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Report for 1970 - Part1

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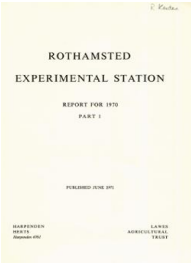

Entomology Department

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ENTOMOLOGY DEPARTMENT

C. G. JOHNSON

Invertebrates and pasture productivity

Little is known about the damage done to grass by pests, but results of applying insecticides to old pasture or a newly-sown ley suggest it is considerable. Various pesticides were applied either singly or in combination; one large dressing was given of the persistent ones, such as aldrin, chlordane and chlorbenside, and several dressings of the less stable ones such as menazon, dimethoate, parathion and metaldehyde. As might be expected, populations of invertebrates were most affected where all the pesticides were used, and yield was also increased most. Yield of the old pasture began to increase during September from treatments started in June 1969, but increases were much greater in 1970 when they reached 30%. With the newly-sown ryegrass at the Grassland Research Institute, Hurley, where there was no increase in yield in 1969, yield was increased by 25% in 1970. Pesticides aimed at specific groups of animals gave smaller increases in yield than the mixture. The yield of the old pasture was increased more by pesticides that killed animals in the soil than by those that mainly killed animals living in foliage, whereas the reverse was true with the newly-sown leys.

The botanical composition of the old pasture has been unchanged but the ryegrass ley given most insecticides has fewer weeds than other plots.

Ryegrass was more severely attacked by stem-boring Diptera when grazed by sheep than when cut by forage harvester. (Henderson)

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, and the small summer populations on beans in Hertfordshire were as predicted; indeed, aphids were so scarce that work on the effects of *A. fabae* on the yield of field beans was seriously hindered. Also, the beans suffered from drought

TABLE 1

Effects of insecticides against bean aphids on yield of field beans

		Max. % infested stems	Yield cwt/acre	Tonnes/ha
1	No insecticide	97	8·6	1·07
2	Phorate granules on foliage, 1 lb a.i./acre (1·12 kg/ha) at start of flowering 16 June	15	12·8	1·61
3	Phorate granules as above, and also 7 July	32	11·8	1·48
4	Demeton-s-methyl spray, medium volume, 6 fluid oz a.i./acre (421·3 ml/ha) at start of flowering 15 June	23	11·8	1·48
5	Demeton-s-methyl spray as above at end of flowering 16 July	65	11·0	1·38
6	Demeton-s-methyl spray as above 15 June and 16 July	13	11·1	1·39
	S.E. of yield difference		±0·58	±0·072

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and attack by *Sitona*, and many were infected with viruses. Because there was no natural infestation in an experiment on the timing of insecticide sprays in relation to toxicity to bees and the growth and yield of the crop, the untreated and late-sprayed plots were artificially infested with aphids on both 19 and 30 June. Aphids were too few to infest all plots, and this made comparisons between treatments somewhat artificial. Infestations were largest at the end of July and, as in previous years, yields were negatively correlated with the duration and intensity of attack (Table 1). (Bardner, Fletcher, with Stevenson, Insecticides Department)

The effect of *Sitona* attacking roots of field beans

The small differences last year in yield between plots of field beans with and without dieldrin suggested that feeding by larvae of *Sitona* spp. was damaging. This suggestion was confirmed this year in experiments at Woburn and Saxmundham, in which γBHC applied to the soil at 2 lb/acre (2·24 kg/ha) halved the larval populations of *Sitona*, and at 4 lb/acre brought them to a tenth of populations in untreated plots: plants on plots with γBHC also had bigger root systems, with more nodules, and less blackening, so were presumably less attacked by fungi. The mean number of larvae/root on untreated plots was 7·2 at Woburn and 21·3 at Saxmundham. As elsewhere, yields were small, particularly at Woburn even on the plots treated with insecticides. At Woburn, plants on untreated plots became very yellow and probably lacked nitrogen because the weevil larvae destroyed the root nodules. Increase in yield (approximately 10–30%) was greater with 2 lb/acre γBHC, probably because 4 lb/acre damaged the beans (Table 2), but was only significant at Woburn. The increase reflected more pods set; the height of the plants, number of nodes, position of pod-bearing nodes on the stem or the size of seeds were unchanged by the insecticide.

TABLE 2

Effects of insecticides against Sitona *on yield of field beans*

	Woburn		Saxmundham	
	cwt/acre	tonnes/ha	cwt/acre	tonnes/ha
No insecticide	5·0	0·63	19·5	2·45
γBHC at 2 lb a.i./acre (2·24 kg/ha)	6·6	0·82	21·3	2·68
γBHC at 4 lb a.i./acre (4·48 kg/ha)	6·4	0·81	20·9	2·62
S.E. of treatment difference	±0·395	±0·049	±1·73	±0·220

Adult weevils moved during autumn from the bean crop to both wild and cultivated leguminous plants in fields and hedgerows. From September to November, many were feeding on undersown red clover at Rothamsted; this crop was ploughed in, and soil sampling showed that both adults and larvae over-wintered in the soil. (Fletcher and Bardner)

Weevils, aphids and virus diseases of field beans

Broad bean stain virus (BBSV) was more common in field beans than in 1969, and was more common than bean leaf roll or other aphid-transmitted viruses (Table 3). The proportion of plants with symptoms in six crops of variety Maris Bead at three sites ranged from 14 to 60%; however, the actual incidence was certainly greater, because the virus was later isolated from plants without obvious symptoms.

The main vectors of BBSV are different species of *Apion* and *Sitona* weevils. It was transmitted by 20% of adult *Apion vorax* and *A. aethiops* (not separated in transmission

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TABLE 3

Incidence of virus in field beans, July 1970

Site		Estimated virus incidence (% infected plants)		
		Broad bean stain	Bean leaf roll	Pea enation and bean yellow mosaic
Rothamsted:	Pastures	60	16	1
	Great Field 1	54	17	0
	Barnfield	30	10	3
Woburn:	Stackyard B	22	6	2
	Lansome	14	4	0·3
Broom's Barn:	The Holt	19	5	0

tests, but mainly *A. vorax*), and by 1% of adult *Sitona lineatus* and *S. hispidulus* (mainly *S. lineatus*) that fed for five days on infected plants and then for five days on healthy broad bean seedlings in the glasshouse. In another test, it was transmitted by 37% of *A. vorax* and *A. aethiops*, and by 1% of *S. lineatus* and *S. hispidulus*, collected from beans in the field late in July and then fed for five days on healthy seedlings. It was not transmitted by mustard beetles (*Phaedon cochleariae*), blossom beetles (*Meligethes* spp.), pygmy beetles (*Atomaria* spp.) or plaster beetles (*Lathridius* spp.) that were kept on infected plants for five days.

BBSV may also be transmitted by contact between infected and healthy plants in the field, because 10% of healthy broad bean seedlings became infected when their leaves were rubbed, without causing obvious damage, against infected leaves; 70% became infected when rubbed with enough pressure to damage the leaves slightly. The virus remains infective in dried bean leaves for at least six months at 20°C.

One experiment assessed the effects of natural infection with BBSV on the yield of field beans in a crop that was sprayed with menazon three times to keep it free from aphids. Plants that developed symptoms before, during or after flowering, or were without symptoms early in August, were marked and later harvested separately. On average, plants with symptoms yielded only 44% as much as plants without symptoms (Table 4). Some without symptoms were infected and 2% of seeds from symptomless plants were infected compared with 4% from plants with symptoms.

TABLE 4

Effects of infection with broad bean stain virus on yield of field beans

	Stage when symptoms first observed			
	Before flowering	During flowering	After flowering	No symptoms
Number of plants	67	65	68	47
Mean yield beans/plant (g)	1·6	2·5	4·6	6·6
% decreased	76	62	31	—
% infected seed*	3	5	4	2

* 100 seeds/treatment

Infection of seed sometimes, but not always, produces discoloration or necrosis of the testa. For example, in one test with seed from plants with symptoms, 7% of discoloured and 6% of seemingly normal seed were infected. Symptoms in some plants from infected seed were mild and difficult to diagnose (infection of them was confirmed by examining sap in the electron microscope) but symptoms in others were severe and the plants stunted.

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Samples of red and white clover, lucerne and hop trefoil from crops at Rothamsted in mid-July were not infected with BBSV. However, as hop trefoil and sainfoin became infected when inoculated in the glasshouse, some species of biennial and perennial legumes may act as overwintering sources of BBSV.

One experiment compared the effects of insecticides on weevil- and aphid-infestations, virus infection and yield of field beans (Maris Bead). There were five replicates of five treatments:

(1) Untreated,
(2) γBHC applied to the soil before drilling in early April, 1 lb a.i./acre (1·12 kg/ha),
(3) γBHC applied to the foliage on five occasions between mid-May and late July, 0·5 lb a.i./acre (0·56 kg/ha),
(4) Menazon applied to the foliage on five occasions between early June and early August, 0·25 lb a.i./acre (0·28 kg/ha),
(5) Aldicarb ('Temik') applied to the soil before drilling, 10 lb a.i./acre (11·2 kg/ha).

TABLE 5

Effect of insecticide treatments on number of adult weevils, incidence of broad bean stain virus and yield of field beans

	Untreated	γBHC (soil)	γBHC (foliage)	Menazon (foliage)	Aldicarb (soil)
Number of adult *Apion**	14	15	11	11	8
Number of adult *Sitona**	92	94	97	59	4
Incidence of BBSV (%)	49	50	31	41	19
Mean yield (cwt/acre)	9·6	10·7	13·8	11·2	21·3

* Total counted on 125 shoots of each treatment on five occasions

Aldicarb gave best control of adult weevils and BBSV (Table 5). On average, there were 1·8 times as many *Apion* and 23 times as many *Sitona* on untreated as on aldicarb-treated plots between early June and early August. *Apion* was most abundant early in June (3/25 shoot tips on untreated plots), and *Sitona* late in July (7·8/25 shoot tips). The apparent incidence of BBSV, based on foliage symptoms, on 20 May, 8 and 25 June and 20 July was 2·3, 4·1, 39 and 49% in untreated plots, and 0·5, 0·7, 7 and 19% in aldicarb-treated plots. Although γBHC, applied to the soil or foliage, apparently did not control adult weevils, the incidence of BBSV was lessened by a third after application as a foliage spray.

Menazon and aldicarb had more effect than γBHC on bean leaf roll virus (BLRV). The most plants infested by *Acyrthosiphon pisum* on menazon- or aldicarb-treated plots was 3%, and by *Aphis fabae*, 6%; on untreated plots corresponding figures were 56 and 46%. Late in July 6% of plants in menazon-treated plots, 8% in aldicarb-treated and 18% in untreated, had bean leaf roll.

The difference in yield between γBHC soil-treated and untreated plots was not significant, and between menazon-treated and untreated plots barely significant ($P = 0·10$) (Table 5); hence aphid-infestation and infection with aphid-transmitted viruses affected yield little this year. On average, γBHC-sprayed plots yielded 4·2 cwt/acre (0·53 tonnes/ha) more than untreated plots, and aldicarb-treated plots 11·7 cwt/acre (1·47 tonnes/ha) more. Much of the increase from aldicarb came from killing adult weevils and checking spread of broad bean stain virus, but some may reflect control of other pests in the soil, including larvae of *Sitona* (see p. 184), other soil arthropods (see p. 194) and nematodes (see p. 161). (Cockbain)

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Aphids and virus diseases of peas

Experiments at Swaffham, Norfolk, and Navenby, Lincolnshire, assessed the effects of time of spraying with insecticide on aphid infestation, virus infection and yield of two varieties of vining pea, Jade and Scout. Previous tests showed Jade to be very susceptible, and Scout resistant to infection with bean leaf roll virus (BLRV) (*Rothamsted Report for 1969*, Part 1, 233). There were four replicates of four treatments:

(1) Unsprayed,
(2) Early spray ('Metasystox' 55 at 70 ml/ha, applied 28 May at Swaffham, 29 May at Navenby),
(3) Late spray ('Rogor E' at 140 ml/ha, 29 and 30 June),
(4) Three sprays (first and third as for early and late sprays, second as for early but applied 10 and 11 June).

'Rogor E' replaced 'Metasystox' as the late spray because the peas matured early.

Seed of variety Scout was treated with captan and germinated well (on average, 120 seedlings/5 m-row at the two sites), whereas Jade was untreated and gave only 23 seedlings/5 m-row. Thus direct comparison of yields of the two varieties are not valid because of different spacing between plants.

Alatae of *Acyrthosiphon pisum* infested plants at both sites late in May, and by the second week of June, 16% of unsprayed and 3% of early sprayed plants at Navenby, and 6% unsprayed and 2% sprayed plants at Swaffham, were infested. Unfortunately the experiment at Navenby was then affected by drift of 'Rogor E' when the surrounding pea crop was sprayed from the air; this lessened the aphid population on all plots. Late in June, before the final spraying, 14, 16 and 1% of unsprayed, early-sprayed and twice-sprayed plants respectively at Navenby, and 34, 17 and 2% of plants at Swaffham, were infested. No difference in the infestation of the two varieties of peas was observed at either site.

Pea enation mosaic was the most common virus at Navenby; at harvest unsprayed plots and plots sprayed three times had 16 and 0·5% infected plants respectively. Bean yellow mosaic was the most common virus at Swaffham, where unsprayed plots averaged 12% infected plants and plots sprayed three times, 4%. No difference was observed between the susceptibility of the two varieties to either virus. Bean leaf roll was rare at both sites; 2% of plants of variety Jade were infected in unsprayed plots and none in plots sprayed three times at Navenby, and 5 and 0% at Swaffham. No plants of the variety Scout showed bean leaf roll and the virus was not isolated from plants sampled in the unsprayed plots at either site.

At Navenby, four 5 yd-lengths of row of each variety/plot were pulled by hand on 6 July and the peas shelled by miniature viner; this caused some loss of peas. Mean yields of Jade were 0·677 (unsprayed), 0·640 (late-sprayed), 0·725 (early-sprayed) and 0·755 (three-times sprayed) kg/total of 20 m-length of row; corresponding values for Scout were 1·024, 0·950, 1·131 and 1·096 kg. Differences between individual spray treatments were not statistically significant, but plots sprayed in May (plots sprayed early or three times) yielded 12% more than unsprayed and late sprayed plots (difference significant for both varieties, $P = 0{\cdot}05$).

At Swaffham 40 plants of each variety/plot were pulled on 9 July and the peas shelled by hand. Mean yields of Jade were 0·392 (unsprayed), 0·424 (late sprayed), 0·466 (early sprayed) and 0·525 (three-times sprayed) kg/40 plants; corresponding values for Scout were 0·238, 0·259, 0·275 and 0·278 kg. Again, differences between individual spray treatments were not significant, but plots of Jade sprayed in May yielded 22% more than

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unsprayed and late sprayed plots ($P = 0{\cdot}05$), and plots of Scout yielded 12% more ($P = 0{\cdot}10$). (Cockbain, with Etheridge, Insecticides Department)

Ecology of cereal aphids

Aphid infestations in cereal crops near Harpenden were again surveyed regularly as part of a programme organised by the National Agricultural Advisory Service. Populations of *Rhopalosiphum padi* and *Sitobion fragariae* were extremely small and scattered; *Rhopalosiphum maidis*, *R. insertum* and *Metapolophium festucae* were not found in nine fields inspected (oats, barley, and winter wheat). The first alate *S. avenae* were caught in the 40-ft suction trap at Rothamsted on 23 May and *Metapolophium dirhodum* on 28 May; *S. avenae* was found in the fields on 29 May and *M. dirhodum* on 4 June. Populations on tillers remained small, but the proportions of infested tillers increased, until 22 June, when populations increased rapidly and became large. In one field, on 7 July, heavy rain lessened large populations of *M. dirhodum* and *S. avenae* by 65 and 80% respectively. *M. dirhodum* (20–30/tiller) and *S. avenae* (2–3/tiller) were most abundant in mid-July, about a week earlier than in 1969, when populations rapidly fell to zero by 8 August. *S. avenae* was about twice, and *M. dirhodum* at least 200 times, more numerous than on crops surveyed in 1969.

Movements of aphids between plants, and from initial invasion points, were studied by field surveys and regular inspections of marked plants. So few alatae invaded the cereals that they were difficult to find. Numbers/sample remained small during most of June because many aphids from the 3rd-instar onwards moved away from invasion foci. Small scattered groups of nymphs were also deposited near the main foci, and numbers of aphids/0·3-m sample increased only after most of the crop area had become infested. Dense colonies of *M. dirhodum* and *S. avenae* were rare because the older aphids tended to wander, and because many were killed either by bad weather or by predators and fungi. *M. dirhodum* seemed to colonise more exposed parts of the field, and occupied the leaves, whereas *S. avenae* was more abundant along sheltered perimeters and on the ears.

Flight activity. A 9-in. suction trap was sited at crop level in a barley field $\frac{1}{3}$ mile from the suction trap at 40-ft above ground. *M. dirhodum* had morning and afternoon peaks of flight and small catches indicated that *S. avenae* was similar.

Few *M. dirhodum* and *S. avenae* (<1/day) were caught in the suction trap 40-ft above ground until 11 and 23 June respectively; none was caught at crop level over the barley until 27 June. *M. dirhodum* was denser at crop level than at 40-ft until after 15 July, and densities coincided with maximum populations on the crop. *S. avenae* was denser at 40-ft than at crop level throughout June and July. Various observations suggest that different factors affect the production of alatae in the two species. The flights of *S. avenae* indicated by catches in the trap 40-ft above ground were undoubtedly migratory, and away from the crop, throughout the period of alate production from late June onwards. Emigration from the crop by *M. dirhodum* occurred mainly after mid-July when populations were large and the leaves were mature and senescing.

Colour variation. The colour of *S. avenae* in the field ranged from dark brown to a green resembling that of *S. fragariae*, and some individuals had a mosaic of both brown and green across the body. The brown forms were first seen late in May, and green aphids only after 10 June when brought in from the field. The green form produced only green nymphs, but the brown variety, in addition to producing many brown nymphs,

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produced a few green ones and these in turn produced only green nymphs. During autumn, some green *S. avenae* produced many males, whereas the brown individuals did not.

The relative abundance of the brown and green forms of *S. avenae* among 853 adults collected from four fields during June–July ranged from 1·3 : 1 to 3·5 : 1 (mean 2·0 : 1).

Parasites. Braconid wasps (*Aphidius* spp.) parasitised *Rhopalosiphum insertum* on apple during April and May. The first parasitised aphid mummy seen in a spring cereal field was hyperparasitised by a cynipoid on 9 June, about 1–2 weeks after the first aphid invasion. Mummies that produced *Aphidius* were not collected until 15 June, and thereafter increased to a peak in late July. Greater proportions of *M. dirhodum* than *S. avenae* were parasitised.

Aphidius wasps were the commonest parasite, and few *Praon* sp. were found after 24 June. Many of the mummies collected produced Proctotrypoidea, Cynipoidea (*Phaenoglyphus* sp.) and Chalcidoidea (*Coruna clavata*) which were probably hyperparasitising the braconid parasites. However, the proportion parasitised was less than during 1969 and rarely exceeded 10%.

Predators. Coccinellidae, rare in 1969, were very numerous this year. *Adalia 2-punctata* was common early in June but scarce in July. *Coccinella 7-punctata* and *Propylea 14-punctata* were the commonest predators attacking cereal aphids, but *C. 10-punctata*, *C. 11-punctata* and *Thea 22-punctata* were found occasionally. Coccinellid adults were few at first, larvae were first seen on 10 June, became relatively abundant between 26 June and 24 July, and the first pupae were seen on 26 June; after 10 July adults became very common and were most numerous early in August, when very few aphids remained in the cereals.

Syrphidae were also more numerous than in 1969. Adults of *Melanostoma mellinum*, *Syrphus balteatus* and *Sphaerophoria* sp. were seen within the crop after mid-June and the first larva on 24 June. Larvae increased rapidly after 3 July and were most numerous between 17 and 31 July. *M. mellinum* larvae appeared before, and *Sphaerophoria* after, *S. balteatus*; *S. balteatus* was more common, and *M. mellinum* less common, than *Sphaerophoria*. The first pupae (*M. mellinum*) were found on 10 July and the new generation of adult flies began to emerge and became abundant at the end of July.

Coccinellidae and Syrphidae were the commonest and most important predators of cereal aphids. However, *Chrysopa carnea* (Neuroptera) from mid-June onwards, and staphylinid beetles (*Tachyporus* sp.) and Anthocoridae (*Anthocoris nemoralis*) in July, preyed on both aphid species. (Dean)

Fungal pathogens. *Entomophthora* spp. infected many *M. dirhodum* and *S. avenae*. *E. planchoniana*, first found on 26 June, attacked *M. dirhodum* more frequently than *E. thaxteriana* or *E. aphidis* ($P = <0{\cdot}05$). *E. thaxteriana* infected *S. avenae* more often, and *E. aphidis* less often, than *E. planchoniana* ($P = 0{\cdot}001$).

Another survey showed the three species of fungus to be equally common in dead *M. dirhodum* collected from perimeters of the two sheltered fields, but *E. thaxteriana* was least common along perimeters of an exposed field ($P = < 0{\cdot}001$). *E. aphidis* was relatively less abundant than *E. planchoniana*, 36·6 m into the crop ($P = < 0{\cdot}05$). All these differences probably reflect differences in the microclimate and behaviour of the two species of aphid.

The *Entomophthora* attack began late in June just after a 39-day dry period (<0·1 mm rain). Infection spread slowly, though aphids rapidly increased in numbers after 22 June

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TABLE 6

Cereal Aphids, 1970: dates of first appearance in fields and traps

Aphid species				*R. padi*			*M. dirhodum*			*M. festucae*		
				Date found		Days earlier in trap	Date found		Days earlier in trap	Date found		Days earlier in trap
N.A.A.S. Region	Field No.	Crop	Trap site	Field	Trap		Field	Trap		Field	Trap	
N. Scotland	i	SB	Dundee	10/6	29/5	+12	n.f.	6/5	+	n.f.	16/7	+
N. Scotland	ii	SB	Dundee	11/6	29/5	+13	n.f.	5/6	+	n.f.	16/7	+
N. England	i	SB	Newcastle	15/6	1/6	+14	25/6	6/7	−11	n.f.	27/6	+
N. England	ii	SW	Newcastle	26/6	1/6	+25	26/6	6/7	−10	n.f.	27/6	+
N. England	iii	SB	Newcastle	23/6	1/6	+22	23/6	6/7	−13	n.f.	27/6	+
N. England	iv	SB	Newcastle	n.f.	1/6	+	25/6	6/7	−11	n.f.	27/6	+
Yorks. & Lancs.	i	SW	H. Mowthorpe	n.f.	23/5	+	n.f.	21/6	+	n.f.	26/6	+
W. Midlands	i	SB	No trap	28/5	n.t.		20/5	n.t.		19/6	n.t.	
W. Midlands	ii	SW	No trap	27/5	n.t.		19/5	n.t.		3/6	n.t.	
E. England	i	SW	Brooms Barn	28/5	18/5	+10	n.f.	19/6	+	n.f.	18/5	+
E. England	ii	SW	Brooms Barn	25/6	18/5	+38	n.f.	19/6	+	n.f.	18/5	+
E. England	iii	SW	Brooms Barn	28/5	18/5	+10	n.f.	19/6	+	n.f.	18/5	+
E. England	iv	SW	Brooms Barn	28/5	18/5	+10	n.f.	19/6	+	n.f.	18/5	+
E. England	v	SO	Brooms Barn	n.f.	18/5	+	16/7	19/6	+27	n.f.	18/5	+
S.E. Wye	i	SB	Wye, Kent	n.f.	22/5	+	2/6	20/5	+13	n.f.	18/5	+
S.E. Wye	ii	SB	Wye, Kent	n.f.	22/5	+	3/6	20/5	+14	n.f.	18/5	+
S.E. Reading	i	SB	Silwood Park	n.f.	16/5	+	28/5	12/5	+16	n.f.	8/5	+
S.E. Reading	ii	WW	Silwood Park	n.f.	16/5	+	28/5	12/5	+16	n.f.	8/5	+
S.E. Reading	iii	SB	Silwood Park	n.f.	16/5	+	28/5	12/5	+16	n.f.	8/5	+
S.W. Bristol	i	SW	Long Ashton	n.f.	7/5	+	n.f.	9/5	+	n.f.	7/5	+
Wales: Cardiff	i	SB	Long Ashton	n.f.	7/5	+	8/6	9/5	+29	n.f.	7/5	+
S.W. Starcross	i	SO	Starcross	16/6	15/5	+32	3/6	9/5	+25	17/6	12/5	+36
Wales: Aberystwyth	i	SO	Aberystwyth	n.f.	15/5	+	9/6	8/6	+ 1	n.f.	22/5	+
Wales: Aberystwyth	ii	SO	Aberystwyth	n.f.	15/5	+	n.f.	8/6	+	n.f.	22/5	+
Wales: Bangor	i	SB	No trap	n.f.	n.t.		29/6	n.t.		n.f.	n.t.	
Wales: Bangor	ii	SB+W	No trap	n.f.	n.t.		n.f.	n.t.		n.f.	n.t.	

SB = Spring barley
SW = Spring wheat
SO = Spring oats
WW = Winter wheat
SB&W = Spring barley and wheat

n.f. = aphids not found
n.t. = no trap in vicinity
+ means that the trap detected aphids, though field samples had none

and light rain fell on most days until after 7 July, when a rapid spread followed a heavy rainstorm. After mid-July, up to 75% of adult *M. dirhodum* and up to 80% *S. avenae* were infected; aphids died within 2–5 days of becoming infected. *S. avenae*, which mainly infested the ears, were attacked more slowly than *M. dirhodum*, which were mainly on the leaves, probably because the leaves provided a more humid environment. (Dean, with Wilding, Bee Department)

The Rothamsted Insect Survey

Suction traps. Four more suction traps operating at 40-ft above ground were added to the 12 in Great Britain and one in Holland operating in 1969; one at Starcross, near Exmouth, began on 5 February; one at Long Ashton Research Station on 6 April; one at the Building Research Station, Watford, on 11 June and one at Aldroughty Experimental Farm, Elgin, Inverness-shire on 6 August. All traps except the last two operated daily from 10 a.m. BST on 6 April to 10 a.m. on 5 November.

Monthly totals of 32 species of aphids (or groups of aphids) from the 13 traps that operated in 1969 are given in *Rothamsted Report for 1970*, Part 2, 170–176, Table 1a–g, and a weekly bulletin of these species was sent to 71 people; in the bulletin the genus *Aphis* was separated into '*fabae* group' and 'other species'.

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TABLE 6 (*continued*)

Cereal Aphids, 1970: dates of first appearance in fields and traps

S. fragariae			*S. avenae*			*R. insertum*						
Date found		Days earlier in trap	Date found		Days earlier in trap	Date found		Days earlier in trap				
Field	Trap		Field	Trap		Field	Trap		Trap site	Crop	Field No.	N.A.A.S. Region
25/6	27/7	−32	n.f.	8/7	+	n.f.	8/6	+	Dundee	SB	i	N. Scotland
25/6	27/7	−32	n.f.	8/7	+	n.f.	8/6	+	Dundee	SB	ii	N. Scotland
n.f.	n.f.		n.f.	26/6	+	n.f.	1/6	+	Newcastle	SB	i	N. England
n.f.	n.f.		n.f.	26/6	+	n.f.	1/6	+	Newcastle	SW	ii	N. England
n.f.	n.f.		23/6	26/6	−3	n.f.	1/6	+	Newcastle	SB	iii	N. England
n.f.	n.f.		25/6	26/6	−1	n.f.	1/6	+	Newcastle	SB	iv	N. England
24/6	13/6	+11	24/6	21/6	+3	n.f.	1/6	+	H. Mowthorpe	SW	i	Yorks. & Lancs.
28/5	n.t.		4/6	n.t.		n.f.	n.t.		No trap	SB	i	W. Midlands
27/5	n.t.		19/5	n.t.		19/5	n.t.		No trap	SW	ii	W. Midlands
n.f.	12/6	+	n.f.	28/5	+	n.f.	1/6	+	Brooms Barn	SW	i	E. England
n.f.	12/6	+	n.f.	28/5	+	n.f.	1/6	+	Brooms Barn	SW	ii	E. England
n.f.	12/6	+	25/6	28/5	+28	28/5	1/6	−4	Brooms Barn	SW	iii	E. England
n.f.	12/6	+	n.f.	28/5	+	n.f.	1/6	+	Brooms Barn	SW	iv	E. England
n.f.	12/6	+	n.f.	28/5	+	n.f.	1/6	+	Brooms Barn	SO	v	E. England
n.f.	27/5	+	n.f.	31/5	+	n.f.	31/5	+	Wye, Kent	SB	i	S.E. Wye
n.f.	27/5	+	9/6	31/5	+ 9	n.f.	31/5	+	Wye, Kent	SB	ii	S.E. Wye
n.f.	18/5	+	20/5	15/5	+ 5	n.f.	1/6	+	Silwood Park	SB	i	S.E. Reading
n.f.	18/5	+	22/5	15/5	+ 7	n.f.	1/6	+	Silwood Park	WW	ii	S.E. Reading
n.f.	18/5	+	28/5	15/5	+13	n.f.	1/6	+	Silwood Park	SB	iii	S.E. Reading
11/6	19/5	+23	11/6	7/5	+35	n.f.	7/6	+	Long Ashton	SW	i	S.W. Bristol
n.f.	19/5	+	2/6	7/5	+25	n.f.	7/6	+	Long Ashton	SB	i	Wales: Cardiff
27/5	18/5	+ 9	27/5	18/5	+ 9	n.f.	n.f.		Starcross	SO	i	S.W. Starcross
n.f.	12/5	+	9/6	8/6	+ 1	n.f.	2/6	+	Aberystwyth	SO	i	Wales: Aberystwyth
9/6	12/5	+28	9/6	8/6	+ 1	n.f.	2/6	+	Aberystwyth	SO	ii	Wales: Aberystwyth
4/6	n.t.		n.f.	n.t.		n.f.	n.t.		No trap	SB	i	Wales: Bangor
n.f.	n.t.		26/5	n.t.		n.f.	n.t.		No trap	SB+W	ii	Wales: Bangor

SB = Spring barley
SW = Spring wheat
SO = Spring oats
WW = Winter wheat
SB&W = Spring barley and wheat

n.f. = aphids not found
n.t. = no trap in vicinity
+ means that the trap detected aphids, though field samples had none

To lessen work on identification when catches were greatest, the volume of air sampled was halved by fitting a diaphragm in the fan inlet. This diaphragm was used from 10 a.m. on 25 June to 10 a.m. on 6 August at Broom's Barn, Rothamsted Tower, Garston, Silwood, Wye and Long Ashton, and on all traps except Rothamsted Farm and Goes, Holland, from 10 a.m. on 1 October to 10 a.m. on 29 October. The Rothamsted Farm sample of air was halved on alternate days from 10 a.m. on 11 June to 10 a.m. on 29 October to study how the change affected the catch. Preliminary results suggest that the catch was also halved in traps with the diaphragm. Aphids flew earlier and increased faster, but totals of most species were fewer than in 1969; there were fewer *Cavariella aegopodii* and *Hyalopterus pruni* but more cereal aphids.

A trap, identical with that used in the survey is being prepared for use in 1971 at Stirling University, Scotland, where its prime use will be to correlate insect catches with clutch size in House Martins.

Before daily trapping began in April the trap at Rothamsted Tower was dismantled and examined for signs of deterioration. The PVC pipe had become so brittle that it broke as it was lowered; also the top of the main body of the trap and some of the lower sections of the trap sides were rotten. The fan was dismantled and found to be in good order. This indicates a life of six to seven years for the woodwork and PVC piping; the nets have a maximum life of two years. In November 1970 the trap at Dundee (in

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constant use since May 1965) was also dismantled and replaced completely. The PVC tube, though brittle, was still usable and the woodwork of the trap sound except at the lower part of one side. (Taylor and French)

N.A.A.S. field trials. Field samples of aphids were again collected by N.A.A.S. Officers from cereal crops (along two transects/field/week) in various parts of the country to relate the first appearance of seven species on the crops with their first appearance in the survey traps. Keys and colour photographs of the aphids were provided for the field workers by the Plant Pathology Laboratory and checks of identifications made in the field showed some errors, especially in identifying the nymphs of *S. fragariae* and *M. festucae*. *R. maidis* was not found in the routine field samples but a few were caught in most traps in June and October. On 35 occasions the suction trap caught aphids on average 17 days before they were found in the nearest field; on nine occasions aphids were found in crops before they were caught in traps, on average 13 days afterwards (Table 6). Of these nine fields six were in northern England where *M. dirhodum* was found in four and *S. avenae* in two, only three days before these aphids were caught in the trap. In northern Scotland, *S. fragariae* was found in two fields on the same days as aphids were trapped. This geographical distribution of fields in which aphids were detected before being trapped contrasts with 1969, when such fields were distributed evenly over the whole country. On 62 occasions aphids were caught in traps this year without later being found in the nearby crops; aphids were never found in a crop without also being caught in the appropriate trap. (Taylor, French and Cole with Mr. K. George of the Ministry of Agriculture, Fisheries and Food, and Mr. R. Gair of the National Agricultural Advisory Service)

Light traps. Catches of 31 species of night-flying moths in the traps operating continuously at 62 sites in 1969, are listed in Table 2 in Part 2, p. 237 of the Report. This year traps were operated at 130 sites. A bulletin, sent to all voluntary workers operating traps and identifying insects, contained reports on Trichoptera by M. I. Crichton, on melanism in *Phigalia pedaria* Fb. by D. R. Lees, on Culicoides by J. Boorman, on Lepidoptera migration in 1967 and 1968, on the phenology of *Diarsia mendica* and a discussion on light trap sampling by R. A. French, J. Nicklen and L. R. Taylor. (Taylor and French)

Light trapping in Africa

Effects of moonlight. The effect of moonlight on catches of insects at a light trap in Kawanda (Uganda) (*Rothamsted Report for 1969*, Part 1, 240) was analysed and an 'index of trap effectiveness' devised. This index is based on the distance from the light source at which light from the trap equals background illumination which, with the type of bulb used (a 125 W mercury vapour bulb) changes by a factor of about 15 between its maximum at no moon and its minimum at zenith full moon. Various periods of moonlight during single nights and the amount of moonlight from different phases and elevations of the moon, lessens this in practice and the average 'index of trap effectiveness' changes then by a factor of about 10 between maximum and minimum. Using the index for catches of different species, a series of theoretical curves, standardised for changes in moonlight, was constructed. The theoretical curves reflect various notable features of curves of actual catch of different taxa which indicates that the distance at which illumination from the background and the trap is equal, is an appropriate basis for the analysis of light trap catches.

A persistent anomaly, that catches of many species at full moon are much greater

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than expected from the average index of trap effectiveness, indicates that many taxa fly more during moonlight than during darkness; catches of *Isoptera*, Bostrychidae and *Spodoptera triturata* increase at full moon.

Catches in relation to large-scale meteorology. Changes in numbers of insects caught by the Kawanda trap, in relation to large-scale weather features, were further studied. During the period between the southerly retreat of the Inter Tropical Front (ITF) and its return northward over Uganda, that is to say between November/December and April/May, increased catch of many taxa is consistently associated with a shift of wind to a southerly or southwesterly direction, which produces a moist, or moister, air stream. During the period April/May to November/December, when the ITF is north of Uganda and the country is under the influence of the south-east or south-west monsoons, this association is much less evident, as might be expected. In the western half of Uganda at least, the important air streams seem to be those associated with the Congo air mass and many insects are brought to Uganda in air masses coming from the south or west. Presumably therefore, the sources also of at least some of the insects trapped are south, south-west or west of Kawanda. *Spodoptera exempta*, which is associated with air moving from the Congo (*Rothamsted Report for 1969*, Part 1, 241), is apparently often carried by southwesterly air streams, and the large catches at the beginning of the 1961 outbreak of Army Worm at Kawanda were also associated with the arrival of south-westerly air. Thus, this outbreak at Kawanda probably had a different source from the more or less simultaneous outbreaks in more easterly areas of East Africa.

Although catch often increases on the day of a wind shift, the biggest increases are one to three days later, when the new air mass is well established and of some depth. This suggests that the biggest concentrations of insects are not at air mass boundaries (or fronts) but in the deeper air stream behind a boundary. Light trapping in the Sudan during October and November supported this suggestion. A northward transit of the ITF over the trapping site, 50 miles south of Khartoum, was connected with a simultaneous rise in catch of several species of insects; but the catch was much larger two days after the transit when the ITF was a long way north of Khartoum and the trap site under a deep southerly air flow. Other results from West Africa, Uganda and the Sudan suggest that, although insects are increased at the ITF, the main entomological significance of the ITF and its movements may be to indicate the boundary between, and the change in position of air of northern origin which is dry and carries few insects, and air of southern origin which is moist and carries many. (Bowden)

Soil fauna

The effects of pesticides on predatory beetles. Carabid beetles help to keep some important pests in check by eating their eggs. Therefore, when possible, pesticides that affect them least should be used. Last year the effects of chlorfenvinphos, diazinon and phorate and this year chlorfenvinphos, trithion and dyfonate applied at 8 lb a.i./acre (8·97 kg/ha) were tested with the same methods as before (see *Rothamsted Report for 1969*, Part 1, 246). There were only 40% as many carabids in plots treated with trithion and 10% as many in the dyfonate as in the untreated plots. By contrast, and like last year, more beetles were trapped in plots treated with chlorfenvinphos than in the untreated plots. (Edwards, Lofty and Holdaway)

Pesticides and earthworms. How pesticides applied to soil affect earthworms needs to be known, not only because earthworms break down organic matter and turn over soil,

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but because they are eaten by birds and moles, which concentrate pesticides. When applied to soil at recommended amounts for killing pests, the organochlorines, aldrin, γBHC, DDT, dieldrin and telodrin had no effect on earthworm populations, nor did the organophosphates, chlorfenvinphos, diazinon, disulfoton, dyfonate, 'Gardona', menazon, parathion, fenitrothion, thionazin and trithion. Larger amounts of chlorfenvinphos, disulfoton and thionazin than are usually recommended, killed some earthworms. In contrast, carbaryl, chlordane, endrin, heptachlor and phorate killed many earthworms, even at recommended doses. The three fumigants, 'D-D', metham sodium and methyl bromide, killed nearly all the earthworms in experimental plots.

There have been many reports that earthworms concentrate organochlorine insecticides from soil into their bodies, but all such reports are from analyses made during surveys at some arbitrary time after treatment. We therefore measured the rate at which such insecticides increase in earthworms kept in treated soil, and the rate they are excreted when the earthworms are put into uncontaminated soil.

Earthworms were kept in soil containing about 1 ppm (dry weight) of DDT. Samples of soil and earthworms were analysed by gas–liquid chromatography each week. The amount of DDT and DDE increased at all samplings, even up to the last (at 9 weeks), when it was about 1 ppm of their fresh body weight; at that time two-thirds was DDE. Earthworms that had spent their whole lives in soil containing DDT in the field, were put in uncontaminated soil and the amounts of pesticide or its residues they contained measured at intervals. All the DDT was excreted in less than four weeks, but the worms still contained some DDE after nine weeks. (Edwards, Lofty and Whiting, with Jeffs, Insecticides Department)

Pesticides and soil fauna. Experiments begun in 1969 showed that 'Talcord' and 'Gardona' at 8 kg/ha affected the total soil fauna only slightly and affected mainly the prostigmatid mites, whereas endrin killed many soil animals, especially most species of mites, isotomid Collembola, adult and larval Coleoptera and larvae of Diptera.

A nematicide, aldicarb ('Temik') was also investigated (for details of experiment, see p. 186). This pesticide had drastic effects on numbers of mites, on the Collembola that live at or above the soil surface and on nematodes. There was only about one-third as many root aphids in the treated as in the untreated plots but the total numbers of Coleoptera and Diptera were similar in both.

Some mites, springtails and enchytraeid worms were diminished in numbers, by the herbicide simazine (*Rothamsted Reports for 1964, 1965*). This year, a closely related herbicide, 'Bladex' was used at 2 and 4 kg/ha cultivated into the soil in some plots and left on the surface in others. Mesostigmatid and oribatid mites, isotomid Collembola and enchytraeid worms were fewer in treated than untreated plots, but earthworms were significantly more numerous in treated plots. (Edwards, Lofty and Stafford)

The effects of cultivation on earthworm populations. The experiment described last year (*Rothamsted Report for 1969*, Part 1, 247) to see how cultivations affect the population of soil invertebrates in old pastures, continued. Arable land usually contains fewer earthworms than pasture, and mechanical damage to the worms by cultivations is widely thought to be responsible for the smaller populations. However, after the first cultivations in 1969, populations of all other invertebrates were smaller, but not of earthworms. Table 7 shows that, in the second year (1970), earthworms were fewest in the unploughed plots, intermediate in those given minimal cultivation, and most abundant in those cultivated most, especially those ploughed during autumn and then, as with all others, cultivated several times during spring. Rather than that ploughing kills earthworms, it

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TABLE 7

Earthworm populations in cultivated plots

Treatment	Earthworm populations			
	wt/g m² (wet wt)	% control	No./m²	% control
Control (unploughed)	6·28	100	4·18	100
Minimal cultivation (ploughed once, spring 1969)	6·35	101	5·06	121
Minimal cultivation (annually spring ploughed)	6·50	104	4·37	104
Maximal cultivation (ploughed once, spring 1969)	8·13	129	5·30	127
Maximal cultivation (annually spring ploughed)	7·35	117	5·55	133
Maximal cultivation (ploughed once, autumn 1969)	8·66	138	6·39	153
Maximal cultivation (annually autumn ploughed)	10·30	164	6·88	164

seems more probable that they are usually fewer in arable land, because it contains less organic matter and would be less suitable for the multiplication of some species. (Edwards and Lofty)

Effects of moisture and temperature on populations of soil invertebrates. Two further field experiments were made on the effects of artificially modifying temperature and amounts of water on populations of soil invertebrates. One started in January was an experiment as described last year (*Rothamsted Report for 1969*, Part 1, 248) but was replicated, with some plots kept 5°C above the ambient temperature, others kept dry and others flooded. The extra heat again greatly increased numbers of oribatid mites and thrips, also those of isotomid Collembola, which were unaffected in the previous experiment. Prostigmatid and predatory mesostigmatid mites, and other groups of Collembola were little affected and dipterous larvae were fewer in heated plots. Flooding greatly decreased numbers of mesostigmatid mites, podurid and isotomid Collembola and dipterous larvae, but significantly increased those of sminthurid Collembola.

These results invite the criticism that the soil gradually dried in the heated plots so combining the effects of heating and drying. Hence another experiment was begun, which included heated plots, that also had water added when tensionmeter readings indicated this was needed to keep the soil moisture as in the control plots. This experiment began in October 1970, so there are results from only two months. Nevertheless, the trends are as in the previous two experiments. Enchytraeid worms disappeared almost as rapidly from heated and moistened plots as from heated plots and prostigmatid and oribatid mites and thrips increased even more rapidly in heated, moistened plots than in plots that were merely heated. Diptera and Coleoptera were less numerous in this experiment which began in autumn and the heating had little effect on their numbers; heating in previous experiments may have made them fewer by accelerating their development and migration from soil. (Edwards, Haines and Stafford)

Wheat Bulb fly

The effect of hedges on the distribution of infested plants. Eggs and larvae of Wheat Bulb fly, and attacked plants, were only slightly aggregated within small areas last year (see *Rothamsted Report for 1969*, Part 1, 252), and for most purposes could be regarded

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as randomly distributed. Nevertheless, infestations often vary considerably in intensity from one part of a field to another. Because adult flies must move from crops of wheat to land under root crops or to fallow land, where the eggs are laid, it seems reasonable to suppose that field boundaries might affect the distribution of eggs within a field.

Stackyard Field, which has been used for experiments on Wheat Bulb fly for several years, has a large hedge on the northern boundary. There are usually fewer larvae near the hedge, and numbers increase as distance from it increases. To study this further, a rectangular plot of winter wheat 190 × 100 ft (58 m × 30 m) was sown, its long axis at right angles to the hedge, which was 36 ft from the edge of the plot. The plot was divided into sub-plots each 10 ft^2 (3·5 m^2). Previously any gradient of egg population was undetectable because of variability between samples; therefore the sub-plots were sampled for larvae, shoots and plants on four occasions in the spring. The plant density, before any plants had been killed by larvae, was uniform throughout the plot, but the number of larvae/sub-plot increased in the sub-plots the further they were from the hedge, and was four times as many at the south end of the plot furthest away from the hedge. There was also a smaller gradient from west to east, numbers of larvae increasing with the distance from the site of an infestation of the previous season immediately adjacent to the west side of the plot. An aerial photograph in late summer showed that the crop was thinnest where larval populations were greatest.

There were several possible explanations for this distribution; namely that predators of eggs and larvae were most numerous nearest to the hedge, or that flies resting in the hedge needed to fly a minimum distance before laying eggs, or that flies used the hedge as a marker to position themselves in the field, or that egg-laying flies avoided the shadow cast by the hedge, or that the hedge affected flies by affecting air currents. To begin a study of these possibilities, a fence 5 ft (1·5 m) high of 50% permeability was erected in a N–S direction on the fallow part of the field and was kept there during the egg-laying period. A line of water traps at right angles to the fence showed female Wheat Bulb flies became gradually fewer from the western boundary of the field to the fence 100 ft (30 m) away, with a peak mid-way between the fence and the edge of a crop of infected wheat some 60 ft (18 m) to the east of the fence. Other Diptera of a similar size (7–10 mm) did not show this peak and were most abundant at the edges of the fallow. Possibly egg-laying Wheat Bulb flies were using the fence as a marker or, more probably, avoiding the shadow cast by the crop or the fence. (Bardner, Fletcher and Whitaker)

Sampling Wheat Bulb fly eggs. Several fields at Rothamsted were sampled for Wheat Bulb fly eggs during the autumn. Eggs were relatively numerous, >1·5 million eggs/acre (>3·75 million/ha) on most fallowed areas, and 0·5 million/acre (1·25 million/ha) on Whittlocks Field and Long Hoos IV after potatoes. (Fletcher)

Artificial rearing of Wheat Bulb fly. The physiology and behaviour of a pest can be studied intensively only when it can be bred readily, and to speed work with the Wheat Bulb fly we have tried methods of rearing it in the laboratory. In the field, flies emerge during June and July and lay most of their eggs during August. The eggs hatch during February and the larvae feed, mainly on winter wheat, until they pupate late in April or during May. Thus field work on any stage of the fly is confined to a brief period during any one year.

To obtain flies out of season, the diapause of the egg must either be extended or broken. Eggs laid in August and kept at 0°C until the following June hatched larvae that infested Cappelle wheat seedlings and pupated to produce normal males and females; so, too, did eggs kept at −6°C for 14 months, of which 32% developed into adult flies in plants

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kept at 15°C, 38 % at 10°C, but none did at 20°C, although newly-hatched larvae attacked wheat shoots. Eggs frozen at −26°C in an attempt to break the diapause produced no viable larvae. So larvae were produced during the year by extending the diapause.

Eggs take 5–6 weeks to mature in the ovarioles of the adult flies and during this time males and females must be able to mate. Flies did this when kept in a large cage at 15–25°C containing several potted wheat plants infested with cereal aphids, to provide honey dew as food for the flies. Extra protein was provided as blood, *Septomyxa* culture, yeast or dried milk, also honey or sucrose. Once or twice a day water was sprayed over the plants. The flies fed and mated and after five or six weeks the females were transferred to breeding chambers where they laid eggs. These eggs, after being kept at 20°C for 56 days were put at 0°C for another 56 days and then used to innoculate more plants, and in this way flies have been obtained throughout this year.

Development of the egg. Eggs of Wheat Bulb fly mature similarly to those of other cyclorraphous flies. Females emerge from the puparium with very small, triangular germaria at the head of each ovariole. During the next six weeks ova are cut off from the germaria; the ova are at the same stage of development in all the ovarioles. The stages of development are: 00, the ovum is cut from the germaria; 0, it divides into eight cells; I, one of the eight cells develops denser protoplasm and can be identified as the potential egg; II, the egg cell gradually enlarges and forms a wall while the other cells form the nurse cells; III, the egg fills half the ovum; IV, the egg swells and the nurse cells are pushed to the blunt end of the developing egg and are gradually absorbed; V, the nurse cells have disappeared and the egg is ripe and ready to be laid.

During the maturation of the first batch of eggs, more ova are cut off from the germarium, and when the first eggs are ripe, the second batch has reached stage III, the third stage 0, and there may be a fourth at stage 00.

At oviposition, the egg breaks free from the surrounding sheath or intima and, as it passes down the oviduct, is fertilised by spermatozoa from the spermatheca passing through the micropyle at the blunt end. The eggs seem to be laid singly, one alternately from the two ovaries.

When the eggs are laid, each intima, together with the remains of the nurse cells and the follicular epithelium, shrinks and ultimately becomes a small yellow mass. The second egg matures similarly, and the cast intima forms another small, yellow plug at the distal end of the ovariole. Provided the fly remains healthy, more eggs develop in the same way. Counting the remains of the intima in the ovarioles shows the number of batches of eggs laid and the age of the female.

External surface of the Wheat Bulb fly egg. The stereoscan microscope shows that the surface of the egg is made of many longitudinal ridges and furrows, coalescing at the pointed end where there are areas of small pores each forming a plastron. Some eggs have plastron areas also laterally on the ridges. The blunt end of the egg, where the head of the larva develops, has no ridges but a central micropyle surrounded by leaf-like areas containing small pores and each forming a rose-shaped plastron.

Emergence in the field. The fine May and June favoured the development of the flies, which emerged on Stackyard Field in great numbers between 22 and 26 June, the earliest peak for four years. During June and July 762 flies emerged from 20 square yards, i.e. 38 flies/yd^2, more than in 1967, 1968 or 1969.

Feeding and behaviour. Adult flies were dissected to see the state of the eggs and whether flies had fed on spores of *Septomyxa affinis*. *Septomyxa* spores were first found in the

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crop of flies caught on 3 July, and occurred in 22% of all the flies examined. Many flies were attacked by the fungus *Entomophthora muscae* and many of the females caught died before they laid any eggs; 10% of the flies dissected, which had no external signs of the fungus, were infected. Few flies caught by sweeping crops during June, July and August had laid more than two batches of eggs, and most had laid only one. By the beginning of August, the winter wheat was ripe, the stems and leaves were dry and it was difficult to sweep any flies. Many had transferred to a greener and younger crop of oats on Fosters field and to green tillers growing from plants cut to enlarge a pathway. There were still many cereal aphids on these plants producing honey dew, on which the adult Wheat Bulb flies fed. Flies caught from oats had also been feeding on *Septomyxa* spores.

White water traps on fallow land during July and August caught both mature females with ripe eggs, young females and females infected with fungus. Several of the females caught during August had laid some, but not all, of their eggs; thus although all eggs of a batch in a female are ripe at the same time, they are not all laid together. (Jones)

An extra generation of frit fly in 1970

Frit fly (*Oscinella frit* L.) usually has three generations a year in Great Britain, one during the autumn and winter when the larvae feed mainly on grass shoots, one when they feed on oat shoots during spring, and one in the oat panicles during July and August. The summer weather this year favoured rapid development, and several frit flies were caught during September in cages over sprouting wheat, showing there had been a fourth generation of flies. (Jones)

Slugs

Formulation of baits. Some carbamates are strongly molluscicidal, most acting as stomach poisons. To control slugs, the compounds must be formulated so as to remain effective in the field for long periods. Existing pellet formulations, based on bran or a similar cereal product, break down quickly and soon become unattractive to slugs, especially in wet weather.

Whether small gelatin disks could be a substitute for bran was studied. Substances that are relatively insoluble in water can easily be incorporated in a warm gelatin solution, which can then be dried and cut. Gelatin is not readily eaten by slugs but is when it contains a palatable additive. The dried gelatin sheet softens and absorbs about 10% w/w of water, but when treated with formaldehyde, hardens and becomes almost insoluble. Thus treated, when moistened it softens slowly and will release pesticide some time after it is put out in the field. Twenty per cent of weight of Croda 1134 gelatin was used in all the tests described below. At this concentration, the hot solution can be poured into a mould to give sheets 3 mm thick which, when set, can be cut into small disks 1·0 mm thick.

Gelatin sheets, while still soft, were kept in an atmosphere of formaldehyde vapour for up to 45 minutes and disks from them were air-dried and then immersed in water at 20°C. The time taken for the disks to swell and soften ranged from 40 to 80 minutes, according to the period they were exposed to formaldehyde.

Untreated disks left undisturbed in water at 20°C dissolved within 72 hours but treated disks, though softened, were only partly dissolved after 28 days. Disks exposed out of doors on bare soil were intact after 74 days and free from mould. All softened after rain, especially the untreated gelatin, but all hardened again as the soil dried. Thus, untreated gelatin disks survived in the field in moist air at temperatures below 20°C

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(but not waterlogged soil) for long periods. Hardened gelatin was also unaffected by very long exposure but softened when thoroughly wetted. It seems that hardening may not be necessary.

Metaldehyde/bran and carbamate/bran pellets were coated with gelatin containing 1·0% w/v of either of the fungicides Nipagin M, copper sulphate or 8-hydroxy-quinoline sulphate. The dried pellets were exposed out of doors on bare soil. After 14 days, and 1·42 in. (36 mm) rain, 80% of the untreated pellets had completely broken down, whereas pellets coated three times with gelatin were intact; those treated with the 8-hydroxy-quinoline sulphate were the least mouldy.

Adult *Agriolimax reticulatus* were offered disks of untreated and treated gelatin on moist filter paper in Petri dishes kept at 15°C in darkness. After seven days, none of the treated and very little of the untreated gelatin had been eaten. However, untreated gelatin disks containing finely ground bran were eaten but became mouldy.

Samples of 20 g wheat bran were refluxed for 3 hours with 100 ml acetone or water and the filtered extracts concentrated to oily liquids smelling strongly of wheat. Adult *A. reticulatus* were offered a choice of filter papers moistened with water or the concentrate. After 12 hours the mucus tracks made by the slugs showed that the acetone extract repelled them and they had not fed; however, the water extract was acceptable and palatable, for the paper had been eaten. Gelatin disks made from the dilute aqueous extract of wheat bran were readily eaten by *A. reticulatus*, as was the paper on which the disks rested. The palatability of the water soluble constituent of wheat bran is thus confirmed.

The formulation of a molluscicide. The compound 'Shell 21959' is an effective though slow-acting contact molluscicide. All the *A. reticulatus* found alive, but moribund, in tests failed to survive. At least 45 minutes contact with it was needed to kill half the slugs exposed.

Gelatin sheets were impregnated with 20% aqueous extract of de-fatted wheat bran and 0·75% w/v 'Shell 21959'. Dried disks, 0·5 cm^2, were freely scattered on the surface of garden loam in a shallow box 1·0 m^2 with drainage holes and a lid covered with terylene mesh. The average distance between the disks was 5·0 cm. After wetting the soil, 10 starved adult *A. reticulatus* were put in the box and the lid sealed. The box was kept out of doors at ground level in the shade, and the soil wetted daily. After 96 hours the dead and moribund slugs were counted. In two tests 95% were dead or moribund.

Some of the gelatin pieces from the box were dried and hardened, and tested again in the laboratory on moist soil, when all the test slugs were killed. Thus, a contact molluscicide can be effectively used in gelatin, and its use is now being tested in the field.

Similar tests were made with 5% w/v of the stomach poison 'Bayer 37344' incorporated in gelatin with bran extract. Pieces about 1·0 cm^2 were placed on the surface of the soil in the box. After 96 hours all ten adult *A. reticulatus* were dead or dying. The gelatin had softened and many pieces had been partly eaten by the slugs. Thus, a stomach poison also can be effective when formulated in gelatin. (Stephenson)

Insecticides and slugs. Whereas the insecticides chlorfenvinphos, diazinon, dyfonate and trithion at 8 lb a.i./acre had no detectable effect on the numbers of slugs in treated plots surrounded by polythene barriers, phorate sprayed on to soil around wheat plants, at the same dose kept slug populations to about 15% of those in untreated plots for about two months after treatment; thereafter populations began to increase.

Analysis of slugs and the treated soil showed that chlorfenvinphos and diazinon were several times more concentrated in the slugs than in the soil; phorate was less concen-

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trated in the slugs than the other two. This behaviour of slugs contrasts with earthworms which usually do not accumulate organophosphate insecticides. (Edwards and Stafford)

Staff

Mrs. Margaret G. Jones and Jennifer B. Sherrard were appointed and Mrs. Marjory G. Morris left. T. Lewis was seconded to work at the Citrus Research Station, Trinidad, for three years.

C. G. Johnson visited Costa Rica, Trinidad and Bermuda under the auspices of the United Nations Organisation and the Overseas Development Administration. J. Bowden visited Kenya and the Sudan under the auspices of O.D.A. and Ciba Research Foundation. C. A. Edwards and R. Bardner attended the Soil Zoology Symposium, Dijon. E. Judenko and R. Bardner attended the VII International Congress of Crop Protection, Paris, and R. Bardner also attended meetings of the Organisation International pour la Lutte Biologique at Wageningen and of the European Plant Protection Organisation at Arnhem, Holland. I. Woiwod and H. Franklin visited Mr. D. Hille Ris Lambers at Bennekom, Holland.

I. H. Haines joined the Department with a studentship of the Agricultural Research Council. Other visitors included Mr. T. M. Whitaker of Brunel University and Mr. R. G. Fairbotham of Wolverhampton College of Technology (sandwich-course students), Dr. D. C. Guevara Benitez of the University of Granada, Dr. H. Philipsen of the Royal Veterinary and Agricultural University, Copenhagen, and Mr. G. P. Vickerman of the University of Newcastle-upon-Tyne.

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