ROTHAMSTED RESEARCH

Report for 1974 - Part 1

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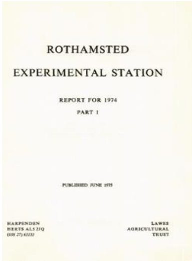

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Introduction

During 1974, suction traps at two new sites became operational, making a total of 18 sites in Great Britain and two on the Continent at which aphids and other airborne insects are sampled continuously for the Rothamsted Insect Survey (RIS). Whereas catches of aphids at the Zeeland site conformed reasonably well with expectations based on catches at sites in south-eastern England, catches at the site near Copenhagen were very different from those at sites at about the same latitude in north-eastern England and south-eastern Scotland. This increases the evidence about aphids, possibly viruliferous ones, invading Britain from the Continent, which would further complicate the inherently difficult problems of pest assessment and control in Britain where crop damage has always been erratic. In this context, the continuous monitoring of airborne pests by RIS has

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again shown its value. The seed potato disaster in Scotland, whatever the other contributory factors may be, has been clearly shown to be related to the migrations of potato aphids during the last two years only because all airborne aphids are monitored by RIS whether they are currently thought to be important or not (p. 105).

Monitoring of pests by suction-trapping is not, unfortunately, effective for some species, such as the pea moth, the present spray-warning system for which is based on field counts of its eggs, which is not only laborious but also often unreliable. The discovery of substances controlling the behaviour of pea moths has made it possible to devise a more sensitive, convenient and economical method of detecting the presence of this pest at many sites over a wide area, and thus providing more accurate local assessments of the need to spray (p. 109).

Examination of the possibility of controlling aphids attacking various crops by using parasitic fungi has reached the stage where field trials are worthwhile. The problem is that although field observations have shown conclusively that fungi kill many of these pests, they tend to do so after the aphids have done much damage. This may be because the fungi are not abundant enough early in the year to diminish the early aphid population sufficiently to prevent it building up to serious proportions. Methods of culturing the fungi have been developed and ways of dispersing them in the field early in the season are being tried (p. 107).

The Rothamsted Insect Survey

The first aphid bulletin was issued for the week 1–7 April, two weeks earlier than in 1973 and three weeks earlier than the average for the previous six years; it recorded seven species. The spring migration of aphids south of Newcastle was early and large and numbers continued to be above average until well into June; north of Edinburgh this migration was late. In contrast, the summer migration was larger than average north of Edinburgh and well below average south of Newcastle, except at Starcross, Devon, thus confounding most expectations. After the middle of July, numbers of all species were below average, with the striking exception of *Myzus persicae* which was three times as common as usual at the end of July and beginning of August.

Over the whole of Britain the autumn migration of aphids has been small, less than ever recorded for some species, and daily flights fluctuated violently with temperatures near to flight thresholds. The last bulletin issued was No. 31, 28 October–3 November. This is the largest number of bulletins issued in a season, the previous highest being 29 in 1973.

Taking the year as a whole, all the cereal aphids were less common than usual except *Metapolophium festucae*; *Aphis fabae* was uncommon in many areas and *Pemphigus* spp. were abnormally so. In contrast, the potato aphids, *Aulacorthum solani*, *Macrosiphum euphorbiae* and *Myzus persicae*, were twice as common as usual (see later). In all, eight species of aphids were more abundant than usual and 12 species less common (Table 1).

Two new aphid sampling stations began operating in 1974; one at Lancashire College of Agriculture, Preston, which was included in the 1974 bulletins, and the other at the West of Scotland Agricultural College, Auchincruive, Ayr, which will be incorporated in 1975.

Aphid catches at the only temporary sampling station, that at Rainham, Essex, have justified the claims made by farmers and ADAS officers, that this area is infested earlier, on average, than the surrounding ones. However, it does not appear to receive a greater influx of aphids than elsewhere so that, if the resulting damage is greater, this tends to confirm the view that the timing of infesting migrations is at least as important as their size.

Aphid transmitted potato viruses, especially leaf-roll, have increased in the Scottish

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TABLE 1

Level of pest aphid populations in 1974 compared with mean values for the previous five years' catches, by regions

	Annual mean/trap					1974 as % of annual mean				
	All traps	SE	Mid-lands	N	SW	All traps	SE	Mid-lands	N	SW
A. pisum	114	266	43	32	22	35	16	37	104	52
A. fabae grp.	803	1090	1365	575	265	45	55	30	67	43
Aphis spp.	201	208	401	107	89	66	123	39	73	87
A. rubi	5	8	7	3	6	277	144	224	329	442
A. solani	11	10	28	4	18	268	395	106	967	113
B. helichrysi	629	1098	1309	199	592	169	151	141	141	195
B. brassicae	148	308	114	10	169	23	16	17	102	11
C. aegopodii	416	787	1135	119	185	139	91	127	147	185
Cinara spp.	11	14	10	11	7	208	323	117	173	115
D. platanoidis	670	687	763	1017	410	92	40	205	83	76
D. plantaginea	31	64	27	2	28	94	134	53	16	64
E. abietinum	303	128	43	720	190	44	125	122	18	120
E. ulmi	111	178	267	71	38	56	11	61	117	25
H. pruni	1071	1664	842	677	233	30	32	48	13	44
H. lactucae	47	69	69	17	40	72	89	31	157	64
M. euphorbiae	64	68	78	63	37	189	300	100	266	125
M. viciae	5	8	12	2	3	89	98	59	93	77
M. dirhodum	901	1321	158	723	142	29	28	90	56	35
M. festucae	72	127	83	57	37	251	329	213	118	120
M. ascalonicus	56	95	105	35	33	229	293	153	170	103
M. ornatus	6	7	9	4	9	207	237	126	202	217
M. persicae grp.	329	257	189	118	117	203	65	43	123	20
N. ribisnigri	20	25	23	9	28	66	108	61	100	37
Pemphigus spp.	586	467	424	442	1000	17	18	32	20	8
P. fragaefolii	8	1	3	1	1	194	167	22	227	464
P. humuli	527	631	2569	9	101	162	291	48	51	774
P. fagi	109	282	78	234	14	31	15	69	19	47
R. insertum	2729	1918	1941	3182	3723	31	22	85	28	28
R. maidis	25	20	9	29	25	21	32	40	6	40
R. padi	7053	5432	5664	7065	7375	30	31	20	45	12
S. avenae	1098	2364	618	393	461	39	32	43	67	77
S. fragariae	154	260	253	60	131	80	76	50	134	99

Regions: SE is ADAS regions South-east and East, SW is Wales and South-west, Midlands is East and West Midlands and Lancashire, N is Yorkshire, the remainder of northern England and Scotland.

seed growing areas during the last two years and are causing concern. Dr. L. A. D. Sparrow, of the Department of Agriculture and Fisheries for Scotland at East Craigs, and Dr. M. W. Shaw of the North of Scotland College of Agriculture have independently concluded from examination of the Survey records that early migration of *Myzus persicae*, like *Macrosiphum euphorbiae* and *Aulacorthum solani*, during the last two years, is a likely cause. It is planned to investigate this possibility by attempting to relate aerial population to crop infestation near the Scottish trap sites. The relation between aphids, especially *M. euphorbiae*, and potato disorders in England is mentioned elsewhere in this Report (p. 241).

ADAS officers have for many years examined 160-leaf samples of apple trees from about 50 orchards in the southern half of England, to monitor the annual abundance of oviparae

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of *Rhopalosiphum insertum*. The annual changes in mean numbers recorded from 1968 to 1973 agree remarkably well with changes in the total number of migrant gynoparae returning in autumn as determined by RIS trap samples in the same area from mid-September to the end of October (Table 2). Although this relationship requires biological interpretation, it adds considerably to the confidence with which aerial samples may be used instead of crop samples to monitor certain species of pests. (Taylor and French)

TABLE 2

Rhopalosiphum insertum *autumn population monitoring in southern England, 1968–73*

	1968	1969	1970	1971	1972	1973
Crop sample (ADAS) (oviparae/10 leaves)	18	50	7	19	44	4
Aerial sample (RIS) (gynoparae in hundreds)	22	46	7	29	19	4

Bean aphids

Population studies of *Aphis fabae* on its winter, summer and autumn host plants were continued in collaboration with Professor M. J. Way (Imperial College). The number of eggs on spindle bushes (*Euonymus europaeus*) were relatively high (0·2 eggs/bud) in the winter 1973/74 and the heavy infestations of spring beans in 1974 were correctly forecast. Preliminary results indicate that in the Harpenden district *A. fabae* populations will be much smaller in 1975. (Fletcher)

Cereal aphids

Ecology. As in 1973, sample counts of aphids on spring barley and winter wheat were made at Rothamsted, twice a week from mid-May until the end of July. Aphids were counted on the plants growing in ten, 0·3-m lengths of row, distributed both within and at the edges of each crop.

On 16 May, *Sitobion fragariae* was the first aphid to be found on the edge and within a crop of winter wheat, but from 20 May onwards, *S. avenae* and *Metopolophium dirhodum* were commoner. The greatest numbers of aphids were found on 27 June at the edge of the crop and on 1 July within it, thereafter their numbers declined rapidly and an increasing proportion were found to be parasitised, reaching 100% both at the edge and within the crop by 17 July. Afterwards there was a further small colonisation of plants at the edge of the field by alatae of the above three species together with *Rhopalosiphum padi*. From 1 July, some aphids infected by fungi, *Entomophthora* spp., were found.

The pattern of infestation of spring barley by aphids was similar to that of winter wheat. On 16 May, nymphs of *S. avenae* and *M. dirhodum* were found on plants at the edge of the crop and one nymph of *M. dirhodum* within it. Thereafter the number of aphids increased more rapidly at the edge than within the crop, reaching their peaks on 27 June and 20–24 June, respectively. An alate *S. fragariae* with nymphs was found at the edge of the crop on 22 May and another within it on 29 May, but there were many fewer of them than of *S. avenae* and *M. dirhodum*. After the June peaks, fewer live aphids were found but more dead ones that were parasitised by insects and fungi. (Jones)

Alternate hosts. The relative abundance of cereal aphids on wheat, barley and on six of the commonest grass species was studied in a field experiment in which colonising alate aphids were offered plots of each potential host growing in pure stands. Results during the establishment year were affected by the differences in rates of germination and growth of cereals and grasses, but marked differences in aphid populations on each host were found.

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It became clear that sampling techniques that were suitable for use with cereals were inappropriate with grasses, and a suction-sampling method was found to be the most efficient way of collecting samples from each kind of crop, while reducing sampling variation caused by varying plant density and weather conditions. Identification of the many, small, wingless aphids collected has been facilitated by developing a chromatographic technique for this purpose. (Henderson and Welch)

Fungal diseases of aphids

Infection of aphids by *Entomophthora* spp. Histopathological studies of aphids infected by species of *Entomophthora* have been continued to find out more about the ways in which these parasitic fungi develop and infect new hosts. Such information should help explain field observations on the rates at which they spread, and on changes in the relative abundance of the different species and in host susceptibility. This information will, it is hoped, enable ways to be devised of using these fungi to help control aphid pests.

Formation of rhizoids by *Entomophthora aphidis*. Rhizoids of *E. aphidis* begin to differentiate, before the cystidia, as swollen hyphae just within the ventral surface of an infected pea aphid, *Acyrthosiphon pisum*. The most anterior rhizoids are the first to penetrate the aphid's cuticle, emerging between its fore-legs, usually before it dies. Each rhizoid is a single, multinucleate hyphal filament, which, on reaching the substrate, produces finger-like branches at its apex to form a holdfast; the swollen base of the rhizoid remaining inside the aphid becomes highly vacuolated.

Infection of bean aphids by *Entomophthora planchoniana*. Studies of the infection of *Aphis fabae* by *E. planchoniana* show that the fungal conidia adhere to any part of the host's body; some germinate immediately but others not until 36 h later. The germ tube penetrates the aphid's cuticle and multiplies in its haemocoele, but does not invade its solid tissues until shortly before the aphid dies; indeed parts of some tissues have not been attacked by the time that conidiophores begin to appear. The rhizoids, bundles of apparently undifferentiated hyphae, emerged after the host died but before the conidiophores emerged along a central band on the ventral surface of the abdomen. Conidiophores formed from hyphae that converged dorsally and laterally, but not ventrally, to points just beneath the cuticle. They did not form in the head. (Brobyn and Wilding)

Wheat bulb fly

Population studies. The number of eggs in Stackyard field, Rothamsted farm, decreased from 4·2 million/ha in the winter 1972/73 to 1·5 million/ha in the winter 1973/74. Plant attack in 1974 began at the end of January, the larval population reaching its peak of 1·2 million/ha by early March. However, larval mortality was unexpectedly high, the number of larvae becoming very small by early April. Investigation showed that the site had, unfortunately, been sown with insecticide-dressed seed and further work had to be abandoned.

Adult activity. Because of a great reduction in the number of flies emerging in Stackyard and Great Harpenden fields (0·025 million/ha) and the scarcity of other emergence sites on Rothamsted farm, a considerable decrease in adult activity was expected. However, many flies were caught in these fields during 1974, indicating that flies had flown in from elsewhere.

Other evidence was obtained supporting earlier indications that adult wheat bulb flies disperse quickly and widely when they emerge in early summer. Late-sown spring wheat was especially attractive to gravid female flies in late August and September, suggesting that it could be used as a trap-crop on which to kill them with insecticides.

The greatest number of females with ripe eggs was caught during the first fortnight of August, although some contained them on 16 July, and a few had laid their first batches of eggs by 22 July. No evidence was obtained of females laying their second batches of eggs before the last week of August, and none were found that had laid a third batch by 30 September, when trapping ceased.

No correlation was obtained between the numbers of eggs found at eight sites on Rothamsted farm and the numbers of adult, female flies caught in water traps at these sites, showing that such local trapping is useless as a method of forecasting the number of eggs that will be laid in a field. (Fletcher and Jones)

Alternative hosts. Further laboratory work, using six genera (nine species) of wild grasses, demonstrated the ability of the wheat bulb fly to complete its life cycle on several grasses. The bulb flies completed their development on all of these except cocksfoot (*Dactylis glomerata*) and winter oats (Peniarth). Survival rates on most grasses compared favourably with those on winter wheat, and on couch grass (*Agropyron repens*) were even greater. Three per cent of the shoots of samples of couch grass collected on Rothamsted farm were infested with wheat bulb fly larvae, but no adult flies were subsequently caught at the sites from which the samples were taken. Field investigations have so far failed to implicate wild grasses as important reservoirs of this pest. (Fletcher)

Infection by *Strongwellsea castrans* and *Entomophthora hylemyiae*. The resting spores of *S. castrans* and the conidia of *E. hylemyiae* have never been described. As both species of fungus attack the same few species of flies, including the wheat bulb fly, they might represent different stages in the life cycle of the same fungus. In order to find out, healthy female wheat bulb flies were infected with conidia of *S. castrans*. Four of the 25 flies infected in this way were subsequently found to contain resting spores of *E. hylemyiae*, indicating that the latter is the resting spore stage of *S. castrans*.

Flies that emerged in cages and old flies collected in the field that were resistant to infection by *E. muscae* were found to be susceptible to infection by *S. castrans*. This accords with the observation that *S. castrans* usually infects wheat bulb flies in the field during August and September when the peak of infection by *E. muscae* is usually well past. It is not known, however, whether older flies are more susceptible to infection by *S. castrans* than younger ones or whether the fungus is absent from the field in an infective form until August. (Wilding)

Infection by *Entomophthora muscae*. A previous observation (see *Rothamsted Report for 1972*, Part 1, 207–208) that adult wheat bulb flies collected in the field were much more susceptible to infection by *E. muscae* than adults reared (in cages in an outdoor shelter) from puparia collected in the field has been confirmed. However, flies collected in the field as adults also lost their susceptibility when kept for a few days in cages in the shelter. Flies reared from puparia in such cages were no more susceptible to *E. muscae* transferred from infected flies caught in the field where these puparia had been collected than to *E. muscae* from other sources. This suggests that the difference in susceptibility between flies reared from puparia and those caught in the field was not due to adaptation of the fungus to the flies from this particular area. Perhaps it was due to the absence of some chemical in the flies that emerged in cages that is essential for fungal development.

The susceptibility of adult flies collected in the field diminished as the season progressed and the flies became older. This corresponds with field observations that maximum infection occurs in July when most of the flies are still young. (Wilding)

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Field incidence of fungal infection. Samples of about 100 adult wheat bulb flies were taken each week from 2 July until the end of August from sites at Pondersbridge, Cambridgeshire, and at Hunsdon, Hertfordshire, to estimate the incidence of fungal infection. *E. muscae* infected many flies at Hunsdon in early July (maximum 68% on 9 July) but was not found at Pondersbridge until 18 July and then infected few flies. No infected flies were found at either site after 14 August. Resting spores were found in five of a total of 11 infected flies from all samples at Pondersbridge and in six of 149 at Hunsdon.

S. castrans first infected flies at Pondersbridge on 25 July, the proportion infected reaching a maximum of 75% on 21 August. At Hunsdon, the first fly infected with *S. castrans* was caught on 6 August and the percentage infected was greatest (43%) on 14 August. The proportion of infected flies containing resting spores (= *E. hylemyiae*) increased progressively during the season. (Wilding)

Phenology of insects in a wheat field

Studies of populations of insects in Stackyard field, part of which is under wheat and part under bare fallow every year, using pitfall and emergence traps, were continued, a similar picture to those of previous years being obtained. From the drilling of winter wheat in November 1973 until mid-March 1974 spiders and beetle larvae were the principal animals caught in the pitfall traps, thereafter more adult carabid and staphylinid beetles appeared, but catches were smaller than in 1973. Until mid-May more were caught in the fallow than in the young wheat crop, but thereafter the position became reversed. The cold, wet weather after harvest diminished the beetles' activity, fewer being caught.

Many entomobryid springtails, small dipterous flies and a few parasitic hymenoptera were caught in emergence traps over the stubble in October 1973. In February 1974 many small chironomid and some cecidomyid flies were caught in the emergence traps on the fallow. During the spring and summer small diptera were dominant, the greatest number of species being caught in mid-June. (Jones)

Pea moth

Flight and mating behaviour. Pea moths (*Cydia nigricana*) can fly when the air temperature at crop level reaches 18°C; most flight activity in June and July occurring between 16.00 and 18.00 h B.S.T. Evidence collected on their dispersal is conflicting; some moths readily fly upwards and are blown downwind, but most appear to fly locally just above the crop. Virgin female pea moths attract males by emitting a potent sex pheromone, from glands at the tips of their abdomens, to which males quickly respond by flying upwind to the source of attractant. (Lewis, Macaulay and Wall)

Monitoring with traps. The number of males caught in sticky and water traps containing live virgin females as lures was compared with catches in standard 23 cm diameter suction traps exposed at overwintering sites. The sticky traps caught on average 17 times more moths than the suction traps, and the water traps 130 times more. On warm afternoons, when the virgin females in the traps emitted sex pheromone (called) persistently, catches in sticky and water traps were, respectively, about 25 and 300 times greater than in the suction traps. This suggests that traps containing sex pheromone could be used to detect the presence of males at population densities two to three orders of magnitude less than suction traps, and that they would, therefore, detect the arrival of immigrants into pea crops sooner than suction traps or than field workers could do by searching for their eggs.

For a widespread monitoring system based on pheromone-trap catches to be practic-

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able, an extract of the natural pheromone, or a synthetic preparation, is required. Work on the isolation, identification and synthesis of the pea moth's own pheromone is proceeding, but as this was not available in 1974, field trials were made with extracts of the natural pheromone and with synthesised materials known to be attractive to males of closely related species of moths. Extracts of the natural pheromone were very attractive as was a large (1·0 mg) dose of synthetic sex attractant of the female codling moth. The latter can, therefore, be used for experimental monitoring of pea moth until more attractive compounds are available. (Lewis, Macaulay, Wall, with Greenway, Insecticides and Fungicides Department)

Only limited success has been achieved in rearing on artificial diets the many hundreds of pea moths required for this work, and most have so far had to be reared on fresh peas which, fortunately, can be grown throughout the year. Thirteen successive generations and several thousand moths have been reared and means of overcoming naturally-occurring resting stages in the life cycle have been discovered.

Much effort has been spent in developing a reliable, laboratory behavioural assay for the female sex attractant, and in designing and constructing apparatus to detect and record behaviour automatically. Preliminary trials on the effect of light regimes suggest that flight, mating and egg-laying rhythms are all photoperiodic and entrainable.

The duration of each stage of the life cycle and of the preoviposition period in adults at different temperatures are being measured as a basis for predicting the most effective time at which to apply an insecticide after immigrant moths have been detected in a pea field. (Lewis, Wall, Macaulay, Sturgeon and Dibley)

Invertebrates and pasture productivity

Investigations into the role of invertebrates on the productivity of grassland were continued in collaboration with members of the Grassland Research Institute, Hurley.

Long-term effect of pesticides on grassland. In a field experiment at Hurley in which S24 perennial ryegrass has received regular insecticide treatment since 1969, herbage yields from treated plots were greater than those from untreated plots for the fifth successive year. The weight of dry matter harvested in six cuts taken between May and November was 31% greater on plots receiving 188 kg/ha (150 units) fertiliser N, and was 14% greater on plots receiving 753 kg/ha (600 units) N. The build-up of a surface layer of undecomposed litter continued but has not yet had a detrimental effect on plant growth. The experimental plots are neither trodden by grazing animals nor suffer much damage from farm machinery and, under these conditions, the soil structure does not appear to have suffered from the absence of soil animals. (Henderson, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Invertebrate damage in England. The geographical extent of such pesticide-induced yield responses has been examined for a second year on young ryegrass swards receiving 377 kg/ha (300 units) N, at ten widely separated sites. Four cuts were taken between May and September and the annual dry matter yields measured. Statistically significant increases were not obtained on the experimental plots in Nottinghamshire and Essex. At the other eight sites, in Cheshire, Gloucestershire, Herefordshire, Lincolnshire, Northamptonshire, Shropshire, Somerset and Wiltshire, yields from treated plots exceeded those from untreated ones by between 9% and 32%. (Henderson, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Damage prevented by chemical control. The possibility of recovering some or all of the apparently widespread loss of yield of grassland by chemical control methods was tested

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in a field experiment started at Hurley in 1973. Sprays of the short-persistence organophosphorus insecticide dimethoate were applied regularly to a young sward of S23 perennial ryegrass, receiving 377 kg/ha (300 units) N/annum, over a range of concentrations applied at increasing intervals of time.

Annual yields, assessed in four cuts taken between June and October, were increased by up to 28% on plots receiving 210 ml/ha a.i. dimethoate or more at least every 12 days. (Henderson, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Dipterous stem-borers in grasses. The reason why some grass species or varieties are preferentially attacked by species of *Geomyza* and *Oscinella* has been explored.

Adult flies laid eggs on all the grasses offered—i.e. *Lolium perenne* (S23, S24, and Reveille), *L. multiflorum*, *Dactylis glomerata* (S31, S37, and commercial), *Phleum pratense* (S48, S50, S351), *Agrostis tenuis*, *Holcus lanatus*, *Festuca rubra*, *Poa trivialis* and *Avena fatua*. The observed differences in stem-borer infestation between grass species and varieties were caused by differences in the ability of the newly-hatched larvae to penetrate the tissues of the different host plants and become established. This resistance to larval penetration is a function of inherent specific or varietal morphological features and characteristic rate of growth. (Idowu and Henderson)

Soil fauna

Cutworms. Catches of species of economic importance at 12 sites continued, and tended to be considerably smaller than in 1972 and 1973. Larval rearing at controlled temperatures has continued and much information on the bionomics of the commoner species obtained. As in previous years, the Heart and Dart moth (*Agrotis exclamationis*) and the Large Yellow Underwing (*Noctua pronuba*) were the commonest species. (Edwards and Whiting)

Virus infections of cutworms. Many polyhedrosis viruses of Lepidoptera, including the cytoplasmic virus of *Noctua pronuba* and the nuclear polyhedroses of *Agrotis exclamationis* and of the Turnip moth, *A. segetum*, are believed to be transmitted via their eggs. In 1973, work was begun to see whether this occurs amongst local populations of these moths trapped on Rothamsted farm. Female moths were caged individually, the eggs laid by each removed daily and the resulting larvae kept in the laboratory under crowded conditions. However, no polyhedroses occurred, suggesting that these viruses were either absent or scarce in the local populations or that transmission via eggs is uncommon.

In 1974, some of the *A. exclamationis* larvae died for no obvious reason when in the final instar. An ultrafiltrate of these larvae injected into two groups of apparently healthy *A. exclamationis* larvae killed 96–100% within 48 h. Similar results were obtained with an ultrafiltrate of the killed larvae injected into other healthy larvae. (Sherlock)

Electron microscope study of the original ultrafiltrate showed small numbers of isometric virus-like particles about 30 nm across.

Many species of apparently healthy insects are known to be infected with non-occluded viruses. To find out whether *A. segetum* larvae are similarly infected, an ultrafiltrate prepared from apparently healthy individuals of *A. segetum* was injected into further larvae of this species. Significantly more of these died than the controls, but further passaging of similar ultrafiltrates did not give significant results, and no virus-like particles were found. (Sherlock, with Woods, Plant Pathology Department)

Leatherjackets. Populations of leatherjackets (larvae of craneflies) fluctuate from low to very high numbers every six to ten years and, if the established pattern is repeated,

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1974 or 1975 could be outbreak years when extensive damage may occur. The regional ADAS surveys showed a marked increase in populations of *Tipula paludosa* in the winter 1973/74 compared with 1972/73, populations exceeding 1 million/ha being common. However, in many areas, particularly in the west and south-west, there was an abnormally large decline in numbers, of over 90% in some cases, between autumn and spring. In spite of this decline, spring populations in 1974 were big enough to presage large numbers of adult *T. paludosa* later in the year and the likelihood of large leatherjacket populations in the winter 1974/75.

There are now four years' records of adult *T. paludosa* caught in two light traps on Rothamsted farm. From 1971 to 1972 there was little change in the numbers of this species that were caught, the totals in the two traps being 143 and 202, respectively. In 1973, a five-fold increase to 1023 was recorded, and in 1974 a further small increase to 1152 occurred. The large increase in catch between 1972 and 1973 did not result in any obvious abundance of adults in 1973, whereas the relatively small change between 1973 and 1974 was associated with widespread reports of a plague of craneflies. The explanation, certainly for Rothamsted and apparently for most of the country, is that in 1973 peak emergence was spread fairly evenly over four weeks, whereas in 1974, 80% of the catch was obtained in one week.

The five-fold increase between 1972 and 1973 followed an exceptionally dry autumn, which might have been expected to keep numbers low. Rainfall nearer average in 1973 was followed by a small increase in catch in 1974, so that the wet autumn of 1974 could cause large numbers of larvae in the winter 1974/75 and of adults in 1975. But this may not be so. Females of both *T. paludosa* and *T. oleracea* normally emerge from their pupae with fully matured eggs. In 1974, a large proportion of the female *T. paludosa* population has had completely undeveloped ovaries at emergence and have not matured any eggs during the adult life span. The proportion of immature females has varied from 75 to 90% in places such as Rothamsted and Cornwall, to about 50% in Kent, and has been recorded from localities throughout England. It is therefore possible that, notwithstanding favourable conditions, there will be a drop in larval populations. The drop will depend, in any given place, on the proportion of immature females of *T. paludosa* and the relative abundance of *T. oleracea*, females of which have not changed in reproductive status. (Bowden)

Effect of direct-drilling on soil fauna. Long-term investigations on the effects of direct-drilling on soil animals were begun in 1963 and have been greatly extended during 1974 because of the increased adoption of this technique in Britain. Comparisons of populations of animals, including earthworms, slugs, millipedes, carabid and staphylinid beetles, shoot-boring dipterous flies and leatherjackets, are being made in direct-drilled and traditionally cultivated cereal crops on various soil types at sites near Reading (silt loam, Hamble series) by courtesy of the Letcombe Laboratory, near Wantage (clay loam, Evesham series) by courtesy of the Weed Research Organisation, in Meadow field at Rothamsted (silty clay loam with flints), and near Cambridge (clay loam). At each of these sites, the plants in ten 35-cm lengths of row were examined for shoot-boring larvae during April or May, slugs were sampled in spring and autumn with traps baited with bran, millipedes and carabid and staphylinid beetles and other arthropods were sampled at intervals throughout the year with pitfall traps, and leatherjackets in spring by extraction by washing from soil cores. Total soil animal populations were also estimated in spring by extracting them from soil cores in a modified, high gradient Tullgren apparatus. Earthworm populations were estimated by treating 51 cm × 51 cm quadrats with dilute formalin to bring them to the surface of the ground. Preliminary results are given in Table 3. (Edwards and Lofty)

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TABLE 3

Comparison of the numbers of soil animals present in direct-drilled, chisel-ploughed and conventionally cultivated plots at two sites, sown with winter wheat*

		Soil animals				
Site	Treatment	Earthworms	Millipedes	Carabid beetles	Staphylinid beetles	Dipterous stemborers
Rothamsted (0·13 ha/treatment)	Direct-drilled	919	23	142	89	4
	Chisel-ploughed	649	30	134	145	9
	Conventionally cultivated	628	18	265	122	7
Boxworth (0·15 ha/treatment)	Direct-drilled	813	180	187	338	54
	Chisel-ploughed	517	119	222	388	104
	Conventionally cultivated	667	156	289	339	178

* Mouldboard ploughed + light cultivation

Pesticides and the soil fauna. The effects of some herbicides on the soil fauna have been described previously (see *Rothamsted Reports for 1971, for 1972, for 1973*, Parts 1, 211, 213, 205). During 1974, four herbicides that are closely related to benzoyl-prop-ethyl and used to control wild oats were studied in a field trial in Sussex. Soil arthropods were sampled at intervals, and earthworms in the autumn. Mesh bags containing discs cut from lime leaves were buried at the site and periodically examined to assess the activity of the soil fauna. The results obtained indicate that the benzoyl-prop-ethyl herbicides had little adverse effect on the soil fauna. (Edwards, Lofty and Stafford)

Herbicides and predatory beetles. A laboratory method of screening pesticides for toxicity by topical application (*Rothamsted Report for 1972*, Part 1, 211) was further developed and used to compare the toxicity to carabid beetles of several new herbicides of the benzoylprop-ethyl group. None of these appeared to harm any of the three species used, *Harpalus rufipes, Feronia melanaria* and *F. madida*. (Edwards and Stafford)

Slugs

When offered a choice of bare soil comprised of the aggregates retained by 3·0, 5·0, 10·0 and 12·5 mm sieves, immature and mature specimens of *Agriolimax reticulatus* chose to rest in soils comprised of 10·0 or 12·5 mm aggregates. The finer soils were, however, preferred as egg-laying sites. The slugs insinuated themselves into the spaces between the aggregates and it is suggested that response to contact stimuli may be partly responsible for causing them to remain in such places. Such behaviour could help explain the aggregations of slugs that occur in arable land.

Agriolimax reticulatus is well-known to damage winter wheat seed when it is exposed in the spaces between soil aggregates. In laboratory experiments, seed sown in soil having a moisture content of 25% and comprised of aggregates retained by a 6·0 mm sieve, was protected from slugs when a pressure of 390 kg/m^2 or more was applied to the soil surface after sowing. This pressure broke down the aggregates so that the seed was covered by the finer soil produced and this protected it from the slugs. The larger aggregates retained by a 12·5 mm sieve did not break down so much under the pressures used, leaving many seeds exposed to slug damage. (Stephenson)

Honeybees

Swarming. In 1972, it was shown that restricting the total hive space available to colonies without limiting the amount of space allowed for brood can make them swarm,

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and can also make them rear queens despite having laying queens, which otherwise strongly inhibit queen rearing. In 1973, the opposite treatment—that of limiting space for brood without limiting total hive space—was tested. The colonies with limited space for brood were smaller, on average, than the controls with unrestricted space, but there was little difference in the incidence of queen rearing, or swarming, between the two groups. (Simpson and Greenwood)

Ivy honey as winter food. A report was received from a honey farmer in Ireland that many of his colonies of bees had died during the winter 1973/74 because their winter stores, which consisted entirely of honey, had granulated (crystallised) excessively. In the Alpine regions of Europe such granulation frequently occurs of the poorly soluble trisaccharide sugar melezitose, which the bees collect in 'honeydew' excreted by insects feeding on coniferous trees. In the present case, the beekeeper suggested that the unusual honey was derived from nectar secreted by the flowers of ivy (*Hedera helix* L.). The amount of ivy pollen found in the honey supported this idea, but examination of the sugars by chromatography showed that the excessive granulation was not due to melezitose, but to an exceptionally high proportion of glucose, the only sugar with respect to which ordinary honeys are supersaturated. This result agrees with the observation of Wykes (see *Rothamsted Report for 1950*, 98–99) that ivy nectar contains an extremely, perhaps uniquely, high proportion of glucose. Granulation may be followed by slow water loss by evaporation, thus rendering the overall water content of the food too low to enable bees to survive when the weather is too cold for them to leave the hive to collect water. (Simpson and Greenwood, with Greenway and Rhenius, Insecticides and Fungicides Department)

Footprint substance of the worker honeybee. Several fatty acids and the methyl esters of some of them have been identified in the footprint (trail-marking) pheromone of the worker honeybee. Of the compounds that have been identified and assayed for biological activity, only one, palmitic acid, when presented at rates of 1 mg or more, was active. Since a large amount of palmitic acid is required to produce a positive response, it is probable that at least one other compound in the footprint substance acts as a synergist. (Butler and Welch, with Greenway, Insecticides and Fungicides Department)

Drone rearing. Observations on drone production throughout the year by colonies of different sizes showed that small colonies produced few, if any, drones, and that the more bees there were in a colony the more worker and drone brood there were present and the larger the number of adult drones. However, when a colony contained 10 000 bees or more, the amount of drone brood present was not proportional to its size, the amount of worker, but not of drone, brood diminishing as a colony grew larger. In general, the proportion of drone : worker comb built by a colony depended on the amount of drone comb already present; colonies continued to build drone comb long after they had ceased to rear drones, even in mid-winter. Although many eggs were sometimes laid in drone comb when it was provided early in the year, most disappeared and few drones were reared before the end of April. The proportion of drone : worker brood was highest in May and June; no more eggs were laid in drone cells after July.

Expulsion of drones from colonies by workers in autumn was greatly curtailed when syrup was fed to them or their queens were removed; these effects being additive. Colonies prevented from foraging at any time of year, expelled their drones. (Free and Williams)

Pollination

Colony management. During 1972, experiments were made to determine the relationship

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between the distance of a colony of honeybees from a flowering crop, such as sweet cherry or kale, and the number of its bees foraging on it. It was found that, provided the flowers of a crop contained plenty of food and did not have to compete strongly with other flowers nearby, the amount of pollen collected diminished greatly when the distance of a colony from the crop was increased by as little as 0·4 km. These results emphasise the importance of placing colonies of honeybees in the fields of crops requiring pollination rather than relying on foragers from neighbouring colonies to visit them. (Free and Williams)

Production of hybrid onion seed. Use is made of cytoplasmic male sterility to prevent self-pollination of the flowers when producing hybrid onion seed, and to obtain adequate cross-pollination while avoiding pollination from foreign sources, pairs of inbred cultivars (male-sterile yielding little or no pollen and male-fertile producing much pollen) are caged with honeybees. Because hybrid seed is produced only by the male-sterile plants, the proportion of male-fertile plants used to provide pollen should be minimal, and observations have been made to determine how the amount of seed produced by male-sterile plants in cages and in the open is influenced by their proximity to male-fertile plants. It was found that restricting male-fertile plants to one row in nine, with rows 0·6 m apart, did not reduce the amount of seed set significantly. Furthermore, no advantage was obtained by having more than one male-fertile row of plants between blocks of male-sterile ones. The need to attract pollinators does not appear to be important when deciding planting distances in the rows because increasing the numbers of flowers per row did not greatly increase the bee population per row. Although seed yield was as great on caged as on uncaged plants, indicating that, at the time of the particular experiment, it was unnecessary to cage honeybees on the crop in order to obtain sufficient pollination, caging is the only certain way of preventing contamination from outside sources.

The honeybees foraging on the onion flowers were almost all nectar-gatherers, none collecting pollen without also collecting nectar. In general, however, bees with or without pollen loads moved freely between male-sterile and male-fertile flowers, and many of the nectar-gatherers, as well as the few pollen-gatherers, carried sufficient pollen on their bodies to fertilise the male-sterile flowers. (Free and Williams)

Bee diseases

Slow paralysis virus. During surveys for bee virus X (see *Rothamsted Report for 1973*, Part 1, 209–210) varying numbers of particles of other known bee viruses were detected in samples, from various parts of Britain, of adult honeybees, mostly from colonies that had died in late winter for no obvious reason. Acute bee-paralysis and chronic bee-paralysis were especially common and sacbrood virus less so. Occasionally isometric particles, about 30 nm in diameter, that did not react with antisera of any of the known bee viruses, occurred in the samples. Bees injected with preparations of these particles died after two or three weeks, suffering a partial paralysis before they died. The particles sediment at about 178S and aggregate irreversibly in agar containing 0·85% sodium chloride or equivalent concentrations of other salts. These and other properties, including serological characteristics, differentiate this virus, named slow paralysis virus, from any other bee virus.

Much slow paralysis virus multiplied when injected into over-wintering adult bees, but comparatively little was obtained from bees injected in summer. However, at least ten times as much virus per individual was obtained from young pupae injected with the virus than from overwintering adult bees. Pupae injected with terminally infective dilutions of slow paralysis virus matured successfully and slightly sooner than healthy

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pupae but they died within nine days, whereas adults reared from pupae injected with water lived for several weeks. All the other known bee viruses, except bee virus X, also multiplied when they were injected into young pupae, much more than they do in adult bees. (Bailey and Ball)

Bee virus X. Injection of the virus into bees failed to cause multiplication sufficient to be seen by electron microscopy. However, when newly emerged bees were each fed between 10^6 and 10^9 particles and then kept at 30°C they contained about 10^{10} particles after three weeks and 10^{11} after five weeks, although they still appeared as healthy as control bees which contained no particles. Very few particles were seen in extracts of similarly inoculated bees when they were kept at 35°C. Most particles, in bees from the field or in individuals that had been fed bee virus X in the laboratory, were in the abdomen and were concentrated in the gut. Sufficient virus was in the abdomen of many field bees in late winter, and of young bees four or five weeks after they had been inoculated, for crude extracts to give dense precipitin lines in immunodiffusion tests. (Bailey)

Arkansas bee virus. Preparations of Arkansas bee virus from pupae injected with the virus contained two components, sedimenting at different rates, as obtained from adult bees infected with the virus. However, there was a higher proportion of the fast sedimenting component, preparations of which, in neutralised phosphotungstic acid (PTA), contained moderate numbers of dimers. These had not previously been seen in preparations of the virus from adult bees, but had been assumed to occur and account for the fast sedimenting component. These seem to disaggregate readily. Many of the particles from pupae were penetrated by PTA at pH 7·0, which made them appear empty, whereas they all seemed full when stained at pH 4·0. About 10% of the particles from pupae appeared featureless, whereas the remainder, which were very slightly smaller, showed an obvious though indistinct, uneveness of surface after staining with PTA. These preparations reacted only with antisera prepared against Arkansas bee virus and formed a single line in immunodiffusion tests. Therefore, most particles of Arkansas bee virus may lose parts of their surfaces during purification, to give their uneven appearance, or, if they do not, the featureless particles must be those of an unknown virus. (Bailey, with Woods, Plant Pathology Department)

Chronic paralysis virus. Isometric particles about 17 nm across, sedimenting at 46S and with an absorption spectrum typical of a nucleoprotein, were found consistently associated with chronic paralysis virus. They did not react with antiserum to chronic paralysis virus. Infectivity tests suggest that the particles do not multiply alone and may, therefore, be of a satellite dependent on chronic paralysis virus. They seemed more numerous in paralysed bees in spring than later in the season. (Bailey and Ball, with Woods, Plant Pathology Department)

A small sample from India of the Eastern honeybee, *Apis cerana*, suffering from a disease resembling chronic paralysis, contained material only distantly related, according to serological tests, to chronic paralysis virus. Anisometric particles seen in extracts appeared smaller on average than those of chronic paralysis virus. (Bailey, with Woods, Plant Pathology Department)

Staff

In the spring, C. A. Edwards spent ten days at the International Institute for Tropical Agriculture, Ibadan, on behalf of the Ministry of Overseas Development (ODA). In May, he visited Zurich for three days to attend a Working Group of the International Organisation for Biological Control to discuss the effects of pesticides on beneficial

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insects. In July, he gave a plenary address at the Third International Congress of Pesticide Chemistry in Helsinki, and during October and November he visited the Agricultural University, Bangalore, as a consultant to set up a soil ecology department and give a course of lectures.

J. B. Free visited Jamaica for three months as a beekeeping and crop pollination specialist for ODA, and, in July, lectured at the International Beekeeping Technology and Economy Institute, Bucharest.

R. A. French visited Norway in March to lecture to the Scandinavian Association of Agricultural Scientists on the Rothamsted Insect Survey and to advise on the establishment of monitoring systems.

T. Lewis visited the Seychelles for ODA in February and March to help establish a research and control programme on the crazy ant, *Anoplolopis longipes*.

N. Barker, Jennifer Haines, H. D. Loxdale, Barbara Stanley and M. Tiller left and Brenda Ball, R. Betts, M. Gibb (an ARC scholar), Susan Jones, R. Moore, Partricia Roberts and Dolores Sturgeon joined the department. A. R. Burrows and H. D. Loxdale obtained B.Sc. degrees. M. Goulding, I. McLean and J. Pratt worked as sandwich course students for six months. In October, C. G. Butler was appointed Visiting Professor in the Department of Zoology and Applied Entomology, Imperial College, London.

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