ROTHAMSTED RESEARCH

# Report for 1973 - Part1

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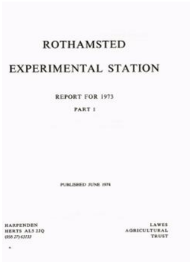
ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1973
PART 1

## Entomology Department

### C. G. Butler

C. G. Butler (1974) *Entomology Department ;* Report For 1973 - Part1, pp 192 - 211 **- DOI: https://doi.org/10.23637/ERADOC-1-130**

# ENTOMOLOGY DEPARTMENT

C. G. BUTLER

## Introduction

The task of the department is to explore the relationships between the yields of field crops and the activities of pest and beneficial insects and other organisms, such as slugs and earthworms, in order to acquire a rational basis on which to develop methods of controlling pests and making the best use of beneficial organisms.

The aphid survey has now developed sufficiently to give good early warning of the presence of airborne aphids in most parts of Britain. The appointment of J. Bowden has enabled a start to be made in finding out whether the samples of many kinds of insects caught in the network of suction and light traps can be used to monitor pests other than aphids and moths.

Preliminary experiments during the last few years to explore the possibility of increasing the productivity of grass by suppressing its pests, have given promising results and have been concluded. It seems likely that worthwhile increases can best be obtained by continuously protecting high yielding, well managed pasture from the time it is sown. Further work is in progress, in collaboration with members of the Ecology Department of the Grassland Research Institute, Hurley, to find ways of decreasing pest damage both by chemical and cultural methods. Pesticides, whether applied to pasture or to arable land, often do considerable harm to beneficial organisms, such as predatory beetles, mites and earthworms, as well as controlling the pests at which they are aimed. A long-term reference experiment was, therefore, started in 1972 to measure the effects of pesticides on beneficial organisms and should give useful information on interesting new compounds that will be included as they become available. The information that has been obtained in earlier experiments is important when considering ways to manipulate pest populations so that they do not cause economic damage, without affecting beneficial and harmless animals. The possibility of using insect pathogens for this purpose is being actively explored. It has been found, for example, that populations of cereal aphids and wheat bulb flies are greatly depressed by parasitic fungi in certain circumstances, some of which have now been analysed. Further work is aimed at using them to help control these pests before they damage crops. The use of viruses for such purposes has been much canvassed recently, and is being studied. However, studies of Nodamura virus which infects mosquitoes in nature, but can kill bees, wax moths and suckling mice, points to the need for caution before deliberately dispersing such organisms in the field.

Members of the newly organised insect pest behaviour and physiology section have also started studying aspects of insect behaviour which might be exploited in pest control with, or instead of, conventional insecticides. They are trying to develop ways of monitoring incipient pest populations at low densities to show where and when treatment, whether by insecticides or other means, can be applied most effectively. However, before an insecticide or anything else is used to control a population of insects it is desirable to know whether any treatment, however efficient, is likely to be economically worthwhile. Forecasts of crop loss resulting from the growth of an insect population are very difficult to make, and considerable long-term field work is necessary to obtain the data with which to construct a model. This has, however, been done fairly successfully with bean aphid and wheat bulb fly, and improvements are being made. With many other insects assess-



https://doi.org/10.23637/ERADOC-1-130 

ment of the damage that populations of different sizes can do, which is an essential preliminary to forecasting likely damage, has yet to be made.

The value of honeybees as pollinators of important fruit and seed crops is now well recognised and no longer need be stressed. But, because fewer people keep bees than did so a few years ago, it has become more important to use them to the best advantage. To do so we must find which crops benefit most by being pollinated by honeybees, and how best to prepare and use colonies for this purpose. For example, we have recently found that self-fertile apple trees benefit little from honeybee visits, whereas they help greatly when producing hybrid onion and kale seed. The foraging and other activities of honeybees are greatly diminished by several viruses with which most colonies are infected. Indeed, they perhaps damage colonies more than the better known pathogens. The possibility of procuring and maintaining virus-free stock is, therefore, being actively investigated, but must be regarded as a relatively long-term objective. It is also becoming increasingly clear that very many honeybee activities, including foraging, are partly controlled by compounds (pheromones) produced by the queen and other bees. The possiblities of directing bee behaviour by various means, including the use of synthetic pheromones, so as to make management simpler and foraging more effective, are kept constantly in mind.

## The Rothamsted Insect Survey

**Suction traps.** The principal function of the weekly aphid bulletin, giving details of aphids of agricultural importance caught in the nation-wide network of suction traps, is to direct the attention of entomologists to those pests that are currently present in their regions. It thus serves to concentrate attention where and when it is necessary, so obviating the need to search for pests that have not yet arrived and, indeed, may not do so in appreciable numbers in a particular season. Furthermore, the Survey must be able to detect the first arrival of pests in a district more economically and, if possible, efficiently than can be done by field officers regularly searching for them on the crops. That this is already possible for several species of aphids, and likely to become so for others, has been demonstrated (see *Rothamsted Report for 1973*, Part 2, 202–239).

The number of suction traps was increased to 18 in 1973, and it is planned to extend the network with an additional trap at Auchincruive, Ayrshire, and another at Preston, Lancashire, during 1974. This network of 20 carefully sited traps is expected to cover Britain satisfactorily for current purposes.

The first bulletin, for the week commencing 16 April, was published eight days earlier than in 1972 and recorded eight species. The last bulletin issued was for the week ending 4 November.

The first large catches of aphids were made in mid-May, a month earlier than last year, but within the range recorded over the years that the traps have been operating. The drop in numbers which occurs annually in late summer was also a month early, and the autumn peak began early and was very irregular. Total numbers in the summer were a little higher and more varied than usual; in Scotland numbers were abnormally high (Table 1). Taking the year as a whole, the following aphids were caught in much larger numbers than usual: *Elatobium abietinum*, *Myzus ascalonicus* and *Myzus ornatus* (three early flying aphids favoured by the warm spring), *Macrosiphum euphorbiae*, *Pentatrichopus fragaefolii*, *Phorodon humuli* (three times last year's total) and *Phyllaphis fagi*. Aphids that were much scarcer than usual were: *Drepanosiphum platanoidis*, and three cereal aphids, *Metopolophium dirhodum* (also caught in small numbers in 1972), *Sitobion avenae* (only half last year's total) and *Rhopalosiphum insertum*. *Rhopalosiphum padi* was slightly above average, and more than last year; *Myzus persicae* was more abundant



https://doi.org/10.23637/ERADOC-1-130 

TABLE 1

*Level of pest aphid populations in 1973 compared with mean values for the previous five years' catches*

| Species | Annual mean/trap | Total/trap 1973 | 1973 as % of annual mean |
|---|---|---|---|
| *Acyrthosiphon pisum* | 114 | 66 | 58 |
| *Aphis fabae* group | 803 | 530 | 66 |
| *Aphis* spp. | 201 | 186 | 92 |
| *Amphorophora rubi* | 5 | 4 | 80 |
| *Aulacorthum solani* | 11 | 13 | 118 |
| *Brachycaudus helichrysi* | 629 | 793 | 126 |
| *Brevicoryne brassicae* | 148 | 103 | 70 |
| *Cavariella aegopodii* | 416 | 463 | 111 |
| *Cinara* spp. | 11 | 15 | 136 |
| *Drepanosiphum platanoidis* | 908 | 245 | 27 |
| *Dysaphis plantaginea* | 31 | 27 | 87 |
| *Elatobium abietinum* | 303 | 868 | 286 |
| *Eriosoma ulmi* | 111 | 152 | 137 |
| *Hyalopterus pruni* | 1071 | 1086 | 101 |
| *Hyperomyzus lactucae* | 47 | 36 | 77 |
| *Macrosiphum euphorbiae* | 64 | 106 | 166 |
| *Megoura viciae* | 5 | 6 | 120 |
| *Metopolophium dirhodum* | 901 | 417 | 46 |
| *Metopolophium festucae* | 72 | 77 | 107 |
| *Myzus ascalonicus* | 56 | 86 | 154 |
| *Myzus ornatus* | 6 | 10 | 167 |
| *Myzus persicae* group | 329 | 407 | 124 |
| *Nasonovia ribisnigri* | 20 | 17 | 85 |
| *Pemphigus* spp. | 586 | 581 | 99 |
| *Pentatrichopus fragaefolii* | 1 | 2 | 200 |
| *Phorodon humuli* | 527 | 839 | 159 |
| *Phyllaphis fagi* | 109 | 334 | 306 |
| *Rhopalosiphum insertum* | 2729 | 1129 | 41 |
| *Rhopalosiphum maidis* | 25 | 15 | 60 |
| *Rhopalosiphum padi* | 7053 | 7743 | 110 |
| *Sitobion avenae* | 1098 | 551 | 50 |
| *Sitobion fragariae* | 154 | 109 | 71 |

than usual, and reached twice last year's total, but *Aphis fabae* was below average, with only half last year's total, although it arrived very early.

**Light traps.** During 1973, many additional tungsten light traps were set up in Wales and a few more in England, thus providing adequate coverage of Britain as far north as Lancashire and Yorkshire.

Apart from invasions of such migrants as the Silver Y moth (*Plusia gamma*), which was a serious problem in some areas, the weather during 1973 favoured many moths, larger numbers than usual being caught.

A provisional summary of the numbers of the more important pest species of moths caught in each of the last five years is given in Table 2. Surprisingly, it is not yet known which species of cut-worms should be regarded as pests, so the pest status of the various species is being investigated (see p. 204).

Annual distribution maps have now been prepared for most of the species of moths



https://doi.org/10.23637/ERADOC-1-130 

**TABLE 2**

*Number of individuals and sites (italics) at which pest moth species were caught, 1968–72*

| No. | Species Name | 1968 | 1969 | 1970 | 1971 | 1972 |
|---|---|---|---|---|---|---|
| 273 | *Euxoa nigricans* (Garden Dart) | 31<br>*11* | 101<br>*14* | 62<br>*19* | 122<br>*27* | 30<br>*18* |
| 277 | *Agrotis segetum* (Turnip Moth) | 136<br>*20* | 35<br>*17* | 135<br>*31* | 220<br>*36* | 163<br>*40* |
| 278 | *Agrotis vestigialis* (Archer's Dart) | 19<br>*6* | 41<br>*9* | 16<br>*4* | 17<br>*6* | 48<br>*9* |
| 285 | *Agrotis exclamationis* (Heart and Dart) | 2918<br>*53* | 2361<br>*65* | 8550<br>*84* | 11 229<br>*92* | 5960<br>*89* |
| 286 | *Agrotis ipsilon* (Dark Sword Grass) | 82<br>*25* | 47<br>*26* | 98<br>*35* | 12<br>*10* | 7<br>*6* |
| 331 | *Noctua pronuba* (Large Yellow Underwing) | 861<br>*60* | 818<br>*74* | 1409<br>*83* | 1188<br>*94* | 1437<br>*88* |
| 346 | *Melanchra persicariae* (Dot Moth) | 137<br>*23* | 515<br>*46* | 360<br>*53* | 129<br>*40* | 203<br>*44* |
| 378 | *Cerapteryx graminis* (Antler Moth) | 1717<br>*32* | 3344<br>*44* | 2146<br>*45* | 1222<br>*43* | 567<br>*41* |
| 448 | *Apamea sordens* (Rustic Shoulder Knot) | 93<br>*31* | 109<br>*27* | 155<br>*46* | 118<br>*38* | 85<br>*35* |
| 456 | *Apamea secalis* (Common Rustic) | 1709<br>*54* | 2353<br>*72* | 2216<br>*76* | 2071<br>*87* | 1737<br>*84* |
| 462 | *Procus strigilis** (Marbled Minor) | 775<br>*51* | 563<br>*55* | 693<br>*67* | 824<br>*81* | 586<br>*64* |
| 469 | *Luperina testacea* (Flounced Rustic) | 2749<br>*42* | 3985<br>*53* | 3682<br>*63* | 7745<br>*79* | 6361<br>*73* |
| 488 | *Gortyna micacea* (Rosy Rustic) | 2459<br>*57* | 2985<br>*69* | 2714<br>*78* | 2846<br>*87* | 2388<br>*80* |
| 635 | *Plusia gamma* (Silver Y) | 1923<br>*60* | 3849<br>*74* | 810<br>*79* | 3528<br>*99* | 469<br>*70* |
| 266 | *Hepialus humuli* (Ghost Swift) | 57<br>*27* | 128<br>*38* | 108<br>*39* | 124<br>*40* | 59<br>*28* |
| 267 | *Hepialus lupulina* (Common Swift) | 367<br>*32* | 335<br>*36* | 899<br>*60* | 2301<br>*67* | 1679<br>*57* |
| Maximum possible number of sites | | *63* | *76* | *85* | *99* | *89* |

* Not fully identified

shown in Table 2, and certain features are appearing. It must be emphasised, however, that at present only tentative conclusions can be drawn from these because only five years' records are available. It appears that most of these species of moths have fairly well-defined patterns of distribution. This does not mean, of course, that the distribution pattern of each species is the same each year, on the contrary, pronounced variations occur. It is hoped to establish a background pattern for each species against which to compare such variations when trying to forecast population trends. At one extreme, the total numbers and distribution of some moths vary little from year to year (by a factor of



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about ×2)—e.g. *Hepialus humuli*, *Gortyna micacea*, *Luperina testacea*, *Procus strigilis* and *Apamea secalis*. At the other extreme, two well-known migrants, *Agrotis ipsilon* and *Plusia gamma* exhibit no recognisable patterns of distribution and their total populations vary greatly (by a factor of about ×10) from year to year. Forecasting their occurrence will have to wait until we know more about their patterns of migration over Africa and Europe. Meanwhile, their local abundance will have to be measured each year. Between these two extremes is a group of moths which behave differently. Those of this group—e.g. *Hepialus lupulina*, *Agrotis exclamationis*, *Euxoa nigricans*, *Melanchra persicariae*, *Agrotis segetum* and *Cerapteryx graminis*—exhibit well-marked distribution patterns and a moderately wide range of population densities (about ×5). It remains to be seen whether they follow sufficiently regular cycles to allow useful forecasts to be made. (Taylor and French)

### Bean aphids

Work continued on the prediction of outbreaks of *Aphis fabae*, in collaboration with Professor M. J. Way (Imperial College). Large populations were found on the winter host plant, *Euonymus europaeus*, in 1972/73 and heavy infestations of field beans and sugar beet during 1973 were correctly forecast. Further studies of late summer/early autumn secondary hosts of *A. fabae*, and of field to field variation in infestation levels were made to improve the accuracy of the forecasting technique.

Methods and times of applying insecticides before and after flowering, when pollinating insects are not at risk, were again compared on Rothamsted Farm. In contrast to previous years, a damaging infestation of aphids occurred and results (Table 3) showed that

TABLE 3

*Yield (t/ha) of field beans treated with demeton-S-methyl spray (0·25 kg a.i./ha) and phorate granules (1·1 kg a.i./ha) immediately before (6/7 June) and after (9 July) flowering*

| Date | Treatment: phorate | Treatment: demeton-S-methyl |
|---|---|---|
| 6/7 June | 4·38 | 4·21 |
| 9 July | 3·65 | 3·90 |
| 6/7 June and 9 July | — | 4·27 |
| No treatment | 3·70 | |

(S.E. of difference between yields ±0·237)

pre-blossom treatments were effective, whereas application after flowering was not. (Bardner and Fletcher, with Stevenson, Insecticides and Fungicides Department, and Moffatt, Farm)

### Ecology of cereal aphids

Twice a week, from mid-May until the end of July, sample counts were made at Rothamsted of aphids on spring barley and winter wheat. Aphids on the plants growing in ten, 0·3-m lengths of row, distributed both within and at the edges of each crop, were counted on each occasion.

Two apterous *Sitobion avenae* were found on wheat on 22 May, and two alate *Rhopalosiphum padi* with nymphs and one alate *S. avenae* on barley on 28 May. Thence forward populations of *S. avenae* and of another aphid, *Metopolophium dirhodum*, increased until diminished by heavy rain at the end of June. Three alate *R. padi* with nymphs were found on wheat at the end of May, and four alatae and two apterae on barley between the end of May and mid-June. Three alate and five apterous *Sitobion fragariae* with nymphs were found on wheat, the first on 5 June, while eight alate and 25 apterous specimens of



https://doi.org/10.23637/ERADOC-1-130 

this aphid, all with nymphs, were found on barley from early June onwards. Only two alate *Metopolophium festucae*, neither with nymphs, were found, both early in June. No aphids were found on the barley after 20 July, and only three dead *S. avenae* on wheat.

The first parasitised aphid (aphid mummy) was found on 4 June on wheat and 18 June on barley. From 113 mummies collected, 50 *Aphidius* spp. and 20 hyperparasites had emerged by the end of October; 41 entire mummies remained. (Margaret Jones)

## Fungal diseases of aphids

**Field incidence of *Entomophthora* spp. infecting bean aphid.** *Entomophthora* spp. infected few of the adult apterous bean aphids (*Aphid fabae*) remaining on the overwintering host plant, the spindle tree, *Euonymys europaeus*, in May and June. By 21 June most of the aphids had migrated to their secondary, summer hosts, including field beans.

The numbers of aphids on field beans in Highfield field, Rothamsted Farm and Mill Dam Close II field, Woburn Farm, began to increase rapidly at both sites about mid-June, reaching maxima of about 1900 aphids/plant on 9 July in Highfield and 1600/plant on 16 July in Mill Dam Close. Most aphids had left the beans by 30 July at Highfield and 6 August at Mill Dam Close. The percentage of aphids infected with *Entomophthora* spp. began to increase by 25 June in Highfield and 26 June in Mill Dam Close, when the aphid populations averaged about 525 and 125 aphids/plant, respectively. The percentage of aphids infected with *Entomophthora* spp. remained consistently above 30% from 2–16 July in Highfield and from 10–30 July in Mill Dam Close, during which periods there was always an average of more than 1000 aphids/plant. Peaks of infection of 71% in Highfield and 66% in Mill Dam Close occurred on 16 and 24 July, respectively, shortly after the peak aphid population at each site. Large percentages of infection were not obviously associated with wet weather.

On 2–3 July, most infected specimens were in the smallest colonies of aphids. Possibly at this early stage in the infestation of the crop, most of the large colonies of aphids had developed from the healthiest small ones. Thereafter, no consistent relationship between the percentage of infected aphids and colony size was found, probably because the many airborne fungal spores had by then become a more important mode of infection than contact between diseased and healthy aphids.

Of the infected apterous aphids, 30, 1, 49, 20 and 0% in Highfield, and 13, 1, 50, 33 and 3% in Mill Dam Close, were infected with *Entomophthora aphidis*, *E. fresenii*, *E. planchoniana*, *E. thaxteriana* and *E. virulenta*, respectively. This is the first time that *E. virulenta* has been found in the field in England. *E. thaxteriana* infected more aphids earlier in the season than it did later, but there were no other obvious changes in the frequency of occurrence of different species during the season.

Numerous emigrants from the bean crops alighted on 'trap' broad bean plants sited about 35 m from the crops, between 26 June and 10 July in Highfield, and between 3–31 July in Mill Dam Close. At each site, 26% of the aphids were infected; a peak of 44% being reached in Highfield on 10 July, and of 38% in Mill Dam Close on 24 and 31 July. Of these, 44, 6, 28, 22 and 0% in Highfield and 35, 5, 46, 7 and 7% in Mill Dam Close were infected with *E. aphidis*, *E. fresenii*, *E. planchoniana*, *E. thaxteriana* and *E. virulenta*, respectively.

On 10 and 17 October, 16% of alate *Aphis fabae* on spindle trees were infected. None of the few alates found subsequently was infected.

The observations indicate that the percentage of infected aphids became large only when the aphid population became dense, that infection was spread from aphids on one secondary host plant to those on another and to those on the winter host by migrating,



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alate aphids, and that some aphids on the winter host plant in spring were infected before they migrated to bean plants. (Wilding and Brobyn)

**Infection of the pea aphid by Entomophthoraceae.** Histopathological studies were made on the infection of the pea aphid, *Acyrthosiphon pisum*, by *E. aphidis* and *E. thaxteriana* by preparing serial sections of aphids collected at six-hourly intervals after 4 h exposure to conidia shed from infected aphids. Conidia of both species adhered to the aphids for up to 48 h after discharge. The conidia of *E. thaxteriana* often became trapped in deep cuticular folds especially between the head and thorax of an aphid, and those of *E. aphidis* frequently adhered to the cuticle in clumps. Most conidia of *E. thaxteriana* germinated and penetrated the host cuticle within 24 h, and those of *E. aphidis* within 36 h, after discharge. There was no evidence that germ tubes penetrated the host aphid via the spiracles, sensory pores or alimentary tract, or of a preferential penetration site, though the hard head capsule was rarely penetrated. Some cuticular layers were displaced where the germ tube penetrated, suggesting a mechanical means of entry, and the appearance of cleared regions in other layers around the penetrating germ tubes also suggested some enzymic action. Colonisation of the host was more rapid the greater the number of penetration sites. Hyphae first grew in the haemocoele, where some were phagocytosed by large blood cells, and then began to invade the solid tissues. The order of invasion of aphids infected by *E. thaxteriana* was fat tissue, muscle, central nervous tissue and contained embryos, and in those infected by *E. aphidis*—central nervous tissue, fat tissue, muscle and embryos. Some of the last two kinds of tissue invaded by each species of *Entomophthora* were incompletely destroyed even when the fungus had started to sporulate. The gut and chitinous structures were not attacked. When the aphids died, conidiophores aggregated in groups beneath the cuticle before emerging. Those of *E. thaxteriana* emerged all over the body of the host aphid whereas those of *E. aphidis* were absent from the mid-ventral, antero-posterior region of the abdomen from where the fungal rhizoids emerge. Rosette-like structures, emerging cystidia encircled by developing conidiophores occurred evenly distributed just beneath the cuticle of aphids infected with *E. aphidis*. (Brobyn and Wilding)

**Resting spore formation by *Entomophthora fresenii*.** Resting spores of *E. fresenii* did not form in apterous alienicolae of two week-old cultures of *Aphis fabae* from either long (18-h) or short (6-h) day environments when the aphids were inoculated with conidia that had formed in either of these environmental conditions, and were subsequently incubated in either environment. However, resting spores did form in some alienicolae from four-week-old cultures from either environment, when they were inoculated with conidia that had formed under short-day conditions and were then incubated in the short-day environment. Further tests showed that whereas resting spores did not form in fourth instar pre-alate nymphs, they did form in many pre-sexuparae and sexual females from the same three- to seven-week-old short-day cultures, when the aphids were infected with conidia that had formed in short-day conditions and were kept thereafter in the same environment. These findings show that the formation of resting spores by *E. fresenii* is influenced not only by the environment in which the inoculum was formed, but also by the state of development of the aphid host, and by the day length of the environment in which it is kept after it has been infected. (Wilding and Brobyn)

## Wheat bulb fly

**Population studies.** The wheat bulb fly egg population in Stackyard field, Rothamsted Farm (4·2 million/ha) in the winter of 1972/73 was the highest recorded for seven years



https://doi.org/10.23637/ERADOC-1-130 

on this site which is reserved for studies of this pest. Larval counts at the end of March 1973 were 1·36 million/ha and pupal counts at the end of May were 1·04 million/ha. The adult population that emerged was 0·40 million/ha, equivalent to 9% of the eggs developing to the adult stage.

Adult flies emerged between 19 June and 19 July, reaching a peak between 30 June and 4 July in emergence traps, coinciding with the maximum numbers caught in suction and water traps. This suggests rapid dispersal of the adults soon after they emerged. Measurements of absolute population levels on the crop in July and early August showed a decline with time of males but not of females, and the numbers present on the crop were always smaller than the number of flies that had emerged in the field.

Flies marked with a fluorescent dust and released in Great Harpenden field, 0·4 m distant, were recaptured in Stackyard field and, similarly, flies marked in Stackyard were recaptured in Great Harpenden field. The time the flies took to travel this distance ranged between one day and three weeks. Catches in lines of water traps, radiating 0·4 m in all directions around Stackyard field, showed no detectable gradient of marked flies leaving Stackyard. Few marked flies were recaptured later than two weeks after they had been released.

Continuous suction trapping on both wheat and fallow showed that more flies were active on the fallow between 14.00 and 22.00 h BST than at other times either on the fallow or on the wheat. (Bardner, Margaret Jones and Fletcher)

**Maturation of ovaries.** The number of female wheat bulb flies caught in water traps at ground level on fallow in Stackyard field reached a peak during the week ending 30 July. Of 156 that were dissected, 39% contained ripe eggs, 23% had already laid their first batches of eggs, and 56% were infected by a fungus, probably *Entomophthora muscae*. Of another 116 females caught in water traps at crop height among the growing wheat, 26% contained ripe eggs, 35% had laid their first batches of eggs and 67% were infected by fungus. Therefore, just significantly more females with ripe eggs were caught on the fallow than on the wheat, and significantly more of those caught on the wheat had already laid their first batches of eggs. This supports the view that, having laid their eggs on fallow ground, females return temporarily to cereals to feed before moving once more to fallow ground to lay.

One hundred and four females, caught in water traps dispersed over Rothamsted Farm during the week ending 5 September, were dissected. Twenty-four per cent of these had already laid second batches of eggs and a further 30% were ready to lay them. Fifty-five per cent were infected by fungus. Few females were caught during the last week of trapping which ended on 11 September. Of 13 dissected, six contained ripe eggs, three had laid their second batches of eggs, and seven were infected by fungus. Thus, although third batches of eggs were maturing in some of these flies, none had laid a third batch. It is interesting that the proportion of the population of female flies infected by fungus did not vary greatly from the end of July onwards. (Margaret Jones)

**Adult activity.** An automatic flight-activity recorder was used to measure the activity of adult, laboratory reared flies kept in various light, humidity and temperature conditions. Male and female flies had similar activity patterns, but their activity levels differed with age, the females becoming more active but the males less so. Flies subjected to a 16-h light to 8-h dark cycle, exhibited a diurnal rhythm showing peak activity between 20.00 and 22.00 h, corresponding with activity levels in the field. Flies maintained a similar diurnal rhythm in continuous light. (Bardner and Fletcher, with Arnold, Insecticides and Fungicides Department)



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**Alternative hosts.** Wheat bulb fly are known to infest graminaceous plants other than wheat. Experiments have now been made under controlled, laboratory conditions, to compare the survival rates of larvae attacking some of these with that of larvae attacking winter wheat (Cappelle-Desprez). The number of adults produced from 100 eggs was determined in each case. Fifty-three per cent of those with winter wheat became adults, compared with 64% of those with couch grass (*Agropyron repens*) and 5–27% of those with five other grasses. Of the grasses attacked only couch exhibited the dead centre shoot symptom that is characteristic of wheat plants attacked by wheat bulb fly larvae. Although it is still too early to draw conclusions about the importance of wild grasses as reservoirs of this pest, it seems possible that they may be much more important than has been thought likely. (Bardner and Fletcher)

**Wheat bulb fly populations in Eastern England.** Fluctuations in mean egg densities from field samples in the ADAS Eastern Region for the past 20 years have been analysed to determine factors affecting egg density. In two areas, the Isle of Ely (light soils) and Essex and Suffolk (heavy soils), a linear regression model was used to test the importance of several climatic and land-use factors in determining egg density. Important factors were: (1) availability of egg-laying sites, (2) rainfall in October and November, (3) mean temperature in January, and (4) winter wheat acreage (important for Isle of Ely but not for heavy land). These factors accounted for over 70% of the variation in egg densities between years for both types of soil. Weather during the egg-laying period had no detectable effect, contrary to what was found for wheat bulb fly populations on Rothamsted Farm. There appeared to be no carry over effect of egg density from one year to the next, which supports the idea that strong density dependent factors were operating. (Bardner with Kempton, Statistics, and F. E. Maskell, ADAS, Cambridge)

**Phenology of insects in a wheat field.** Studies were continued, using emergence and pitfall traps, of the populations of insects in Stackyard field, Rothamsted Farm, part of which is now under wheat and part under fallow every year.

A row of 12 pitfall traps, 5 m apart, was sited in the growing crop and a similar row in the fallow. Between 17 November, 1972 and early March, 1973, those in the crop caught 69 small, adult, carabid beetles, 54 of which were *Trechus quadristriatus* and 15 *Bembidion* spp., which feed on the eggs of wheat bulb flies and other Diptera, together with 39 carabid larvae of five different species. Spiders were always caught. The traps in the fallow after the stubble from the previous wheat crop had been ploughed in, caught 149 carabid larvae, 68 adult *T. quadristriatus*, 15 adult *Bembidion* spp., and 17 adult *Notiophilus biguttatus*, and 11 small staphylinid beetles, *Xantholinus* spp. Spiders and a few other carabid beetles were also caught. From mid-March onwards, catches, particularly those of the traps in the crop, became larger and contained more species. From May until the wheat was harvested at the end of August, the commonest adult carabids caught in the crop were *Harpalus rufipes* (427), *Feronia vulgaris* (128), *Agonum dorsale* (70) and *Feronia madida* (67). Between harvest and the beginning of November, adults of another beetle, *Nebria brevicollis*, became the most numerous carabids present (260 caught). Again a few spiders were always present in the catches. On the fallow during these same periods, smaller numbers of the same species of adult beetles were caught: before harvest, *H. rufipes* (141), *F. vulgaris* (74) and *F. madida* (141), and after harvest there was similarly an increased catch of *N. brevicollis* (42). During the period from the end of July until the beginning of September, when wheat bulb flies were laying their eggs in the fallow ground, the number of adult *T. quadristriatus* increased greatly in this part of the field, 708 being caught between 10 August and 2 November, a peak catch of 187 being made during the week ending 14 September, whereas only 22 specimens were caught in the crop



https://doi.org/10.23637/ERADOC-1-130 

during this week. It is probable, therefore, that these small egg predators had congregated where there were many wheat bulb fly eggs.

Ten emergence traps operated continuously over wheat stubble in the autumn 1972 and over fallow in 1973. Small numbers of specimens of several families of Diptera, as well as psocids and springtails emerged. The Diptera included the grass stem-borer, *Opomyza germinationis*. From early spring to mid-summer, Diptera were the dominant group of insects emerging, gall midges being particularly noticeable in May and June. Otherwise, a few parasitic Hymenoptera and some noctuid moths were recorded during the summer. (Margaret Jones)

### Invertebrates and pasture productivity

**Effect of pesticides on old and new grass.** Collaborative work with the Ecology Department of the Grassland Research Institute, Hurley, continued during 1973.

A field experiment at Rothamsted, started in 1969 to examine the effect on yield of continued suppression of various groups of invertebrates with different pesticide treatments, was ended. On this old pasture, sown in 1943 and comprised of about 40% perennial ryegrass, 30% cocksfoot with several other unsown grass species and broad-leaved weeds, five of the treatments induced overall yield increases in the second year (1970). The most severe treatment gave an increase of 30% over the untreated control. Subsequently, in 1971, 1972 and 1973, although increases were obtained in individual cuts during the year, no statistically significant increase in the annual yield of any of the treated plots was found.

In a similar experiment on a newly-sown perennial ryegrass sward at Hurley, started at the same time, two of the pesticide treatments induced an increase in yield in every cut, and in the total annual yield not only in the second year but also in each of the three following years. Additional dry matter output from plots receiving these two treatments ranged from 17 to 23%, and 20 to 29%, respectively, above that of untreated plots during the four years from 1970 to 1973.

Preliminary trials, in Yorkshire, Lancashire, Devon and Kent, during 1971 and 1972, had suggested that increased yield following pesticide application (in this case relatively heavy doses of aldrin and phorate), to grassland (principally perennial ryegrass not more than three years old) might be a widespread phenomenon. Further trials were, therefore, started in spring 1973 to examine the effect of suppressing insect and other invertebrate populations in different parts of England. With the assistance of other Institutes and County Agricultural Colleges, replicated field trials were set up in Cheshire, Shropshire, Herefordshire, Gloucestershire, Somerset, Wiltshire, Lincolnshire, Nottinghamshire, Northamptonshire and Essex. Wherever possible, trials were laid down on recently-established ryegrass. During this first year a response to pesticide treatment, in at least one of the four cuts taken, was obtained at nine of the ten sites. The total annual yield was increased at five of the ten sites, by 6, 8, 9, 12 and 12%, respectively.

Although the yield increases recorded at Rothamsted, Hurley and elsewhere have been obtained using doses of pesticides too heavy to be acceptable for environmental or economic reasons, their existence indicates that even where no pest problem is apparent, it may be worthwhile to reduce the steady drain on the grass crop which starts with its invasion by the insects and other invertebrates normally found there. Benefits from treating old mixed pasture are debatable, but protection of high yielding species such as ryegrass from the time of sowing may be economically worthwhile.

An exploratory field trial to find the smallest dose of a short-persistence insecticide, dimethoate, which will produce a useful yield increase when applied to a young sward of perennial ryegrass, was started at Hurley in spring 1973. No effect on yield was found



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in the first two cuts, but a yield response was obtained in the last cut, its magnitude varying with both the amount of insecticide applied and with the frequency of application.

The field experiments described above have of necessity been conducted under a mowing-only system of management. Most grassland, even that intensively managed, is grazed for at least part of the year. Because this is so, and because some kinds of insects, especially dipterous larvae, become more numerous under a grazing than under a mowing regime, the effect of pesticide treatment of a perennial ryegrass sward previously grazed for five years by sheep was examined. Results from this trial indicate that the yield response is greater, and appears sooner under these conditions. (Henderson, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

**TABLE 4**

*Numbers of noctuid moths trapped in five mercury vapour light traps at Rothamsted during 1973*

| Site / Species | Farm | Stackyard | Garden plots | Ninnings | Manor | Total |
|---|---|---|---|---|---|---|
| Large Yellow Underwing (*Noctua pronuba*) | 616 | 827 | 738 | 690 | 584 | 3455 |
| Lesser Yellow Underwing (*Euschesis comes*) | 94 | 176 | 227 | 205 | 77 | 779 |
| Least Yellow Underwing (*Euschesis interjecta*) | 11 | 25 | 52 | 131 | 41 | 260 |
| Heart and Dart (*Agrotis exclamationis*) | 629 | 469 | 776 | 656 | 811 | 3341 |
| Turnip moth (*Agrotis segetum*) | 30 | 56 | 78 | 48 | 33 | 245 |
| Garden Dart (*Euxoa nigricans*) | 3 | 4 | 2 | 3 | — | 10 |
| Dark Sword Grass (*Agrotis ipsilon*) | — | 1 | 1 | — | 3 | 5 |
| Common Rustic (*Apamea secalis*) | 454 | 970 | 378 | 323 | 82 | 2207 |
| Rosy Rustic (*Gortyna micacea*) | 192 | 52 | 42 | 109 | 151 | 546 |
| Rustic Shoulder Knot (*Apamea sordens*) | 33 | 19 | 28 | 28 | 8 | 116 |
| Flounced Rustic (*Luperina testacea*) | 14 | 5 | — | — | 2 | 21 |
| Marbled Minor (*Procus strigilis*) | 13 | 6 | 20 | 33 | 26 | 98 |
| Tomato moth (*Diataraxia oleracea*) | 214 | 132 | 193 | 120 | 59 | 718 |
| Dot moth (*Melanchra persicariae*) | 8 | 3 | 10 | 4 | — | 25 |
| Silver Y (*Plusia gamma*) | 52 | 39 | 121 | 51 | 70 | 212 |



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**Dipterous stem-borers in ryegrass.** Further aspects of the invasion of perennial ryegrass (S 24) by dipterous stem-boring larvae were examined. As in 1972, four species of *Oscinella* and one species of *Geomyza* were found in the stems, with *O. vastator* the most numerous species. Age of plant and density of stand both influenced the number of larvae found in stems. Age was the more important factor, susceptibility to attack decreasing rapidly as plants grew. The inclusion of small amounts of cocksfoot in stands of ryegrass diminished attack on the latter. (Idowu and Henderson)

## Soil fauna

**Cutworms.** Studies of the biology, ecology and economic importance of several species of cutworms begun in 1972 were continued. The relative abundance of the adult moths

**TABLE 5**

*Numbers of noctuid moths trapped in mercury vapour light traps at seven sites in Great Britain during 1973*

| Site / Species | Kindrogan (Perthshire) | Moorhouse (Cumberland) | Silverdale (Lancashire) | Sutton Bonnington (Leicestershire) | Luddington (Warwickshire) | Long Ashton (Bristol) | Starcross (Devon) | Total |
|---|---|---|---|---|---|---|---|---|
| Large Yellow Underwing (*Noctua pronuba*) | 49 | 200 | 3645 | 207 | 245 | 526 | 127 | 4905 |
| Lesser Yellow Underwing (*Euschesis comes*) | 10 | 52 | 113 | 77 | 29 | 117 | 58 | 456 |
| Least Yellow Underwing (*Euschesis interjecta*) | — | 2 | — | 12 | 9 | 200 | 47 | 270 |
| Heart and Dart (*Agrotis exclamationis*) | — | — | 344 | 244 | 404 | 248 | 246 | 1486 |
| Turnip moth (*Agrotis segetum*) | — | — | 56 | 10 | 3 | — | — | 69 |
| Antler moth (*Cerapteryx graminis*) | 8 | 20 | 6 | 1 | — | — | — | 35 |
| Common Rustic (*Apamea secalis*) | 2 | 2 | 789 | 520 | 113 | — | — | 1426 |
| Rosy Rustic (*Gortyna micacea*) | 252 | — | 45 | 56 | 25 | 23 | 42 | 443 |
| Rustic Shoulder Knot (*Apamea sordens*) | — | — | 17 | 21 | — | — | — | 38 |
| Flounced Rustic (*Luperina testacea*) | — | — | 9 | 38 | 131 | — | — | 178 |
| Marbled Minor (*Procus strigilis*) | — | — | 167 | 77 | 2 | — | 37 | 283 |
| Tomato moth (*Diataraxia oleracea*) | — | — | 16 | 234 | 9 | 28 | 20 | 307 |
| Dot moth (*Melanchra persicariae*) | — | — | 24 | 16 | 8 | — | 2 | 50 |
| Silver Y (*Plusia gamma*) | — | 4 | 641 | 68 | 14 | 60 | 159 | 946 |



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was followed at Rothamsted using five Robinson mercury vapour light traps dispersed over the Station. Total catches (Table 4) were remarkably consistent from trap to trap.

The commonest of the species that are suspected of sometimes causing economic damage in Britain occurring at Rothamsted were the Heart and Dart moth (*Agrotis exclamationis*) and the Large Yellow Underwing (*Noctua pronuba*). However, many specimens of the Tomato moth (*Diataraxia oleracea*) were also caught and numerous reports of damage by this species to outdoor crops in the Evesham area were received. Of the stem-boring noctuids caught at Rothamsted, the Common Rustic (*Apamea secalis*) was very abundant, much more so than the Rosy Rustic (*Gortyna micacea*) and the Rustic Shoulder Knot (*Apamea sordens*).

Similar traps were also operated in Perthshire, Cumberland, Lancashire, Leicestershire, Warwickshire, Bristol and Devon, and larval counts and meteorological records made nearby. It is hoped that climatic and trap records will eventually enable outbreaks to be forecast. Only the Large Yellow Underwing and Lesser Yellow Underwing (*Euschesis interjecta*) were trapped at all sites, other species having a very variable distribution (Table 5); there were considerable differences in the dates that these moths were first caught, the Devon trap catching them much earlier than that in Perthshire. Cutworm larvae found attacking crops by ADAS workers, who kindly sent them to us, were reared and proved to be either the Heart and Dart, Large Yellow Underwing, Turnip or Tomato moths.

From the information at present available, it seems probable that the species with the potential to cause serious economic damage are the Heart and Dart and Large Yellow Underwing moths. The importance of the Turnip moth is more difficult to assess because, even though the number of larvae found was sometimes large, relatively few adults were caught and they seem to be much more locally distributed. (Edwards and Whiting)

**Infection by Microsporidan.** Dead and moribund larvae of the Heart and Dart moth (*Agrotis exclamationis*) were found to have their midguts heavily infected with an unidentified microsporidan. The spores (each approximately $2 \cdot 5 \times 1 \cdot 5\ \mu m$) of this organism infected larvae of another cutworm, *Spodoptera littoralis*, a widespread pest of cotton and many other crops, when fed to them. The spores remained infective to *S. littoralis* after they had been lyophilised within freshly dissected midguts of *S. littoralis* larvae. (Sherlock)

**Pesticides and earthworms.** Field tests of the effects of endosulfan (2·2 kg/ha), tetradifon (2·2 kg/ha), endrin (9·0 kg/ha), phorate (9·0 kg/ha), carbofuran (2·2 kg/ha) and benomyl (11·2 kg/ha) on earthworm populations were made. Tetradifon and endosulfan had no apparent effects of them but the other compounds all greatly decreased their numbers. The results of laboratory tests of toxicity of pesticides to earthworms which were reported earlier (*Rothamsted Report for 1972*, Part 1, 212) suggested that none of the insecticides (monocrotophos, tetrachlorvinphos and 'Ciba C14421'), herbicides (benzoylpropethyl, the triazine herbicide 'Bladex' for which the common name cyanasine is being adopted), or molluscicides (*N*-tritylmorpholine and methiocarb) tested caused significant decreases in numbers at field dose rates. Field trials have now shown that neither the insecticide, monocrotophos, nor either of the herbicides, 'Bladex' and benzoylprop-ethyl, significantly affect earthworm populations. However, whereas 'Bladex' and its breakdown products were not found in earthworm tissues, small amounts of benzoylprop-ethyl were. (Edwards, Lofty and Stafford)

**Earthworms in Park Grass.** Earthworm populations in Park Grass have been sampled as part of an intensive study of the soil fauna of the different plots. In 1972, an electrical



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method of stimulating earthworms to come to the surface of the ground was used, but unfortunately its efficiency was found to vary with the pH of the plot being sampled. So, in 1973, dilute formalin was used to bring the earthworms to the surface. Very great differences in populations and species composition were found to occur with the different fertiliser treatments. In particular, those that had been treated with ammonium sulphate for many years contained no earthworms. The species found in other plots were *Lumbricus terrestris*, *L. castaneus*, *L. rubellus*, *Allolobophora longa*, *A. caliginosa*, *A. rosea* and *Octolasium cyaneum*. A detailed report is being prepared. (Edwards, Lofty and Stafford)

**Effect of cultivation on earthworms.** An experiment to measure the effects of maximum and minimum cultivation of grassland, followed by reseeding, was started in 1969. During the first two years, cultivation considerably increased earthworm populations; the greater the amount of cultivation the larger the earthworm populations became. However, it is now becoming clear that although a single cultivation had this effect, repeated annual cultivation soon began to diminish the populations of most species, particularly those of *Lumbricus terrestris*. After three years, *Allolobophora caliginosa* was the only species whose numbers in the cultivated plots were greater (2×) than in the original pasture. It seems probable that a single cultivation, by opening up the soil, provides better conditions for burrowing and movement, and also favours those species that do not feed on the surface by transferring organic matter to the lower soil layers. (Edwards and Lofty)

**Palatability of leaves to earthworms.** The palatability of various kinds of freshly fallen leaves to earthworms has been measured, and found to be, in decreasing order, sycamore, lime, horse chestnut, sweet chestnut, elm, ash, hazel, oak, apple, hornbeam and beech. However, after weathering, apple leaves become very palatable and all others, except beech, much more palatable. Similar results were obtained when freshly fallen leaves were kept in running water for a week before they were offered to earthworms. It is probable that this treatment leached out soluble polyphenols.

Spraying leaves with chlorfenvinphos, parathion, benomyl, thiophanate-methyl, endosulfan, dieldrin, tetradifon, endrin and diazinon at doses likely to be used in the field, made them very unpalatable to earthworms. (Edwards and Lofty)

**Effects of stubble burning.** Further observations have been made on the possible harm stubble burning does to populations of harmful and of beneficial soil-inhabiting animals. In August, 1973, half of a field of wheat stubble was burned over and the fauna in this and in the untreated half compared during the following three weeks. Samples were collected by means of pitfall and bran-baited traps, and hand-sorting and suction-sampling of soil quadrats was also done. No evidence was obtained that the burning significantly decreased the numbers of beneficial animals such as carabid and staphylinid beetles, centipedes, spiders and earthworms, nor of such potentially harmful animals as millipedes, slugs and fly larvae. However, surface-dwelling springtails were almost all destroyed and the numbers of some kinds of mites greatly diminished. These results clearly support the view that stubble burning has few serious effects on the soil fauna. (Edwards and Lofty)

**Pesticides and the arthropod soil fauna.** A further field trial confirmed that the insecticide monocrotophos, at recommended dose rates, has little effect on soil arthropods.

The direct and indirect effects on the soil fauna of two herbicides, 'Bladex' and benzoyl-prop-ethyl were further studied; direct effects being distinguished from indirect ones by keeping four of the eight control plots weed-free. The new results obtained with



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'Bladex' indicate that some arthropod groups are decreased by chlorotriazine herbicides, but that their populations soon recover. The second herbicide, benzoylprop-ethyl, belongs to a chemical group whose possible effects on the soil fauna had not previously been studied. The results indicate that, like the majority of herbicides, it has little adverse effect on the soil fauna. Gas–liquid chromatography analysis showed that benzoylprop-ethyl persists in the soil much longer than 'Bladex'. (Edwards and Stafford)

**Effects of temperature and moisture on populations of soil invertebrates.** Information on the effects of artificially controlled temperature and moisture on soil invertebrates in uncovered plots in the field, that has been collected since 1969, has been analysed. After 11 months, the total number of arthropods in those plots that had been heated from overhead, but not given extra water, had decreased, whereas the total number in similarly heated plots that were given extra water, had not. Decrease in the total numbers in the former plots was, therefore, probably attributable to partial desiccation. Further analysis showed that heating, without artificial watering, depressed the total numbers of mites and springtails, without having a prolonged effect on the number of soil invertebrates as a whole. Quantitative changes in the composition of the arthropod fauna were also found. For example, about 79% of the total fauna of the heated and watered plots consisted of mites, but only about 52% of that of the heated, unwatered plots did so. Changes in the relative proportions of most orders of mites in the total mite population were also apparent, the Mesostigmata (which contains most of the predatory mites) being one of the exceptions in that its population remained constant regardless of treatment. Similarly, in the springtails, the number of Sminthuridae changed most, whereas the relative proportions of Poduridae and Isotomidae in the total population remained almost constant. It seems probable that such changes are related to changes in the populations of the other soil animals that provide food for those groups whose numbers were diminished.

Soil sectioning was used to study the effect of treatment on the vertical distribution of the arthropods. The effect of the overhead heating, with or without additional water, was to diminish the size of the total population in the upper layers of the soil. For example, in spring 1971, most mites were found 1–3 cm below the surface in all heated plots, compared with 0–1 cm in unheated, control plots. Similarly, the springtails tended to occur in the deeper layers of the soil, some species more than others. The data suggest that differences in the vertical distribution of arthropods in the different plots were mainly due to the effects of heating on mortality and birth rate, rather than to induced migration deeper into the soil.

The treatments caused changes in the total amount of vegetation on the plots, which may well have affected the fauna. Similarly, the porosity of the surface layers of the soil in the heated and watered plots was decreased, which may also have affected the fauna. (Haines and Edwards)



https://doi.org/10.23637/ERADOC-1-130 

## Slugs

An experiment was made on Rothamsted Farm to compare the protection from slug damage to King Edward potatoes obtained when molluscicides were placed either in the ridge alone, or both in the ridge and in the furrow.

Methiocarb (4·0%) and 'Talcord', for which the common name thiocarboxime is being adopted (1·3% a.i.), formulated in cross-linked gelatin with sucrose as an arrestant were used. The gelatin formulations were each applied at the rate of 5·6 kg/ha during drilling, either all in the ridge or half the quantity in the ridge and half in the furrow. The results are shown in Table 6.

**TABLE 6**

*Effect of molluscicide dispersal on slug damage to potatoes*

| Treatment | % damaged tubers from 60 plants |
|---|---|
| None | 17·9 |
| 'Talcord' in ridge only | 9·4 |
| 'Talcord', in ridge and furrow | 6·5 |
| methiocarb, in ridge only | 10·4 |
| methiocarb, in ridge and furrow | 7·1 |

Both methiocarb and 'Talcord' gave better results when incorporated in the ridges and furrows than they did when placed in the ridges only. (Stephenson)

## Field beans

**Damage caused by *Sitona* larvae.** Last year's experiment to determine the effect on yield of damage to the roots of beans by larvae of the weevil *Sitona lineatus* was repeated. Although the number of adults attacking the crop was greater than in 1972, the number of larvae attacking the roots was much smaller (1972, 40 larvae/root; 1973, 6 larvae/root). Nevertheless, the yield obtained from plants grown from virus-free seed in West Barnfield was significantly increased when the *Sitona* larvae were controlled with insecticides, whereas the yield from plants grown from virus-infected seed in Great Knott field was not (Table 7). (Bardner and Fletcher, with Cockbain, Salt and Hornby, Plant Pathology Department)

**TABLE 7**

*Effect of chemical control of* Sitona *larvae on the yield of field beans*

(Virus-free seed sown in W. Barnfield, virus-infected seed in Gt. Knott)

| Treatment | Larvae/root | | Yield (t/ha) | |
|---|---|---|---|---|
| | Gt. Knott | W. Barnfield | Gt. Knott | W. Barnfield |
| None | 4·1 | 7·7 | 3·18 | 3·73 |
| 'Dexon' (fungicide) | 4·4 | 7·2 | 3·10 | 3·40 |
| aldicarb (nematicide) | 2·6 | 4·4 | 3·61 | 3·78 |
| BHC (insecticide) | 1·2 | 1·2 | 3·33 | 4·31 |
| dieldrin (insecticide) | 0·8 | 2·2 | 3·32 | 4·01 |
| S.E. of difference between yields | | | ±0·277 | ±0·133 |

## Honeybees

**Influence of queen 'piping' on swarming.** Swarming by colonies that have only young virgin queens rarely occurs unless the colonies confine other, mature, young queens in their cells and both they and the free queens make the sound known as 'piping'. Preliminary tests in which application of recorded, or artificial, piping sounds to a few colonies was associated with swarming in otherwise very unlikely circumstances, have been followed with a controlled experiment. Ten out of 20 small colonies with young, virgin



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queens were exposed to an artificially generated piping sound. Five of these ten swarmed, whereas none of the ten without sound did so. It seems likely, therefore, that a function of the sound of queen piping is to induce a swarm to leave the hive. (Simpson and Greenwood)

**Communication.** A successful honeybee forager helps other bees of its colony to find a food source by leaving bee-produced scent on the source, conveying scent of the source and its surroundings back to the nest, and performing an excitatory dance on a comb in the nest. The dance also represents the polar coordinates of the position of the source relative to the nest and the direction of the sun, thus potentially giving the bees stimulated by the dance more precise guidance than the scents alone could. That the coordinate information is, in fact, communicated to the recruits has been questioned. In order to obtain more information on this point, observations were made of the rate of recruitment of bees over a distance of 470 m on Rothamsted Farm. When the observation hive in which the colony from which the bees were recruited was made alternately vertical (the normal attitude) and horizontal (in which condition a bee cannot make its dance represent the directional coordinate), the rate of recruitment with the hive horizontal was approximately half that with the hive vertical. This result indicates either that dances on a horizontal comb are less stimulatory than those on a vertical comb, or that the recruits do use the directional information in the dance when it is performed on a vertical surface. The latter interpretation is considered to be the more probable. (Simpson and Greenwood)

**Footprint substance of the worker honeybee.** One of the bee-produced scents that worker honeybees leave on food sources and with which they mark the entrances of their hives is footprint pheromone. An active fraction has been obtained by extracting footprint substance, collected in glass tubes through which bees were compelled to leave and enter their hives, with hexane or dichloromethane, followed by chromatography of its neutral compounds upon thoroughly cleaned silica gel: all activity was associated with the neutral fraction. Chemical tests indicate that this pheromone is an unsaturated compound with an hydroxyl group. This is supported by its chromatographic behaviour. (Butler and Welch, with Greenway, Insecticides and Fungicides Department)

**Factors determining food storage and brood rearing in comb.** Some of the factors determining whether particular cells are used for storing food or brood rearing have been discovered. Special combs prepared experimentally from groups of cells (sections) that had, immediately beforehand, been used by bees for various, different purposes were given to colonies whose reactions were then noted. Bees stored honey and pollen in worker cells in preference to drone cells. The choice of worker or drone cells for brood rearing varied with the time of year; the queens often laid several consecutive eggs all in drone cells or all in worker cells. Whereas workers with developed ovaries preferred to lay in drone cells, queens whose spermathecae were empty, and that laid unfertilised eggs only, did not prefer to do so in drone cells. For storing food, bees preferred worker cells in which brood had been reared, in preference to new cells; and also preferred cells in which food had been stored to new cells. Queens were equally ready to lay in new cells and those in which brood had been reared, preferring these types to cells that had contained food. It seems clear, therefore, that the use to which a cell has recently been put influences its future use. No evidence was obtained that when bees clean dirty cells they prepare them in ways that influence their future use. However, the position of a cell in relation to others in a comb containing brood and food does appear to be important. Normally food is stored in cells above those containing brood, and when combs were rotated so that their



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faces were in the horizontal rather than the normal vertical plane, this system was disrupted, and food storage cells became interspersed among brood cells. (Free and Williams)

## Pollination

**Self-fertile apple trees.** Attempts have been made to discover whether the yield of self-fertile apple trees is increased when pollinating insects visit their flowers. Although introducing bees considerably increased the amount of pollen transferred to the flowers' stigmas, it did not increase the yield of fruit significantly, so presumably pollination was adequate without insect visits, and using bees to pollinate self-fertile apple trees is unnecessary. (Free and Williams, with Drs B. D. Smith and K. G. Stott, Long Ashton Research Station)

**Hybrid brussels sprouts.** It was confirmed that honeybees and bumblebees sometimes fail to discriminate between the flowers of some cultivars of brussels sprout, while discriminating well between others. Because discrimination could result in inadequate pollen transfer between cultivars being grown for hybrid seed, it is desirable to study the ability of bees to discriminate between cultivars of brassicae at an early stage in work to produce new hybrids. Such studies have been made on two cultivars of kale being grown for hybrid seed by the Plant Breeding Institute, Cambridge. One cultivar had larger flowers than the other and many bees tended to 'rob' them of their nectar by inserting their tongues between the bases of the petals and sepals, so failing to get pollen on their bodies. Furthermore, the bees that visited these larger flowers and that had learned to obtain nectar in this way tended to continue to visit them in preference to the smaller flowers of the other cultivar and so helped to reinforce the constancy of bees visiting the different cultivars and limit the amount of pollen transferred between them.

However, many of the bees that entered kale flowers for nectar in the normal way, so getting their bodies dusted with pollen, failed to discriminate between the two cultivars, so a degree of pollen transfer in both directions was, therefore, obtained. This could probably have been increased by using more colonies in this field. (Free and Williams)

## Bee diseases

**Arkansas bee virus.** A search in the USA for viruses of bees revealed a previously undescribed virus from apparently healthy adult bees or their pollen loads in Arkansas. The virus, which contains ribonucleic acid, has isometric particles about 30 nm across, thus resembling some other bee viruses. However, unlike the particles of any other bee virus, their sedementation rate ($S_{20}$, w) is 128 and their density in caesium chloride is 1·37 g $cm^{-3}$. Moreover, the virus is unrelated serologically to any of the other known bee viruses. The virus behaved similarly when injected into bees either from N. America or from Britain. Young bees injected with terminally infective dilutions of Arkansas bee virus died after about three weeks, whereas similar control bees lived for seven or eight weeks. (Bailey)

**Bee virus X.** Laboratory tests with Arkansas bee virus on apparently healthy bees in Britain during the late winter led to the identification of a further previously unknown virus. Its isometric particles contain ribonucleic acid, but differ from all other known bee virus particles as they are about 37 nm across, have a sedimentation rate ($S_{20}$, w) of 187 and a density in caesium chloride of 1·36 g $cm^{-3}$. The virus is also serologically unrelated to any other known bee virus. Surveys showed that this newly recognised virus was extremely common in bees from many parts of Britain in late winter, but was scarce in summer. Named 'bee virus X' because of its uncertain role, it has never been



https://doi.org/10.23637/ERADOC-1-130 

noticed before, probably because bees had not previously been used for the cultivation of viruses during late winter owing to their usually poor condition relative to that at other times of the year. How much bee virus X contributes to this poor condition is uncertain, for it seemed as common, although the viral particles were possibly not so numerous, in live as in dead colonies. It shortened the lives of bees slightly but significantly when injected into them in laboratory tests. (Bailey)

**Acute bee-paralysis virus.** When examining samples of bees from many parts of Britain for bee virus X, samples from most colonies that had died for no obvious reason, as many often do in late winter, were found to contain much acute bee paralysis virus. This virus was not seen, or was very scarce, in bees from live colonies. Up to 35% of individual bees from the dead colonies contained as much acute bee-paralysis virus as in bees killed by the virus injected in laboratory tests. This is the first occasion on which acute bee-paralysis virus has been detected as a likely cause of losses in nature. Previously detected in apparently healthy bees, especially during summer, its ability to kill bees has been known for many years only as a laboratory phenomenon, under experimental conditions that made the effect seem only of academic interest.

Acute bee-paralysis virus appears to cause a slowly progressive infection that becomes severe in nature usually after a long period, as in late winter when most bees are several months old. Bee virus X, and Arkansas virus, may well act similarly. (Bailey)

**Chronic bee-paralysis virus.** A virus isolated from bees in Texas, and cultivated in bees in the USA or in Britain, seemed identical to chronic bee-paralysis virus in most respects. It caused the same symptoms, was composed of three major components, produced a precipitin line in gel-diffusion tests confluent with that of chronic bee-paralysis virus, using an antiserum prepared against the latter, and migrated as a single component in gel-immunoelectrophoresis at the same rate as chronic bee-paralysis virus. However, its components had sedimentation rates ($S_{20}$, w) of about 80, 90 and 100, whereas those of chronic bee-paralysis from bees in Britain average about 100, 115 and 125. (Bailey)

**Nodamura virus.** This virus, discovered elsewhere as an inapparent infection of mosquitoes in Japan and as a lethal for suckling mice, kills bees and wax-moths (*Galleria mellonella*). It multiplied in tissue cultures of *Aedes aegypti* and of *Aedes albopyctus* without causing cytopathic effects, and the infected tissues could be subcultivated, apparently indefinitely. After 7–14 days at 30°C, 1 ml of the tissue culture fluid of *A. albopyctus* contained about $10^8$ LD 50s, by injection for bees (equivalent to the infectivity of an extract of one bee killed by Nodamura virus) or about $10^6$ LD 50s by injection for wax-moth larvae (equivalent to the infectivity of $10^{-2}$ of the extract of one wax-moth larva killed by the virus). (Bailey and Stanley)

The physical and chemical properties of Nodamura virus from bees and wax-moths, and its effect on suckling mice were identical to those of virus derived initially from mosquitoes and subsequently cultivated in mice. (Bailey, with Dr. J. F. E. Newman, Animal Virus Research Institute, Pirbright)

## Staff

T. Lewis returned after working for ODA for three years on leaf-cutting ants in Trinidad; G. J. W. Dean left for Vientiane on a two-year tour for ODA and R. Bardner was seconded for work at the Coffee Research Station, Ruiru, Kenya, for two years. D. G. Gibbs left when his grant expired and Mary Short, an ARC scholar, arrived.



https://doi.org/10.23637/ERADOC-1-130 

## ENTOMOLOGY DEPARTMENT

J. Bowden visited Cairo for a fortnight to study collections of Diptera at the invitation of the Smithsonian Institution, Washington, and the Entomological Society of Egypt. He also visited Geneva as a member of a working party on Aerobiology of the Commission on Agricultural Meteorology, WMO.

C. A. Edwards was a delegate to the V International Colloquium of Soil Zoology in Prague, in September, where he organised a meeting of the Soil Pests Group of the Organisation Internationale de Lutte Biologique Contre les Animaux et Plantes Nuisibles. J. B. Free, Ingrid Williams and C. G. Butler (who acted as President) attended the VII Congress of the International Union for the Study of Social Insects in London in September.

Sandwich course students who worked in the department were P. Elvin, M. P. Nicholls and J. Short.



https://doi.org/10.23637/ERADOC-1-130 