to be identified in bees (*Rothamsted Report for 1975*, Part 1, 133) may, therefore, cause as much damage to colonies as chronic bee-paralysis virus, or any other well-known common pathogen. The incidence of black queen-cell virus in live adult bees decreased markedly during the summer, but the virus was still detected in about 20% of colonies in autumn. Sacbrood virus was also detected, in the same bees, in about 60% of colonies in spring and in about 20% in autumn.

https://doi.org/10.23637/ERADOC-1-133

Black queen-cell virus was probably mistakenly identified in previous surveys of colonies found dead in winter (*Rothamsted Report for 1973*, Part 1, 210) as acute bee-paralysis virus, which seemed to occur commonly. However, the antiserum then used for the diagnosis was recently found to have a high titre against black queen-cell virus as well as acute paralysis virus. Since the two viruses are unrelated serologically, the heterologous titre was almost certainly due to contamination with black queen-cell virus of the semi-purified acute bee-paralysis virus, used to prepare the antiserum many years ago. Accordingly, the natural history of acute bee-paralysis virus is once more in question since it has been identified with certainty only in seemingly healthy adult bees during summer.

Virus-like particles that are 17 nm in diam. and are associated with chronic bee-paralysis virus (*Rothamsted Report for 1974*, Part 1, 116), usually multiplied very little when injected, with chronic paralysis virus, into worker bees of a variety of ages and physiological conditions, and were not detected when similarly injected into worker pupae, even though chronic paralysis virus multiplied in these. However, the associate particle multiplied abundantly, when injected with chronic paralysis virus, into queen bees of any age, including pupae, and it also multiplied very much in some drones. It was especially plentiful in the ovaries and testes of infected individuals. Uncertainties, both in obtaining bees free of it and in separating it completely from chronic paralysis virus preparations, have prevented the making of conclusive tests that would establish whether the particle is a satellite of chronic bee-paralysis virus. However, it has always been detected with chronic paralysis virus and no other virus in bees, and it does not multiply when purified and injected alone. (Bailey and Ball)

Bacterial diseases. Bacteria resembling *Streptococcus pluton* in cell morphology and nutritional requirements were isolated from larvae, sent from India, of *Apis cerana* suffering from a disease resembling European foulbrood. A small proportion of the bacteria also produced colonies that resembled those of *S. pluton* from larvae of *Apis mellifera* with European foulbrood. However, most produced small transparent colonies of various kinds, some of which resembled a type isolated previously from *A. cerana* (*Rothamsted Report for 1972*, Part 1, 223), in that they did not react with antiserum prepared against *S. pluton* unless cultivated in media containing a special yeast extract. They multiplied on an agar containing this yeast extract to produce colonies that resembled those of *S. pluton* from *A. mellifera*. Tests with fractions of the special yeast extract, separated by means of Sephadex columns, indicated that the growth factor was a small molecule, sensitive to acid-hydrolysis, and which dissolved much more readily in water than in chloroform. (Bailey, with Pierpoint, Biochemistry Department, and Greenway, Insecticides and Fungicides Department)

Detecting starved bees. Bees that have died from starvation have been shown to have much less glucose and fructose in their thoraces than bees killed with an insecticide or by freezing. It may thus be possible to distinguish bees killed by insecticides from ones that have starved.

In the autumn of 1975 several samples of dead bees received had their honey stomachs filled with solidified ivy nectar or honey. By feeding to bees in the laboratory an 80% w/w sugar solution with a sugar composition similar to that of ivy nectar it was confirmed that the sugar could crystallise in the bees' honey stomachs, after which they died. However, the dead bees had more sugar in their thoraces than bees killed by freezing, so it seems that death following crystallisation of food in a bee's honey stomach is not due to starvation, but to other physiological or mechanical causes. (Simpson, with Greenway and Stevenson, Insecticides and Fungicides Department)

https://doi.org/10.23637/ERADOC-1-133

Pheromones

Control of queen rearing by queens. Further comparisons between the success of the first stage of artificial queen rearing in colonies with and without queens have shown that the benefit of queenlessness is greater than earlier observations suggested. Rearing was 20–58% successful in six queenless colonies compared with 0–13% successful in six colonies with queens that had access to the queen cells.

Sealed (pupal) queen cells were put into a colony with a laying queen, whose access to different cells was restricted to different distances while that of workers was unrestricted. The workers did not attempt to destroy the queen cells unless the queen herself was within 5 mm of them. Thus, if destruction is induced by the queen's pheromones, these appear to be effective in this function only at very short range. (Simpson)

Pollination

Increasing the pollinating efficiency of honeybee colonies. Honeybees foraging for pollen are more efficient pollinators of many crops than those collecting nectar only, so that the more pollen a colony collects the more effectively does it pollinate. The presence of brood stimulates foragers to collect pollen so experiments were done to discover whether increasing contact between foragers and brood enhanced pollen collection.

Hives were provided with upper and lower entrances. In hives in which an entrance opened directly on to the brood area of a colony, a greater proportion of bees using the entrance collected pollen than when it opened on to an area of the hive with storage comb only. The proportion of pollen gatherers could be diminished or increased by moving brood combs near to or far from the entrance. Bees leaving the hive favoured the entrance near the brood. Hence, to stimulate pollen collection and pollination it is important that lower entrances to a hive lead directly to nearby brood. Contact between foragers and brood was further increased with similar beneficial effects on foraging, in three ways: (1) by directing the foragers along the floor of the hive, using a shallow entrance flush with the floorboard; (2) by extending the entrance as a tunnel as far as the brood combs which were at right angles to it; and (3) by using narrow strips of wood immediately under the brood combs to divert the bees on to them.

The use of two entrances, a lower one adjacent to brood combs and an upper one adjacent to storage combs, should also discourage the undesirable deposition of pollen loads in storage cells from which honey is to be extracted, especially when a queen excluder, which hampers the movement of bees through the hive, is present. (Free and Williams)

Field bean pollination. Attempts have been made to assess whether the yields of commercial crops of field bean are limited by insufficient pollination. Samples of plants in a total of 37 crops were self-pollinated and cross-pollinated by hand and their yield compared with that of plants pollinated naturally.

The advantage of cross-pollination over self-pollination was small but in most crops hand pollinated flowers set more seed than control flowers, indicating that insect pollination of field bean crops is often inadequate.

In fields of more than 12 ha, the seed yield was greater on plants near the edges than at the centre, probably reflecting greater pollinator activity near the margins, and emphasising the need for more pollinating insects in such circumstances.

Fewer pods were produced from nodes at the upper than the lower parts of a stem, and they contained fewer and smaller seeds. (Free and Williams)

Economic aspects

For many years the study of relationships between insect populations and the yields of attacked crops has been an important part of the Department's work. The current eco-

https://doi.org/10.23637/ERADOC-1-133

nomic crisis has re-emphasised the need to ensure that work is relevant to the needs of agriculture, so the economic implications of the various topics studied in the Department are being assessed. This will help in planning research priorities and objectives by indicating where our work is likely to produce the greatest practical benefits.

Slugs in agriculture. The first of these studies is part of the review on 'Slugs in Agriculture' published in *Rothamsted Report for 1976*, Part 2, 169. This shows that losses from attacks by slugs amount to £1·6–£3·6 millions a year for wheat and potatoes (at 1974 prices), which is comparable to the value of losses caused by wheat bulb fly. Although losses are a small proportion of the total value of these crops, losses to individual growers are often unexpected and sometimes large. During the last ten years the effects of changes in the potato cultivars grown and in methods of cereal growing has increased the risk of damage to these crops, possibly by about 50%. Many crops that would benefit from molluscicides do not receive them because of the difficulty of predicting attacks. This cannot be done without quantitative data on slug populations, a deficiency that has also hindered the development of control measures. (Bardner)

Overseas work

Many members of the Department have experience of applied entomology overseas, and advisory links funded by outside agencies, are maintained to the mutual benefit of overseas agriculture and Rothamsted. Contributions to studies of pest problems and beneficial species in Laos, India, Cyprus and Oman have been made during the year.

Plant protection in Laos. From 1973–76, the Ministry of Overseas Development supported the creation of a Plant Protection Department and a study of the insect problems of rice in Laos where a single annual crop of predominantly local, glutinous, varieties is grown. Samples obtained from 1 m^2 quadrats, in sweep nets and light traps, and by tiller dissection showed that the insect populations were generally small. Insecticidal control is often impractical in Laos for economic and logistic reasons but fortunately it was rarely necessary.

The most common pests on upland rice were *Patanga succincta*, *Nezara viridula* and *Leptocorisa* spp. In contrast, these insects were uncommon on lowland paddy rice where there were more of the smaller grasshoppers (*Oxya* and *Euscyrtus* spp.) in the seedbeds, and stem-borers (*Sesamia inferens* and *Chilo* spp.) in the transplanted rice. Other potentially important pests, such as the rice gall midge (*Pachydiplosis oryzae*) and the whorl maggot (*Hydrellia philippina*), were uncommon except very locally.

Few cicadellids and delphacids were found on the local rice varieties, whereas the small, experimental plots of improved IR varieties were often more heavily infested with *Nephotettix* spp. and *Niloparvata lugens*.

A light trap caught more of these insects during the warmer months than in the winter. The results indicated that some pests (e.g. Cicadellidae) become especially abundant when the south west monsoon and its associated Inter Tropical Convergence Zone approach and retreat from South East Asia. (Dean)

Pollination of pigeon pea in India. Observations were made on the behaviour of insects visiting the flowers of pigeon pea (*Cajanus cajan*) during a short visit to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad. This work was part of a programme to determine the isolation distances required between plots of different 'normal-leaved' cultivars to prevent cross-pollination between them. Insects of many different orders were captured on the flowers, but bees, especially *Megachile* spp., were probably responsible for most of the cross-pollination because of their abundance, activity, behaviour on flowers, and the amount of pollen on their bodies.

Bees did not discriminate between 'normal-leaved' cultivars with flowers of different

https://doi.org/10.23637/ERADOC-1-133

colours, but little cross-pollination occurred between plots of a 'normal leaf' cultivar and an 'obtuse' leaved one because *Megachile* spp., preferred the former whereas *Apis dorsata* preferred the latter. (Williams)

***Apis florea* in Oman.** It has been confirmed that the westward distribution of this Asian species extends beyond the Persian Gulf to Oman. In contrast to its behaviour further east, where it usually, if not always, nests in sight of the sky and absconds very readily when disturbed, *A. florea* in Oman nests in caves and its colonies can be moved and easily manipulated by beekeepers. (Simpson, with Mr. R. Dutton, Middle East Centre, Durham University)

Mapping armyworm distribution in Cyprus. Data on armyworm populations collected from pheromone monitoring traps in Cyprus has been used to explore the effects of altitude on the mapping techniques developed in the Department for presenting information on moth distribution. (Taylor, with Dr. D. G. Campion, Centre for Overseas Pest Research)

Staff

We are pleased to record that K. E. Fletcher, N. Wilding and Ingrid H. Williams obtained Ph.D. degrees of the University of London, and congratulate J. Bowden on his election as an Honorary Life Fellow to the Egyptian Entomological Society. T. Lewis was awarded the Huxley Medal and Prize by Imperial College.

C. G. Butler retired as Head of Department on 9 April after a distinguished career at Rothamsted. He is best known for his pioneering studies on honeybee management, behaviour and pheromones, for which he was awarded the OBE and elected Fellow of the Royal Society in 1970. He was succeeded by T. Lewis.

A. M. Dewar was appointed to work on the cereal ecosystem study at North Farm, West Sussex and, to take effect in 1977, J. R. G. Turner to work on genetical and resistance problems in aphids. D. D. Burke was awarded an ARC research studentship to work on slugs.

C. J. Stafford resigned as a voluntary worker to join the Field Experiments Section and R. G. Betts, M. Bigger, B. Carleton, Rita K. Chambers, Mary Creighton, Susan P. Greenwood, Sally A. Hearn, Geraldine Le Brun, M. Gibb, Carol J. Marshall resigned and Mary Short completed her studentship. J. E. Bater, Janice Cook, J. L. Doran, D. G. Garthwaite and Adrienne K. Smith were appointed as assistant staff and K. A. Nicholson as a voluntary worker.

We welcomed Mr. B. Papierok from the Pasteur Institute, Paris, to work for a month on fungal diseases of aphids, and Professor R. Balasubramanian, an FAO Fellow from the University of Agricultural Sciences, Bangalore, briefly studied soil ecological methods in the Department as part of a UNESCO/UNDP project.

P. H. Anderson, Karen Ewen, D. J. Radford and R. J. Sprott worked as sandwich course students for six months.

C. A. Edwards, J. R. Lofty, C. J. Stafford and K. E. Fletcher attended the VIth International Colloquium on Soil Zoology from 20–29 June in Uppsala, Sweden, C. A. Edwards to present a paper and C. J. Stafford a poster exhibit. In October and November C. A. Edwards went to the University of Agricultural Sciences, Bangalore, India as a consultant to set up a soil ecology department and organise an All-India Symposium, and with R. Bardner, went to Göttingen, West Germany to organise a meeting of the International Organization for the Biological Control of Noxious Pests and Diseases (IOBC), Soil Pests Group which was attended by about 40 scientists. L. Bailey was an invited speaker and chairman at a colloquium on honeybee pathology, arranged by the Belgian Ministry of Agriculture in Gent. At the invitation of the Smithsonian Institute,

https://doi.org/10.23637/ERADOC-1-133

J. Bowden visited the University of Cairo and the Egyptian Ministry of Agriculture, Cairo, to study the collections of Bombylidae (Diptera).

C. A. Edwards, T. Lewis and L. R. Taylor each presented papers at the 'XV International Entomological Congress' in Washington, USA; L. R. Taylor extended his visit to give lectures and seminars at Kansas State University, University of Wisconsin and Iowa State University. Neil Wilding visited the USDA, University of Maine in August and September to study aphid pathogens in the field and fungal taxonomy, and also attended the 'First International Colloquium of Invertebrate Pathology' in Kingston, Ontario.

C. A. Edwards read a paper on direct-drilling at the 'Summer Conference of the Association of Applied Biologists' in Edinburgh on 6 and 7 July. T. Lewis presented a paper on pheromone trap design at a joint meeting, in April, of the Society for Chemical Industry and the Association of Applied Biologists, and C. Wall gave a paper on behavioural techniques relevant to control of pea moth at a meeting of the Association for the Study of Animal Behaviour in July.

TABLE 1

Time of arrival of first aphid in 1976 compared with mean dates for the previous seven years' catches, by regions

	Annual mean date of arrival					1976 days earlier (+) or later (−) than mean				
	All traps	SE	Midlands	N	SW	All traps	SE	Midlands	N	SW
A. pisum	3/6	18/5	30/5	19/6	7/6	+10	+13	+14	+4	+15
A. fabae grp.	9/6	30/5	5/6	25/6	7/6	+2	+20	−8	−7	+6
Aphis spp.	2/6	29/5	19/5	22/6	31/5	+8	+21	−4	+3	+14
A. rubi	16/6	7/6	13/6	8/7	8/6	+7	+4	+6	+16	+6
A. solani	28/6	21/5	15/5	27/6	16/5	+14	+16	−1	+23	+5
B. helichrysi	19/5	12/5	19/5	3/6	11/5	+9	+7	+9	+10	+12
B. brassicae	3/7	17/6	23/6	12/8	18/6	+25	+14	+25	+44	+28
C. aegopodii	22/5	18/5	21/5	4/6	16/5	+10	+12	+11	+12	+8
Cinara spp.	23/6	10/6	23/6	6/7	25/6	+13	+15	+10	+13	+15
D. platanoidis	17/5	16/5	14/5	21/5	18/5	+6	+7	+4	+6	+8
D. plantaginea	20/7	19/6	11/7	25/8	22/7	+8	+17	+41	−35	−3
E. abietinum	14/5	13/5	11/5	21/5	10/5	+4	+3	−7	+10	+7
E. ulmi	15/6	11/6	11/6	22/6	18/6	+4	+9	+5	+7	−6
H. pruni	17/6	11/6	16/6	24/6	17/6	+5	+9	+8	—	+4
H. lactucae	4/6	26/5	31/5	25/6	29/5	+8	+11	+1	+15	+7
M. euphorbiae	28/5	20/5	21/5	18/6	22/5	+10	+15	−2	+17	+10
M. viciae	30/6	18/6	28/6	11/7	2/7	+3	+1	−6	+12	none
M. dirhodum	24/5	18/5	16/5	16/6	14/5	+7	+13	+1	+13	+5
M. fustucae	11/5	2/5	5/5	4/6	2/5	−2	−4	−13	+14	−8
M. ascalonicus	26/4	21/4	13/4	14/5	27/4	−3	+11	−15	−2	−3
M. certus	30/5	18/5	28/5	20/6	23/5	+11	+9	+11	+15	+13
M. ornatus	20/5	17/5	15/5	20/6	26/4	+17	+18	−2	+29	+26
M. persicae	31/5	20/5	23/5	30/6	19/5	+19	+21	+13	+30	+14
N. ribisnigri	6/6	27/5	3/6	22/6	3/6	+12	+13	+11	+8	+20
Pemphigus spp.	1/7	24/6	30/6	8/7	1/7	+15	+15	+9	+13	+21
P. fragaefolii	3/7	4/7	23/6	21/7	26/6	+27	+37	+12	+35	+18
P. humuli	9/6	27/5	30/5	3/7	8/6	+9	+11	+2	+12	+13
P. fagi	6/6	29/5	6/6	5/6	13/6	+12	+4	+6	+12	+20
R. insertum	30/5	1/6	19/5	11/6	28/5	+11	+18	+5	+13	+14
R. maidis	11/7	30/6	20/7	19/7	7/7	−61	−40	−87	−62	−55
R. padi	11/5	3/5	14/5	1/6	26/4	+15	+14	+17	+17	+17
S. avenae	24/5	16/5	21/5	14/6	14/5	+10	+10	+11	+15	+10
S. fragariae	1/6	21/5	22/5	27/6	26/5	+11	+6	−1	+25	+16

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-1-133

TABLE 2

Level of pest aphid populations in 1976 compared with mean values for the previous seven years' catches, by regions

	Annual mean per trap					1976 as % of annual mean				
	All traps	SE	Mid-lands	N	SW	All traps	SE	Mid-lands	N	SW
A. pisum	85	202	34	31	20	202	174	471	369	202
A. fabae grp.	493	746	678	403	200	16	19	2	18	25
Aphis spp.	182	227	224	190	93	70	114	63	14	109
A. rubi	9	9	11	4	14	142	213	61	157	139
A. solani	19	18	48	10	21	117	93	116	103	102
B. helichrysi	755	1177	1389	227	678	48	37	42	62	66
B. brassicae	150	302	119	10	149	254	187	649	1158	173
C. aegopodii	368	607	906	111	195	72	58	45	150	101
Cinara spp.	10	14	8	10	6	226	269	341	132	242
D. platanoidis	633	508	946	848	379	203	89	232	191	301
D. plantaginea	26	52	17	1	27	161	115	243	170	297
E. abietinum	283	105	64	536	253	53	90	95	40	76
E. ulmi	79	109	163	60	31	150	60	165	255	72
H. pruni	616	1050	465	532	194	62	73	61	52	63
H. lactucae	49	70	61	33	40	74	49	79	103	82
M. euphorbiae	84	94	143	84	49	122	154	127	65	128
M. viciae	5	7	8	2	3	26	14	16	125	none
M. dirhodum	755	1255	764	699	140	238	176	399	223	489
M. festucae	139	195	395	79	48	70	59	30	148	62
M. ascalonicus	76	118	150	41	38	83	75	79	96	64
M. certus	16	25	46	5	9	251	162	219	224	417
M. ornatus	12	15	12	5	17	114	72	50	256	142
M. persicae	171	240	221	142	96	326	348	670	70	105
N. ribisnigri	17	21	17	9	24	91	101	81	111	75
Pemphigus spp.	476	329	268	319	982	58	35	102	90	47
P. fragaefolii	2	1	2	5	1	110	180	100	44	300
P. humuli	443	784	1451	6	204	60	66	32	83	89
P. fagi	94	75	49	183	12	93	260	82	31	279
R. insertum	1839	1297	1427	2099	2379	35	16	62	55	12
R. maidis	23	27	9	26	19	23	19	41	22	29
R. padi	5374	4409	4367	6252	5849	75	95	82	87	35
S. avenae	1542	2974	1415	716	786	386	269	800	499	376
S. fragariae	140	217	186	57	132	37	26	27	64	52

Publications

Books

1 EDWARDS, C. A. & LOFTY, J. R. (1977) *Biology of earthworms.* 2nd Edition. London: Chapman & Hall, 300 pp.

Theses

2 FLETCHER, K. E. (1976) Studies on soil arthropods, particularly in relation to population assessment. Ph.D. Thesis, University of London.

3 WILDING, N. (1976) *Entomophthora* species (Fungi: Phycomycetes) on aphids (Hemiptera: Aphididae) and wheat bulb fly, *Leptohylemyia coarctata* Fallén (Diptera: Anthomyidae). Ph.D. Thesis, University of London.

4 WILLIAMS, I. H. (1977) The infestation of oil seed rape (*Brassica napus* L.) by *Meligethes aeneus* Fab. and *Ceuthorhynchus assimilis* Payk. Ph.D. Thesis, University of London.

https://doi.org/10.23637/ERADOC-1-133

General Papers

5 Bailey, L. (1976) Viruses attacking the honeybee. *Advances in Virus Research* **20**, 271–304.

6 Bowden, J. (1976) Stem-borer ecology and strategy for control. *Annals of Applied Biology* **84**, 107–111.

7 Bowden, J. & Johnson, C. G. (1976) Migrating and other terrestrial insects at sea. In: *Marine insects*, Ed. L. Cheng. Chap. 5, pp. 97–117.

8 Dean, G. J. W. (1976) A manual for rice entomologists in Laos. Vientiane: Sisanovong Press, 103 pp.

9 Free, J. B. (1976) Insect pollination of tropical crops. *Report of the Central Association of the British Bee-keepers' Association.* 10 pp.

10 Free, J. B. (1976) Beekeeping and pollination in developing countries. *Span* **19**, 73–75.

11 Greenway, A. R., Lewis, T., Mudd, A., Scott, G. C. & Wall, C. (1977) Some chemical and entomological problems in the investigation and the use of behaviour-controlling chemicals. In: *Crop protection agents: their biological evaluation.* Ed. N. R. McFarlane. London: Academic Press, pp. 162–180.

12 Greenway, A. R., Lewis, T., Macaulay, E. D. M., Sturgeon, Dolores M. & Wall, C. (1977) Pea Moth: Sex attractants for Early Warning and Control. *ARC Research Review* **2**, No. 3, 80–83.

13 (Remaudiere, G.) & Wilding, N. (1976) Fungal agents. In: *Studies in Biological Control.* Part 4. *Myzus persicae* Sulz. *An aphid of world importance.* Ed. V. L. Delucchi. International Biological Programme No. 9. Cambridge University Press, 104–109

Papers in Rothamsted Report, Part 2

14 Stephenson, J. W. & Bardner, R. (1977) Slugs in agriculture. *Rothamsted Experimental Station. Report for 1976*, Part 2, 169–187.

15 Taylor, L. R. & French, R. A. (1977) Rothamsted Insect Survey (Eighth annual summary). *Rothamsted Experimental Station. Report for 1976*, Part 2, 195–227.

Research Papers

16 Bailey, L., Ball, B. V. & Woods, R. D. (1976) An iridovirus from bees. *Journal of General Virology* **31**, 459–461.

17 Bowden, J. (1976) Weather and the phenology of some African Tabanidae. *Journal of the Entomological Society of Southern Africa* **39**, 207–245

18 Bowden, J., Haines, I. & Mercer, D. (1976) Climbing Collembola. *Pedobiologia* **16**, 298–312.

19 Edwards, C. A. (1976) The uptake of two organophosphate insecticides by slugs. *Bulletin of Environmental Contamination Toxicology* **16**, 406–410.

20 Free, J. B. & Williams, I. H. (1976) The effect on the foraging behaviour of honeybees of the relative locations of the hive entrance and brood combs. *Applied Animal Ethology* **2**, 141–154.

21 Free, J. B. & Williams, I. H. (1976) Insect pollination of *Anacardium occidentale* L., *Mangifera indica* L., *Blighia sapida* Koenig and *Persea americana* Mill. *Tropical Agriculture (Trinidad)* **53**, 125–139.

https://doi.org/10.23637/ERADOC-1-133

22 Free, J. B. & Williams, I. H. (1976) Pollination as a factor limiting the yield of field bean (*Vicia faba* L.). *Journal of Agricultural Science, Cambridge* **87**, 395–399.

23 Henderson, I. F., Greenwood, S. P. & Loxdale, H. D. (1976) Identification of immature aphids by chromatography. *Ecological Entomology* **1**, 171–173.

24 Henderson, I. F. & Whitaker, T. M. (1977) The efficiency of an insect suction sampler in grassland. *Ecological Entomology* **2**, 57–60.

25 Jones, M. G. (1976) The arthropod fauna of a winter wheat field. *Journal of Applied Ecology* **13**, 61–85.

26 Jones, M. G. (1976) Arthropods from fallow land in a winter wheat–fallow sequence. *Journal of Applied Ecology* **13**, 87–101.

27 Jones, M. G. (1976) The carabid and Staphylinid fauna of winter wheat and fallow on a clay with flint soil. *Journal of Applied Ecology* **13**, 775–791.

28 Jones, M. G. & Dean, G. J. (1975) Observations on cereal aphids and their natural enemies in 1972. *Entomologists Monthly Magazine* **111**, 69–77.

29 (Kempton, R. A.) & Taylor, L. R. (1976) Models and statistics for species diversity. *Nature, London* **262**, 818–820.

30 (Lachaise, D.) & Bowden, J. (1976) Les diptères des savanes tropicales préforestières de Lamto (Côte d'Ivoire). II. Peuplement de Bombyliidae et description de quatres espèces nouvelles. *Annales de Societé Entomologiques de Francais* (*N.S.*) **12**, 319–345.

31 Lewis, T., Wall, C., Macaulay, E. D. M. & Greenway, A. R. (1975) The behavioural basis of a pheromone monitoring system for pea moth *Cydia nigricana*. *Annals of Applied Biology* **80**, 257–274.

32 Lewis, T. & Macaulay, E. D. M. (1976) Design and elevation of sex-attractant traps for pea moth, *Cydia nigricana* (Steph.) and the effect of plume shape on catches. *Ecological Entomology* **1**, 175–187.

33 Lewis, T. & Macaulay, E. D. M. (1976) Towards rational design and elevation of pheromone traps. *Pesticide Science* **7**, 634–635.

34 (MacLeod, D. M., Müller Kögler, E.) & Wilding, N. (1976) *Entomophthora* species with *E. muscae*-like conidia. *Mycologia* **68**, 1–29.

35 Wall, C., Greenway, A. R. & Burt, P. E. (1976) Electroantennographic and field responses of the pea moth, *Cydia nigricana*, to sex attractants and related compounds. *Physiological Entomology* **1**, 151–157.

https://doi.org/10.23637/ERADOC-1-133