Report for 1971

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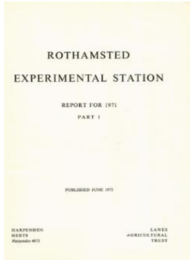

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ENTOMOLOGY DEPARTMENT

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Invertebrates and pasture productivity

Last year we reported that yields of old pasture at Rothamsted and of newly-sown perennial ryegrass at the Grassland Research Institute, Hurley, were increased by 25% or more in the second year after treatment with a mixture of pesticides aimed to kill all the invertebrates. In this, the third year, the treated plots of the old pasture yielded no more than the untreated plots; however, the treated ryegrass still yielded 29% more than the untreated.

It is sometimes said that increased yields after treatment with nitrogenous fertilisers eliminate the need for pesticides on pasture. However, economic considerations apart, results in 1971 showed that this is not so; when a sward of S24 ryegrass at Hurley, sown in 1968, was treated with a mixture of pesticides in 1969, average yields in 1970 increased by 16% and 17% on plots receiving respectively 371 and 1483 units of nitrogen per hectare (150 and 600/acre) and by 17% and 19% respectively in 1971.

So far, such experiments with insecticides have been done only at Rothamsted and Hurley, and to know how pasture responds in other parts of the country, experiments were started on two-year-old swards, all predominantly of ryegrass, in the Agricultural Development and Advisory Service (ADAS) and university farms or centres in Yorkshire (High Mowthorpe E.H.F.), Lancashire (Great House E.H.F.), Kent (Wye College Farm) and Devon (Starcross). These sites have extremes of annual temperature or rainfall. Large doses of aldrin (11·2 kg/ha) plus phorate (3·36 kg/ha) were given in the spring of 1971. So far (December 1971) yields on the two northerly sites have not increased but they have in Devon in three of the five harvests taken, on average by 24%. In Kent yield increased only in the last harvest.

All experiments are continuing, together with attempts to identify the animals most responsible for affecting yield, by analysing their populations on the different plots.

The incidence of ryegrass mosaic virus in plots yielding differently is being examined. Preliminary results suggest that this virus, which can be mite-borne or transmitted mechanically, quickly becomes prevalent even in swards where the populations of insects and mites have been largely eliminated. (Henderson, with Mr. R. O. Clements, Grassland Research Institute, Hurley)

Losses to field beans by *Aphis fabae*

Collaboration with Professor M. J. Way (Imperial College) on predicting *Aphis fabae* infestations on field beans by examining populations on the winter host, *Euonymus europaeus*, continued. Populations were very small, as predicted (and as happened also in 1970), and therefore field experiments on the effects of infestation were abortive. (Bardner and Fletcher, with Stevenson, Insecticides Department)

The effect of *Sitona* larvae attacking roots of field beans

Larvae of bean weevils injure the roots of field beans, and last year we reported that treating the soil with γ-BHC at 2·24 kg/ha killed many larvae and increased yields by up to 30%. Twice as much insecticide killed more larvae but did not result in corresponding

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increases of yield. Experiments with the same amounts of γ-BHC were repeated at Rothamsted and Woburn, where the average numbers of larvae per root on untreated plots were 12·4 and 16·2 respectively. The insecticide lessened the number of larvae by 65% at Rothamsted and 80% at Woburn, but there was no appreciable increase in yield. Evidently, though γ-BHC controls *Sitona*, this is offset by other factors, possibly toxicity to the bean plants (Table 1).

TABLE 1

γ-BHC, applied to the soil, and the yield of field beans

	Yield in tonnes/ha	
	Rothamsted	Woburn
No insecticide	2·59	2·01
γ-BHC 2·24 kg/ha	2·74	2·06
γ-BHC 4·48 kg/ha	2·71	2·07
S.E. of differences	±0·075	±0·130

Another experiment assessed the effects of some organophosphate and carbamate insecticides and compared them with those of γ-BHC. The following insecticides were all applied to the soil surface and rotavated in just before sowing the beans.

γ-BHC	
aldicarb	
'C 10015'	2-(4,5-dimethyl-1,3-dioxalan-2-yl)-phenyl-N-methyl carbamate.
'C 18244'	O-ethyl-O-(2,5-dichloro-4-iodophenyl)ethyl-thiophosphonate.
'DP 1410'	S-methyl 1-(dimethylcarbamoyl)-N-[(methylcarbamoyl) oxy] thioformimidate.
'MC 2420'	S-(N-methoxycarbonyl-N-methylcarbamoyl methyl dimethyl phosphonothiolothionate).

Although all except 'MC 2420' controlled *Sitona* larvae well, only aldicarb, 'DP 1410' and phorate increased yield, and yield was not correlated with control of *Sitona*.

TABLE 2

Soil insecticides, Sitona *larvae and yield of field beans*

Insecticide	Dose kg/ha	Mean no. of larvae/root	Yield tonnes/ha
None	—	14·66	1·76
γ-BHC	2·24	1·78	1·82
	4·48	0·08	1·76
aldicarb	4·48	0·50	2·60
'DP 1410'	4·48	1·50	2·37
phorate	4·48	0·00	2·23
'C 10015'	4·48	0·21	1·95
'C 18244'	4·48	6·38	1·74
'MC 2420'	4·48	10·42	1·64
S.E. of differences		±1·926	±0·206

More work will be needed to explain the increased yields, because aldicarb, 'DP 1410' and phorate also control nematodes and the weevil *Apion*, which is principally responsible for transmitting broad bean stain virus and Echtes Ackerbohne mosaic virus; also to see whether γ-BHC and 'C 10015' damage the beans. (See also report of the Plant Pathology Department). (Bardner and Fletcher, with Griffiths, Insecticides Department)

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Aphids and virus diseases of peas

An experiment drilled at Rothamsted on 29 April again assessed the effects of time of spraying with insecticide on aphid infestation, virus infection and yield of vining peas (var. Jade and Dark Skin Perfection). There were four replicates of four treatments: (1) unsprayed; (2) early spray ('Metasystox 55' at 70 ml/ha, applied 1 June); (3) late spray (applied 1 July); (4) three sprays (second applied 18 June).

Aphids were few on plants in June. In mid-July, 35% of Jade in unsprayed plots and 37% of Dark Skin Perfection, were infested with *Acyrthosiphon pisum*, and 3 and 2% respectively with *Aphis fabae*. At harvest, 15% of Jade in unsprayed plots, and 4% in plots sprayed three times, were infected with bean leaf roll virus; this virus was not found in Dark Skin Perfection. Less than 4% of unsprayed plants of either variety were infected with pea enation mosaic virus.

There was no significant difference in yield between sprayed and unsprayed plots. Mean yields (kg/50 plants) of Jade were 0·54 (no spray), 0·52 (late spray), 0·54 (early spray) and 0·61 (three sprays); corresponding yields for Dark Skin Perfection were 0·44, 0·44, 0·42 and 0·47 kg. (Cockbain, with Etheridge, Insecticides Department)

Ecology of cereal aphids

Some *Sitobion avenae*, *Metopolophium dirhodum* and *Rhopalosiphum padi* overwintered on cereals and grasses sheltered near hedges. Because the winter and spring were mild, the first alate *R. padi* was caught at Rothamsted, on 15 April, 37 days earlier than in 1970. The first *S. avenae*, *S. fragariae* and *M. dirhodum* were 13, 9 and 21 days earlier, respectively than in 1970. *M. festucae* was caught 20 days earlier and in larger numbers than in 1970. These five species were found in spring wheat 4–34 days after the first trap capture (see p. 205). On average there were fewer than 1 aphid/1 ft sample until early June, but after mid-June all the samples were infested with *S. avenae* and *M. dirhodum*. Populations were smaller than in 1970, but larger than in 1969, with maxima of 49/1 ft for *S. avenae* (14 July) and 65/1 ft for *M. dirhodum* (12 July). *R. padi* had two much smaller population peaks of 0·5/1 ft on 24 May and 1·4/1 ft on 14 July. The alatae of this species deposited only a few nymphs on cereals. *M. festucae*, mainly alatae and nymphs, was as abundant as *M. dirhodum* (1·5/1 ft) up to 16 June but the numbers of the former declined to zero by mid-July. There were no apparent correlations between numbers of alatae trapped and number of aphids infesting crops.

A slow population growth during June was associated, in general, with rain and cold. *Aphidius avenae* was the dominant parasite attacking cereal aphids from late May onwards; relatively few *Praon volucre* and *Ephedrus plagiator* mummies were collected, but hyperparasites were common. Most aphids were killed during the first week of July, deaths reaching 48%, 49% and 60% for *S. avenae*, *M. dirhodum* and *M. festucae*, respectively. The fungus *Entomophthora* (*planchoniana*, *thaxteriana*, *aphidis*) was found infecting aphids in late May, and maximum infection for *S. avenae* (49%) was on 1 July, for *M. dirhodum* (74%) on 13 July and for *M. festucae* (69%) on 22 June. In early July, 58–84% of aphids were dying from parasitism and fungus but this lessened during the rest of the season.

The ladybird, *Coccinella 7-punctata*, was common in cereals during early May only, and *Propylea 14-punctata* then became dominant, though less abundant than in 1970. Egg masses were common in late June and early July but larvae were not as common as expected. Eggs of the hoverflies (*Syrphus balteatus*, *Melanostoma mellinum*, *Sphaerophoria scripta*) were commonly seen in late June and early July, and larvae were fairly abundant until the third week of July when large flocks of sparrows ate many aphids, predators

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and parasites within the crop. Anthocorids, earwigs, spiders, *Tachyporus*, and occasionally a very few, small beetle larvae, killed relatively few aphids, and larvae of the lacewing *Chrysopa carnea* were not seen, though the adults were common in traps. Syrphid larvae seemed to be the commonest and most important predators. (Dean)

The Rothamsted Insect Survey

Suction traps. Daily sampling began on 13 April at Elgin near Inverness, Dundee, Edinburgh, Newcastle, High Mowthorpe, Aberystwyth, Broom's Barn, Rothamsted (two traps), Garston, Long Ashton, Silwood Park, Wye, Starcross, Rosewarne and Zeeland (The Netherlands). Aphid bulletins were issued weekly for all traps except Garston and Rothamsted Farm, from the week beginning 13 April to the week ending 4 November. New traps begun to operate on 12 July at Rosemaund Experimental Husbandry Farm, near Hereford, and on 1 July at the Zoologisk Institut, Copenhagen, increasing the inland network, which checks the effective area applicable to the sample, and also tests the effect of wider expanses of sea as barriers to migration. The inland network in South England will be further strengthened when the new trap at the ADAS Centre at Shardlow near Derby begins to operate in 1972. Samples from Broom's Barn, Aberystwyth and Zeeland were again identified by G. D. Heathcote, Mr. J. A'Brook (Welsh Plant Breeding Station) and Mr. D. Hille Ris Lambers (Bladluisonderzoek T.N.O.).

Unfortunately the results from the Zeeland trap, in Holland, ceased to appear in the bulletin from 18 July but the samples are now being identified. The East Craigs trap, near Edinburgh, was burned down on 3 October. The trap at Broom's Barn was replaced after eight years service and, after minor replacements, is now used in experiments on Rothamsted Farm. The standard four-week totals for the 31 species of aphids that are published in the bulletin, and from the 16 traps that contribute to it are in *Rothamsted Report for 1971*, Part 2, 181–199.

The rate at which air is sampled was halved in traps at Broom's Barn, Rothamsted (two traps), Garston, Silwood Park, Wye and Hereford from 25 June to 6 August (weeks 26–31 inclusive) and in all traps in the United Kingdom from 24 September to 22 October (weeks 39–42 inclusive). Tables in the bulletin and Annual Report are corrected to full sample volume.

Aphid migration began, on average, about four weeks earlier than in 1970; hence there is an extra four-week table in Part 2 of the *Rothamsted Report*. Many *Drepanosiphum platanoidis* flew at the beginning of the season, as in 1970, and the flight of *Elatobium abietinum* at the same time was the greatest in our experience, and was especially large at Elgin and Aberystwyth. By the beginning of June *Brachycaudus helichrysi* and *Cavariella aegopodii* were becoming numerous and later the cereal aphids *Metopolophium dirhodum*, *Sitobion avenae* and *Rhopalosiphum padi* appeared, with fewer *Aphis fabae* and *Hyalopterus pruni*. Only one-third as many *A. fabae* were caught at Broom's Barn as in 1970, but the first specimen was caught six weeks earlier than last year; only one-ninth as many *Myzus persicae* were caught there as last year. In August and early September aphids in flight become fewer, especially in the south. The autumn migration in September and October, is more consistent from year to year than migrations earlier in the year and much less diverse, consisting largely of *Rhopalosiphum insertum* and *R. padi* with some *Pemphigus* spp., *B. helichrysi* and *D. platanoidis*; males also became progressively more common; these are recorded separately in the bulletins but not in the tables in Part 2 of the *Rothamsted Report*.

All the aphids listed in the bulletin have occurred in all the traps, except *Phorodon humuli* which was not found at Elgin and *Brevicoryne brassicae* not at East Craigs

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(Edinburgh). Also, the following species, not listed in the bulletin, were found in all traps (except Copenhagen, Zeeland and Hereford, for which information is lacking): *Schizolachnus pineti*, *Periphyllus testudinaceus*, *Myzocallis coryli*, *Tuberculoides annulatus*, *Eucallipterus tiliae*, *Kallistaphis basilis*, *Betulaphis quadrituberculata*, *Euceraphis punctipennis*, *Rhopalosiphum nymphaeae*, *Ceruraphis eriophori*, *Cavariella pastinaceae*, *C. theobaldi*, *Jacksonia papillata*, *Myzus cerasi*, *M. ligustri*, *Tubaphis ranunculina*, *Capitophorus hippophaes*, *Rhopalosiphoninus latysiphon*, *R. staphyleae*, *Microlophium evansi*, *Metopolophium albidum*, *Macrosiphum gei*, *M. rosae*, *Schizoneura patchae*, *Tetraneura ulmi*.

The peach–potato aphid (*Myzus persicae*) may be overwintering as eggs on peach and related trees or in the asexual form on weeds, crops or in potato and sugar beet clamps; the proportion doing so is important (but controversial) because the fundatrigeniae flying from the primary tree hosts, are without viruses of crops but the virginoparae flying from secondary hosts such as weeds and crops may be infective. Fundatrigeniae and virginoparae can probably be separated morphologically but reliable widespread aerial samples have not existed previously, because the yellow traps commonly used may catch the two kinds with different efficiency. Dr. J. A. T. Woodford of the Cambridge School of Agriculture is examining the *M. persicae* from the suction traps to try to solve this problem.

For the third year ADAS officers sampled cereal crops, wherever possible near survey traps, to investigate the efficiency and reliability of the survey traps in forecasting the first arrivals of cereal aphids on crops. These samples were coordinated by Mr. R. Gair (ADAS) and Mr. K. S. George (MAFF Plant Pathology Laboratory, Hatching Green) (Table 3).

Fields of spring cereals were sampled weekly along two transects. The aphids found were removed and identifications in the field were later verified by Mr. H. L. G. Stroyan; nymphs are very difficult to identify and, for the second year, only 60–70% of identifications in the field were found to be correct. By contrast identification of alatae in the laboratory, e.g. of those caught on survey traps, is accurate, probably with errors of less than 1%.

Table 3 compares each field sample with those from the nearest trap, which may be more than 50 miles away. The traps caught a particular species before it was found in a field sample on 79 occasions; first records in trap and field coincided twice and the field samples gave earlier records than the traps on 25 occasions. On 120 occasions the traps registered migration when the field samples did not, but no field infestation was found that was not recorded by the nearest trap.

The effect of distance of trap from a field on the relevance of the trap sample is also now becoming clearer; 38 cereal fields were sampled (26 last year) and some were far distant from any trap. Of 22 fields in the ADAS Regions of southern England and Wales, only four were seen to be infested by one of the six species of cereal aphids before a trap, within 50 miles, detected migration. By contrast, in the Midlands and North including Scotland, where distances between fields and traps were greater, of 16 fields infested, some by more than one species of aphid, 12 showed infestation before traps detected migrants. The Midlands will be better served by traps in 1972, but there is no immediate prospect of more traps in the North.

Differences in the comparative efficiency of crop and air sampling for different cereal aphids are becoming evident. *M. dirhodum* was most often found in the crop before being trapped, especially in the North; *R. padi*, which was very common in the air, was not found on the crop south of the Midlands before being trapped. Overwintering in the crop, crop condition at the time of migration and the difficulty of finding some species by sampling crops, are factors that may possibly cause these differences.

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TABLE 3

Cereal aphids, 1971: dates of first appearance in fields and traps

Aphid species				*R. padi*			*M. dirhodum*			*M. festucae*		
				Date found		Days earlier	Date found		Days earlier	Date found		Days earlier
ADAS Centre	Field No.	Crop	Trap site	Field	Trap	in trap	Field	Trap	in trap	Field	Trap	in trap
N. Scotland	i	SB	Dundee	8/6	25/5	+14	27/5	7/6	−11	23/6	11/5	+43
N. Scotland	ii	SB	Dundee	16/6	25/5	+22	2/6	7/6	− 5	2/6	11/5	+22
N. Scotland	iii	SB	Dundee	12/6	25/5	+18	22/6	7/6	+15	12/6	11/5	+32
W. Scotland	i	SB	East Craigs	n.f.	20/5	+	n.f.	1/6	+	n.f.	1/5	+
W. Scotland	ii	SB	East Craigs	n.f.	20/5	+	26/5	1/6	− 6	n.f.	1/5	+
W. Scotland	iii	SB	East Craigs	n.f.	20/5	+	n.f.	1/6	+	n.f.	1/5	+
N. England	i	B	Newcastle	3/6	23/5	+11	2/7	1/7	+ 1	25/5	19/5	+6
N. England	ii	B	Newcastle	24/6	23/5	+32	9/6	1/7	−22	3/6	19/5	+15
N. England	iii	B	Newcastle	14/6	23/5	+22	9/6	1/7	−22	4/6	19/5	+16
N. England	iv	B	Newcastle	18/6	23/5	+26	4/6	1/7	−27	18/6	19/5	+30
N. England	v	B	Newcastle	18/6	23/5	+26	10/6	1/7	−21	10/6	19/5	+22
W. Midlands	i	SB	H. Mowthorpe	21/6	23/5	+29	10/5	30/6	−51	25/5	20/5	+ 5
W. Midlands	ii	SW	H. Mowthorpe	10/6	23/5	+18	11/5	30/6	−50	25/5	20/5	+ 5
E. Midlands	i	SW	H. Mowthorpe	n.f.	23/5	+	n.f.	30/6	+	n.f.	20/5	+
E. Midlands	ii	SB	H. Mowthorpe	22/6	23/5	+30	n.f.	30/6	+	17/6	20/5	+28
E. Midlands	iii	SB	H. Mowthorpe	n.f.	23/5	+	7/6	30/6	−23	n.f.	20/5	+
Eastern	i	SW	Brooms Barn	n.f.	20/5	+	n.f.	14/5	+	n.f.	21/5	+
Eastern	ii	SW	Brooms Barn	24/6	20/5	+35	17/6	14/5	+34	n.f.	21/5	+
Eastern	iii	SW	Brooms Barn	n.f.	20/5	+	17/6	14/5	+34	n.f.	21/5	+
Eastern	iv	SW	Brooms Barn	n.f.	20/5	+	3/6	14/5	+20	n.f.	21/5	+
Eastern	v	SW	Brooms Barn	n.f.	20/5	+	n.f.	14/5	+	n.f.	21/5	+
S.E. Wye	i	SB	Wye, Kent	n.f.	19/4	+	1/6	28/5	+ 4	n.f.	10/5	+
S.E. Wye	ii	SW	Wye, Kent	n.f.	19/4	+	n.f.	28/5	+	n.f.	10/5	+
S.E. Wye	iii	SB	Wye, Kent	n.f.	19/4	+	8/6	28/5	+11	n.f.	10/5	+
S.E. Reading	i	WW	Silwood Park	n.f.	15/4	+	n.f.	29/4	+	n.f.	21/4	+
S.E. Reading	ii	SB	Silwood Park	n.f.	15/4	+	n.f.	29/4	+	n.f.	21/4	+
S.E. Reading	iii	SW	Silwood Park	n.f.	15/4	+	n.f.	29/4	+	n.f.	21/4	+
S.W. Bristol	i	SW	Long Ashton	n.f.	21/4	+	19/5	5/5	+14	n.f.	30/4	+
S.W. Bristol	ii	SW	Long Ashton	n.f.	21/4	+	20/5	5/5	+15	n.f.	30/4	+
Wales: Cardiff	i	SW	Long Ashton	n.f.	21/4	+	27/5	5/5	+22	19/5	30/4	+19
S.W. Starcross	i	SO	Starcross	n.f.	9/5	+	n.f.	12/5	+	n.f.	8/5	+
S.W. Starcross	ii	SB	Starcross	n.f.	9/5	+	11/5	12/5	− 1	n.f.	8/5	+
S.W. Starcross	iii	SB	Starcross	n.f.	9/5	+	12/5	12/5	+	n.f.	8/5	+
Wales: Aberystwyth	i	O	Aberystwyth	n.f.	15/4	+	26/5	4/5	+22	n.f.	11/5	+
Wales: Aberystwyth	ii	O	Aberystwyth	n.f.	15/4	+	18/5	4/5	+14	n.f.	11/5	+
Wales: Aberystwyth	iii	O	Aberystwyth	n.f.	15/4	+	18/5	4/5	+14	n.f.	11/5	+
Wales: Bangor	i	B	Aberystwyth	n.f.	15/4	+	n.f.	4/5	+	n.f.	11/5	+
Wales: Bangor	ii	B	Aberystwyth	n.f.	15/4	+	n.f.	4/5	+	n.f.	11/5	+

SB = Spring barley
B = Barley
SW = Spring wheat
WW = Winter wheat
SO = Spring oats
O = Oats

n.f. = aphids not found
\+ means that the trap detected aphids, though field samples had none

Light traps. Catches are listed in Part 2 of the Report of 31 species of moths of economic interest or known to be migrants (the same species as in 1969) from 68 traps in 1970. Traps are now operating at 128 sites, 119 on the mainland of Great Britain, six on off-shore islands. Distribution maps of moths are beginning to show that traps are still too few in the Welsh and Scottish Borders, Wiltshire and Norfolk, the off-shore islands, North and Western Scotland. Some species, such as *Plusia gamma*, are distributed widely and remarkably uniformly and in this respect have much in common with aphids. In 1970, for example, sites as widely spread as Chester-le-Street in Durham, Leighton Moss in Lancashire, Spurn Head in Yorkshire, Isle of Man, Bath in Somerset, Rosewarne in Cornwall and Starcross in Devon yielded only a range of from 4 to 25 individuals

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TABLE 3 (*continued*)

Cereal aphids, 1971: dates of first appearance in fields and traps

S. fragariae Date found Field	*S. fragariae* Date found Trap	*S. fragariae* Days earlier in trap	*S. avenae* Date found Field	*S. avenae* Date found Trap	*S. avenae* Days earlier in trap	*R. insertum* Date found Field	*R. insertum* Date found Trap	*R. insertum* Days earlier in trap	Trap site	Crop	Field No.	ADAS Centre
2/6	31/5	+ 2	2/6	13/6	−11	n.f.	1/7	+	Dundee	SB	i	N. Scotland
2/6	31/5	+ 2	16/6	13/6	+ 3	16/6	1/7	−15	Dundee	SB	ii	N. Scotland
12/6	31/5	+12	18/6	13/6	+ 5	n.f.	1/7	+	Dundee	SB	iii	N. Scotland
n.f.	28/5	+	26/5	6/5	+20	n.f.	8/6	+	East Craigs	SB	i	W. Scotland
n.f.	28/5	+	26/5	6/5	+20	n.f.	8/6	+	East Craigs	SB	ii	W. Scotland
n.f.	28/5	+	26/5	6/5	+20	n.f.	8/6	+	East Craigs	SB	iii	W. Scotland
2/7	16/6	+16	3/6	23/5	+11	n.f.	12/6	+	Newcastle	B	i	N. England
29/6	16/6	+13	29/6	23/5	+37	n.f.	12/6	+	Newcastle	B	ii	N. England
24/6	16/6	+ 8	4/6	23/5	+12	15/7	12/6	+33	Newcastle	B	iii	N. England
10/6	16/6	− 6	4/6	23/5	+12	n.f.	12/6	+	Newcastle	B	iv	N. England
6/7	16/6	+20	25/6	23/5	+33	6/8	12/6	+55	Newcastle	B	v	N. England
n.f.	28/5	+	19/5	17/6	−29	25/5	22/6	−28	H. Mowthorpe	SB	i	W. Midlands
18/5	28/5	−10	18/5	17/6	−30	18/5	22/6	−35	H. Mowthorpe	SW	ii	W. Midlands
n.f.	28/5	+	1/6	17/6	−16	n.f.	22/6	+	H. Mowthorpe	SW	i	E. Midlands
8/6	28/5	+11	8/6	17/6	− 9	n.f.	22/6	+	H. Mowthorpe	SB	ii	E. Midlands
n.f.	28/5	+	7/6	17/6	−10	n.f.	22/6	+	H. Mowthorpe	SB	iii	E. Midlands
n.f.	30/5	+	n.f.	17/5	+	n.f.	2/7	+	Brooms Barn	SW	i	Eastern
n.f.	30/5	+	13/5	17/5	− 4	n.f.	2/7	+	Brooms Barn	SW	ii	Eastern
n.f.	30/5	+	3/6	17/5	+17	n.f.	2/7	+	Brooms Barn	SW	iii	Eastern
n.f.	30/5	+	6/6	17/5	+20	n.f.	2/7	+	Brooms Barn	SW	iv	Eastern
n.f.	30/5	+	3/6	17/5	+17	n.f.	2/7	+	Brooms Barn	SW	v	Eastern
n.f.	29/5	+	25/5	7/5	+18	25/5	3/7	−39	Wye, Kent	SB	i	S.E. Wye
n.f.	29/5	+	n.f.	7/5	+	n.f.	3/7	+	Wye, Kent	SW	ii	S.E. Wye
n.f.	29/5	+	3/6	7/5	+27	n.f.	3/7	+	Wye, Kent	SB	iii	S.E. Wye
n.f.	18/5	+	2/6	4/5	+29	n.f.	11/5	+	Silwood Park	WW	i	S.E. Reading
n.f.	18/5	+	2/6	4/5	+29	n.f.	11/5	+	Silwood Park	SB	ii	S.E. Reading
18/5	18/5	+	18/5	4/5	+14	18/5	11/5	+ 7	Silwood Park	SW	iii	S.E. Reading
19/5	18/5	+ 1	19/5	11/5	+ 8	n.f.	24/5	+	Long Ashton	SW	i	S.W. Bristol
3/6	18/5	+16	3/6	11/5	+23	n.f.	24/5	+	Long Ashton	SW	ii	S.W. Bristol
n.f.	18/5	+	19/5	11/5	+ 8	n.f.	24/5	+	Long Ashton	SW	i	Wales: Cardiff
n.f.	14/5	+	n.f.	5/5	+	n.f.	22/6	+	Starcross	SO	i	S.W. Starcross
n.f.	14/5	+	11/5	5/5	+ 6	n.f.	22/6	+	Starcross	SB	ii	S.W. Starcross
2/6	14/5	+19	n.f.	5/5	+	n.f.	22/6	+	Starcross	SB	iii	S.W. Starcross
n.f.	18/5	+	18/5	22/5	− 4	n.f.	1/6	+	Aberystwyth	O	i	Wales: Aberystwyth
26/5	18/5	+ 8	2/6	22/5	+11	n.f.	1/6	+	Aberystwyth	O	ii	Wales: Aberystwyth
n.f.	18/5	+	n.f.	22/5	+	n.f.	1/6	+	Aberystwyth	O	iii	Wales: Aberystwyth
2/6	18/5	+15	2/6	22/5	+11	n.f.	1/6	+	Aberystwyth	B	i	Wales: Bangor
2/6	18/5	+15	2/6	22/5	+11	n.f.	1/6	+	Aberystwyth	B	ii	Wales: Bangor

SB = Spring barley
B = Barley
SW = Spring wheat
WW = Winter wheat
SO = Spring oats
O = Oats

n.f. = aphids not found
\+ means that the trap detected aphids, though field samples had none

during the season; in 1971 these sites yielded from 13 to 132, a population five times as big with still only one order of magnitude in range. The very large population of *P. gamma* during the autumn of 1971 was certainly correlated with the fine weather, but was also associated with an influx of other migrant species. The similarity in the distribution of *P. gamma* and some aphids may be further illuminated by studies, at Broom's Barn by G. D. Heathcote, at Aberystwyth by J. A'Brook and at Rothamsted, on the aphids caught in light traps. A study of moths in suction traps may also strengthen the link between the two sampling systems.

Comparison in Kenya of the Rothamsted light trap with the Muguga light trap used in the East African Armyworm Survey, with various lights and at different heights,

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made some progress towards the essential, but difficult, standardisation of the Rothamsted trap used in the Survey. Analysis of suction trap samples at different heights, also at Muguga showed that lunar cycles in the light trap catches were not explained adequately by changes in density and distribution of the moths. Although these experiments are more tedious when done at Rothamsted, where there are fewer insects, some evidence on the sphere of influence of the Rothamsted trap has already been obtained and an attempt will be made to relate Rothamsted light trap samples of some pest species to absolute density, measured by suction traps, in a woodland. This will be a further step in a continuing effort to standardise the light trap as a sampling instrument.

Most of the light-trap catches up to the end of 1970 are now on computer cards or paper tape, and the suction-trap catches are also being prepared for punching. Table 2 in Part 2 of this Report was produced by computer from the card records with the cooperation of R. A. Kempton (Statistics Department).

Distribution maps. Density distribution maps are being produced for the pest species of Lepidoptera in the United Kingdom (listed in Table 2, *Rothamsted Report for 1971*, Part 2, 192–197), using the Symap V Program (Laboratory for Computer Graphics, Harvard). Similar maps for some of the common aphid species from the suction traps were produced so that we can compare changes in density and distribution during the season and from year to year. The diversity of some insect groups in different places is also now being plotted, for a new approach to the study of the stability of populations and hence the development of some species into pests. An essential first step is to select a suitable index of diversity; α, the index derived by R. A. Fisher from the log series and used by C. B. Williams will be used until a more suitable one is found.

Ancillary studies. Material from both sampling networks is increasingly used for ancillary studies. Caddis flies of the family Limnophilidae from light traps at 52 sites were identified and the distribution, sex proportions and phenology analysed and used as a basis for classifying seasonal flight periodicity by Dr. M. I. Crichton (University of Reading) and published in the *Journal of Zoology* (1971), **163**, 533–563.

One of the moths caught in the light traps is *Apamea sordens* (Noctuidae). Its larvae damage wheat grains and the discolouring of wheat flour by fungus is thought to be associated with this damage. The numbers and distribution of *A. sordens* are being mapped to provide Dr. N. A. Kent of the Flour Milling and Baking Research Association with information to correlate with the distribution of damage to flour.

Mr. P. J. Alma used material from a survey light trap, along with suction trap samples, to analyse the flight and reproductive behaviour of the top-fruit pest *Operophtera brumata*, which has a winged male and a wingless female, and to compare it with other winter-flying *Erannis* spp. pests (*Entomologists Monthly Magazine* (1969), **105**, 258–265).

Variability in wing pattern in the Lepidoptera helps field studies in population genetics and the survey provides widely distributed samples of many species. For example Mr. D. R. Lees of Oxford University is using results from the survey to study the distribution of melanism in the polymorphic species *Phigalia pedaria* whose melanic form is thought to have been favoured by the darkened vegetation in industrial areas against which they are inconspicuous, so diminishing predation by birds; in industrial areas up to 75% are melanic which suggests that the species may have been favoured by melanism before the industrial revolution (*Ecological genetics and evolution*, Ed. R. Creed (1971) Chapter 8).

Mr. G. J. Miller at Heys School is studying the wing pattern of *Spilosoma lubricipeda* in relation to site location and land use, and Mr. C. E. M. Dale at Manchester University regional polymorphism in *Noctua pronuba*, a cutworm. The light trap survey largely

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depends on voluntary workers too numerous to list; Mr. D. C. Carter, Mr. D. S. Fletcher and Mr. A. L. Goodson (British Museum (Natural History)) again identified difficult Lepidoptera; Mr. H. L. G. Stroyan (MAFF Plant Pathology Laboratory, Harpenden), Dr. V. F. Eastop (British Museum (Natural History)) and Mr. C. I. Carter (Alice Holt Forest Research Station) again identified difficult Aphididae.

Neuroptera (excluding Coniopterygidae) were separated, and most identified by Bowden from all suction trap samples since January 1970, or from the first samples of those traps installed later. *Chrysopa carnea* a principal predator of aphids is the species caught in greatest numbers at all localities. Four other species of *Chrysopa* and four Hemerobiidae together comprise a very small proportion of the total Neuroptera trapped both in particular traps and generally. Catches are episodic, and some of the surges in numbers caught are associated with the passage of weather fronts.

Several species other than Lepidoptera are being recorded also from light traps at Rothamsted, particularly at the Geescroft and Barnfield I sites. Primarily Neuroptera and Diptera are being recorded, but also a few species of Hymenoptera, Coccinellidae and Cercopidae. Fourteen species of Neuroptera (including Coniopterygidae) have been identified; as in the suction traps, *Chrysopa carnea* is the dominant species, but many more Hemerobiidae and more species of them are caught than in suction traps. Of about 150 species of Diptera so far identified, all Tipulidae (18 species), Bibionidae (six species), Empididae (34 species), Syrphidae (14 species), almost all aphidivorous species of *Syrphus*, *Platycheirus* and *Melanostoma*) and Sapromyzidae (14 species) are being recorded. (Taylor, French, Woiwod, Cole, Nicklen and Dupuch)

Light trapping in Africa

Effects of moonlight. Statistical procedures were developed for analysing the relation between moonlight and the catch of various taxa from the Kawanda light trap (*Rothamsted Report for 1970*, Part 1, 192). Very strong correlations, up to 0·98, were obtained between the amount and duration of moonlight and average nightly catch in any one phase of the moon. The importance of moon phase, and hence moonlight, compared with other factors influencing nightly catch differs greatly between species. Thus, consistent differences between catches of *Marasmia trapezalis* (Pyralididae) at different moon phases account for a quarter of the within-month variance, but for only 2% with *Amata monothyris* (Ctenuchidae). From the shape of the curves of average nightly catch plotted against moon phase, the periods during the night when some species are most active can be inferred. (Bowden, with Church, Statistics Department)

Phenology and relation of catch to meteorological factors. Light-trap catches from the Sudan Gezira between October and December 1970 were analysed, that is, from the end of the main rains but in the middle of the cropping season in this irrigated area. Hourly catches were obtained from 1800 to 2300 hours each night. The following kinds of change in catch occurred in the different months; they were shown in various combinations by different taxa.

(1) On 19–20 October acridids, and the moth *Chilo partellus*, increased suddenly after the northward passage of the Intertropical Front (ITF) (*Rothamsted Report for 1970*, Part 1, 193).

(2) From 15 to 18 or 20 November, gryllids, and the moths *C. partellus* and *Sesamia cretica* increased logarithmically.

(3) An increase from about the middle of each month, followed by irregular fluctuations and by decrease up to 15 days later, occurred with all taxa studied (various Orthoptera and Lepidoptera, and tabanids (*Atylotus agrestis*); and changes of types

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(1) and (2) above were superimposed on it. Catches of all taxa decreased simultaneously on the 28–29 October after the ITF moved to the south of the trap site. All taxa in November were fewer, and in December only the sphingid *Celerio livornica* was numerous.

The rate of increase in type (2) differed between taxa, and there was a close relation between the rate of increase from night to night and the hourly pattern of catch within nights. The rate was greatest in gryllids, of which very few were caught by 2300 hours (the end of the nightly trapping period), least in *Sesamia* where large catches at the end of the trapping period suggested that the hourly catch was still increasing; thus the apparent rate of increase from night to night depends not only on the nocturnal curve of catch but also on the time within it when traps were run: the increase and its timing, however, are realistically recorded by the light trap catches.

Changes of type (3) took place roughly during the period between full moon and new moon. Increases of type (2) began at the time of full moon and were greatest when the moon no longer rose until after the end of the trapping period.

Three suction traps at 10, 20 and 50 ft were run in the Gezira, in the same locality as the light-traps, at various times from October to December 1970. Catches of cicadellids and cercopids gave evidence of dispersal in the air circulation associated with the ITF at the time of its northward passage over the trap site in October. Change in catch for 2 hours after sunset from 11–15 November was examined in relation to phase of the moon, which rose full at sunset on the 13. Fewest cicadellids and cercopids, beetles and ceratopogonids were caught when the moon did not rise until the end of the trapping period, most when the moon was high throughout the trapping period. Catches of chironomids varied little between days. (Bowden and Gibbs)

Soil fauna

The effects of pesticides on predatory beetles. The numbers of predatory beetles, mainly the carabid *Feronia melanaria*, that eat the eggs and larvae of some pests such as Cabbage Root fly and Wheat Bulb fly are affected differently by different pesticides and knowledge of their effects could help in selecting the most suitable pesticide to use. The effects of chlorfenvinphos, disulfoton and parathion, applied at 9 kg/ha, were tested in plots surrounded by polythene barriers to prevent immigration and emigration of beetles (see *Rothamsted Report for 1969*, Part 1, 246). As found previously, chlorfenvinphos greatly increased the catch of live beetles in pitfall traps from the beginning of June, until the end of August. By contrast, with disulfoton and parathion, each at 9 kg/ha, very few of these beetles were caught; these two insecticides had a greater effect than any tested previously (Table 4).

Table 4 summarises results from all the experiments, in terms of total catch of beetles throughout the sampling periods. These insecticides are all commonly applied to soil but usually in rather smaller amounts. None of these experiments extended into a second season to assess the residual effects of the insecticide treatments because cultivating cereal crops within such barriers is difficult, but such effects will be sought in future experiments using clover in the first season, followed by swedes in the second. (Edwards, Lofty and Holdaway)

Pesticides and the arthropod soil fauna. The effects of nematicides on populations of soil invertebrates have been little studied, but last year we reported preliminary results with the nematicide aldicarb ('Temik'). This year we compared it at 6·8 kg/ha with two other compounds, methomyl ('Lannate') (11·2 kg/ha) and dazomet (364 kg/ha) in plots cropped with wheat. For six months after the soil was treated in March, the total soil

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TABLE 4

Effects of insecticides on predatory beetle populations

(All doses in terms of active ingredients)

1968 Treatment	Control	chlorfenvinphos (8·8 kg/ha E.C.)		chlorfenvinphos (8·8 kg/ha granules)		chlorfenvinphos (22·0 kg/ha E.C.)	
Species	No. caught	No. caught	%	No. caught	%	No. caught	%
Feronia melanaria	2251	3864	172	2318	103	2284	102
F. madida	414	103	25	280	68	284	69
Harpalus rufipes	—	—	—	—	—	—	—
Totals	2665	3967	149	2598	98	2568	96
1969 Treatment	Control	chlorfenvinphos (8·8 kg/ha E.C.)		diazinon (8·8 kg/ha E.C.)		phorate (8·8 kg/ha granules)	
F. melanaria	2484	2643	106	866	35	552	22
F. madida	704	635	90	512	73	261	37
H. rufipes	141	151	107	117	83	103	73
Total	3329	3429	103	1495	45	916	28
1970 Treatment	Control	chlorfenvinphos (8·8 kg/ha E.C.)		carbophenothion ('Trithion') (8·8 kg/ha E.C.)		fonofos ('Dyfonate') (8·8 kg/ha granules)	
F. melanaria	1327	1387	105	725	55	482	36
F. madida	83	105	127	43	52	5	6
H. rufipes	163	192	118	166	102	109	67
Total	1573	1684	107	944	60	596	38
1971 Treatment	Control	chlorfenvinphos (8·8 kg/ha granules)		disulfoton (8·8 kg/ha granules)		parathion (8·8 kg/ha granules)	
F. melanaria	2616	2762	106	326	12	231	9
F. madida	26	27	104	10	38	5	19
H. rufipes	41	49	120	18	44	6	15
Total	2683	2838	106	354	13	242	9

arthropods were only half or two-fifths as many with aldicarb, methomyl or dazomet as in untreated plots; mites and springtails were particularly susceptible. Only populations of predatory mites had recovered completely by September. None of the nematicides affected populations of insects, other than Collembola, in the soil.

The insecticides endrin, tetrachlorvinphos ('Gardona') and monocrotophos ('Azodrin') were compared in a field experiment planted to sugar beet. As in 1970, endrin (1 kg/ha) was by far the most toxic, especially to Collembola. Monocrotophos (1·5 kg/ha) killed predatory mites but had little effect on other arthropods and tetrachlorvinphos (4 kg/ha) had little effect on any of the soil arthropods. (Edwards, Stafford and Lofty)

Pesticides and earthworms. The effects of pesticides on earthworms (*Rothamsted Report for 1970*, Part 1, 193) were further studied in field experiments with the nematicides methomyl, aldicarb and dazomet, the insecticides endrin, tetrachlorvinphos and 'Talcord' (S-2-cyanoethyl *N*-[(methylcarbamoyl)oxy]thioacetimidate and the herbicide 'Bladex'. Some were applied to the surface, others were cultivated into the surface layers of soil. The earthworm populations were assessed 4–5 months after treatment (Table 5).

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TABLE 5

Effects of pesticides on numbers of earthworms

(Expressed as percentage of numbers in untreated plots)
(All doses in terms of active ingredient)

Pesticide	*Lumbricus terrestris*	Other spp.	Total
A. *Nematicides*			
methomyl (11·2 kg/ha cultivated)	164	88	111
aldicarb (6·8 kg/ha cultivated)	91	96	95
dazomet (364 kg/ha cultivated)	45*	25*	31*
B. *Insecticides*			
endrin (8 kg/ha surface)	37*	82	69
endrin (1 kg/ha surface)	65	102	92
endrin (8 kg/ha cultivated)	36*	65	55
tetrachlorvinphos ('Gardona') (8 kg/ha surface)	54	35*	43
tetrachlorvinphos (4 kg/ha surface)	77	54*	57
tetrachlorvinphos (8 kg/ha cultivated)	91	53	66
'Talcord' (3 kg/ha surface)	83	52	94
'Talcord' (3 kg/ha cultivated)	54	56	55
'Bladex' (4 kg/ha surface)	105	267*	257
'Bladex' (2 kg/ha surface)	77	87	85
'Bladex' (4 kg/ha cultivated)	155*	144*	148*

* Significant at $P = 0{\cdot}05$.

Of the nematicides, only dazomet significantly affected numbers. The most toxic insecticides were endrin, which killed more *L. terrestris*, and tetrachlorvinphos, which was most toxic to other species. Tetrachlorvinphos is more soluble than endrin and hence is washed into the upper layers of the soil where most species of earthworm live. *L. terrestris*, although a deep-dwelling species is a surface feeder and would thus come into contact with surface-applied endrin.

The larger doses of 'Bladex' significantly increased numbers of earthworms, possibly because it killed the weeds and produced decaying organic matter which favoured worms. (Edwards, Lofty and Stafford)

The effects of cultivation on earthworm populations. We reported last year that the numbers of earthworms in reseeded leys or in land previously pasture were increased by cultivations, which are widely thought to make earthworms fewer. This effect has been maintained; also in the third year, as in the second, there were more earthworms in all of the various reseeded plots than in the original old pasture. Plots that had been cultivated once, then reseeded, had the most, plots cultivated three times an intermediate number, and uncultivated plots fewest. This supports the suggestion made last year that any direct effect of cultivation on numbers of earthworms is less important than the loss of organic matter that occurs with repeated cultivation. (Edwards and Lofty)

Paraquat and slit-seeding. An experiment, started in 1965, on old pasture at White Horse Field, Woburn, was cropped with spring wheat in the first year and winter wheat in each succeeding season. Half the plots were ploughed and half uncultivated, both being sown with a slit-seeding drill.

The experiment aimed to find whether direct seeding affected attack by pests and whether soil invertebrates turned over and aerated the unploughed soil. In general, the direct-seeding succeeded, for wheat yields have usually differed little between direct-seeded and ploughed plots (*Rothamsted Report for 1969*, Part 1, 247).

Plots were subdivided and one-half of each treated with a mixture of pesticides that

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killed earthworms and most of the other soil invertebrates; nematode numbers were affected only in 1971 (see p. 174). Yields were usually greater from the insecticide-treated halves of the plots, which suggests that the activities of soil invertebrates did not enhance yield of wheat in unploughed land. However, the lightness and lack of compaction of the soil at Woburn, plus the activities of many moles, may have masked the effects of invertebrates. There were consistently more arthropods in the paraquat-treated than in the ploughed plots, especially rhodacarid and tyroglyphid mites, entomobryid and sminthurid springtails, symphylids, Thysanoptera and Coleoptera (particularly wireworms). There were usually more of the larger predatory mites and dipterous larvae in the ploughed plots.

The effect of the treatments on earthworm populations varied during the experiment. *Lumbricus terrestris* gradually became fewer in all plots; but paraquat plots always had more than ploughed ones. After 1968, populations of other species were about equal in both kinds of plot and, although they have since remained fairly constant in the ploughed plots, they have gradually become fewer in the paraquat plots. This year there were about 2½ times more worms of species other than *L. terrestris* in the ploughed than in the other plots. This difference is probably caused by the failure of litter and organic matter to be incorporated in the surface layers of the soil, where species other than *L. terrestris* live; by contrast *L. terrestris* pulls litter deep down and so would probably suffer less from lack of organic matter.

Pests seemed more prevalent in direct-seeded than in ploughed plots, but without causing differences in yield except in the first year when the wireworm attack was greatest in direct-seeded plots and in 1966/67 when slugs devastated the direct-seeded but not ploughed plots. Nematode populations differed little.

Yields have steadily declined during the experiment, because 'take-all' has steadily increased. Yields were so small in 1971 that the experiment is not worth continuing. (Edwards, Lofty and Whiting)

Effects of temperature and moisture on populations of soil invertebrates. Another experiment on effects of soil temperature on populations of soil invertebrates (*Rothamsted Reports*, Part 1, *for 1969* and *for 1970*) began in October 1970, with eight hexagonal plots with sides of 1·5 m, each surrounded by a sheet of galvanised iron 75 cm wide, half buried to prevent horizontal migration of animals. Six plots were left open to the weather and two were covered with PVC sheeting. Of the six open plots, four were heated with 800 watt infra-red heaters, one on each of the six sides; two plots were left unheated as controls. Because heat dries the plots, two of the four were watered to keep the moisture content of the soil the same as in the unheated controls. Temperatures and soil moisture contents were regularly recorded in all plots. Eight soil cores 5 cm diameter × 15 cm deep were taken from each plot every two weeks and the animals extracted in a modified high-gradient Tullgren apparatus. The sorting of more than 2000 samples progresses, but trends are evident. Heating and adding water greatly increased populations of prostigmatic mites (especially *Pygmephorus* and *Scutacarus* spp.), some of the predatory mites (especially rhodacarids), oribatid mites (such as *Minunthozetes* and *Oppia* spp.) some Collembola (particularly *Onychiurus* sp.) and Thysanoptera. Increases were smaller in heated plots without added water. Enchytraeid worms and beetle larvae became fewer in all the heated plots whether watered or not. By contrast, keeping the soil dry with covers, increased the numbers of prostigmatid and uropodid mites, and isotomid springtails.

Although there were fewer coleopterous larvae in the heated plots, more adult beetles (especially click beetles) and more millipedes were caught there in pitfall traps, possibly because their activity was increased.

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How soil temperature affects the rate different species develop in the soil and the life cycles of soil pests is also being studied at five field sites; Kindrogan Field Centre, Perthshire; Leighton Moss Bird Reserve, Silverdale, Lancashire; School of Agriculture, Sutton Bonington, Leicestershire; Luddington Horticultural Research Station, Warwick; ADAS Sub-Provincial Headquarters, Starcross, Devon. At each site, soil samples are taken monthly and a Rothamsted light trap and pitfall traps have operated since October 1971. The development and numbers of selected species in the soil mesofauna, and also wireworms, leatherjackets, cutworms and chafer and swift moth larvae, are being studied. The emergence from the soil of clickbeetles, crane flies, noctuid moths, chafers and swift moths is being studied with light traps and pitfall traps. (Haines and Edwards)

Slugs

Work on the use of gelatin as a carrier for molluscicides reported last year (p. 198) was extended to compare some of the properties of gelatin unhardened and hardened by exposure to formaldehyde vapour, as they affect its use in molluscicide formulations, have been investigated.

Absorption of water. Air-dried gelatin discs were kept on wet filter paper in Petri dishes for 8 hours at room temperature, and the rate at which they absorbed water was measured by weighing them at hourly intervals. After 8 hours the unhardened gelatin was too soft to weigh accurately and the hardened material was soft but intact. Hardening slowed the uptake of water, and whereas unhardened gelatin increased in weight by 314% after 8 hours, gelatin exposed to formalin vapour for 1 hour increased by 150% and that exposed for 2 hours by only 100%.

Release of a water soluble ingredient. As hardening slows water uptake, it can also be expected to slow the loss of water-soluble ingredients. This was tested using boric acid (whose solubility in water is 6·3 g/100 ml at 20°C), because it is simpler to measure than the molluscicides used later. Boric acid is only a little more soluble than some of the molluscicides that might be used in gelatin formulations. A saturated solution of the acid was used to make unhardened and hardened gelatin discs, which were then stood on wet filter papers. At hourly intervals the discs were removed and the hot water washings, 2×10 ml, were titrated for their boric acid content. Boric acid was lost much faster from the unhardened than from the hardened gelatin.

Durability of unhardened and hardened gelatin containing 1·5% 'Talcord' (S-2-cyanoethyl N-[(methyl carbamoyl)oxy]-thioacetimidate). Groups of discs were first put on terylene mats and buried in holes in bare soil 50, 100 or 150 mm deep. After 28 days, during which the total rainfall was 44 mm, all unhardened discs had disappeared, whereas 60% of the hardened discs still remained, most in the deepest holes. All contained enough active ingredient to kill slugs in the laboratory. The missing discs had either dissolved or been destroyed by micro-organisms. The persistence of the hardened gelatin suggests that insecticides formulated in this way might be useful to control soil-borne pests. They could be cultivated into the soil and would slowly release the active ingredient (a.i.).

Test of 1·5% 'Talcord' in unhardened and hardened gelatin. The gelatin was made with 20% w/v aqueous wheat bran extract and hardened in formaldehyde vapour for 60 minutes. Discs 3 mm in diameter were set out on 2 m² plots in a 50 mm mesh grid pattern where clover plants had been cut down to soil level. Birds were kept off the plots by nylon nets and upturned saucers provided cover for the slugs. Fifteen field-collected,

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adult *Agriolimax reticulatus* were scattered on each plot at 1700 hours daily and the dead and moribund slugs were counted and removed next day at 0900 hours. Unless rain fell, the equivalent of 2 mm of rain was applied to the plots just before the slugs were distributed. During the 14-day trial, a total of 150 mm of water (as rain, and applied) fell on the plots. The total number of slugs found on each plot was 210 and the total numbers of dead and moribund slugs were 107 from plots with unhardened discs and 122 from those with hardened discs. The daily fluctuations in the catches were similar with both treatments. The most slugs were killed after heavy rain. Thus the hardening of the gelatin does not adversely affect the toxicity of the baits. Few unhardened discs remained at the end of the trial but about 70% of the hardened ones did and these still contained enough a.i. to kill slugs in the laboratory.

Hardened gelatin made with aqueous wheat bran extract and containing molluscicide does not disintegrate in wet weather and continues to kill slugs in the field for at least two weeks. The molluscicide used also killed many earthworms and millipedes.

Preparation of large quantities of slug bait. The baits used in the preliminary trials were cut from gelatin sheets with a cork borer. Gelatin in the form of small irregularly shaped lumps (noodles) can be obtained commercially. On the advice of Dr. A. Jobling (Croda Gelatin, Luton, Ltd.), a large quantity of baits in this form, using low grade gelatin, was made containing 4·0% metaldehyde to be compared with pelleted bran formulations in a field trial.

Gelatin baits for leaf-cutting ants. Citrus pulp is used as an attractant and carrier in baits for leaf-cutting ants in Trinidad but it disintegrates in heavy rain. Preliminary tests were made using unhardened and hardened (30 minute formaldehyde vapour) gelatin made with 20 w/v aqueous citrus pulp extract. Many 10 mm squares 1 mm thick were taken into the nests in laboratory cultures of both *Atta cephalotes* and *Acromyrmex octospinosus*. Larger pieces were cut up by the ants before being removed. Pieces more than 2 mm thick or that were very soft or very hard were not readily accepted.

Extracts of citrus pulp, 10% w/v in acetone or 1 : 1 : 1 chloroform–ether–methanol mixture were allowed to evaporate on filter paper. 5 mm squares of the paper were quickly taken into the nests but similar pieces moistened with an aqueous extract of citrus pulp were ignored. Evidently the constituents of the organic solvent extracts were more attractive to the ants than those of the aqueous extract. To avoid the expensive organic solvent extraction, late tests were made with gelatin in which finely ground, oven dried citrus pulp was incorporated. Unhardened and hardened baits containing 20% w/v ground citrus pulp were offered to the ants in separate tests in the absence of other food. The ants picked up 20 pieces of hardened and unhardened bait in the same time.

Baits were made as in the previous trial and 2·0% sunflower-seed oil was stirred into the mixture before it was cast into sheets. The oil droplets could be seen in the gelatin matrix with a hand lens when the sheets had cooled and set. Ten 10 mm diameter discs were offered to the ants and their responses noted after 30 minutes. *A. cephalotes* took only six each of hard and soft baits and *A. octospinosus* accepted only one soft and three hard baits into the nest.

These results confirm that sunflower seed oil is only moderately attractive to both species of ant. The presence of the oil is necessary as a solvent for aldrin, the insecticide most commonly used in leaf-cutting ant baits. Water was absorbed by baits containing oil, much slower than by baits without oil. This could be advantageous in prolonging the field life of the baits in tropical rain. In collaboration with T. Lewis (seconded from this department) samples of baits containing sunflower-seed oil are being tested in the field in Trinidad. The possibility of making a more attractive bait in which mixtures of sugars

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replace the citrus pulp are being investigated in collaboration with Dr. J. M. Cherrett, University College of North Wales, Bangor. (Stephenson)

Wheat Bulb fly

Egg laying and dispersal of adults. Last year we reported (p. 196) that in Stackyard Field Wheat Bulb flies laid fewer eggs near hedges than towards the centre of the field. Further sampling showed that eggs and larvae were similarly fewer near boundaries of some other fields but not all, and that where they were fewer they were in shadow from trees during the late afternoon and early evening, that is to say when most eggs are laid. Sometimes there were less than a quarter in shadow than elsewhere.

Movement of adult flies was therefore studied with white-painted water traps, mostly on the fallow on Stackyard Field, but also in cereal crops both on Stackyard and elsewhere, and with five 9 in. suction traps. Neither type of trap alone can distinguish variations in catch that result from different numbers of flies breeding in the vicinity from those caused by changes in the activity of the flies; the results are thus difficult to interpret. Both types of trap showed a sharp peak in the numbers of both sexes in late July over the fallow in Stackyard, three to four weeks after the peak emergence of the females, and when the first batch of eggs was ready to be laid. There was a second smaller peak of females in late August when the second batch of eggs was ready for laying. The size and timing of the peaks seem not to be strongly correlated with any weather factor, and movement to egg-laying sites seems to be controlled primarily by the physiological condition of the flies.

Water trap catches in cereals were similar to those over fallow, but the numbers caught each day by suction trap over cereals diminished when most were caught over fallow. About twice as many flies were caught by suction traps between 1600 and 0930 and 1600 hours BST, confirming that most fly after the hottest part of the day. (Bardner, Fletcher and Margaret Jones)

Sampling Wheat Bulb fly. At Rothamsted eggs were very numerous in the autumn of 1971 not only on most fallowed areas, including Broadbalk Field with 4·5 million/ha, but also on some fields after potatoes (Whittlocks Field 3·5 million/ha). Fields at Woburn had an average of 2·5 million eggs/ha after fallow but very few after potatoes.

Several fields also had large populations of larvae in the spring of 1971. There was approximately 3·2 million/ha on Broadbalk where only 20% of the larvae in the plants were dead, presumably killed by the dieldrin seed dressing. The early date of drilling Broadbalk in 1970 enabled other stem-boring Diptera to lay eggs during the autumn, and 1–2% of the plants were infested by *Oscinella frit*, *Opomyza florum*, *Opomyza germinationis*, *Meromyza* sp. and *Chlorops* sp. (Fletcher, Bardner and Margaret Jones)

Effect of attack by Wheat Bulb fly on individual plants of three wheat varieties. The effects of attack by Wheat Bulb fly on yield have been studied almost entirely with the variety Cappelle Desprez, although different varieties might be expected to respond differently, especially as Raw found the seedlings of different species and varieties differ in their ability to survive attack. Therefore we compared the growth of individual marked plants in crops of Cappelle Desprez, Maris Widgeon and Maris Ranger grown on infested land at Rothamsted. The sowing was deliberately late (11 November 1970) to give a severe test of the capacity of the plants to withstand attack. Unexpectedly poor growing conditions before the larvae attacked during February resulted in a poor and patchy stand of less than 1 million plants per hectare, instead of the expected 2–3 million; differences in yield between replicates were very large compared with differences between

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varieties. The plants were attacked by larvae when side shoots were starting to develop; about 60% of the plants were initially infested, and eventually 80–90% were injured. Most of the plants that died (47–63% of the total) did so by early May, before the attack ended, and were killed directly by the larvae rather than by competition with other plants. So few plants survived that there was little or no competition between them, so the surviving attacked plants had as many and as large ears as plants in an unattacked crop.

This contrasted with our earlier results with Cappelle, where the infestation was less and the plants more dense. Thus attacked plants that survived produced 1·5–2·5 ears/plant, whereas unattacked plants produced between 3 and 7 ears/plant. By contrast, this year attacked plants that survived produced between five and seven ears each and unattacked plants between nine and ten. The earlier experiments also showed that the yield of unattacked plants but not of attacked plants is negatively correlated with their density. This year unattacked plants were too few to detect a correlation of yield with density, but again with none of the varieties was yield and plant density of attacked plants correlated, despite their very large yield. This difference is probably because attacked plants vary much more than unattacked ones in their subsequent growth. (Bardner and Fletcher)

Emergence and survival in the field. May was fine but June wet and cool. Wheat Bulb flies emerged in Stackyard from 15 June–23 July, with peak numbers on 1, 2 and 3 July, a week later than in 1970. There were many eggs and larvae but only 3·6% of the eggs laid produced flies, whereas 15% did in 1970. Examination of the flies caught in the emergence cages showed that the main Braconid parasite, *Phaenocarpa* sp. emerged at the same time as the fly, in June and July, and was five times commoner than in 1970.

The reproductive system. In the adult male fly each testis is elongated, orange coloured, and becomes more pointed with age. The vas deferens runs from the distal end into the ejaculatory duct, where two other ducts from two, large colourless accessory glands also open. These glands are solid in newly emerged males but the central areas disintegrate, so in older males the walls, consisting of several layers of cells, enclose a colourless fluid. Each testicular follicle contains zones of development with apically-placed spermatogonia surrounded by large nutritive cells, developing posteriorly into spermatocytes and then into spermatids. The spermatids form long spermatozoa with long tails. Newly emerged males already have spermatozoa with tails near the exit to the vas deferens, and as they age, more of the testicular follicle becomes filled with mature sperm. Many sperm pass head first down into the ejaculatory duct at the same time. After copulation the spermatozoa are stored in the three, black spermathecae of the female. Ten to 14 days after the females emerge, when the first batch of ovarian follicles is half developed, the spermathecae contain many spermatozoa.

The first fly caught with ripe eggs in the ovaries was on 14 July, a month after the first recorded emergence; a fly caught on 20 July had laid all the first batch of eggs, another caught on 18 August had laid two batches and another, caught on 15 September on Stackyard Field had laid three batches. During the egg-laying period many flies were attacked by the fungus *Entomophthora muscae* and during the weeks 22–29 July, 29 July–5 August, 5–12 August, 12–19 August, 19–26 August, 63%, 43%, 57%, 72% and 47% respectively of all the flies taken from water traps and dissected contained fungal hyphae. Between 21 July to 23 August, 63% of the flies caught by suction traps over fallow and 66% over the crops were similarly infected. Some infected flies kept in cages in the laboratory succeeded in laying most of their eggs but others died with the ovaries still full of unlaid eggs.

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The light trap on Barnfield also caught female Wheat Bulb flies; of the 30 dissected between 20 July and 7 September, six contained ripe eggs. Eleven (37%) had laid one batch, five (17%) two batches, none three batches; 12 (40%) contained fungus. Only one, caught on 21 July, contained unripe eggs in the ovary, and its abdomen was full of hyphae; from this and from the many infected females caught in water traps on fallow, it seems that some at least of the flies whose abdomens are distended with fungal hyphae behave as if the ovaries were extended by eggs and fly to the oviposition site. Throughout the season only two flies of many caught in the field laid all of the eggs of the third batch.

Artificial rearing of Wheat Bulb fly. Using the methods described last year (p. 196) a supply of larvae and adults was maintained throughout the year, and used to study factors affecting the development of larvae. Temperature was important but so also was the nutrition of the plant, and in the fully illuminated Saxcil Cabinet at 10°C they developed from egg to adult in about 70 ($\pm$3) days but took about 84 ($\pm$2) days at 10°C with strip lighting four a.c. watt tubes.

To simplify breeding and avoid the need of winter wheat plants, attempts were made to rear larvae on artificial diets composed of filter paper clippings, yeast, dried milk, sucrose and extracts from the bulbs of wheat seedlings kept at 15°C. One male and one female were obtained but the medium is not yet satisfactory.

The phenology of insects in a wheat field. During a year a wheat field is ploughed, harrowed, sown, treated with herbicide and harvested. The arthropod population of the soil also changes with the season, and can be studied with pitfall traps and emergence cages. Ten traps were placed in the soil in a fallow area during October, removed while winter wheat was sown and replaced in the growing crop. In February, two more traps were added at the outside edge. The traps always contained spiders. During October and November, the carabid larvae, *Harpalus* sp., *Feronia* sp. were very active but became scarcer with the snows and frost of December and January. A few small carabids, *Bembidium* sp., *Acupalpus* sp. were caught throughout the year, and *Trechus* sp. during autumn. The numbers of *B. lampros* and of species and individuals of staphylinid beetles increased in the traps in late April and May. The small, voracious beetle *Agonum dorsale* was common in June but the commonest carabids during June, July and August, were *Harpalus ruficornis*, *Feronia vulgaris* and *F. madida*. Other species, of *Amara* and *Harpalus*, were caught in smaller numbers, as well as several small staphylinid species. Many predacious beetles (*H. ruficornis*, *F. vulgaris*, *F. madida* and *A. dorsale*) were active when Wheat Bulb flies were emerging from the puparia and when most vulnerable to predators.

Ten, small, all-weather emergence cages (basal measurement 74·5 cm^2) were left on the fallow or on the stubble (not over the growing crop), and the catch examined twice a week. Except for a few weeks when snow covered the ground, the traps always contained some spiders; *Sciara* sp. was also very common, especially during October and April and May. Several species of small phorids occurred during September and October, and disappeared during the winter, reappearing in May. *Lonchoptera lutea* was commonly caught over stubble in September, October and November 1971, but in 1970, when the stubble was ploughed earlier in October and the cages stood on the soil for most of the autumn, there were few. Adult cecidomyid flies disappeared during the winter but many emerged in May. All through the winter a few Nematocera, chiefly culicids, chironomids and tipulids were observed in flight. *Sitona* sp. (chiefly *S. lineatus*), usually considered to feed on leaves of leguminous plants, was common over the soil except when there was frost and snow, and especially so during April and May; 81 were caught between 13 and 20 April. Many *Sitona* sp., therefore, overwinter in soil. In May, many muscid flies,

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closely related to Wheat Bulb fly, emerged from the soil with a peak (52 flies) between 17 and 25 May. Many of these flies have more than one generation a year, so their larvae and pupae could act as hosts to parasites of the Wheat Bulb fly which has only one generation a year.

Parasitic Hymenoptera did not fly during the winter, but emerged in May and were common throughout the summer and autumn. All groups, braconids, proctotrupids, ichneumonids, cynipids and chalcids were flying from the stubble. The chalcids, *Cyrtogaster vulgaris* and *Callitula bicolor*, parasites of small stem borers such as *Oscinella frit*, were commonly found in September and October.

There was no definite fourth generation of frit fly as there was in 1970. (Margaret Jones)

Flight and migration

***Plusia gamma* (Lepidoptera, Noctuidae).** The experiment aimed to detect any special feature in the post-teneral, pre-reproductive flight activity that might indicate a migratory or non-migratory state. Adults were reared from larvae fed on broad bean plants and the females allowed to emerge from pupae placed in automatically recording aktographs at 20°C and a 14/10 hour regime of artificial light. They were supplied with honey solution and their flying was recorded without the insects having been handled as adults. During the three days after they emerged, most moths flew intermittently, but frequently, both in the light and darkness. Later flight was almost entirely during darkness. Table 6 shows the number of hours (but not total flight duration) in each successive day after emergence in which the insects flapped their wings, expressed as a percentage of the number of hours of the light or dark period (means for about 20 moths). Few moths laid eggs before the seventh day and none during the first three days. Moths given only water were also fairly active in the light and the dark during the first three days, but most died shortly afterwards without laying eggs (Table 6). The duration of time when the water-fed moths flew was positively and linearly related to their weight at emergence. For example, one moth weighing 188 mg flew for approximately 20 hours during the three-day period, others of about 150 mg flew for a maximum of 13 hours and the smallest moths of about 100 mg flew for no more than 3 hours.

TABLE 6

Proportion of hours in light and dark when ten female Plusia gamma *flew in the days after emergence*

Day	1	2	3	4	5	6	7	8	9	10
	Females given sucrose solution									
light	40	45	25	12	12	13	12	12	12	11
dark	55	58	85	80	68	70	57	62	61	65
	Females given water									
light	20	31	30	—	—	—	—	—	—	—
dark	61	60	47	—	—	—	—	—	—	—

These moths flew most when young and were then least affected by changing light intensity. The response is basically unaffected by food of the adult. Such behaviour is typical of many species of migrant moths in nature and suggests that post-emergence activity in the aktographs reflects a migratory condition.

Adults fed on sucrose (AR) solution alone matured and laid eggs. The hypothesis, in the literature, that adults need to be fed tocopherol (vitamin E) to develop their ovaries was tested but not confirmed.

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Exceptionally many *P. gamma*, mostly with an appearance of being young, were seen flying in many parts of the United Kingdom in late September, especially around flowers during the day time. Fifty such females were dissected. They still contained the meconium, which is usually voided at the start of tethered flight; all had large fat bodies and undeveloped ovaries. Nine insects taken in a light trap were also very fresh and when placed in the aktograph flew both in the light and dark. The moths seen in the field were thus behaving like the young moths in the aktograph, and could perhaps be regarded as incipient migrants although the presence of the meconium suggests they had not flown far. More work will be needed to establish the significance to migration of the light–dark flight of young moths. (Macaulay)

The cotton stainer, *Dysdercus intermedius* (heteroptera)

The cotton stainer, an important pest of cotton, is also a migratory insect but not all adults migrate. The factors that affect the ability to migrate have been little studied, although mated females are known to lose their capacity of flight soon after they emerge because mating triggers autolysis of the flight muscles. Little is known also about intrinsic duration of flight, so this was studied with tethered insects. The insects were bred on cotton seed at 29°C and, after the teneral period, the adults were tethered and flown at about 25–28°C; some individuals were tested daily, for up to seven weeks after they emerged. Fed virgin insects of either sex flew without stopping for the longest periods when they were four to five days old, and the longest observed flight, thought to be continuous, exceeded 23 hours. However, insects often flew for several hours on subsequent days, with the flight duration gradually shortening over a period of five to seven weeks with insects fed daily, and two to three weeks with unfed ones.

Mating profoundly affected flight and mating is affected by feeding. When males and females are kept together in small groups and fed cotton seed, females rarely fly because their flight muscles begin to autolyse soon after they mate; males retain the ability to fly. There seems to be a connection between feeding and mating. Insects fed on cotton seed in culture after they emerge soon mate, but when they do not feed they either fail to mate or do so only after a long delay: unfed insects of both sexes fly. Mating is also delayed between males and females of which only one sex has fed; fed males mated more often, but not very successfully, with unfed females than unfed males with fed females; females from both kinds of group remain able to fly for a long time.

These observations raise interesting ecological and phenological problems for field work. *Dysdercus* is gregarious and the sexes meet frequently after they emerge. Mating in another species, *D. sidae*, is stimulated by feeding on cotton seed. If *D. intermedius* behave similarly, and some individuals need to feed on cotton seed to mate, the time and place they do so would greatly affect their subsequent dispersal. Those that fail to find cotton seed at the emergence site would then be the migrants, so the proportion of migrants in a habitat might depend on when seed is produced in relation to the population growth of *Dysdercus*. (Sherrard and Johnson)

Staff

A. J. Cockbain transferred to the Plant Pathology Department and E. Judenko left. R. W. Gibson was appointed, supported by a grant from the Potato Marketing Board.

C. G. Johnson visited the Cocoa Research Institute of Ghana, as an assessor of the ODA Virus Research Team, and Holland as guest of the Nederlandse Entomologische Vereniging when he was made Honorary Member. G. Dibley visited Trinidad to work with T. Lewis (seconded to Overseas Development Administration). I. Woiwod and

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H. Franklin visited Denmark to install a survey suction trap at Den kgl. Veterinaer-og Landbohøjskole, Zoologisk Institut, Copenhagen. C. A. Edwards read a paper at the 34th Winter Congress of the Institut International de Recherches Betteravières, Brussels.

Miss G. Hale (Brunel University), Mr. D. W. Lloyd (Wolverhampton Polytechnic) and Mr. C. Backhouse (Bradford University) joined as Sandwich Course Students.

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BEE DEPARTMENT

C. G. BUTLER

Field work was much delayed by the late spring, but favoured by good weather later in the summer. Our main studies continued to be directed to making beekeeping more efficient, to improving the ways of using honeybees and other insects as pollinators, and to controlling bee diseases.

Behaviour and physiology

Swarming. Before colonies with recently hatched virgin queens swarm they produce the sound known as 'piping', made both by the free virgin queen and by other mature virgin queens confined by the worker bees to their cells. Queen piping has also been observed before swarming by colonies in observation hives containing laying queens and only immature queen cells. In both these circumstances, the queens may be encouraged to pipe by the presence of occupied queen cells. However, this summer, two very small colonies in observation hives, without occupied queen cells, absconded (i.e. completely deserted their hives, leaving no bees behind) and in each the queen was piping immediately before the absconding. This not only supports the idea that queen piping is closely related to swarming and that all kinds of swarming are interrelated, but also shows that conditions in a colony other than the presence of occupied queen cells can make a queen pipe. (Fernando and Simpson)

Effect of removing queen cells from honeybee colonies. Many beekeepers remove occupied queen cells from their colonies at intervals during the summer in the belief that this prevents, or at least delays, swarming. As an exploratory test of its effectiveness, 18 colonies had their hive space limited to 37 litres to encourage swarming and ten of them had their occupied queen cells cut out each week (the maximum frequency of removal commonly practised). Only 11 of the 18 colonies outgrew their hives and produced queen cells with larvae before mid-July. Five of these 11 colonies were in the group from which queen cells, when they were found at the weekly inspections, were removed. Three of the five swarmed, the queen of one was superseded and the queen of the other died. Of the six colonies that were in the group from which queen cells were not removed, two swarmed, the queen of one died and the queens of the other three survived. Of two colonies from which queen cells were removed, neither swarmed and one failed to outgrow its hive, but both produced sealed queen cells, showing that some queen cells (which need have contained only eggs) were overlooked at the weekly inspection. The results show the difficulty of removing all queen cells (commercial beekeepers usually do not try to remove all the ones with eggs), that weekly inspection is not an infallible method of swarm prevention, and that a colony that has outgrown its hive can swarm without *sealed* queen cells. They further show that experimental use of queen-cell removal to determine whether queen cells encourage colonies to swarm is difficult, because of the number of colonies required, the difficulty of removing all the queen cells, and the frequency with which they must be removed to ensure that there are no cells beyond the egg stage. (Simpson and Moxley)

Handling larvae for queen rearing. Attempts were made to test the effects of various factors that may affect the survival of larvae transferred from worker cells to queen

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cells to rear queens. Two hours' exposure to cold (12° and 5°C), or to desiccation (in an incubator at 35°C and 100% relative humidity) had little or no effect on the proportion of larvae that yielded sealed queen cells. In contrast, turning the larvae from the side on which they were lying to their other side considerably diminished survival in two experiments, though not in a third. Turning a larva over and back again in a dry queen cell was also detrimental, so the effect probably reflected mechanical damage and not drowning by getting the spiracles of both sides filled with food. Thus, it seems easier to damage larvae mechanically than by exposure *after* transfer. (Simpson and Moxley)

Wintering queens in mating nuclei. For many years the department has kept queen bees during their mating period, and then until needed in the same summer, in small colonies (nuclei), four of which are contained in a single 37 litre hive compartment. Hitherto it has proved impossible to get these nuclei to survive the winter, but as equally small colonies survive in unheated observation hives in a heated laboratory, it seemed that the small colonies possibly died outside because they became too cold. During the winter of 1970–71, colonies survived outside in the small colonies when each hive compartment containing four of them was kept warm with a 40 W ,7·5 V heating element covering the sides and bottom. Outside the heating element the surface of the compartment was covered with a 25 mm thick glass-wool blanket and the entrance of each colony was restricted to a 12 mm tube. The power supply to the transformer providing the low voltage was controlled by a thermostat set to operate at 15°C and placed in a similar empty hive compartment. These overwintered nuclei not only provided queens during the spring, but also could immediately be used for mating further queens. (Butler, Moxley and Simpson)

Egg-laying. The queens of colonies were interchanged in attempts to measure the extent to which the workers of a colony influence the rate their queen lays eggs. Moving queens from colonies with a few eggs into colonies with many made them lay more eggs, whereas moving them from colonies with many eggs into colonies with few eggs made them lay fewer. Eight days after the queens had been interchanged the number of eggs in each colony approached the number there before the queens were interchanged, suggesting that the colony influences egg laying. (Free and Williams)

Communication. Stimuli that induce bees to communicate with others by dancing in the hive have been suggested to be correlated with those that also induce bees to communicate by dispersing Nassanoff gland scent at a food source. To examine the suggestion bees were trained to collect sugar syrup either from dishes less than 30 m from their hive or more than 100 m from it, and their scenting and dancing on each of their visits to the dishes were noted.

The amount of scenting and dancing differed much between experiments, even when the distances between the hive and the dishes were similar. On average, about one-third of the bees danced in the hive immediately after visiting a dish for the first time each day, but few of them scented. Although the proportion that danced remained almost constant throughout the day, the proportion that scented gradually increased but never became as great as the proportion that danced. Consequently, most bees that danced before leaving the hive to visit a dish did not scent when they got there, whereas a few scented on reaching a dish although they had not danced before leaving their hive. Hence there was no apparent correlation between these two modes of communication, although some that danced also scented more than those that did not dance. (Free and Williams)

Attempts to increase the number of bees visiting plots of flowers by exposing synthetic Nassanoff scent (geraniol 200 parts : citral 8 parts) nearby failed. (Butler, Free and Williams)

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Male genitalia of *Apis* spp. In *Apis mellifera* the bulbous portion of the aedeagus, in which the semen and mucus are stored transiently during copulation, has a very thick epicuticular (staining strongly with azo-carmine) lining bearing large sclerites. After the contents are ejaculated, this lining becomes detached and often remains lodged in the queen's sting-chamber as the 'mating sign'. The aedeagus bulb of the other three *Apis* spp. has no sclerites, but otherwise its structure is unknown. Serial sections show that the epicuticular lining is much thinner in *A. cerana* than in *A. mellifera*. In *A. dorsata* it consists only of separate and easily detached angular particles, and the only similarly staining materials in *A. florea* are pebble-like bodies within the lower layers of the cuticle of the bulb and adjacent structures. If other species than *A. mellifera* shed 'mating signs', these 'mating signs' must differ from those of *A. mellifera*. (Simpson and Moxley)

Pheromones of queen honeybees. Attempts were continued to isolate the pheromone, or pheromones, additional to those in a queen's mandibular gland secretion, that inhibit queen rearing (*Rothamsted Report for 1970*, Part 1, 202). Small amounts of 9-oxo- and 9-hydroxy-decenoic acids were detectable in the heads of queens even ten days after their mandibular glands had been removed and they had been returned to their colonies, despite the fact that they seemed free from any mandibular-gland tissue. Some evidence was obtained suggesting that the second source of inhibitory pheromone is in the queen's head, perhaps in the so-called 'fat-cells' that form a closely applied tube round each of her mandibular glands. It was not detected in her post-cerebral glands, which were considered likely candidates, or in her blood or brain tissue.

Difficulty was encountered in examining postcerebral glands of queens by the usual technique of combined gas chromatography and mass spectrometry. A crude but effective technique was discovered in which a pair of glands was put whole into a small quartz cup that was then introduced directly into the ion source of a mass spectrometer. The temperature was then raised slowly over the range 100° to 400°, giving an effect of fractional distillation. The results from different queens differed considerably, but three groups of compounds were recognised: (i) long-chain normal aliphatic hydrocarbons, tricosane, pentacosane, and heptacosane; (ii) sterols of molecular weight 412 and 414, including a compound with a mass spectrum closely resembling that of fucosterol; (iii) a material in the least volatile fraction with some resemblance to a triglyceride, but not one of the commoner ones. Traces of palmitic and oleic acids were also present. The presence of sterols is of interest. This technique of analysis should be applicable to other analyses on a few small glands or secretions obtainable only in microgramme quantity. (Butler and Simpson, with Callow, Insecticides Department)

Further work on the stimuli from queens that attract worker honeybees confirmed that some of the compounds, such as 9-oxodec-*trans*-2-enoic acid, in the secretion from a queen's mandibular gland are important olfactory attractants to swarming bees that have left the hive. Also, as first shown by N. E. Gary in 1961 (*Science*, **133**, 1479–1480), they attract workers when a queen is presented to them in a wire-gauze cage placed over the top-bars of the combs in a hive. However, this secretion seems to play little, if any, part in attracting the bees of a normal colony to form a 'court' round her. Whereas queens without mandibular glands fail to attract swarming bees in the field, and, similarly, the attractiveness of such queens when offered in cages to bees (using Gary's bioassay) is greatly diminished, nevertheless they attract as many bees to form 'courts' as unmutilated queens and have a similar percentage of these bees licking them. These comparisons are difficult to make with great precision, however, because of the extreme variation in the numbers of bees attending different queens at different times and in different colonies. There is some evidence that the material that attracts bees to form 'courts' consists, at least in part, of the 'footprint odour' (*Rothamsted Report for 1969*,

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Part 1, 256) of a queen, and is effective only over a distance of a few millimetres. (Butler and Koster)

Acoustic communication. Possible acoustic communication between a queen and her 'court', and between bees that had been in contact with a queen and other members of their colony, was investigated. Ultrasound production was studied with a tunable ultrasound detector kindly lent by Dr. J. D. Pye of King's College, London. The detector showed that honeybees produce much ultrasound in the course of their ordinary activities. Bursts of ultrasound often coincided with wing vibration and the accompanying audible sound. The frequency of the ultrasound was spread over a wide band, from 20 to 80 kHz. No ultrasound was detected that had any kind of pattern or that seemed capable of being a form of communication. Sound production in the audio range was studied with a Kudelski Nagra IV tape recorder and a Sennheiser MKH 815 condenser microphone placed 10 mm from the insects and with no partition interposed. No patterned sounds, or any sounds that could be interpreted as communication, could be heard either from the recordings or during direct monitoring with Beyer DT 48 headphones. (Butler, with Dr. D. R. Ragge, British Museum (Natural History)).

Field behaviour

Pollination. A further attempt was made to determine whether pollen applied by hand to the flowers of apple trees is distributed by visiting bees. All the flowers of 66 clusters spaced at intervals in the centre three rows of a five-row block of 'Tydeman's Late Orange' were hand pollinated with abundant 'Sunset' pollen during each of four consecutive days of flowering (10–13 May 1971). Bees flew well throughout this period, and many from six colonies distributed along the centre row of trees visited the flowers. On 3 June a mean of 54% of the flowers of the hand-pollinated clusters had set fruit, compared with 31, 31, 34 and 36% of the flowers of labelled clusters 30, 60, 120 and 240 cm respectively from the hand-pollinated trees. Hence, with no evidence that clusters of flowers near the hand-pollinated ones received more of the compatible ('Sunset') pollen than more distant clusters, it seems improbable that bees distributed the hand-applied pollen. This confirms our previous results; conditions can rarely be more favourable for such pollen transfer than this year, so the practice of applying pollen that needs bees to distribute it widely seems of questionable benefit. (Free and Williams)

Transfer of pollen between bees' bodies. Honeybee foragers leaving their hive still had thousands of pollen grains on their bodies and, although pollen of the kind of flower a bee was currently visiting predominated, on average 10% of the total pollen came from three of four other kinds of flowers. The pollen of the flower that most of a colony's foragers were collecting usually occurred on all the foragers whether or not they were visiting flowers of this kind. The presence of much pollen on the bodies of marked bees of pre-foraging age, and on newly emerged bees that had been on the combs for a few hours only, indicated that pollen is directly transferred between bees in the hive and that this is probably the principal way in which foragers become contaminated with pollen of flowers other than those they visit. The relative amount of extraneous pollen remaining on bees caught when foraging depended on their behaviour. For example, the bodies of bees collecting nectar from red clover flowers through holes bitten by bumblebees at the bases of their corolla tubes had much extraneous pollen, and those of bees collecting pollen from the same flowers had less extraneous pollen than those of bees collecting only nectar from them.

Pollen that is transferred in the hive between the bodies of foragers that are visiting flowers at opposite extremes of the foraging area of their colony may well be effective in

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pollinating flowers far from its original source. This may help to explain how the flowers of fruit trees are sometimes fertilised although they are growing a long way from other varieties whose pollen is necessary to cross-pollinate them. It may also explain the small, but persistent, amount of contamination that occurs in seed crops thought to be well isolated. Because bees can sometimes pollinate flowers with pollen of another species, even while remaining constant to one particular foraging area and species of flower, they may have played a greater part in producing hybrids between species than previously thought.

Pollen-gathering honeybees had more pollen on their bodies of the species of flower they were visiting than did nectar-gatherers visiting the same species, so pollen-gatherers were the more likely to pollinate the flowers. The relative amounts of pollen a honeybee collected on its head and body, respectively, depended on the kind of flower it was visiting. The few species of bumblebees and solitary bees examined usually had relatively more pollen on their bodies than honeybees. Some carried much extraneous pollen but this may simply reflect their greater tendency than honeybees to visit two or more kinds of flowers on any one foraging expedition. (Free and Williams)

Bee diseases

Paralysis. Chronic bee-paralysis virus was detected in the heads of some mature, seemingly healthy, pupae in many samples taken from within the sealed cells of apparently healthy colonies that had no history of paralysis. This result, and the failure of attempts to establish inapparent infections experimentally in adult bees by feeding them sublethal doses of chronic paralysis virus, suggested that infection, also often detected in seemingly healthy adult bees from normal colonies, originates in larvae or eggs. However, when individually identified larvae were fed chronic paralysis virus, virus was not detected in the subsequent pupae. Further, the pupae of offspring from queens fed sublethal doses of virus contained no more virus than pupae from untreated queens; also when queens, bred from colonies with severe paralysis, were fed sublethal doses of virus, their colonies suffered no more paralysis than colonies headed by untreated queens. Nevertheless, the possibility remains that chronic paralysis virus is transmitted in eggs. For example, it was detected in the ovaries of a few apparently healthy queens, although it was not in most of several queens tested, including most of those heading colonies that were losing many bees from paralysis, and all of several that were fed sublethal amounts of virus. Perhaps there is too little virus in most inapparently infected bees to be detected by infectivity tests, which, although most sensitive, will detect no more than about 10^2 particles of virus per μl of an extract. (Bailey and Stanley)

Serological tests suggested that between 8 and 75 % of the dead bees falling between mid-January and the end of March from each of the winter clusters of four apparently healthy colonies had died of paralysis, whereas bees from nine similar colonies in May did not react with antiserum. Tests on dead bees taken the same day in May from 13 apparently healthy colonies headed by queens reared from colonies with severe paralysis, showed that about 20% of the dead bees from them contained much paralysis virus. All these results, and the common occurrence of chronic paralysis virus in seemingly healthy bees suggest that the virus multiplies in many, possibly most, bees but that it does so only slowly, eventually killing some individuals that do not die early of other causes, perhaps usually only in late winter when they have lived longest, whereas it can multiply quickly in susceptible bee strains, sometimes spreading and causing severe outbreaks of disease in their colonies. (Bailey)

Nosema apis. Workers elsewhere suggested that the infective dose of spores of *N. apis* is about 10^4, and that individual bees, although infected by smaller doses, can recover

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at 30°C, the optimum temperature for multiplication of the parasite. However, when accurately measured volumes of known concentrations of spores in dilute honey were fed to individual bees, the median infective dose of fresh preparations was about 20 spores and the infected bees did not recover. The median infective dose of spores from infected bees that had been anaesthetised and then preserved at − 20°C for two years was about 200, a much greater loss of infectivity than suggested by recent tests done elsewhere with similarly preserved material, but by the insensitive technique of feeding groups of bees the equivalent of many thousands of spores per individual. (Bailey)

Sacbrood. Several effects of infection with sacbrood virus on adult bees are strikingly similar to those caused by anaesthetisation with carbon dioxide. For example, either treatment prevented young bees from eating pollen; also, bees infected with sacbrood virus or anaesthetised for five minutes with carbon dioxide, when they were five days old, began to forage much sooner than untreated bees; but, in contrast to untreated bees, very few treated ones collected pollen. Both treatments cause the same behavioural effects probably through a common mechanism. This may be activated in bees infected with sacbrood virus as a result of damage to their mitochondriae, indicated by the brain cells lacking cristae, the only histopathological effects seen. Damage to mitochondria suggests that oxidative metabolism will be deranged and, consequently, that acid metabolites will accumulate. Anaesthesia with carbon dioxide also may well cause acid metabolites to accumulate, and these have been suggested as a cause of the changed behaviour of anaesthetised bees. The effects of sacbrood virus have now provided some evidence to support this suggestion. (Bailey and Fernando, with Turner, Plant Pathology Department)

Damage to mitochondria by sacbrood virus suggests that infected bees will metabolise slower than healthy bees, and infected bees at 30° ate less sucrose syrup. However, healthy and infected bees ate the same amount at 35°, about the same as infected individuals at 30°C. This suggests that infection prevents bees from increasing their metabolic rate when they are at temperatures below their optimum, and explains previous observations that infected young bees cluster tightly within colonies as though chilled, and become immobilised sooner than healthy bees by cold. (Bailey and Fernando)

Preliminary results indicate that the ovaries develop sooner in virgin queens infected with sacbrood virus than in uninfected ones which, again, resembles the effect of anaesthesia with carbon dioxide.

Other abnormalities in adult bees infected with sacbrood virus are that the protein granules in their fat-body cells and the secretory globules in the cells of their hypopharyngeal glands become fewer. Bees from colonies in autumn, when they have most protein reserves, died about three weeks after they were injected with virus and then kept in cages at 35°C, much sooner than similar untreated bees. Newly emerged bees also live only about three weeks in cages at 35°C when infected with sacbrood virus or when deprived of pollen, whereas other healthy young bees given plenty of pollen lived about eight weeks. The most severe effect on adult bees of sacbrood virus seems, therefore, to be deprivation of their protein reserves. The multiplication of acute bee-paralysis virus, which has particles closely resembling those of sacbrood virus, also made the protein granules of fat-body cells fewer but, by contrast with sacbrood virus, it did not affect their hypopharyngeal glands. (Fernando)

Pathology of other insects

Entomophthoraceae

Field incidence in Wheat Bulb fly. One hundred Wheat Bulb flies were captured each week, from 22 June to 18 August in Stackyard field, to estimate the incidence of

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fungal infection. The peak in the emergence of flies was from 1–3 July, 10 days later than in 1970. The first flies infected with *Entomophthora muscae* were caught on 6 July and the last on 11 August. The maximum percentage that died infected, 44% (36·5% of males and 49·1% of females), was in a sample taken on 21 July, two weeks later than in 1970. Resting spores were first found in females caught on 21 July, also two weeks later than in 1970; they were found in only one male throughout the season. In 1970 no males contained many resting spores, but of flies that died without showing disease symptoms and were later examined, six males and nine females contained some. In 1971, as in 1970, the proportion of infected females with conidiophores that also had resting spores increased during the season, from 38% on 21 July to 88% on 11 August. However, on other species of fly, including cabbage root fly, *Erioischia brassicae*, *E. muscae* produced conidiophores as late as 21 September. Therefore, resting spores are probably induced to form by physiological differences between young and old flies rather than by changes in the climate. This contrasts with *E. fresenii* on *Aphis fabae* (*Rothamsted Report for 1970*, Part 1, 207) but it would explain resting spores being more common in female than in male flies, as the females live much longer.

Wheat bulb flies infected with *E. muscae* were very numerous at West Wickham (Cambs.) and Barton (Beds.), but fewer at Clavering (Essex) and Earith (Cambs.); as in 1970, no flies were infected with any other *Entomophthora* species.

Field incidence in aphids. Two samples of 100 adult apterous pea aphids, *Acyrthosiphon pisum*, were taken each week from 28 April to 10 October and one sample per week from 7 October to 11 November from lucerne on Highfield to estimate the incidence of *Entomophthora* species. The aphid population remained constant during May and early June at about 1 aphid/g dry weight of lucerne; it then increased steadily to a peak of 4 aphid/g by 8 July, but soon decreased till there were very few by the end of July. Aphids remained very scarce until the first week in October but by 28 October the population had again reached 4 aphids/g. An average of 16% of aphids were infected with *E. thaxteriana* in May and June with a peak of 35% on 13 May. Few aphids were infected with *E. thaxteriana* after 8 July and none from 1 September to 7 October. However, some were infected in October when the population increased. *E. planchoniana* infected an average of only 6% of aphids from 13 July to 29 July and *E. aphidis* infected only two individuals, both in July. Aphids were parasitised, mainly by *Aphidius* spp. (Hymenoptera, Braconidae), throughout the year but most frequently during July and August; the maximum percentage parasitised, 35%, was recorded on 29 July. (Wilding)

Staff

P. J. Naylor (Hatfield Polytechnic), a sandwich-course student, left and another, Dorothy E. Gennard (Hatfield Polytechnic) arrived.

N. Wilding attended the 1st International Congress of Mycology at Exeter in September.

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