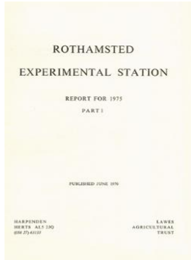
Report for 1975 - Part 1

Full Table of Content


ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1975
PART 1

Entomology Department

C. G. Butler

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Introduction

In yet another mild winter, aphids were caught in the high level suction traps of the Insect Survey as early as the first week in January. Indeed, before the first aphid bulletin of the year had been published, that for the week ending 13 April, 93 aphids belonging to 17 different species, 12 of which are of agricultural importance, had been caught. Fortunately, however, despite this early start, the cold weather in April greatly diminished the size of the primary migration of aphids to most agricultural crops. Some cereal crops were already infested by this time, otherwise what threatened to be an early and bad year for aphid damage did not materialise (p. 118). This emphasises once again the unpredictability of crop infestation in Britain and the necessity for regular monitoring of the movements of pests.

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In 1974, virus damage to potatoes and sugar beet was widespread. Fortunately, it was not repeated on the same scale during 1975, probably because the cold weather in April affected *Myzus persicae*, the aphid vector of this disease. However, the serious damage experienced in 1974 resulted in renewed interest in this aphid, which is still probably our most dangerous agricultural pest. An effort is now being made, in collaboration with entomologists in ADAS, DAFS, MAFF, SHRI and the North and West of Scotland Agricultural Colleges, to relate aerial samples of this aphid to crop samples of it on potatoes, and on sugar beet in collaboration with workers at Broom's Barn, the ultimate objective being to provide an efficient and economical early warning scheme for *M. persicae* on *all* crops.

The possibility mentioned in last year's Report of monitoring pea moth economically and efficiently by means of pheromone traps has been the subject of a feasibility study, made in collaboration with Dr. M. Saynor and other ADAS workers. Trapping at 13 sites in East Anglia and Kent has confirmed the advantages of this method. Even though the traps used proved subsequently to be of a relatively ineffective design and were baited with codling moth sex pheromone (instead of that of the pea moth which was not then available) moths were detected at 12 of the sites 2–21 days before eggs were found. The rapid progress that has been made in identifying and producing a pea moth sex attractant, and in trap design and placement, since this feasibility study was completed, offers prospects of much more sensitive monitoring and efficient early warning of infestation (p. 123).

Further comparative observations on pest damage to direct-drilled and conventionally sown crops by insect and other soil animal pests continue to indicate that direct-drilled crops tend to be less severely attacked by insect pests, but more by slugs, than conventionally sown ones. However, attacks by soil insects, such as leatherjackets and wireworms, have not been heavy at any of the experimental sites so far and results of further trials will be awaited with interest (p. 127).

Slug damage, particularly to direct-drilled crops, has stimulated further work to try to improve upon the current, unsatisfactory methods of slug control. The chief problem seems to be that of bringing the slugs into contact with molluscicides. The possibility of doing this by exploiting their normal food-finding and other behaviour mechanisms is, therefore, being explored (p. 130).

The harm done to honeybees by viruses has become more than ever apparent during the past few years. Apart from the now well-known virus diseases of chronic paralysis and sacbrood, both of which are much commoner than was once believed, there are losses, seemingly mostly in late winter, caused by acute bee-paralysis virus and bee virus X. Probably harm is done, in Britain at least, by two more viruses—Arkansas bee virus and slow paralysis virus—found in recent years. Now, a further virus that sometimes destroys many queen prepupae has been found in Britain, and two viruses, which can multiply in the Western honeybee, *Apis mellifera*, have been isolated from the Eastern honeybee, *Apis cerana*. All these viruses are unrelated to each other, and most of the properties of many of them, together with their natural history, require elucidation (p. 132).

The Rothamsted Insect Survey

The aphid bulletin was sent out regularly each week, but occasionally with some missing values, because of postal delays in trap catches reaching Rothamsted.

The differences between aphid species, in both the size of populations and in seasonal timing, were striking and resulted as much from the hot, dry summer as from the unusual spring. The bean aphid, *Aphis fabae*, was notably absent in 1975 because of failure of the 1974 autumn migration (Table 1) due to bad flying weather in September and October.

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TABLE 1

Mean number of Aphis fabae *per site for the spring, summer and autumn migrations in the South of England (south of latitude 52°N), 1965–75*

Number of sites	Year	Spring	Summer	Autumn
1	1965	80·0	390·0	2·0
1	1966	6·0	100·0	51·0
2	1967	38·0	573·5	5·0
3	1968	4·3	16·7	16·7
4	1969	15·2	1249·7	54·5
6	1970	12·3	387·2	10·8
6	1971	22·2	202·3	10·8
6	1972	4·2	677·8	60·3
7	1973	46·6	265·4	89·9
7	1974	28·0	310·1	6·1
8	1975	3·1	94·5	8·1

TABLE 2

Time of arrival of first aphid in 1975 compared with mean dates for the previous six years' catches, by regions

	Annual mean date of arrival					1975 days earlier (+) or later (−) than mean				
	All traps	SE	Midlands	N	SW	All traps	SE	Midlands	N	SW
A. pisum	2/6	16/5	28/5	18/6	9/6	−4	−13	−8	−7	+14
A. fabae grp.	4/6	27/5	24/5	23/6	5/6	−23	−18	−49	−13	−14
Aphis spp.	3/6	28/5	23/5	21/6	2/6	+3	−9	+14	−4	+10
A. rubi	8/6	8/6	13/5	4/7	10/6	−11	+4	−30	−27	+12
A. solani	29/5	20/5	18/5	28/6	18/5	+10	−4	+10	+20	+12
B. helichrysi	20/5	15/5	18/5	4/6	14/5	+10	+18	−5	+9	+18
B. brassicae	5/7	19/6	27/6	14/8	21/6	+16	+16	+16	+14	+18
C. aegopodii	23/5	17/5	22/5	4/6	18/5	+3	−4	+4	−4	+15
Cinara spp.	25/6	9/6	25/6	6/7	1/7	+8	−7	+9	+5	+26
D. platanoidis	18/5	16/5	14/5	21/5	20/5	+4	−1	+2	+1	+11
D. plantaginea	14/7	12/6	29/6	23/8	23/7	−27	−48	−50	−14	+7
E. abietinum	14/5	13/5	11/5	21/5	11/5	=	−1	−3	+2	+3
E. ulmi	14/6	9/6	10/6	21/6	16/6	−8	−12	−3	−3	−14
H. pruni	13/6	8/6	11/6	22/6	11/6	−24	−18	−21	−16	−41
H. lactucae	3/6	25/5	27/5	24/6	31/5	−5	−4	−16	−11	+11
M. euphorbiae	30/5	21/5	24/5	21/6	24/5	+13	+6	+12	+16	+18
M. viciae	29/6	14/6	28/6	12/7	2/7	−4	−23	+1	+9	−3
M. dirhodum	24/5	23/5	16/5	16/6	12/5	+23	+38	+1	+1	+19
M. festucae	14/5	7/5	8/5	5/6	5/5	+18	+36	+2	+9	+16
M. ascalonicus	28/4	25/4	17/4	15/5	27/4	+13	+31	+10	+4	+2
M. certus	24/5	19/5	16/5	22/6	25/5	+10	+4	+15	+7	+13
M. ornatus	26/5	21/5	23/5	24/6	4/5	+36	+27	+33	+28	+56
M. persicae	1/6	22/5	23/5	2/7	21/5	+11	+11	−2	+15	+19
N. ribisnigri	5/6	27/5	30/5	21/6	3/6	−7	−6	−18	−8	+1
Pemphigus spp.	27/6	20/6	25/6	6/7	29/6	−21	−32	−20	−15	−16
P. fragaefolii	9/7	10/7	24/6	27/7	5/7	+30	+34	+6	+36	+45
P. humuli	8/6	26/5	28/5	3/7	8/6	−3	−8	−8	+3	+1
P. fagi	5/6	29/5	4/6	6/6	14/6	−5	−24	−6	+5	+5
R. insertum	28/5	30/5	13/5	9/6	28/5	−11	−11	−22	−16	+4
R. maidis	11/7	28/6	24/7	21/7	2/7	−2	−8	+16	+13	−30
R. padi	18/5	7/5	26/5	4/6	5/5	+40	+26	+48	+20	+65
S. avenae	25/5	17/5	22/5	15/6	16/5	+8	+6	+5	+6	+13
S. fragariae	3/6	22/5	24/5	3/7	28/5	+10	+8	+6	+7	+19

S.E. = ADAS South-eastern and Eastern Regions
Midlands = ADAS East and West Midland Regions and Lancashire
N. = Yorkshire the ADAS Northern Region and Scotland
S.W. = ADAS Wales and South-western Regions

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The summer migration, mainly from beans and beet, was very low in 1975, in contrast to that of 1974, producing a low autumn migration in spite of suitable weather for flight. It is expected, therefore, that bean aphid damage in 1976 will be slight.

The cabbage aphid, *Brevicoryne brassicae*, and the potato aphid, *Macrosiphum euphorbia*, were early, whereas the mealy plum aphid, *Hyalopterus pruni*, was late. Cereal aphids of the genera *Metopolophium* and *Sitobion* were early, but *Rhopalosiphum insertum* was late. Two of the *Myzus* species, *ascalonicus* and *ornatus*, were very early but, apart from an isolated very early flier, *persicae* was not (Table 2). *M. dirhodum*, *M. festucae* and *S. avenae* were abundant, especially in the Midlands, whilst *R. insertum* was scarce. *M. certus* and *M. ornatus* were very common, whilst *Megoura viciae*, the vetch aphid, was as rare as *A. fabae* (Table 3), and the carrot aphid, *Cavariella aegopodii*, was almost so.

TABLE 3

Level of pest aphid populations in 1975 compared with mean values for the previous six years' catches, by regions

	Annual mean per trap					1975 as % of annual mean				
	All traps	SE	Mid-lands	N	SW	All traps	SE	Mid-lands	N	SW
A. pisum	79	229	34	32	20	58	42	115	87	95
A. fabae grp.	710	1009	1047	544	240	11	18	1	20	7
Aphis spp.	181	216	319	102	87	58	66	14	149	93
A. rubi	8	8	10	4	9	200	200	110	75	400
A. solani	18	15	29	9	19	217	160	324	100	152
B. helichrysi	895	1193	1487	213	686	93	131	70	160	55
B. brassicae	126	265	83	10	144	171	187	270	110	91
C. aegopodii	588	775	1239	128	211	10	15	5	21	14
Cinara spp.	12	19	10	12	8	42	21	30	75	62
D. platanoidis	758	619	1030	988	394	36	6	55	36	32
D. plantaginea	30	67	23	2	27	30	19	22	25	70
E. abietinum	249	133	47	621	196	87	28	221	33	264
E. ulmi	122	151	233	73	33	8	7	6	18	12
H. pruni	740	1476	695	578	211	17	6	4	66	11
H. lactucae	43	68	53	18	34	142	135	164	117	132
M. euphorbiae	71	90	78	80	38	224	127	379	142	297
M. viciae	6	8	11	2	3	33	12	36	100	7
M. dirhodum	528	1164	153	670	127	225	128	1427	136	136
M. festucae	97	175	115	59	38	351	46	893	291	218
M. ascalonicus	81	126	124	39	34	123	82	154	126	168
M. certus	10	19	13	2	6	540	274	900	125	400
M. ornatus	8	9	9	4	10	300	311	211	225	420
M. persicae	155	242	153	122	101	175	147	267	189	91
N. ribisnigri	20	25	20	9	25	60	60	65	78	48
Pemphigus spp.	490	403	327	383	846	36	50	58	23	26
P. fragaefolii	1	1	2	1	1	800	80	150	2600	200
P. humuli	795	832	2124	8	214	13	25	8	37	19
P. fagi	167	381	70	203	13	19	1	7	57	31
R. insertum	2399	1670	1847	2803	3275	15	15	25	12	11
R. maidis	18	18	7	24	22	111	83	186	162	59
R. padi	5418	4809	4151	6416	6295	63	53	141	42	41
S. avenae	853	2096	501	371	444	350	164	723	630	578
S. fragariae	164	250	211	63	131	65	55	65	60	87

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Cutworm damage has been reported, particularly on carrots, and autumn populations on sugar beet are high. Analysis of changes in the annual distribution of pest species, initially *Agrotis segetum*, *Apamea secalis* and *Noctua pronuba* have been started to try to discover sites for short-term forecasting of their numbers, if this is feasible, and to provide background phenology and population dynamics for work on their pathology (p. 129).

The succession of mild winters and this year's very hot summer in some areas, produced unusual records for moths, as for aphids. Some winter species appeared much earlier than usual, e.g. *Phigalia pilosaria*, the pale brindled beauty, was caught in early December at Wye, whereas it is usually recorded in February and March, and *Oporinia* spp. were recorded from August onwards at many sites whereas late September to November are their expected months for flight. (Taylor, French and Woiwod)

Bean aphids

Production of area forecasts for *Aphis fabae* infestations was continued in collaboration with Professor M. J. Way (Imperial College). Egg counts and peak aphid numbers on the winter host, *Euonymus europaeus*, in 1974/75 were low and a correct forecast of 'unlikely damage' was made. Preliminary results indicate that in the Harpenden district *A. fabae* populations will be small in 1976. (Fletcher)

Cereal aphids

Ecology. Cereal aphids attacking winter wheat were monitored during May, June and July. Weekly counts being made on all plants in ten, 0·3 m lengths of row, distributed both within and at the edges of the crop. Aphids on a small strip of spring wheat nearby were counted in July only.

On 14 May, nymphs of *Sitobion avenae* and *Metopolophium dirhodum* were found at the edges, and one apterous adult *S. avenae* with nymphs in the centre, of the field. Numbers increased slowly during June, and a few *S. fragariae* were found, but total numbers remained small. However, during the last week in June and the first fortnight in July, the number of *S. avenae* increased greatly when migrating alatae settled on the developing ears and produced many nymphs. The greatest number of specimens of *M. dirhodum* were found at the edges of the crop on 9 July. After this date, the numbers of both species of aphids declined rapidly, presumably because of the many predators present, and on 28 July only one *S. avenae* was found within the crop. The principal predators were: Coccinellidae (*Halyzia 14-guttata*, *Coccinella 14-punctata*, *C. 7-punctata*, *Adalia 2-punctata*), Chrysopidae (*Chrysopa carnea*), a few Syrphidae (*Syrphus balteatus*, *S. lunata*, *Melanostoma mellinum*) and Anthocoridae (*Anthocoris nemorum*). The greatest number of aphids on the spring wheat were found on 15 July, a week later than on winter wheat, when many specimens of all stages of *S. avenae* were counted, mainly on the ears. However, the greatest number of *M. dirhodum* was found during the previous week, many specimens in all stages being present. Predators were again active and the aphids had disappeared by the end of July.

In June 1975, fewer parasitised aphids ('mummies') were found than in the same month in 1974. From 62 mummies that were collected, chiefly in July, the following were reared: 39 *Aphidius* spp. (chiefly *A. uzbekstanicus*, *A. urticae* and *A. picipes*) and 23 hyper-parasites (6 *Asaphes vulgaris*, 5 *Dendrocerus carpenteri*, 3 *D. breadalbimensis*, 5 *Alloxysta victrix*, 1 *Phaenoglyphis* sp.). (Jones)

Alternate hosts. Established plots of the grasses *Poa trivialis*, *Festuca rubra*, *Agrostis tenuis*, *Holcus lanatus*, *Dactylis glomerata*, *Lolium perenne*, and of spring wheat and barley were regularly examined for cereal aphids. *Rhopalosiphum padi* was the most abundant

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species attacking the grasses, being present on all of them in every month except April. It was commonest on *P. trivialis*, *A. tenuis* and *R. perenne*, but became much more abundant on the wheat and barley. *Metopolophium dirhodum* was present on the grasses only in very small numbers and then only during the period May–July when it was plentiful on adjacent cereal plots. *Sitobion avenae* was less numerous than *M. dirhodum* on the cereals, but more abundant on the grasses, being found on all six species but, like *M. dirhodum*, only during May, June and July. (Henderson, Welch and Greenwood)

Carabid beetles and aphid populations. Although there have been many reports of carabid beetles preying on cereal aphids, no quantification of this possibly important relationship seems to have been attempted. In 1975, therefore, carabid populations on a crop of winter wheat were manipulated by means of polythene barriers, some plots having naturally occurring populations and others experimentally diminished or increased populations. The numbers of carabids in all plots were assessed three times a week and cereal aphid populations were assessed every ten days. Unfortunately, the numbers of cereal aphids and of beetles were low, nevertheless significant negative correlations were obtained between numbers of cereal aphids and total carabid beetles, and also between cereal aphids and the numbers of three species of carabids, *Harpalus rufipes*, *Feronia madida* and *Agonum dorsale*, respectively. (Edwards and Jones, with Mr. K. George, MAFF Plant Pathology Laboratory)

Fungal diseases of aphids

***Entomophthora* spp. attacking bean aphids.** Observations on Rothamsted farm have shown that fungi of the genus *Entomophthora* often kill many bean aphids (*Aphis fabae*). Unfortunately they usually fail to do so until after the bean crop has become seriously damaged and it is probable that these fungi are not sufficiently abundant early enough in the season to prevent this damage. The possibility of controlling the aphids before serious damage occurs, by increasing the populations of suitable fungi present early in the season, was investigated in 1975. Separate experimental plots were treated in one or other of the following ways: (1) with a suspension in water of resting spores of *E. virulenta* on 10 and 25 July and (2) with live aphids infected in the laboratory with *E. aphidis*, *E. fresenii*, *E. planchoniana* and *E. thaxteriana* on 9, 10 and 11 July. After treatment, numbers of aphids and incidence of infection by *Entomophthora* spp. in each plot were assessed weekly. It was found that the percentage of infected aphids in the treated plots was no greater than in the untreated ones, in which the mean maximum level of infection, mainly by *E. planchoniana*, was 48% on 23 July. Perhaps the fungi were distributed too late in the season, or too sparsely, or the dry conditions during the trial prevented the resting spores from germinating and the fungi from spreading. Nevertheless, *E. fresenii* was found in samples a week earlier in those plots in which infected aphids had been released than in the other plots, and *E. virulenta* was detected in two aphids from a plot that had been treated with resting spores of this species. These results suggest that these two fungi can be artificially introduced into bean aphid populations and that further trials aimed at causing a high level of infection early in the growing season are desirable. (Wilding and Brobyn, with Mr. C. A. Dedryver, École Nationale Supérieure Agronomique de Rennes)

Infection of bean aphids by *Entomophthora fresenii*. The process of infection of *A. fabae* by *E. fresenii* has been studied histologically as part of a series of studies of the processes affecting the distribution and abundance of those species of *Entomophthora* that commonly attack aphids in Britain.

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Anadhesive secondary conidia of *E. fresenii*, but probably not primary conidia, are directly infective and aphids were inoculated as follows. Primary conidia discharged from infected aphids were collected on tap water agar. Within 16 h most of these had germinated to form anadhesive conidia on long, vertical, capillary conidiophores. Healthy aphids were inoculated by touching them gently against the conidia which instantly dehisced from the conidiophores and adhered to the aphids. In less than 4 h some of the conidia had germinated and the tip of each short germ tube had swelled and flattened against the insect's cuticle to form an appressorium, a structure that has not previously been recorded for any fungus in this genus. Further development either continued immediately or ceased for up to 54 h. A fine tube, 3μ diameter, passed directly from the appressorium into the aphid and almost spherical hyphal bodies budded off into the haemocoele where they multiplied by binary fission. The solid tissues, in the approximate order, fat tissue, anterior ganglion, muscle and embryo, were invaded only after the aphid's haemocoele had become packed with hyphal bodies, shortly before it died. Whereupon, the hyphal bodies lengthened and produced conidiophores which emerged uniformly over the surface of the aphid, as in aphids infected in nature. They did not aggregate in groups like the conidiophores of other species investigated. Also, as in nature, pseudocystidia and rhizoids were not produced, and infected aphids remained attached to the host plant by their probosces inserted in the plant tissue. Infected aphids died four or five days after inoculation at 20°C. (Brobyn and Wilding)

Culture of *Entomophthora muscae*. *E. muscae* is an important pathogen of adult wheat bulb flies, especially in early July soon after the flies have emerged. However, even at this time, infective material for use in experiments cannot regularly be obtained from the field. Accordingly, attempts were made to culture this fungus in the laboratory. It grew weakly on bacteriologically-filtered, but not heat-sterilised, beef extract agar supplemented with citrated human blood, but did not survive subsequent transfer to fresh medium. (Wilding and Boucher)

This fungus cannot be cultured in wheat bulb flies that have been reared in the laboratory because they are not susceptible (*Rothamsted Report for 1972*, Part 1, 207–208). However, cabbage root flies (*Erioischia brassicae*) cultured in the laboratory were readily infected by caging them in a moist atmosphere with infected cabbage root flies from the field. The fungus can be transmitted from them to healthy wheat bulb flies caught in the field, which can then be released again to infect further adult wheat bulb flies. (Wilding)

Wheat bulb fly

Population studies. Populations of eggs in fields on Rothamsted farm in the winter 1974/75 were moderate. Stackyard had 1·5 million ha^{-1}, somewhat less than Great Harpenden and Broadbalk, both of which had 2·4 million ha^{-1}. The larval population in Stackyard had been almost eliminated early in 1974 by sowing, accidentally in the autumn of 1973, seed that had been dressed with insecticide, so that the substantial egg population the following winter must have been laid by flies originating elsewhere on Rothamsted farm or surrounding land. This supports earlier evidence indicating considerable local movement of adult flies.

Development from eggs to adults emerging in the summer of 1975 was followed in Great Harpenden and Stackyard fields. The survival rate was exceptionally low, being 5·5% in Great Harpenden and 1·4% in Stackyard, compared with a mean of 18% in Stackyard for the years 1964–74. Larval mortality was not excessive and most deaths seem to have occurred either during the pupal stage or during adult emergence, perhaps because of the unusually hot and dry weather at the time. (Fletcher, Jones and Bardner)

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Adult activity. In both Great Harpenden and Stackyard fields adult activity was small in the autumn of 1975, and the egg populations were 0·17 and 0·20 million ha^{-1}, respectively.

Records of adult activity in Stackyard field for the last six years are now available. These were mostly obtained from water traps, which provide a reasonable comparison of adult activity over the crop and over bare fallow, and correlate with data on times of emergence and times of egg-laying. Unfortunately, water-trapping is of little use for predicting egg populations. Water trap catches are not correlated with the numbers of eggs laid in different fields in the same season (*Rothamsted Report for 1974*, Part 1, 108), and the same is also true for differences between years in Stackyard. Thus, the mean catch of adult females per trap per day on bare fallow during the egg-laying period was 0·11 in 1972 (when 4·2 million eggs ha^{-1} were laid) and 0·56 in 1973 (when only 1·5 million eggs ha^{-1} were laid). The colour of the traps affects the numbers caught, indicating that flies are attracted by the traps, and it seems that attractiveness of the traps varies from season to season. Three years' data obtained by suction-trapping in Stackyard appear to be better related to the numbers of eggs laid. (Fletcher, Jones and Bardner)

Effect of larval attack on young wheat plants. Winter wheat seedlings at seven different stages of growth were inoculated with newly hatched wheat bulb fly larvae, placed in controlled environment cabinets, and development of the plants followed. The growth stages used ranged from plants with a single shoot and one leaf to plants with three shoots and eight leaves. Eighteen pots of each growth stage, ten plants in each pot, were divided into three groups: (1) each pot inoculated with five wheat bulb fly larvae, (2) each pot inoculated with five wheat bulb fly larvae and after four weeks the unattacked plants removed, (3) control pots with no larvae. The temperature and lighting in the controlled environment cabinets were arranged to correspond with field conditions.

Most of the plants with a single shoot and a single leaf succumbed; plants that had two or three leaves when attacked had survival rates of 40 and 80%, respectively; plants attacked at later growth stages did not die. In every growth stage, plants whose main shoots were attacked grew more slowly than those whose tillers were attacked, and ear emergence was delayed. Little or no difference in growth rates and times of ear emergence were observed between plants with attacked and unattacked tillers. (Jones and Fletcher)

Phenology of insects in a wheat field

Studies, using pitfall traps, of populations of insects in Stackyard field, part of which is under wheat and part under bare fallow every year, were continued. In May, many specimens of the carabid beetle, *Agonum dorsale*, moved into the crop from the outside and gradually dispersed throughout it. During the hot weather in June and July, the commonest carabids present, *Pterostichus melanarius* and *Harpalus rufipes*, were very inactive in comparison with earlier years. During September and October, many adults of another beetle, *Nebria brevicollis*, moved into the field and became widely dispersed in it. (Jones)

Strawburning

The practice of burning straw after harvesting cereals has become common and widespread and, since 1973, studies have been made to determine its effects on soil animals. Soil animal populations have been compared in plots treated in four ways: (1) straw chopped and spread, (2) straw baled and removed, (3) straw spread and burnt, (4) straw burnt in rows. Populations of surface-living animals were studied by pitfall trapping and by sampling with a portable suction apparatus. Soil-living species were sampled in soil

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cores, which were divided into strata, the animals being extracted from them in modified high gradient Tullgren funnels. The results have been very clear-cut in all experiments: (1) populations of earthworms were unaffected, (2) numbers of true soil invertebrates remained unchanged, (3) populations of surface-living macro-fauna, especially slugs and carabid beetles, were slightly decreased, (4) numbers of surface-living micro-fauna were drastically decreased (Table 4). (Edwards and Lofty)

TABLE 4

Effects of strawburning on arthropod numbers

(Suction samples)

	Burnt spread	Burnt in rows	Straw removed unburnt	Straw chopped and spread
Acarina	10	60	368	89
Araneida	17	48	161	174
Collembola	1605	804	4813	8752
Insecta	1	4	100	41
Total	1633	916	5442	9056

Studies of the effects of stubble burning in Stackyard field have also been made, using pitfall and emergence traps to sample populations of Coleoptera, Diptera, Hemiptera and Psocoptera, with similar results. (Jones)

Pea moth

Further work on developing a monitoring system for pea moth has followed two main lines: finding and field-testing attractants for adult males, and the design and placement of attractant traps.

Sex attractants. In 1974, various unsaturated alcohols and acetates were field-tested as attractants for male pea moths, and the sex pheromone of the closely related codling moth [(E,E)-8,10-dodecadienol] was found to be weakly attractive (*Rothamsted Report for 1974*, Part 1, 109–110). Subsequently, the electroantennographic (EAG) responses of the male pea moth to a range of saturated and unsaturated aliphatic compounds were examined and many of these substances were tested in the field during the summer of 1975.

EAG responses to saturated alcohols and acetates (C_{10}–C_{16}) were compared with the response to (E,E)-8,10-dodecadienol as a standard (figures quoted are mean responses of five insects on a scale with standard = 1). These tests showed that the acetate function is much more important than the hydroxyl; for example, the mean response to dodecyl acetate was $3{\cdot}21 \pm 0{\cdot}41$, compared with $0{\cdot}006 \pm 0{\cdot}006$ for dodecanol. There is also a sharp decrease of activity in acetates with chain lengths greater than C_{12} (e.g. mean response to tridecyl acetate = $0{\cdot}52 \pm 0{\cdot}13$). These results suggested that the shorter chain compounds, particularly C_{12} acetates, might affect the sexual behaviour of the males. Tests with mono-unsaturated alcohols and acetates strengthened this prediction. The C_{12} acetates elicited much larger responses than C_{12} alcohols or C_{14} acetates, although the pattern of responses with respect to position of unsaturation was similar in all three groups of compounds. In any one group the largest response was recorded when the double bond was at C-10: (E)-10-dodecenol = $1{\cdot}18 \pm 0{\cdot}19$, (Z)-10-tetradecenyl acetate = $0{\cdot}92 \pm 0{\cdot}08$, and (E)-10-dodecenyl acetate = $21{\cdot}06 \pm 3{\cdot}66$. The pattern of responses was similar to that obtained by Roelofs *et al.* (*Science* (1971), **174,** 297) with codling moth, using mono-unsaturated C_{12} alcohols, and which led them to predict that

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its sex attractant is a C-8, C-10 di-unsaturated C_{12} alcohol. Thus, with pea moth, large EAG responses were obtained to dodecenyl acetates with the double bond at C-8 and C-9, as well as at C-10. This, together with the weakly attractive properties of the di-unsaturated alcohol [(E,E)-8,10-dodecadienol] suggested that the di-unsaturated acetate [(E,E)-8,10-dodecadienyl acetate] might be active. EAG tests confirmed this, the level of response being similar to that for the most promising mono-unsaturated acetate [(E)-10-dodecenyl acetate]. Field trapping confirmed the EAG results; the two acetates, (E)-10-dodecenyl acetate and (E,E)-8,10-dodecadienyl acetate, were the only compounds with attractive properties. They are both better attractants than (E,E)-8,10-dodecadienol ($\times$ 47 and $\times$ 12, respectively) but at one-tenth the dose. Thus the prospects for a sensitive monitoring system for the pea moth based on sex attractant traps have been greatly improved, and a patent covering the use of these attractants has been filed. (Wall with Greenway, Insecticides and Fungicides Department)

Antennal morphology. The electrophysiological sex attractant bioassay in its present form is based on the measurement of the summated electrical potential responses of many sense cells. One complication is that it is difficult to attribute behavioural significance to the results; thus an inhibitor might be indistinguishable from an attractant. Accordingly, the detailed morphology of the antenna of the pea moth has been examined in preparation for single sensillum electrophysiological assays; the prime objective being to identify the receptor(s) for the sex attractants and to establish whether compounds having synergistic or inhibitory activity are perceived at the same or different receptor sites.

There is little sexual dimorphism in gross antennal morphology; in both sexes there are about 55 flagellar segments, 60–70 μm long by 60–100 μm wide. Each segment bears several types of sensillum on its ventral surface—the principal sensory area. Five main types of sensillum have been found. (Wall, with Jones and Turner, Plant Pathology Department)

Trap design and placement. Field experience in 1974 had shown wide variability in catches by different types of trap containing virgin female pea moths as lures, but because the females 'called' (released sex pheromone) erratically, comparison between designs was difficult. In 1975, six designs of trap containing synthetic sex attractant were compared to find an effective and convenient model, and to try to establish some basic principles by which trap design could be rationalised. Simple, horizontal, sticky plates, roofed with a bent aluminium sheet to form a tube of equilateral triangular section (18 cm long $\times$ 8 cm wide) consistently caught most moths, often more than 100 per trap per day. Generally, the more elaborate designs, including traps with solid or perforated baffles, caught fewer moths. Observations, and film of moths approaching traps, showed that the flight path towards a triangular trap, from 2–3 m down wind, was more direct than to most other designs. An explanation for these differences was sought using smoke dispersed from traps to simulate the probable shape and track of pheromone plumes emanating from each model sited in pea fields. The plumes were photographed, their shape and extent measured, and compared with wind direction. The greater the linearity imparted to the plume by a trap, the greater the catch. Wind tunnel tests using 'cold' smoke dispensed from scale models of traps confirmed this. These results not only provide a basis for improving the design of pheromone traps in general, but give important leads to understanding the behavioural mechanisms involved in orientation by weakly-flying insects to pheromone sources.

The vertical placement of traps within a crop was also shown to be extremely important. Profiles of wind speed measured in a pea crop from ground level to twice crop height showed a marked change in velocity at about half crop height. Below this level wind

https://doi.org/10.23637/ERADOC-1-132

speed was very slow in calm or windy weather, but above it speed increased rapidly. These differences were reflected in the catches at different levels, the vertical distribution of moths changing with different wind speeds. In winds of more than 2 m s^{-1} (measured at crop level), traps at ground level were most effective, whereas in winds of less than 2 m s^{-1}, traps at twice crop height caught most moths. As well as demonstrating an interesting aspect of behaviour by the adult pea moth, these results show that the trap position most useful for consistent monitoring during a period when the weather is uncertain is at approximately half crop height, not above the crop as has hitherto been widely believed. (Lewis and Macaulay)

Culturing and developmental studies. The basis for much of the work on the pea moth has been the cultural and developmental studies in the laboratory. Some progress has been made in developing an artificial diet but most moths have still to be cultured individually on fresh peas. Measurements of the duration of the preoviposition period and incubation of eggs at different temperatures have been continued. (Sturgeon, with Professor T. Bosman, University of Natal)

Pests of maize

The agronomic problems of growing grain maize and sweet corn have been studied for several years. The principal pests are chloropid flies. Unfortunately, there is a complex of species which are very difficult to distinguish from each other, the commonest being the frit fly, *Oscinella frit*. The incidence of attack by this 'frit complex' varies considerably from year to year. In 1974, for example, the percentage of plants showing symptoms of attack was 100% for sweet corn and 33% for grain maize in plots unprotected from attack, whereas the comparable figures for 1975 were 10% and 1%. It is still uncertain whether this variation between years is caused by fluctuations in the populations of egg-laying flies, or whether it is caused by variation in the time of seedling emergence relative to the time when adult flies lay eggs. Ten per cent phorate granules drilled with the seed at the rate of 1·68 kg phorate ha^{-1} is the most consistently satisfactory method of controlling frit fly.

TABLE 5

Effect of phorate on yields of grain maize and sweet corn

	1973	1974
Grain maize t ha^{-1}		
No insecticide	6·48	1·23
phorate	6·64	1·38
SE of differences	±0·311	±0·100
Sweet corn, saleable cobs, t ha^{-1}		
No insecticide	3·70	0·66
phorate	8·60	2·01
SE of differences	±0·506	±0·420

Phorate more than doubled the yield of sweet corn, as will be seen in Table 5, but had no measurable effect on the yield of grain maize, even when 33% of the plants showed symptoms of attack, as in 1974.

Possible reasons for this difference in response have been examined in the laboratory. There was no difference in the oviposition preferences of flies between grain maize and sweet corn, though both were much less attractive than oat seedlings. There was also little difference in the survival of larvae in the two maize varieties, although, in the field, fewer grain maize plants showed symptoms of attack. The greater tolerance of grain maize to attack seems to be due to its much faster growth rate. The response to phorate

https://doi.org/10.23637/ERADOC-1-132

treatment may not be entirely due to the control of frit fly. Judenko (*PANS* (1969), **15**, 553–557) found that phorate increased yield even when plants were not attacked by this pest. However, glasshouse experiments with both sterilised potting loam and unsterilised field soil from Rothamsted farm failed to show any effect of phorate on the growth of sweet corn.

The other major pests of sweet corn are birds, which preferentially attack sweet corn seedlings when they are grown beside grain maize. However, phorate and other insecticide treatments had no effect on the numbers of plants damaged by birds. (Fletcher and Bardner)

Invertebrates and pasture productivity

In collaborative work with members of the Grassland Research Institute, Hurley, on the importance of the invertebrate fauna of grassland it has been found that application of pesticides to reduce insect populations often results in increased growth of grass. During 1975, further aspects of this phenomenon were examined.

Upland pastures. Previous research was concentrated chiefly upon intensively managed swards, consisting entirely or mostly of ryegrass, in lowland situations. During 1975, an exploratory series of small field trials was initiated on upland and enclosed hill pastures of more varied composition at around 300 m above sea level. Applications of aldrin and phorate were made in 13 replicated, small-plot experiments in ten counties of England and Wales. In contrast with the results obtained on more productive lowland ryegrass swards no significant increase in yield of dry matter was obtained. (Henderson, Welch and Greenwood, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Seasonal distribution of herbage yield. The growth rate of a sward of S_{24} perennial ryegrass, receiving 376 kg N ha^{-1} year^{-1} and cut at 28-day intervals, was raised by the application of insecticide. The effect was most pronounced at the beginning and end of the growing season. Between early April and mid-May, growth of the treated sward exceeded that of the untreated by between 2 and 10 kg dry matter ha^{-1} day^{-1}. From early June the treated sward grew progressively faster than the untreated, until in late September its growth rate was greater by 19 kg dry matter ha^{-1} day^{-1}. (Henderson, Welch and Greenwood, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Varietal differences in sward deterioration. Although it is possible to diminish yield losses in ryegrass swards by frequent application of very small doses of a non-persistent insecticide, the use of possible plant resistance to pest damage is to be preferred. Considerable variation in the response of grasses to the same insecticide treatment was obtained in a field trial with nine species or varieties of ryegrass, and one each of timothy and cocksfoot. Diploid varieties of perennial ryegrass appeared to benefit less from treatment, or to be more resistant to pest damage, than tetraploid varieties. It was interesting that while the normally short-lived westerwolds ryegrass (Baroldi), hybrid ryegrass (Grasslands Manawa), and Italian ryegrass (RVP) died out under normal management, they persisted when treated with insecticide. (Henderson, Welch and Greenwood, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Long-term effects of insecticide treatment. Continued treatment of a sward of S_{24} perennial ryegrass, started at Hurley in 1969, with large doses of persistent insecticides, increased the yield of grass in the first and last harvests, in July and September, respectively. However, for the first time the annual yield of dry matter was not increased to a significant extent. The fall in performance of the treated sward may perhaps be associated

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with the continued build-up of litter on these plots and of the increased density of their soil. (Henderson, Welch and Greenwood, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Soil fauna

Leatherjackets. The limited amount of ADAS regional survey data available, mainly from the south west region, suggests that where, in 1974, there were high larval populations, in 1975 populations showed very little increase, in some cases a marked decrease, whereas those places with low populations in 1974 have shown increases. Since the places with high 1974 populations are those most likely to have had high levels of infertility among adult females, and those with low larval populations little or no adult infertility, the observed changes in larval populations are much as anticipated (*Rothamsted Report for 1974*, Part 1, 111–112).

Catches of adult *Tipula paludosa* in two light traps at Rothamsted showed a slight increase in numbers to 1384 in 1975, compared with 1152 in 1974. Because in 1974 a large proportion of adult females did not develop eggs, this small increase in adult numbers presumably reflects a high rate of survival in a small larval population in very favourable conditions. The pattern of catch in 1975 was similar to that of 1971–73, peak numbers occurring over five weeks, in contrast to 1974 when the great majority of adults were caught in one week. Those females that emerged early in July and August, had normal, fully-developed ovaries. Many of those trapped during the September peak carried no eggs; preliminary examination indicates that in some ovaries did not develop, but there also seems to have been a much higher proportion than usual of individuals that had already laid their eggs. (Bowden)

An experiment was begun in 1974 on Road Piece field, Rothamsted Farm, to study the factors controlling leatherjacket populations. When the experiment began the leatherjacket population was nearly 7·4 million ha^{-1}. Cages (3·6 × 2·7 m) covered with 200 mm aperture nylon mesh were placed on plots in November 1974 and February 1975. Also in November some plots were covered with sheets of corrugated plastic (3·6 × 3·0 m) supported on wooden posts. Soil samples were taken in May and July 1975, and the leatherjackets extracted from them (Table 6).

TABLE 6

Effect on leatherjacket populations of protecting plots from rain and predation by birds

Treatments	Number of leatherjackets recovered
Caged in November 1974	24
Caged in February 1975	16
Uncaged	10
Protected from rain	0

There is a strong suggestion that predation and desiccation are important in controlling larval populations. (Edwards and Lofty)

Effects of direct-drilling on the soil fauna. Long-term studies on the effects of direct-drilling on soil animals were continued and expanded in 1975. The results previously reported (*Rothamsted Report for 1974*, Part 1, 112–113) for earthworms, millipedes, carabid and staphylinid beetles, and dipterous stemborers, have been confirmed in rotational experiments sponsored by the Letcombe Laboratory at three sites and by NIAE on continuous wheat, at two sites, and on continuous barley, at one site. Attacks by stemborers were consistently greater in conventionally-planted crops than in direct-

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drilled ones. More carabid and staphylinid beetles were active in ploughed than in unploughed soil. Slug attacks were consistently greater in direct-drilled crops, and more earthworms were present under direct-drilled crops than under conventionally-cultivated ones (Table 7), *Lumbricus terrestris* in particular being favoured by direct-drilling. Leatherjacket attacks tended to be greater on conventionally-cultivated crops than on direct-drilled ones.

TABLE 7

Effects of direct-drilling (D-d) on earthworm populations

		Numbers in field quadrats		
Group	Site	Direct-drilled	Ploughed	Ratio D-d: ploughed
Lumbricus terrestris	Rothamsted	61	25	2·4
	Woburn	323	103	3·1
	Boxworth	22	4	5·5
	Silsoe	150	48	3·2
Other species	Rothamsted	858	603	1·4
	Woburn	1315	1140	1·2
	Boxworth	789	663	1·2
	Silsoe	492	196	2·5

Total soil animal populations have been assessed by means of soil sampling and some of the results are summarised in Table 8. There were consistently more soil animals in the direct drilled land than in that which was conventionally-cultivated. Soil mites (Acarina) tended to be favoured by direct-drilling rather more than the springtails (Collembola). Conversely more insect larvae were present in conventionally-cultivated soil. (Edwards and Lofty)

TABLE 8

Effects of direct-drilling (D-d) on arthropod populations

		Number extracted from soil		
Group	Site	Direct-drilled	Ploughed	Ratio D-d: ploughed
Acarina (Mites)	Rothamsted	922	629	1·5
	Boxworth	2551	2340	1·1
	Silsoe	95	50	1·9
	Northfield	476	400	1·2
	Englefield	1231	398	3·1
	Compton Beauchamp (A)	1407	656	2·1
	Compton Beauchamp (B)	1577	918	1·7
Collembola (Springtails)	Rothamsted	99	77	1·3
	Boxworth	485	447	1·1
	Silsoe	451	117	1·3
	Northfield	389	294	1·3
	Englefield	765	327	2·6
	Compton Beauchamp (A)	473	335	1·4
	Compton Beauchamp (B)	1777	1568	1·2
Insecta	Rothamsted	36	44	0·8
	Boxworth	123	156	0·8
	Silsoe	8	12	0·7
	Northfield	7	18	0·4
	Englefield	57	12	4·7
	Compton Beauchamp (A)	114	138	0·8
	Compton Beauchamp (B)	42	49	0·8

Pesticides and the soil fauna. Several new pesticides were tested in 1975. The effects of diflubenzuron ('Dimilin'), a compound that kills insects by interfering with chitin deposition, were studied. It had no effects on earthworms in laboratory or field. Labora-

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tory assays on adult carabid beetles showed no effects; however, in field tests some diminution of populations was caused, probably by inhibiting pupation. Most soil animals, except Collembola, were relatively unaffected by this insecticide in the field.

The effects of two other insecticides, carbophenothion and chlorpyrifos on soil animals were also tested in the field. Neither had much effect on earthworms or soil arthropods. (Edwards and Lofty)

Effect of a herbicide on the soil fauna. An intensive study of the effects of chlorthiamid, a dichlorthiobenzamide, on the soil fauna was made in 1975. Populations of soil animals have been sampled periodically in a long-term orchard trial of this herbicide which started in 1962. Plots have been treated annually with 4, 8 or 16 kg a.i. ha^{-1}. This herbicide has been found to be slightly toxic to earthworms and the cumulative effect in plots given 16 kg ha^{-1} has been to eradicate earthworms completely in five years; the toxic effects being reinforced by shortage of live or dead plant material on which they could feed. In some plots on which treatments ceased in 1967 there are now signs of recolonisation by earthworms, although there are still many fewer than in untreated plots. The effects of this compound on arthropod populations has been comparatively slight, but the breakdown of beech leaf discs buried in the treated plots in nylon mesh bags has been about half that in untreated plots. (Edwards and Stafford)

Pathogens of cutworms

Pathogenicity and host range. A cytoplasmic polyhedrosis virus (CPV) from *Noctua pronuba* and a microsporidan from *Agrotis exclamationis*, both of which infect midgut tissue only, can kill caterpillars relatively quickly when fed in sufficient concentration, although both these types of pathogen are usually considered to cause chronic infections of low pathogenicity. Doses of either the CPV, in the range 5×10^3 to 5×10^6 polyhedra per larva, or of the microsporidan, in the range 1×10^5 to $6{\cdot}4 \times 10^6$ spores per larva, killed all larvae before pupation. With the most concentrated inocula, the CPV killed some *N. pronuba* larvae after only 11 days, and the microsporidan killed some *A. exclamationis* larvae after only 15 days.

When the microsporidan from *A. exclamationis* was fed to the larvae of another noctuid moth, *Spodoptera frugiperda*, feeding and growth of the larvae were significantly decreased within 9–12 days; preliminary observations on the original host, *A. exclamationis*, had indicated a similar effect. The growth rates of some *N. pronuba* larvae infected with CPV had also become significantly depressed within nine days of inoculation.

Tests on the host range of various noctuid pathogens showed that CPV from *N. pronuba* infected larvae of *Phlogophera meticulosa* but not of *A. exclamationis* or *A. segetum*; neither was *A. segetum* infected by a CPV from *Trichoplusia ni*. A nuclear polyhedrosis virus (NPV), isolated elsewhere from *Autographa californica*, infected *A. exclamationis* and *S. frugiperda* larvae. The microsporidan from *A. exclamationis* infected larvae of *N. pronuba* and *P. meticulosa* in addition to *S. littoralis* and *S. frugiperda* but not those of *A. segetum*. The identical morphology of the spores obtained from the different hosts suggests that these infections were of the inoculated microsporidan rather than of latent microsporidan infections stimulated by the experimental conditions. (Sherlock)

Slugs

Estimation of slug populations. The efficiency of the Bristol ADAS leatherjacket soil-washing apparatus in recovering slugs from soil samples has been tested. Soils seeded with known numbers of immature slugs were treated. Ninety per cent of the specimens of

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Agriolimax reticulatus and 100% of those of *Arion hortensis* were recovered from six 300 × 300 × 150 mm samples of garden loam. Smaller percentages of *A. reticulatus* (81%) and of *A. hortensis* (78%) were recovered from five similar samples of heavy clay with flints in which timothy grass was growing. This loss of slugs was probably due to the grinding action of the flints and stones in the soil-washing drum. Each sample took about 1 h to wash and all the vegetation in the sample had to be teased separately. It was concluded that use of this machine offered little advantage over other methods of estimating slug populations, especially when samples of heavy clay soils were involved. (Stephenson)

Attraction of slugs by plant extracts. A bioassay technique has been developed by means of which it is possible to compare the attractiveness of aqueous plant extracts to slugs. The conventional Y-tube olfactometer has been modified so that hungry, dark-adapted slugs (*Agriolimax reticulatus*) are induced to move to the junction of the arms of the Y, where they choose between filter-paper substrates saturated with the test solutions. Their choices are recorded after 15 min and 20 replicates are run in each trial. Using this technique, the attractiveness of extracts of plants occurring in the slug's natural habitat have been compared with that of the well-known bait, aqueous wheat-bran extract. The relative attractiveness of extracts of young and senescent leaves has also been examined.

Extracts of *Taraxacum officinale*, *Chenopodium album*, *Plantago major*, *Ranunculus repens*, *Polygonum aviculare*, *Glechoma hederacea* and *Urtica dioica*, although not repellent to slugs, attracted them significantly less than a standard wheat-bran extract. Extracts of *Daucus* sp. root and of *Zea mays* meal were at least three times as attractive as the wheat-bran standard. The reasons for such preferences are being sought. Slugs failed to distinguish between extracts of fresh and senescent leaves of *Urtica dioica* and of *Plantago major*. (Stephenson and Butler)

Sexual behaviour. A field population of *Agriolimax reticulatus* has been examined to determine the relative weights at which slugs become sexually mature, copulate and lay eggs. *A. reticulatus* tends to copulate with individuals of similar weight, though the weight range over which copulation may occur is large (300–1200 mg).

Keeping slugs in constant darkness for three or four weeks abolishes their diurnal rhythm of activity, and dark-adapted slugs have been used in behavioural experiments to assess whether *A. reticulatus* follows slime trails. Neither immature, nor sexually mature inactive slugs, exhibit this phenomenon to any great extent, but slugs that had been engaged in courtship behaviour before being used in tests did follow the slime trails of their partners. This response appears to be species specific. The physiological basis of this behaviour is being investigated. (Gibb)

Honeybees

Queen rearing and swarming. It has been stated that a honeybee colony can be induced to swarm by removing its queen (thus allowing queen rearing) and then returning her when the colony has produced and sealed some queen cells. This treatment failed to produce swarming when applied to small colonies in August and September 1967, in an attempt to induce efficient queen supersedure. Few colonies swarm naturally in August and September, so in 1975 the experiment was repeated on ten small colonies in June, a time of year when natural swarming is frequent. Whereas in the August and September experiments the queen cells produced were immediately destroyed when the queens were returned, in June they mostly survived until the queens began to emerge from them. Despite their toleration of queen cells, however, none of the colonies treated in June swarmed. (Simpson)

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Queen rearing methods. Because the presence of a queen in a honeybee colony usually inhibits the colony from rearing queens spontaneously, it has generally been thought that a colony that is to be used for queen rearing must be made and kept queenless—at least during the earliest stages of queen cell development. Recent evidence from Israel has suggested that queenlessness is only beneficial after the queen cells have been sealed by the bees, but preliminary tests at Rothamsted have suggested that, although at each stage of the queen rearing process, colonies that have not been dequeened often perform satisfactorily, they also sometimes fail disastrously.

It has been commonly recommended that the process of transferring larvae from worker cells to artificial queen cell cups to be reared as queens should be done at relatively high temperatures (25°C or more). However, exposing larvae for 2 h to cold, desiccation or starvation, failed to do obvious damage (*Rothamsted Report for 1971*, Part 1, 222–223). With exposures of about 24 h, keeping larvae at 35°C (the temperature in a honeybee colony) or at room temperature, either with uncontrolled humidity or in a saturated atmosphere to avoid desiccation, killed nearly all of them, whereas many larvae kept at 10° or 15°C survived. It seems, therefore, that when larvae have to be kept temporarily out of a colony, they do better when kept cool than warm. Low temperature probably delays starvation by lowering the metabolic rate, and certainly makes humidity maintenance unnecessary. (Simpson)

Queen recognition by workers in a colony. In the behaviour known as 'balling' a tight, buzzing mass of worker bees forms round a queen and slowly kills her. Worker bees only ball something that they can touch, or to which they can get very close. When a queen with a small ball around her was suspended in a wire-gauze cage in an observation hive, the ball extended outside the cage only when and where it touched the cage walls. If the ball did not touch the walls, the worker bees outside the cage appeared to ignore it even when air was blown into the cage, over the ball and through the cage walls to the bees in the hive. Nevertheless, since a ball does not grow to a diameter of more than 10–15 cm its growth cannot be only by a chain reaction and must be limited by attenuation of something coming from the queen or from the few bees that can touch her. A large ball can form on a piece of filter-paper on which a queen's mandibular glands, but not other parts of her head or body, have been crushed. It was shown that the active substances were volatile, unstable, or present only in trace amounts or only effective at high concentrations. (Simpson)

Substitutes for the queen honeybee pheromone, 9-oxodec-2-enoic acid. Wright (*Nature* (1972), **239**, 226) has claimed that insects respond to chemical stimuli on the basis of their infra-red (i.r.) vibrations rather than by a 'stereochemical fit' mechanism. According to this theory, a compound, the i.r. absorptions of which are sufficiently similar to those of another compound known to elicit a particular behavioural response, would stimulate the same response even though chemically dissimilar. To test this theory further, various readily available compounds (2-heptanone, 2-octanone, 3-octanone, p-methyl acetophenone, benzyl acetone, phenyl acetate, citronellyl acetate, dibenzyl ether, secbutylamine and methyl N-methylanthranilate) were selected from a library of i.r. spectra for their similarity to 9-oxodec-2-enoic acid and were field tested for attractiveness to drone honeybees; none of these compounds proved to be attractive, neither did they inhibit nor synergise the attraction of 9-oxodecenoic acid. (Butler and Welch, with Greenway, Insecticides and Fungicides Department, and Professor R. H. Wright, University of British Columbia)

Value of white clover to honeybees. The verges of motorways are sown with a seed

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mixture of four grass species and white clover. The variety of white clover most commonly used is S.100. However, beekeepers have reported that honeybees do not obtain much, if any, nectar from this strain, and would prefer a variety that yields abundant nectar. In order to choose a better variety for sowing on motorway verges, five varieties of white clover, Wild White, New Zealand, Sabeda, S.184 and S.100, were sown and counts of bees foraging on their flowers were made regularly. In 1975, the variety S.100 was visited for both nectar and pollen as freely as the other varieties. Measurements of the flower parts showed that the mean length of the corolla tube was slightly greater than that of Sabeda but less than those of the other varieties, so that the nectaries were easily accessible to honeybees. Thus, no evidence was obtained that the variety S.100 is of less value to honeybees or that honeybees might benefit if the variety in the seed mixture used was changed. However, because the weather was exceptionally dry in 1975 and nectar production may have been abnormal, observations will be continued in 1976. (Free and Williams)

Pollination

Pollination requirements of oilseed rape. Oil from many varieties of oil-seed rape contains up to 50% erucic acid which may be associated with certain heart ailments. Plant breeders have produced new varieties of both *Brassica napus* and of *B. compestris* which have little erucic acid, some of which are now being grown commercially in this country. The *Brassica napus* varieties grown in the past are regarded as self-fertile whereas the *B. campestris* varieties are believed to require cross-pollination to set seed. To ascertain any differences between varieties, the pollination requirements of seven varieties of *B. napus*—Oro, Midas, Zephyr, Turret, Janetshis, Erglu and Maris Haplona—and of two varieties of *B. campestris* have been compared with those of the main spring rape variety of *B. napus* grown in 1974, Gulle.

Flowers of plants grown in a glasshouse were either left untreated, self-pollinated by hand with pollen from the same plant, or cross-pollinated by hand with pollen from another plant. The *B. napus* varieties varied greatly (30–80%) in their ability to set pods by autopollination in the still air of the glasshouse. Both self- and cross-pollination increased the percentage of flowers that set pods, but cross-pollination did not increase set more than self-pollination. The number of seeds per pod was also greater on self- and cross-pollinated plants than on the untreated controls. *B. campestris* varieties set only about 10% of their flowers with no hand-pollination and the resulting pods contained few seeds. Self-pollination increased both the percentage of flowers that set and the number of seeds per pod, but not as much as cross-pollination.

It is not yet known whether the new varieties, particularly those with little ability to autopollinate, are adequately pollinated in the field. (Free and Williams)

Bee disease

Several previously undescribed viruses have been isolated from honeybees: *Apis* iridescent virus and Kashmir *bee* virus from the Eastern honeybee, *Apis cerana*, and black queen-cell virus from the Western honey-bee, *Apis mellifera*.

Apis iridescent virus. This virus occurred abundantly in a sample of several hundred specimens of *Apis cerana* found sick in Kashmir (Central Bee Research Institute, Khadi, and Village Industries Commission, India) and sent to Rothamsted for diagnosis. Almost all the bees were also infested with *Acarapis woodi*, but a similar sample, received almost a year later, contained much *Apis* iridescent virus only.

Apis iridescent virus is at present the only virus of its kind isolated from Hymenoptera, and it very closely resembles the iridescent viruses previously found in Diptera, Coleoptera

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and Lepidoptera. It is, for example, physically indistinguishable from *Tipula*, *Sericesthis* and *Wiscana* iridescent viruses, and similarly contains DNA; but it is only distantly related serologically to these viruses and, unlike them does not multiply in *Galleria mellonella*. It infected *Apis mellifera* in laboratory tests, by injection and feeding, and it multiplied in various tissues, such as the hypopharyngeal glands and fat-body, which became iridescent blue. However, the infected bees showed no outward symptoms, and their length of life in laboratory tests was not shortened. In the field, therefore, *Apis* iridescent virus might well take long to cause obvious sickness, as do the iridescent viruses of other insects. Nevertheless, eventually it appears to cause severe damage to honeybee colonies. (Bailey and Ball, with Woods, Plant Pathology Department)

Kashmir bee virus. This virus occurred in small amounts in the first sample of *A. cerana* from which *Apis* iridescent virus was isolated. It multiplies abundantly when injected into *A. mellifera* in the laboratory and kills adult bees within a few days. It has isometric particles about 30 nm across and contains RNA, but it is serologically unrelated to any of the other known bee viruses. (Bailey and Ball, with Woods, Plant Pathology Department)

Black queen-cell virus. In many batches of worker larvae grafted into queenless honeybee colonies, to be reared as queens, a few individuals die as prepupae and from time to time batches occur in which a substantial proportion of the individuals die in this way. Characteristically, black patches develop on the walls of the queen cells, probably due to moisture and fluids from the decomposing prepupae. Some of these prepupae were found to have been killed by sacbrood virus, but in July many contained much of a previously unrecognised virus. The virus has isometric particles about 30 nm across, and contains RNA. It is serologically unrelated to any other known bee virus, but it reacted fairly strongly with antisera that had been prepared against (1) partially purified acute bee-paralysis virus from adult bees in 1969 at Rothamsted and (2) partially purified Arkansas bee virus from adult bees in 1972 in the USA. This suggests that black queen-cell virus is widespread, and is commonly carried as an inapparent infection by adult bees. The virus does not appear to multiply much when injected into adult bees, but worker larvae are susceptible when the virus is fed to them and freshly killed prepupae resembled those killed by sacbrood. Although in these and other respects black queen-cell virus resembles sacbrood virus, it differs markedly from it in several important ways, including the fact that it has only one major protein, whereas sacbrood virus has three. (Bailey, Ball and Simpson, with Carpenter and Woods, Plant Pathology Department)

Staff

In March, T. Lewis and C. Wall attended a symposium at Wageningen, Netherlands, on 'The evaluation of biological activity', and, in October, accompanied by E. D. M. Macaulay, they visited Wageningen again to attend the inaugral meeting of the OILB Pheromone Working Party.

J. B. Free visited Iran for a fortnight in April to give advice regarding the beekeeping industry, and in October spent three weeks visiting the International Crops Research Institute for the Semi-Arid Tropics at Hyderabad, India, to give advice on legume pollination. Ingrid H. Williams also visited this Institute at the end of the year to give specialist advice and participate in a study of insect pollinators of the pigeon-pea.

L. Bailey attended the III International Congress of Virology in Madrid in September, at which he convened a workshop on RNA viruses of insects.

C. A. Edwards visited Copenhagen in March to attend a meeting of the Cereal Pests Group of the International Organisation for Biological Control. He also organised a

https://doi.org/10.23637/ERADOC-1-132

symposium for the Soil Pests Group of which he was chairman, which J. R. Lofty also attended. In June, he attended a meeting of the Pests and Diseases Group of IIRB in Louvain, Belgium. From 19 July to 4 August he visited the International Institute for Tropical Agriculture, Ibadan, Nigeria as a consultant on behalf of the Ministry of Overseas Development.

J. Bowden also visited Africa from 15–21 December at the invitation of the Entomological Society of Nigeria.

Dr. A. Tomlin, Canada Agricultural Research Branch, London, Ontario, worked in the soil animal section of the department from September 1974 until August 1975, and Professor G. K. Veeresh, University of Agricultural Sciences, Bangalore, India, also spent July and August working on soil animals. Professor T. Bosman, University of Natal, South Africa, worked on pea moth diets with members of the insect behaviour and physiology section from April to August 1975. Mr. C. A. Dedryver of the École Nationale Supérieure Agronomique de Rennes, also visited the Department during July to August and worked on pathogenic fungi.

Gillian Barwise, A. Burrows, Derek Holdaway, Susan Lewin, Audrey McReath and Jane Soul left and Ann Cameron (Potato Marketing Board scholar), Brenda Cox, Mary Creighton, Barbara Goult and J. I. Laband joined the department. I. H. Haines and O. L. Idowu obtained Ph.D. degrees of London University and Sally Wallbank obtained an HNC in applied biology. S. Boucher, B. Hughes, Joanne Laker and Jane Wickham worked as sandwich course students for six months.

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https://doi.org/10.23637/ERADOC-1-132 pp 21

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