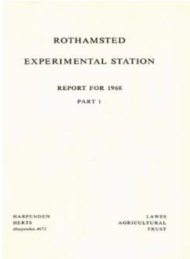
Report for 1968 - Part 1


ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1968
PART 1
HARPENDEN
HERTS
LAWES
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TRUST

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Entomology Department

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ENTOMOLOGY DEPARTMENT

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Effects of insect attack on growth and yield of plants and crops

Wheat Bulb fly

Predicting effects on yield. There is need to be able to predict the effects of attack by Wheat Bulb fly on the yield of wheat crops from infestations in spring. Badly attacked crops are often ploughed in because it is thought they would yield little, but some badly attacked crops recover to produce reasonable yields because they produce extra ear-bearing tillers. Now, for the first time, yield has been related quantitatively to measurements made in March of the density and stage of growth of plants and to the intensity of attack. This was done by analysis of results for 11 field trials with insecticides done by the National Agricultural Advisory Service. Seventy per cent of the variation in yield of Cappelle wheat was accounted for by a multiple regression based on the numbers of larvae, and of shoots or plants/acre, and the number of shoots/plant. The unexplained variation probably reflects differences in soil fertility and summer weather, because the trials were done in different places during a period of 10 years.

The wheat was sown in November in Huntingdon, Cambridgeshire and Essex and the relation of yield to the infestation and stage of growth and density of the crop in spring, as indicated by the means and regression coefficients, differed between fen and peat soils. The regressions will be used to attempt to predict the effects of attack in these areas; other measurements would be necessary for varieties other than Cappelle and for other areas. (Bardner, with Ross, Statistics Department and Mr. F. E. Maskell, National Agricultural Advisory Service)

The distribution of attacked plants. Wheat Bulb fly usually attacks patches of plants, which makes it more damaging than if it attacked scattered, individual plants. There are several possible causes for this patchy distribution, one of which, the clumping of eggs in the soil, was studied in an infested field on Scout Farm. An area 20 × 10 yd was divided into 200 plots each 1 yd square and soil taken from each plot to estimate the number of eggs there: plants were also taken from each plot in late April to assess infested shoots. Examination of the soil samples is not yet complete but the number of damaged shoots in different plots seems to be positively related to the number of eggs there. (Fletcher and Bardner)

Little is known about the relation between the distribution of attacked plants and yield losses. Work on this, started in 1967, was continued, and using the spring wheat cultivar Colibri the yields of ungapped plots with 32 rows of plants were compared with those of plots of 22 rows of plants when eight rows lacking plants were arranged evenly as single rows or in groups of two or four. In 1968 1-ft gaps totalling the equivalent of eight rows/plot were also made and arranged unevenly, randomly or grouped around the central four rows. Table 1 shows that the plots without gaps yielded an average equivalent to 34·7 cwt/acre. Therefore the yield of

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TABLE 1

Yield of spring wheat with gaps of different sizes

Treatment	0 gaps	8 gaps of 1 row	4 gaps of 2 rows	2 gaps of 4 rows	1-ft gaps arranged evenly	randomly	aggregated
Mean yield cwt/acre at 85% dry matter	34·7	31·9	30·5	28·8	31·3	30·6	30·2

S.E. of means ± 0·79

each gapped plot would be equivalent to 25·44 cwt/acre, provided there was no compensatory growth. However, the yields all exceeded this, because from 30 to 80% more ears were produced in the rows adjacent to the gaps, with the greatest increases near the widest gap; the extra ears were the same weight as the others. Even 1-ft gaps spread evenly through a plot caused a significant loss of yield, and it is not yet known how small a gap must be before yield is unaffected. (Bardner and Fletcher)

Effects on the growth and yield of individual plants. A field on Scout Farm with about half-a-million Wheat Bulb fly eggs/acre was sown on 7 December 1967 with seed of Cappelle wheat dressed with dieldrin; a small strip was also sown with undressed seed. All the plants in ten areas of 0·26 sq m, five with dressed and five with undressed seed, were labelled in mid-April with small plastic rings round the base, to distinguish attacked and unattacked plants. The plants were removed before harvest, when the stems and ears were counted and the grain/ear weighed.

Of the 641 plants marked, 133 attacked and 21 unattacked plants had died at harvest. Seventy-four attacked plants remained and yielded on average, 1·25 g/plant of grain compared with 2·27 g/plant from the 414 remaining unattacked plants. Attacked plants had on average 1·6 ears/plant and unattacked plants 2·4. Both attacked and unattacked plants yielded most on the areas with fewest plants. A crop sown in October 1966 and harvested in 1967 behaved similarly. Thus, although attacked and unattacked plants yield most where plants are least dense, attacked plants that survive grow less well, have fewer ears and yield less grain. (Bardner and Fletcher)

Losses caused by aphids

Cereal aphids on wheat. The cereal aphids, *Sitobion avenae* and *Metapolophium dirhodum*, were widespread and abundant on cereals, especially wheat in the south and east of England. At Rothamsted and Woburn, *S. avenae* was restricted to ears and *M. dirhodum* to the stems and flag leaves of wheat. Maximum numbers of *S. avenae* recorded were 16 aphids/ear at Rothamsted and 22/ear at Woburn. *M. dirhodum* was not counted, nor the plants infected with barley yellow dwarf virus. In attempts to see whether the aphids affected yield, some plots on Butt's Close, Woburn Farm, planted with spring wheat, were sprayed with 'Roger E' (12 fluid oz/60-100 gall water/acre) on 19 July and others were left unsprayed. The sprayed and unsprayed plots given 0·6 cwt N/acre yielded similarly but unsprayed plots given 1·8 and 1·2 cwt N/acre yielded 3·7 and

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5·2 cwt/acre respectively less than sprayed ones though the differences were not significant at $P > 0{\cdot}05$ (S.E. of difference of means = 3·57). On Stackyard Field, Rothamsted, individual ears infested with different numbers of *S. avenae* all yielded about the same. (Fletcher and Bardner)

Aphids on field beans. It is recommended that field beans be sprayed against *Aphis fabae* early in the season, soon after the spring migration ends and when infestations are still small. However, some farmers spray later when beans are in flower, which can endanger honey bees. Small, early infestations may be damaging, although it is not known at what stage in the growth of the plant aphids cause most loss of yield. Some small experiments were therefore done to measure the effects of attack at different stages of growth of the plants.

The four treatments, each with six replicates, were (1) early spray with demeton-methyl on 17 June at the start of flowering; (2) 'late' spray on 12 July at the end of flowering; (3) early and late spray; (4) no spray. There was no natural infestation, so the plants were infested artificially on 5 June with aphids from the glasshouse; moderate infestations developed by mid-July on some rows on unsprayed plots. Yields were increased by spraying and more by the early than by the late spray, suggesting that damage by aphids before the end of flowering has most effect on yield. However, the experiment needs repeating in a year when natural infestations are damaging. (Bardner and Fletcher, with Stevenson of Insecticides and Fungicides Department)

Effect of phorate on frit fly and sweet corn (*Zea mays* L.). We reported that phorate protected sweet corn from frit fly but did not increase yield because it damaged the plants as much as did the frit fly.

The experiment was repeated in 1968 and, although the results confirmed the dangers of estimating the damage caused by a pest by measuring the effect of an insecticide on yield, they reversed those in 1967 for phorate increased yield apart from its effect on the frit fly. The experiments show that increases in yield from the use of an insecticide cannot be automatically attributed to the control of the pest against which it was aimed; that failure to increase yield does not indicate failure to control the pest; and that comparisons of yield of treated and untreated plots do not necessarily indicate losses of yield from the pest being controlled.

As in 1967, phorate was applied as granules in the furrows at 1·5 lb a.i./acre and it approximately halved the number of plants attacked by frit fly. It slightly increased the number of plants, but this was not significant. The year did not favour sweet corn and 88% of the plants without phorate and 71% with it failed to produce marketable cobs.

The plants were all numbered, harvested individually, and random samples taken from the harvested plants by using their individual numbers. On average attacked plants yielded more on treated than on untreated plots though not significantly. However, when only the marketable cobs were considered, unattacked plants yielded 71% more on the treated than on untreated plots and their market value increased by 94%, showing a beneficial effect of phorate on unattacked plants. Phorate increased the

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number of marketable cobs produced by attacked and unattacked plants by 160% and their marketable price by 180%. Thus it not only partially controlled frit fly as in 1967, but in 1968 also increased yield in an unknown way. (Judenko)

Aphid studies

Overwintering of pea aphids. Pea aphids (*Acyrthosiphon pisum*) overwinter as eggs, but there are often far more eggs/unit area of crop during winter than the number of fundatrices that become established from them in spring. This makes it difficult to predict outbreaks of the aphid from counts of eggs. The survival of eggs and of fundatrices is affected by predation, disease, climatic conditions and many other factors. In 1968 the effects of temperature on the viability of eggs were studied, and eggs were also examined for possible pathogens.

Many eggs hatch only after they are chilled. Of eggs laid on lucerne in November, 41, 28, 17 and 3% hatched respectively when incubated at 5, 10, 15 and 20° C in early December. By contrast, the percentage hatch of eggs incubated at these temperatures after exposure to outside temperatures for two months (range −6 to +11° C) was 38, 44, 34 and 36% respectively. After exposure to outside temperatures throughout the winter, 42% of eggs hatched when incubated at 15° C.

Eggs survived better in air colder than 0° C, than when frozen within ice. Thus the percentage hatch at 15° C after 1 and 20 days in air at −6° C was 26 and 24% respectively. After exposure for a similar period in ice, 12 and 6% hatched. Abnormal cold had little effect on survival except when maintained for a long period. Thus after 0, 1, 5 and 20 days at −18° C, 26, 22, 22 and 14% hatched respectively when incubated at 15° C.

Many eggs that failed to hatch were shrunken or had the chorion indented. Forty per cent of these contained well differentiated embryos with eye pigment or appendages, but only 6% contained many micro-organisms. Of apparently normal eggs that failed to hatch by March, 58% contained well-developed embryos, many showed histolysis and 52% contained micro-organisms, mainly bacteria, which were not necessarily pathogens. (Cockbain)

Virus infectivity of pea aphids. About 18 times as many apterae of *A. pisum* were found in April at Rothamsted on third-year lucerne as on a similar area of third-year white clover. Fifty-five per cent of the lucerne aphids and 6% of the clover aphids, were infective with bean leaf roll virus (BLRV). Four per cent of *A. pisum* collected at the same time from common vetch (*Vicia sativa*) were infective with pea enation mosaic virus.

Spring migrants of *A. pisum* were caught alive in suction traps at Rothamsted in early June and tested for infectivity on *Trifolium incarnatum* seedlings. Five per cent were infective with BLRV and 20% with a persistent virus, probably a strain of BLRV, which produced very mild symptoms in *T. incarnatum* and field beans (var. Herz Freya) and peas (Dark Skin Perfection), but stunted French Beans (Prince). Thirteen per cent of the alatae were infective with a persistent virus causing leaf curl

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and vein thickening in *T. incarnatum*, *T. subterraneum* and in peas. This virus persisted in aphids fasted for 6 hours, and through ecdysis, and was transmitted during a four-day acquisition and a four-day inoculation feed; it was not transmitted during probes lasting a few minutes, or by manual-inoculation of sap. Symptoms of the type caused by this virus were not seen in peas in the field. (Cockbain)

Aphids and virus diseases of lucerne. An experiment on the effects of aphid infestation and virus infection on the yield of lucerne in pure stands, and with cocksfoot, continued for a third year. Treated plots were sprayed with 'Metasystox' four times during the year, and aphid populations on treated and control plots were assessed four times between April and September.

Aphids were few throughout the year. Eighty-nine per cent of all aphids on the lucerne were *Acyrthosiphon pisum*, the rest were mainly alatae and young nymphs of *Sitobion avenae*, *Myzus persicae* and *Aphis fabae*. *A. pisum* were most abundant in mid-June, when there were 65/5 ft row of unsprayed lucerne; this was more than in 1967, but fewer than in 1966. On average, *A. pisum* was 3·4 times as abundant on unsprayed as on sprayed plots, and 1·3 times on lucerne in pure stands as on lucerne with cocksfoot.

The incidence of lucerne mosaic virus in late April was 1% in sprayed lucerne and sprayed lucerne/cocksfoot, 13% in unsprayed lucerne/cocksfoot and 24% in unsprayed lucerne (assessed by A. J. Gibbs). The incidence of bean leaf roll virus in early October was 5% in sprayed lucerne/cocksfoot, 13% in sprayed lucerne, 37% in unsprayed lucerne/cocksfoot and 55% in unsprayed lucerne. Only one plant was found showing vein yellowing symptoms when all plots were examined in April.

Plants on all plots suffered from *Verticillium* wilt, which tended to be more prevalent in the unsprayed plots. Thus, in early October, 13% of lucerne shoots in sprayed, and 22% in unsprayed, lucerne plots were severely affected, as were 20% in sprayed, and 27% in unsprayed lucerne/cocksfoot plots.

The number of cocksfoot plants showing cocksfoot mottle or cocksfoot streak assessed by Mr. J. A'Brook in June did not differ significantly between sprayed and unsprayed lucerne/cocksfoot plots.

Plots were cut three times, and yields were taken from each cut. The total yields from lucerne/cocksfoot plots exceeded those from lucerne plots (mean of 100·0 and 58·2 cwt dry matter/acre respectively), but there was no significant difference between yields from sprayed and unsprayed lucerne (61·6 and 54·8 cwt/acre), or between sprayed and unsprayed lucerne/cocksfoot (98·4 and 101·6 cwt/acre).

Much lucerne died and yields from the lucerne plots were 47% less in 1968 than in 1967; by contrast, yields from lucerne/cocksfoot plots were only 16% less, for little cocksfoot died. Thus, in this experiment, in which aphids were few, weed competition and *Verticillium* wilt infection probably decreased the yield of lucerne much more than did aphid infestation and virus infection. In early October there were 57% fewer shoots of lucerne/unit length of row in lucerne/cocksfoot plots than in lucerne plots; by contrast, numbers of shoots were similar on sprayed and unsprayed plots, although there was a difference in aphid-infestation and virus infection of

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these plots. (Cockbain, with Etheridge, Insecticides and Fungicides Department)

Aphids and virus diseases of peas. The incidence of bean leaf roll virus (BLRV) and pea enation mosaic virus (PEMV) in peas, var. Jade, was assessed in shoots taken at random during or after flowering from crops in Norfolk and Lincolnshire. BLRV was found in nine of twelve crops; the maximum incidence was 41%, the mean 9%. The incidence was about nine times greater in Lincolnshire than in Norfolk. PEMV was found in only one crop, with about 5% of the shoots infected.

The presence of BLRV and PEMV in other crops of vining and dry harvesting peas in Norfolk and Lincolnshire was assessed by testing the ability of apterae of *Acythosiphon pisum* that developed on the crops to infect *Trifolium incarnatum* seedlings. Twenty-five crops, of eight varieties, were sampled. The numbers of aphids ranged from 0·2 to 11·8 million/acre. Some aphids from crops of Jade, Johnson's Freezer, Sprite and Dark Skin Perfection peas were infected with BLRV; the range was 0–31% infective aphids, the mean 4%. Aphids from crops of Freezer 69, Scout, Maro and Big Ben were not infective. Some aphids from 3 of the 25 crops were infective with PEMV: the maximum was 4% infective aphids on a crop of Freezer 69.

A trial drilled at Rothamsted on 27 March compared the effects of two systemic aphicides, applied at drilling, on aphid infestation, virus infection and yield of peas. The treatments were menazon seed dressing ('Saphizon D.P.', 0·5% of seed-weight, with a 'Celacol' sticker), disulfoton granules ('Disyston', 20 lb of 7·5% a.i./acre, below the seed), and untreated seed. The pea varieties were Jade and Dark Skin Perfection. The seed dressing had no obvious effect on seedling number or vigour, but the granules decreased the vigour of seedlings of both varieties.

Both insecticides decreased aphid infestation. Thus, in early July, 69% of untreated plants, 18% of menazon-treated plants and 5% of 'Disyston'-treated plants were infested, mainly with *A. pisum*; the mean number of aphids/shoot tip was 7, 1 and 0·2 respectively. Between this date and harvest (11 July for Jade, 18 July for D.S. Perfection) the proportion of infested plants, and the number of aphids/shoot tip, increased on all plots. Tests at this time, in which aphids were caged on leaves for 48 hours, indicated that menazon-treated plants were no longer toxic to aphids and 'Disyston'-treated plants only slightly toxic.

Few plants became infected with viruses, and immediately before harvest there was no obvious difference between plots treated differently. Seven per cent of plants of var. Jade showed chlorosis, often only of the shoot tip and youngest leaves, possibly indicating BLRV infection; BLRV was isolated from 53% of a sample of such plants. Four per cent of plants of var. D. S. Perfection showed similar symptoms; BLRV was isolated from 24% of these. Symptoms of BLRV infection were difficult to recognise in both varieties, but the virus was isolated only from plants with chlorosis. Fewer than 0·5% of plants of either variety were infected with pea mosaic and pea enation mosaic viruses.

The yield of peas in pod of 'Disyston'-treated and untreated plants was

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TABLE 2

Rothamsted Insect Survey: monthly total catches of Rhopalosiphum *spp.* (insertum, maidis *and* padi)

Year	Month	Dundee	Newcastle	High Mowthorpe	Rothamsted Farm	Rothamsted Tower	Broom's Barn	Wye	Total
1967	May	29	4	4	60	140	42	25	304
1968	May	3	0	0	2	3	0	9	17
1967	June	22	101	176	187	194	161	237	1078
1968	June	55	12	15	44	49	61	133	369
1967	July	516	622	8260	1505	1095	4957	832	17787
1968	July	908	457	71	1226	876	1676	367	5581
1967	August	1101	942	500	83	104	85	184	2999
1968	August	2015	4977	1762	175	152	246	210	9537
1967	September	3101	4474	348	139	325	137	632	9156
1968	September	7854	6024	1970	1153	773	908	3513	22195
1967	October	1433	3491	405	376	470	734	860	7769
1968	October	2392	3823	896	2666	2297	2275	10373	24722
1967	Total	6202	9634	9693	2350	2328	6116	2770	39093
1968	Total	13227	15293	4714	5266	4150	5166	14605	62421

TABLE 3

Rothamsted Insect Survey: monthly total catches for Sitobion *spp.* (*mainly* avenae)

Year	Month	Dundee	Newcastle	High Mowthorpe	Rothamsted Farm	Rothamsted Tower	Broom's Barn	Wye	Total
1967	May	0	0	1	19	14	3	22	59
1968	May	3	0	0	3	12	4	1	23
1967	June	11	8	1	95	91	44	176	426
1968	June	0	10	4	299	252	353	143	1061
1967	July	8	13	49	137	106	264	214	791
1968	July	60	33	87	5122	5818	15325	2422	28867
1967	August	19	17	39	28	26	22	70	221
1968	August	1432	412	330	237	313	179	231	3134
1967	September	8	7	0	2	4	6	10	37
1968	September	26	14	11	8	1	1	9	70
1967	October	7	7	0	3	6	2	14	39
1968	October	1	6	0	16	15	5	38	81
1967	Total	53	52	90	284	247	341	506	1573
1968	Total	1522	475	432	5685	6411	15867	2844	33236

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TABLE 4

Rothamsted Insect Survey: monthly total catches for Metopolophium dirhodum

Year	Month	Dundee	Newcastle	High Mowthorpe	Rothamsted Farm	Rothamsted Tower	Broom's Barn	Wye	Total
1967	May	1	0	0	7	17	14	2	41
1968	May	1	0	0	0	3	0	0	4
1967	June	4	9	34	79	63	308	124	621
1968	June	0	6	9	769	383	254	95	1516
1967	July	12	4	104	101	67	891	86	1265
1968	July	599	256	864	2729	2010	3577	746	10781
1967	August	3	0	1	0	0	1	3	8
1968	August	638	192	135	13	8	5	2	993
1967	September	0	1	0	0	1	0	0	2
1968	September	9	1	1	0	1	0	0	12
1967	October	2	2	1	0	0	0	8	13
1968	October	1	5	0	0	4	1	24	35
1967	Total	22	16	140	187	148	1214	223	1950
1968	Total	1248	460	1009	3511	2409	3837	867	13341

TABLE 5

Rothamsted Insect Survey: monthly total catches for Metopolophium festucae

Year	Month	Dundee	Newcastle	High Mowthorpe	Rothamsted Farm	Rothamsted Tower	Broom's Barn	Wye	Total
1967	May	2	2	5	2	2	0	0	13
1968	May	0	0	0	1	1	0	3	5
1967	June	5	14	42	9	6	37	4	117
1968	June	11	11	5	22	21	4	13	87
1967	July	0	2	4	1	3	9	0	19
1968	July	20	5	76	60	47	156	6	370
1967	August	0	0	0	0	0	0	0	0
1968	August	8	0	0	0	0	0	0	8
1967	September	0	1	0	0	0	0	0	1
1968	September	0	0	0	0	1	0	0	1
1967	October	0	2	0	0	0	0	6	8
1968	October	0	0	0	1	0	0	1	2
1967	Total	7	21	51	12	11	46	10	158
1968	Total	39	16	81	84	70	160	23	473

the same, but menazon-treated Jade peas yielded 7% more, and menazon-treated D. S. Perfection peas, 15% more than untreated plants (differences not significant, $P > 0 \cdot 10$). Pea samples taken at harvest from 'Disyston'-treated plants contained a 'Disyston' residue of 0·4 ppm. (Cockbain, with Etheridge, Insecticides and Fungicides Department)

The Rothamsted Insect Survey

Suction traps. Two new 40-ft traps started operating, one at Silwood Park, Imperial College Field Station, and one at Goes, Zeeland, Holland. The trap in Holland is the first outside the British Isles and is operated by Mr. D. Hille Ris Lambers of the Bladluisonderzoek T. N. O. These traps form the beginnings of an east–west transect ending at Rosewarne Experimental Horticultural Station, Camborne, in Cornwall, where another trap will operate in 1969. Two more traps will also operate in 1969, one at Edinburgh in the already existing north–south transect down the east side of England and Scotland and one at Aberystwyth which, together with the trap at Rosewarne, will start a north–south transect down the west side.

During 1968 a reporting service began on the numbers of 32 selected species of aphids caught in traps at Dundee, Newcastle, High Mowthorpe, Broom's Barn, Rothamsted, Silwood Park, Wye and Goes. Bulletins were distributed weekly to about 50 people, including many entomologists in the National Agricultural Advisory Service. Daily catches of aphids from the Dutch trap were identified by Mr. D. Hille Ris Lambers, and all the others were identified by members of the Entomology Department at Rothamsted, by G. D. Heathcote, Broom's Barn Experimental Station or by Mr. H. Stroyan of the Ministry of Agriculture Plant Pathology Laboratory, Hatching Green. Traps were emptied daily between 1 May and 3 November. There have been few difficulties in identification but constant vigilance is needed to detect unexpected and closely allied genera or species. All the aphids caught in 1967 have been identified but the records have not yet been analysed.

It was decided to issue weekly bulletins to assess the cost, speed and efficiency of sorting and identification, to study the potential needs for information delivered soon enough to be useful and to enable advisors to assess their local populations and compare them with those elsewhere. It must be emphasised that this programme is experimental, designed to study the feasibility and practicability of the method; it is not an advisory service as yet. As information accumulates and is analysed, it is hoped that the present system will act as a standard against which to assess the merit and efficiency of other warning and trapping systems. Lack of such a standard has hitherto hindered such a comparison. Questionnaires have also been sent to regular recipients of the bulletins. The replies show much interest in the exercise and the need for this kind of information. It seems unlikely that the information could be disseminated faster than at present, when one person deals with the catches from two traps. Work could be spread more evenly by doubling the sample from each trap in April to May and halving it in July to August, and the possibility of modifying the trap to do this is being investigated.

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The significance of the trapping height of 40 ft. The catch of one aphid/day in the 40-ft survey trap is estimated to correspond to a deposition rate of about 130 aphids/acre in average conditions, that is to say, in moderately turbulent convection with a near-linear log density X log height profile, a gradient where the regression coefficient $b = -1{\cdot}0$, and the average flight time is about 2 hours. For long-distance migrants flying for 12 hours with a density gradient of 0, the equivalent deposition rate is 230/acre; for short-distance migrants flying for half-an-hour in a gradient of $-2{\cdot}0$ the equivalent deposition rate is 5–6000/acre.

The height of 40 ft was chosen for the survey from a study of gradients of insect density with height, to give the best estimate of total aerial numbers by a single trap sampling in a linear log insect density X log height gradient from 0·4 to 4000 ft. It is also the minimum height to avoid too many aphids from local populations, yet not so high that catches are too small. In calm evenings when aphids tend to migrate at low levels for short distances, the above estimates indicate that the 40-ft survey trap will underestimate total numbers moving.

The trap was designed to sample from the general aerial population of aphids, not from local populations. If local movements also are to be assessed and if the total upper content of the air is to be more accurately estimated, another suction trap at another height, say 4 ft, should be operated. The justification for this has not yet been established; it would double the cost of the survey.

Cereal aphids in the suction traps. In 1968 cereal aphids attracted particular attention, both as crop pests and as virus vectors, prompting questions about whether there was a large-scale influx of long-distance migrants. So far there is only 1967 against which to judge the figures for 1968; but monthly total catches for *Rhopalosiphum* spp. (*insertum*, *maidis* and *padi*), *Sitobion* spp. (mainly *avenae*), and the two *Metopolophium* spp., *dirhodum* and *festucae*, give some indication of seasonal trends (Tables 2–5).

Samples early in the season are of special interest for indicating virus vectors, and it is apparent that all the grain aphids were less common in May 1968 than in May 1967 and no more common in June. Populations of *M. festucae*, *M. dirhodum* and *Sitobion* were unusually large during July and August, and there was no simple regional trend in the proportional increase from year to year; Dundee and Broom's Barn showed the greatest gains. In general *Sitobion* increased most and there were about 20 times as many in 1968 as in 1967; *M. dirhodum* had the greatest increase in a month, namely by 200 times, in August at Dundee. *Rhopalosiphum* was not identified to species in 1967, so no comparisons of species between years are possible; but in general in 1968 the genus was only twice as common in the traps as in 1967, and the seasonal trends are complex; for example, in 1968 there were two seasonal peaks of numbers in July and October in the south, and only one in September in the north. In 1968 it was not until October that numbers trapped in the south exceeded those in 1967. It is difficult to generalise about 'cereal aphids'.

The large numbers of cereal aphids in 1968 probably did not make cereal viruses unusually prevalent and important because the increases in popula-

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tion were late. No opinion can be expressed about the possible influx of virus-carrying aphids from abroad, but it seems unlikely that such immigrations entirely account for the irregular distribution of cereal aphids in time and space. Population densities will have to be measured for several years before unusual patterns in regional distribution can be detected and it will be known whether the aphids are important not only as virus vectors but also as pests. (Taylor, French and Palmer)

***Early records of* Myzus persicae.** Sampling for the first migrants of *Myzus persicae* in spring with 40-ft suction trap, by sticky trap and by the crop-inspection scheme of the British Sugar Corporation, during 1965–6–7, showed that the 40-ft survey trap gave the earliest record and the most reliable sample. A bigger proportion of the catch on sticky traps, however, consisted of species of economic importance. (Taylor and Palmer, with G. D. Heathcote, Broom's Barn)

Thresholds for take-off by grain aphids. Aphids start to migrate only when temperature and light permit them to take off. Responses of *Schizaphis graminum* (the Greenbug), *Macrosiphum granarium* (=*Sitobion avenae*), *Rhopalosiphum fitchii*, *Acythosiphum pisum* and of four different strains of *Rhopalosiphum maidis* to light restricted take-off to the day time; only very small proportions of the population of one strain of *R. maidis* KS-2 and *M. granarium* took flight in light equivalent to civil twilight. All other species required much more light, and the Greenbug required light equivalent to full sunlight before 100% of the population took off. The curve of proportions taking off in relation to log light intensity was asymmetrical and differed in very dim light from in brighter light.

In cultures raised in a glasshouse in Kansas, U.S.A., where temperatures often greatly exceeded the usual in Rothamsted cultures, temperature thresholds of the above species and also of *Aphis fabae*, were unexpectedly high and complex. As with *A. fabae* in Britain (*Rothamsted Report for 1967*, pp. 191–192), a large proportion of the alatae in the Kansas cultures did not fly at all. (Taylor, with the late Dr. W. W. Dry, Kansas State University)

When *A. fabae* and *S. graminum* fall through the air some begin to fly, but the proportion that did so lessened as the aphids aged, as light diminished and temperatures fell. Starvation shortened the flying life. However, always more falling *A. fabae* than *S. graminum* responded by flying although *S. graminum* is the aphid more often reported as a long-distance migrant. It was concluded that the long-distance migration of *S. graminum* could not be attributed to any special flight ability or behaviour not possessed by *A. fabae*. (Taylor, with Dr. L. A. Halgren, Kansas State University)

Nevertheless, samples taken by aircraft show that a much larger proportion of the daytime population of flying aphids remains in the air at night over Kansas than over southern England. In summer nights over Kansas the air is warm enough to allow aphids to fly even when light is less than the thresholds for take-off. Provided such aphids continue to fly

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TABLE 6

The Rothamsted Insect Survey—Light Traps: three years' records of moths of econom interest (1965, 1966, 1967)

Pest Species	Year	57 Ardross	58 Elgin	49 Fort Augustus	48 Kindrogan	38 Killiecrankie	29 Rannoch	60 Mull	47 Dundee	39 Chester le Street	103 Durham	68 Harrogate	45 Malham	40 Lancaster	10 Bradford	35 Bangor
Abraxas grossulariata	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Magpie Moth	1966	0	0	0	—	0	0	0	0	24	—	3	0	10	69	0
	1967	0	0	0	0	0	0	0	0	47	8	13	0	1	105	3
Agrotis exclamationis	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Heart and Dart	1966	0	0	0	—	20	0	0	1	1	—	13	0	2	2	49
	1967	0	0	1	1	18	0	0	1	5	3	13	0	2	0	16
Agrotis ipsilon	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dark Sword Grass	1966	4	1	0	—	3	0	3	0	0	—	1	0	0	0	4
	1967	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0
Agrotis segetum	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Turnip Moth	1966	0	0	0	—	0	0	0	0	0	—	0	0	0	0	1
	1967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alsophila aescularia	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March Moth	1966	0	0	—	—	4	0	0	—	1	—	0	—	0	0	2
	1967	2	4	0	0	1	0	1	0	0	5	6	0	0	0	0
Apamea secalis	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Common Rustic	1966	0	1	4	—	2	0	0	23	14	—	23	0	12	13	110
	1967	1	35	22	0	3	0	34	11	29	24	29	0	22	17	45
Apamea sordens	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rustic Shoulder Knot	1966	0	0	11	—	1	0	0	2	6	—	0	1	0	7	0
	1967	1	0	0	4	1	0	0	9	0	14	0	1	0	2	0
Bupalus piniaria	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bordered White	1966	0	0	0	—	0	0	0	0	0	—	0	0	0	0	1
	1967	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Cerapteryx graminis	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Antler Moth	1966	0	0	20	—	83	29	0	0	1	—	1	9	0	1	1
	1967	18	26	83	24	114	111	87	7	0	172	2	17	0	0	3
Diataraxia oleracea	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bright-line Brown-eye	1966	0	0	0	—	0	0	0	0	3	—	1	0	4	0	1
	1967	0	13	0	0	2	0	6	1	3	4	4	0	2	2	0
Erannis aurantiaria	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scarce Umber	1966	50	18	201	—	325	119	0	0	0	—	6	2	0	0	0
	1967	19	1	36	1	15	86	0	0	0	10	0	1	0	0	0
Erannis defoliaria	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mottled Umber	1966	0	2	61	—	57	9	1	1	0	—	3	0	0	0	0
	1967	3	1	42	33	20	16	0	2	0	20	4	4	0	0	0
Euproctis chrysorrhoea	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brown Tail	1966	0	0	0	—	0	0	0	0	0	—	0	0	0	0	0
	1967	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euxoa nigricans	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Garden Dart	1966	0	0	0	—	0	1	0	0	4	—	1	0	0	1	0
	1967	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0
Gortyna flavago	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Frosted Orange	1966	0	0	0	—	0	0	0	1	2	—	0	0	0	0	6
	1967	0	0	0	0	0	0	0	6	1	38	4	0	0	0	0

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18 Flatford Mill	31 Dunmow	34 Rothamsted Allotments	1 Rothamsted Barnfield	22 Rothamsted Geescroft	12 Hatfield A	13 Hatfield B	17 Dale Fort	73 Orielton	16 Stratfield Mortimer	69 Wisley	46 Alice Holt	62 Wye	33 Dungeness	67 Slapton Ley	Year	Pest Species
20	—	—	3	47	3	5	10	—	59	—	—	—	—	—	1965	*Abraxas grossulariata*
3	97	7	7	57	2	8	73	—	38	—	3	0	4	0	1966	Magpie Moth
8	13	43	10	123	4	22	74	23	83	2	1	9	8	24	1967	
10	—	—	72	14	45	19	18	—	24	—	—	—	—	—	1965	*Agrotis exclamationis*
4	73	0	31	15	21	14	22	—	21	—	49	0	120	0	1966	Heart and Dart
11	57	19	33	14	34	12	29	8	4	28	23	34	84	97	1967	
0	—	—	0	0	0	0	4	—	0	—	—	—	—	—	1965	*Agrotis ipsilon*
0	1	9	1	2	0	0	21	—	5	—	1	1	2	2	1966	Dark Sword Grass
0	0	0	0	1	0	0	3	1	1	0	1	1	3	2	1967	
5	—	—	6	4	2	0	2	—	1	—	—	—	—	—	1965	*Agrotis segetum*
0	2	0	0	0	0	0	2	—	1	—	0	0	0	1	1966	Turnip Moth
0	1	3	0	2	0	0	0	0	1	0	1	0	3	0	1967	
68	—	—	4	14	2	3	2	—	27	—	—	—	—	—	1965	*Alsophila aescularia*
30	2	0	4	27	0	0	2	—	4	—	0	0	0	0	1966	March Moth
6	0	0	0	11	0	0	0	9	10	26	7	7	0	19	1967	
10	—	—	19	11	14	5	10	—	8	—	—	—	—	—	1965	*Apamea secalis*
16	17	9	9	14	9	7	58	—	10	—	8	0	9	0	1966	Common Rustic
25	17	21	17	21	2	4	37	44	9	30	4	12	16	47	1967	
0	—	—	1	0	1	1	0	—	0	—	—	—	—	—	1965	*Apamea sordens*
0	0	2	2	3	1	0	0	—	0	—	0	0	1	0	1966	Rustic Shoulder Knot
0	0	6	0	0	0	0	0	0	0	2	0	0	5	0	1967	
0	—	—	0	0	0	0	0	—	0	—	—	—	—	—	1965	*Bupalus piniaria*
0	0	0	0	0	0	0	0	—	0	—	0	0	0	0	1966	Bordered White
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1967	
2	—	—	0	0	0	0	0	—	0	—	—	—	—	—	1965	*Cerapteryx graminis*
0	0	0	0	0	0	0	0	—	0	—	2	0	4	0	1966	Antler Moth
0	0	1	0	0	0	0	0	4	0	1	3	0	0	0	1967	
3	—	—	2	1	2	3	3	—	0	—	—	—	—	—	1965	*Diataraxia oleracea*
6	13	0	3	0	5	5	1	—	0	—	0	0	3	0	1966	Bright-line Brown-eye
4	7	3	3	0	1	1	10	1	1	3	0	1	1	10	1967	
3	—	—	0	28	0	1	0	—	8	—	—	—	—	—	1965	*Erannis aurantiaria*
0	0	0	0	6	0	0	0	—	2	—	0	0	0	0	1966	Scarce Umber
0	0	0	1	8	0	0	0	1	6	16	16	0	0	0	1967	
5	—	—	0	49	1	0	0	—	88	—	—	—	—	—	1965	*Erannis defoliaria*
0	0	0	0	25	0	1	0	—	32	—	48	0	0	0	1966	Mottled Umber
2	0	0	0	50	0	0	1	7	24	16	29	1	0	1	1967	
0	—	—	0	0	0	0	0	—	0	—	—	—	—	—	1965	*Euproctis chrysorrhoea*
0	0	0	0	0	0	0	0	—	0	—	0	0	29	0	1966	Brown Tail
0	1	0	0	0	0	0	0	0	0	0	0	0	32	0	1967	
6	—	—	0	2	0	0	0	—	0	—	—	—	—	—	1965	*Euxoa nigricans*
0	0	1	0	2	0	0	1	—	3	—	1	0	0	0	1966	Garden Dart
0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1967	
1	—	—	3	0	0	0	1	—	4	—	—	—	—	—	1965	*Gortyna flavago*
0	0	3	3	2	0	1	4	—	1	—	1	0	0	0	1966	Frosted Orange
5	0	4	1	1	0	0	0	10	0	0	0	0	1	2	1967	

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TABLE 6—*continued*

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Pest Species	Year	57 Ardross	58 Elgin	49 Fort Augustus	48 Kindrogan	38 Killiecrankie	29 Rannoch	60 Mull	47 Dundee	39 Chester le Street	103 Durham	68 Harrogate	45 Malham	40 Lancaster	10 Bradford	35 Bangor
Gortyna micacea	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rosy Rustic	1966	83	52	17	—	24	97	28	8	7	—	62	0	13	44	4
	1967	132	136	63	50	15	70	39	7	3	154	39	0	7	24	1
Hepialus humuli	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ghost Swift	1966	0	0	0	—	0	1	0	1	2	—	0	1	0	0	0
	1967	0	0	1	0	2	2	0	0	0	1	1	0	1	2	0
Hepialus lupulina	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Common Swift	1966	0	0	0	—	0	1	0	2	3	—	1	0	0	0	0
	1967	0	0	0	0	0	0	0	0	0	0	40	0	0	4	0
Mamestra brassicae	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cabbage Moth	1966	0	0	0	—	5	0	0	0	3	—	0	0	3	1	14
	1967	0	0	0	0	0	0	0	0	11	0	1	0	1	5	11
Melanchra persicariae	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dot Moth	1966	0	0	0	—	0	0	0	0	0	—	0	1	0	0	0
	1967	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
Noctua pronuba	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Large Yellow Underwing	1966	0	0	0	—	7	0	0	6	6	—	12	4	17	16	105
	1967	0	16	3	0	35	0	13	5	3	45	13	8	16	9	33
Operophtera brumata	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Winter Moth	1966	45	0	35	—	198	0	6	4	1	—	15	12	0	0	0
	1967	41	5	35	19	77	43	10	2	1	30	11	30	0	0	1
Operophtera fagata	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Northern Winter Moth	1966	5	3	0	—	174	4087	0	0	0	—	0	12	0	1	0
	1967	3	0	4	0	10	146	0	0	1	2	0	10	0	0	0
Panolis flammea	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pine Beauty	1966	0	0	0	—	0	1	0	0	0	—	0	0	0	0	0
	1967	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
Phlogophora meticulosa	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Angle Shades	1966	1	0	1	—	2	0	1	0	0	—	0	1	0	0	11
	1967	0	0	0	0	0	0	0	0	2	0	0	0	1	1	6
Plusia gamma	1965	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Silver Y	1966	12	12	3	—	15	10	18	14	179	—	62	21	33	24	25
	1967	0	0	1	1	0	0	0	0	24	1	14	3	7	10	1

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TABLE 6—*continued*

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18 Flatford Mill	31 Dunmow	34 Rothamsted Allotments	1 Rothamsted Barnfield	22 Rothamsted Geescroft	12 Hatfield A	13 Hatfield B	17 Dale Fort	73 Orielton	16 Stratfield Mortimer	69 Wisley	46 Alice Holt	62 Wye	33 Dungeness	67 Slapton Ley	Year	Pest Species
19	—	—	5	0	0	6	2	—	3	—	—	—	—	—	1965	*Gortyna micacea*
32	6	19	4	4	5	2	8	—	4	—	28	0	10	0	1966	Rosy Rustic
6	1	27	5	1	0	3	1	91	1	6	14	2	10	20	1967	
0	—	—	0	1	1	0	0	—	0	—	—	—	—	—	1965	*Hepialus humuli*
0	0	0	1	8	1	0	0	—	2	—	5	0	0	0	1966	Ghost Swift
0	0	1	3	1	2	0	0	1	1	3	5	1	0	4	1967	
4	—	—	26	15	2	20	4	—	13	—	—	—	—	—	1965	*Hepialus lupulina*
7	0	9	10	16	3	5	14	—	5	—	4	0	60	0	1966	Common Swift
1	1	18	12	3	3	5	23	2	9	1	1	1	39	0	1967	
0	—	—	2	1	1	7	0	—	1	—	—	—	—	—	1965	*Mamestra brassicae*
3	6	0	0	0	1	2	0	—	0	—	1	0	0	0	1966	Cabbage Moth
1	7	0	0	0	0	2	1	1	1	0	0	0	1	8	1967	
3	—	—	0	0	8	8	4	—	4	—	—	—	—	—	1965	*Melanchra persicariae*
1	23	0	3	0	2	6	1	—	2	—	1	0	0	0	1966	Dot Moth
3	25	1	6	1	4	3	3	3	2	2	1	8	0	49	1967	
3	—	—	4	60	6	7	10	—	5	—	—	—	—	—	1965	*Noctua pronuba*
1	1	9	10	58	33	3	11	—	25	—	10	0	5	0	1966	Large Yellow Underwing
3	1	8	5	112	5	4	3	7	16	3	5	7	0	17	1967	
16	—	—	2	125	1	1	21	—	85	—	—	—	—	—	1965	*Operophtera brumata*
60	0	0	1	81	1	0	5	—	65	—	42	0	0	6	1966	Winter Moth
5	0	1	2	114	0	1	6	6	84	51	40	13	0	9	1967	
0	—	—	0	0	0	0	0	—	0	—	—	—	—	—	1965	*Operophtera fagata*
0	0	0	0	0	0	0	0	—	0	—	0	0	0	0	1966	Northern Winter Moth
0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	1967	
0	—	—	0	0	0	0	0	—	1	—	—	—	—	—	1965	*Panolis flammea*
0	0	0	0	0	0	0	0	—	1	—	0	0	0	0	1966	Pine Beauty
0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1967	
9	—	—	1	0	0	2	15	—	8	—	—	—	—	—	1965	*Phlogophora meticulosa*
12	6	4	2	4	4	0	14	—	8	—	1	0	1	2	1966	Angle Shades
12	0	2	0	7	1	0	13	4	1	4	3	0	0	3	1967	
21	—	—	1	7	1	8	47	—	18	—	—	—	—	—	1965	*Plusia gamma*
41	12	38	14	28	5	68	125	—	28	—	22	30	31	9	1966	Silver Y
23	2	15	5	8	1	18	20	10	12	77	16	12	24	60	1967	

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during the night, they probably travel long distances on the warm, low-level, jet-streams that exist in some countries during the night.

If aphids do not take off in the dark it seems that once aphids are in flight at high altitudes some remain flying there provided the air is warm enough, even at light intensities that would prevent take-off. This implies that it is cold not darkness that clears the aphids from the high altitudes at night, and that it is both darkness and atmospheric stability that prevent the repopulation of the upper air. This, it seems, is why migration over Britain will nearly always be limited to the distance permitted by a single day's flight. (Taylor, with Dr. R. E. Berry, Kansas State University)

Light traps. The following co-operated in running 74 light traps, operating in habitats ranging from built-up urban areas to English rural areas and the Highlands: private individuals, 19; schools, 14; the Forestry Commission, the N.A.A.S., the Nature Conservancy and Agricultural Experimental Stations, 19; Field Centres and Bird Observatories, 12; Universities, Agricultural Colleges and Museums, 10.

We now have four years' records of moths of economic interest, three of which are tabulated (Table 6) and it will soon be possible to assess the value of these, in retrospect, as indicating the incidence of the species as pests. (Taylor and French)

Biology and migration of Lepidoptera

Immigrant Lepidoptera and large-scale meteorology. Records of the Monarch butterfly, *Danaus plexippus* L., were unusually numerous in south-west England and southern Ireland during late September and October. The occurrence of strong westerly winds and the arrival of several species of North American birds suggests that the butterflies may have flown across the Atlantic. Their estimated times of arrival in 1968 and in other years are therefore being examined in relation to the large-scale meteorological conditions and to winds from North America, the Azores and the Canary Islands.

In the evening of 5 June 1968 the large amounts of fine 'desert dust' that were deposited over southern England coincided with the first records for the year of five species of rare immigrant moths. However, the two events were only correlated. The dust originated in the southern Sahara and was borne on a cold air-stream at 15–20000 ft, whereas the moths were associated with a warmer air-stream below 5000 ft and could have come from either north-west Africa or north-west Spain. (French)

The migratory capacity of *Plusia gamma* (Lepidoptera; Noctuidae). *Plusia gamma* is a pest of many crops. Its adults annually migrate into Great Britain from the Continent of Europe and possibly also from North Africa. The insect can be easily cultured and is very suitable for attempting to produce migratory forms by changing breeding regimes. Therefore adults were raised from larvae kept either singly or in crowds (10 in a container of 1 litre), at 20° C, with young broad bean plants as food. Adults from crowded larvae were about 30% heavier when they emerged than those

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reared singly and had about three times as much fat. Adults accumulate fat when fed on honey and after five days feeding on honey, young adults from crowded larvae almost doubled their dry weight, whereas those from larvae reared singly increased weight by only about 30%: most of the increased weight was in fat.

Whether different rearing regimes affect the duration for which tethered adults fly is also being studied, and the physical characteristics of insects bred in the laboratory are being compared with those of insects caught in light traps at different seasons and places. (Johnson and Macaulay)

Migration records. The records for migrant Lepidoptera for 1968 are still incomplete but indicate that the regular immigrants were uncommon in 1968. Both *Vanessa cardui* and *V. atalanta* were, as is usual, more abundant in August and September than at any other time of the year, but both *Colias crocea* and *Macroglossa stellatarum* were scarce. *Nomophila noctuella* and *Plusia gamma* were recorded from early May onwards, but in relatively small numbers until September, when they increased in many areas. Neither of the hawk-moths, *Acherontia atropos* and *Herse convolvuli* were, it seems, more numerous than usual.

The chief interest in 1968 came from the rarer species. *Eublemma parva* had a record year, *Laphygma exigua*, *Plusia ni*, *Heliothis peltigera* (and possibly *Heliothis armigera*) and *Rhodometra sacraria* were all much commoner than is usual. Furthermore all of these species, possibly with *N. noctuella* and *P. gamma*, arrived suddenly together on the night of 30 June/1 July and subsequently.

The only migrant butterfly of note in 1968 was the Monarch (*Danaus plexippus*) many of which arrived and may have exceeded the previous highest annual total of 40 in 1933. (French)

Shelter effects and patterns of distribution of insects

The distribution of insects in the air near hedges resembles in general that behind artificial windbreaks of similar permeability. However, behind hedges these patterns may be modified because insects that hibernate, breed or feed in the hedge spread from it and mix with the aerial population drifting over it from elsewhere. Experiments in 1967 near a hawthorn hedge that separated a field of barley from pasture, showed this effect. For example, thrips drifting over the hedge from the barley were most abundant over the pasture in a broad zone between 2 and 4H to leeward. By contrast, pollen beetles that were breeding and feeding in the hedgerow were most abundant immediately behind it. In 1968 similar contrasts were found between aphids drifting over the hedge and parasitic Hymenoptera living on flowers in the hedgerow.

These results are still being analysed, but they have already shown unsuspected effects from the dual role of the hedge as a physical barrier to the wind and as a source of insects. For example, when migrant insects are blown to a field from elsewhere, as often happens in spring, while parasites and predators spread from overwintering or feeding sites in the hedgerow, the patterns of distribution of host and parasite on a crop may differ. The

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insects originating from a distant source may then be exposed to fewer parasites earlier in the season than insects spreading from the hedge itself. Smaller accumulations near hedges in calm than in windy weather also suggest that the traditional belief, that 'edge infestations' in fields surrounded by hedges are largely caused by the immediate local populations spreading from the sheltering vegetation, may need to be revised. Local populations undoubtedly contribute to some edge-infestations, but the direct effect of the hedge on the flow of air causes many more insects, mostly originating from elsewhere, to accumulate near to it.

The work on shelter over the past four years has practical applications, because from it can be predicted where in a crop most flying insects will arrive, and indicate the most vulnerable zone. For example, it is important to detect as early as possible the arrival of pests that cause damage when they are only few, and they act as vectors of viruses; their detection would be simplified by searching the vulnerable areas intensively instead of sampling the whole field. (Lewis)

In collaborative experiments at Long Ashton, windbreaks were tested for their ability to concentrate pollinating insects in orchards and so to improve the set of the fruit. Two windbreaks, each 7 m tall and projecting about 5 m above the trees were placed 75 m apart in a pear and an apple orchard throughout the flowering period. The number and taxa of flying insects were measured with suction traps and insect visitors to flowers were counted. When winds blew directly against the windbreaks the total number of insects in the sheltered zone increased approximately three-fold. The well-known pollinator insects, hive, bumble and wild bees, amounted to fewer than 1% of all the insects flying in the orchards and to only 17% of all the insects that visited flowers. Small flies, and some larger insects, such as bibionids, were much more abundant in the air and were also frequent visitors to flowers. The results are still being analysed to show the structure and diversity of populations in orchards and to see if the patterns of distribution of these small insects affect yield. (Lewis, with Dr. B. D. Smith of Long Ashton Research Station)

Soil fauna

Insecticides and the soil fauna. DDT in the soil kills gamasid mites (Acarina) and so increases the number of springtails (Collembola) on which they prey (*Rothamsted Report for 1964*, p. 184 and *for 1965*, p. 186). Recent work shows that many organophosphates also do this and indirectly increase numbers of some species of trombidiform and oribatid mites; the effects on populations last for several months longer than the chemical. Clearly many insecticides are lethal to predatory mites. The effects of organophosphorus insecticides on larger insects such as carabid and staphylinid beetles were studied in two field experiments on 12 m-square plots isolated from adjacent land by polythene barriers extending 12 in. below and 18 in. above the soil surface. Pitfall traps caught more staphylinid and carabid beetles in some plots treated with insecticides than in untreated plots (by contrast see frit fly; p. 221). Whether this was because the insecticide killed mites that eat the eggs of the beetles or

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because it made the beetles more active has yet to be determined. The insecticides also decreased populations of earthworms and wireworms (Table 7). (Edwards and Thompson)

TABLE 7

Effects of insecticides (4 lb a.i./acre) on wireworms and earthworms

Insecticide	Numbers as % control: Wireworms Experiment A	Wireworms Experiment B	Earthworms Experiment A	Earthworms Experiment B
Fenitrothion	100·0	—	95·2	—
Trichlorphon	74·4	—	74·4	—
Disulfoton	56·6	—	70·0	—
Thionazin	51·2	—	93·3	—
Carbaryl	51·3	—	55·4	—
Chlorfenvinphos	48·7	40·4	83·1	74·5
Diazinon	43·6	25·0	73·9	98·8
Parathion	23·1	7·7	96·0	82·9
Phorate	9·2	—	19·2	—

The leaching of insecticides from soil and into ponds. Dieldrin emulsion was sprayed, at 20 lb a.i./acre, on four strips of soil, ranging in type from sandy to clay loam, 12 ft away and parallel to the edge of ponds. When the insecticide was left on the soil surface some was washed off and drained down the slope towards the ponds over the soil surface. In the first nine months concentrations of insecticide on the surface soil ranged from 3·3 to 61·3 ppm on the treated strips, 0·01 to 3·53 ppm half-way towards the ponds and 0·01 to 0·42 ppm in the soil near the water's edge. Only minute quantities were detected in the soil 6 in. below the surface on the treated strips. By contrast, when the insecticide was cultivated into the treated strips after it was applied much smaller quantities were detected lower down the slopes than when it was left on the surface.

Chlorfenvinphos ('Birlane'), an organophosphorus insecticide, behaved similarly to dieldrin, but more was detected 6 to 10 in. below the surface of treated soil and less moved down the slope. Evidently both insecticides reached the ponds when they ran off the soil surface; although mud at the bottom of the ponds contained dieldrin (0·19 ppm) or chlorfenvinphos (less than 0·01 ppm) neither was ever detected in the pond water.

As more insecticide seemed to run off the surface than leached downwards, this was tested in other experiments. Silt-clay loam was put into two glass-lined troughs so that the soil surface sloped. The troughs were divided into six compartments by transverse vertical partitions that projected from the bottom to one inch below the soil surface. Emulsions of either dieldrin or chlorfenvinphos were sprayed on the soil surface of the first compartment only at 20 lb a.i./acre and the troughs exposed out-of-doors to rain for 18 weeks (7·78 in.). Analysis of leachates collected from the bottom of different compartments, and of drainage water from the surface collected at the end of the troughs, showed that about eight times more chlorfenvinphos than dieldrin ran off horizontally and leached vertically during the first two months; thereafter chlorfenvinphos but not dieldrin occurred in the leachate. The insecticides were detected only in

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leachates from the treated and two adjacent compartments. One thousand times more of both insecticides was collected during the first two months than during the second two. Presumably the insecticides became adsorbed on the soil, possibly on to organic matter. These results, and those using soil columns (*Rothamsted Report for 1967*, p. 198), indicate that insecticides reach water by run-off rather than by leaching. Chlorfenvinphos emulsion was also sprayed on to the surface of a pond in amounts that gave 6 ppm throughout the pond. Within five hours there were 0·25 ppm in the bottom mud, where 0·15 ppm remained after 34 days. The concentration in the water was less than 1 ppm after 20 hours. The mud contained too few animals for reliable information to show whether the insecticides affected them. (Thompson and Edwards)

Paraquat and slit-seeding. The experiment on White Horse Field, Woburn Farm, to study the effect of paraquat and slit-seeding on soil fauna continued. Some plots were ploughed and sown with spring wheat and others treated with paraquat and slit-seeded. Half of each plot was also treated with a mixture of diazinon, 'Zinophos', chlordane and DDT to kill as many as possible of the invertebrate animals in the soil. In 1965 wireworms were more numerous in slit-seeded plots; in 1966 nematodes were more numerous on ploughed plots, and in 1967 slugs were more numerous on the slit-seeded plots. In 1968 there were no obviously damaging pests, and for the first time the slit-seeded plots yielded significantly more ($P = 0{\cdot}05$) than the plots ploughed and sown conventionally. In the slit-seeded plots the average yield from the halves treated with insecticide (32·5 cwt/acre) exceeded that from the untreated halves (28·0 cwt/acre), indicating that there may have been damage by pests. If so, it was confined to those plots, because yields from the treated and untreated halves of the ploughed plots did not show such differences.

Cryptostigmatid mites (Acarina), onychiurid Collembola and larvae of some Coleoptera and Diptera were fewer after ploughing, but not prostigmatid and mesostigmatid mites (Acarina) or surface-living Collembola. However, populations became similar to those in unploughed land six months after ploughing, and larvae of some Diptera and Coleoptera even became more numerous in ploughed than in slit-seeded plots. Ploughing had most effect on earthworm populations (Table 8), which are also greatly lessened by the insecticide in both ploughed and paraquat-treated plots, but there was no evidence that this affected yield. (Edwards and Lofty)

TABLE 8

Effects of ploughing and insecticides on earthworms

Year	Species	Paraquat: Insecticide (weight g/sq m)	Paraquat: No insecticide (weight g/sq m)	Ploughed: Insecticide (weight g/sq m)	Ploughed: No insecticide (weight g/sq m)
1967	*Lumbricus terrestris*	2·4	56·2	0·9	1·6
	other spp.	4·2	14·7	0	0·4
1968	*Lumbricus terrestris*	0·6	71·8	6·7	17·6
	other spp.	0·7	36·7	3·7	26·1

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Effect of water and temperature on soil fauna. Little is known about how soil conditions affect populations of soil invertebrates. To gain information, some plots carrying winter wheat and others potatoes on a sandy soil at Woburn Farm were irrigated to field capacity and others not, in 1967 and 1968. Plots were sampled at intervals of two months. The irrigated plots had fewer of many groups of animals, especially of tyroglyphid and trombidiform mites and deep-living Collembola, but also of other Collembola and predatory mites. By contrast, larvae of Diptera and Coleoptera were more numerous in the irrigated plots. Results of experiments at Rothamsted in 1967 and 1968 in which the soil was kept dry by covers, or flooded, or warmed by under-soil heaters for different periods, have yet to be analysed. (Edwards and Lofty)

Pests of cereals and grass

Wheat Bulb fly

Permanent reference plots. The numbers of Wheat Bulb fly eggs in the plots on Great Harpenden field have declined steadily since 1964. It is uncertain whether this is because egg-laying females have become fewer or because the plots are so small and close together that the fallow is sheltered by the adjacent wheat during egg-laying. The 10 plots, hitherto each less than $\frac{1}{10}$ acre and only 14 ft wide, are therefore being replaced by two large plots. This is being done in two stages, half in 1968, half in 1969, so that for one year plots of both sizes can be compared.

Phialophora ***infection of Wheat Bulb fly eggs.*** Sixty-seven per cent of female Wheat Bulb flies caught in the field in July 1967, and caged individually, laid eggs; 17% laid eggs infected with the fungus *Phialophora* sp., but all of these also laid uninfected eggs. The largest proportion of infected eggs laid by one female was 21 out of 60.

Phialophora was not isolated from dead females that had laid infected eggs, but previous work (*Rothamsted Report for 1967*, p. 203) indicates that the fungus infects the eggs before they are laid. An attempt was therefore made to infect eggs by feeding the fungus to gravid female flies caught in the field; the food was a mixture of dilute honey and condensed milk containing either citrated beef blood or a washed spore suspension of *Phialophora*. About 1% of 1500 eggs from females fed on the uninfected food, and about 10% of 1500 from females fed *Phialophora* were infected.

Although spores of *Phialophora* have not yet been found in the crops of wild Wheat Bulb flies, these experiments suggest that it may be one of the fungi the adult Wheat Bulb fly eats in the field, and that eggs can be infected within, or externally by contamination from, the adult female. The flies that laid a few infected eggs, although fed on blood, possibly fed on *Phialophora* in the field before they were captured. (Cockbain, with Wilding, Bee Department)

Detection of odour by adult Wheat Bulb flies. Adults of the Wheat Bulb fly have numerous antennal chemoreceptors that detect odours and therefore perhaps food or places for laying eggs. The electrical output from antennae, stimulated by detectable substances in an airstream, can be

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amplified and recorded, as workers at the National Vegetable Research Station have done with a closely-related insect, the cabbage-root fly.

Preliminary tests with female Wheat Bulb flies detected electrical changes from the antennae when flies were exposed to the odour of either fresh green foliage (including wheat leaves) or to old, damp, dead wheat leaves. The insects were fed on blood, yeast extract and spores of the fungus *Septomyxa* sp., but these failed to elicit responses, as did the odour of soil and *Streptomyces* sp. which causes that odour. Flies can therefore detect damp dead wheat leaves on which yeast, *Septomyxa* or other organisms can grow; whether free-living or crawling flies respond behaviourally to these odours is still unknown. (Bardner, Mrs. Margaret G. Jones and Mr. T. M. Coaker of the National Vegetable Research Station)

Frit fly

The distribution of eggs on plants and competition between developing larvae. Female frit flies lay eggs behind the coleoptile of oat seedlings at about the three-leaf stage. When undisturbed, as in the laboratory, they lay from 1 to 50 eggs on a coleoptile, but examination of 1482 seedlings showed that few had 20 or more and 22% had only one.

Plants with various numbers of eggs were transferred singly to small pots and left at 20°–25° C to see how many larvae and pupae developed. After 2 weeks the most larvae in one plant was 10, from 10 eggs. When a plant had several larvae some usually died, and the average was 4 when eggs/coleoptile ranged from 1 to 23. On a different group of plants the maximum number of pupae/plant was 14, from 14 eggs after 20 days, but the mean number/plant was also 4 although the number of eggs/plant ranged from 1 to 30. Plants containing 4 or more pupae often died. Thus, when several eggs were laid on a plant, competition caused some larvae to die.

When individual seedlings, each with many eggs, were surrounded by 8 other seedlings 3 cm away, up to 66% of the larvae (mean 22%) moved to the surrounding seedlings. On another group of plants up to 30% (mean 18%) of pupae were produced on the surrounding plants.

In the field egg-laying frit flies are easily disturbed, especially by predators. This causes fewer eggs to be laid at one time and so lessens competition between larvae in the shoots. In 1968 the weather was very unfavourable for egg-laying when seedlings of Condor oats, sown on 20 April, were at the critical two- to four-leaf stage. From 1800 plants examined, the most eggs found behind a coleoptile was 12 and this was on a plant from a sprayed plot with few predators to hinder egg-laying. Only three coleoptiles were found with eight eggs each, two with seven, three with six and most had only one egg. The plants tillered sooner out-of-doors than in the laboratory but by 27 May, when egg-laying reached its peak in the field, most plants had one tiller. Twenty-three plants with three to eight eggs/coleoptile were potted singly and ten days later they had three tillers each, and enough shoots to feed the larvae without severe competition. One plant with eight eggs/coleoptile and with three tillers on 31 May had two larvae on the central shoot and one, two and three larvae on each tiller respectively. Egg counts early in the season showed a

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maximum of eight eggs/plant and by 10 June 200 plants from the field had 1129 shoots, of which 651 were infested and when dissected provided 590 larvae; one week later 684 infested shoots provided 656 larvae or pupae. This suggests that there was little competition, and the plants had enough shoots for most larvae to develop. (Mrs. Margaret G. Jones)

Ground predators of frit fly. The idea that carabid beetles disturb adult frit fly (*Rothamsted Report for 1967*, p. 206) was confirmed in a field experiment. Thirty plots, each 10 yd square, of late-sown oats in the seedling stage, were treated to exclude or to kill ground predators as follows: 10 were surrounded by a hessian barrier soaked in 0·5% DDT emulsion, 10 by a similar barrier but the ground also sprayed with 0·5% parathion, and 10 were untreated. A pit-fall trap placed in the centre of each plot from 20 May to 15 June indicated the number of predators active in the plots while the frit fly were laying eggs. The traps were emptied every other day. Twice as many carabids were caught in the untreated as in the treated plots; all those caught in treated plots were dead when the traps were emptied and all those in the control plots were alive. Adult frit flies were found resting in the traps, mostly in the sprayed plots, that is to say where predators were fewer and disturbed them less; when there were 100 in traps from sprayed plots there were only five in traps from the other plots. (Mrs. Margaret G. Jones)

Slugs

Varietal differences in susceptibility of potatoes to slugs. Attempts are being made to identify chemicals in potato tubers that may be associated with the differences in susceptibility of different varieties to attack by slugs. Ripe, freshly-lifted tubers of two susceptible varieties, King Edward and Majestic, were extracted with 80% ethanol, acidified with hydrochloric acid, partitioned with chloroform and the aqueous fraction neutralised with sodium hydroxide and concentrated in vacuum at 40° C. The concentrates were chromatographed in one direction only for 16 hours at 15° C on Whatman 3 M paper with water as the solvent. Strips of the dried paper, 0·1 Rf value wide, were put into a tube with one slug, *Arion hortensis* or *Agriolimax reticulatus*, and the relative amounts of paper eaten after 96 hours were assessed by weighing the dried faecal pellets. *A. hortensis* ate much more paper at Rf 0·8, 0·6 and 0·2 with extracts from both varieties than at other values or than of untreated paper. *A. reticulatus* ate most from both varieties at Rf 0·7 and 0·4. Similar but less definite results were obtained with extracts from the leaves.

Sucrose, chlorogenic acid and tyrosine were identified at Rf 0·8 and 0·5. Sucrose stimulates *A. hortensis* to feed, but the slug ate five times more filter papers moistened with a solution of 1% sucrose and 0·01% chlorogenic acid than of paper moistened with 1% sucrose alone, and 15 times more than of paper moistened with distilled water. Other varieties of potato will now be tested on two-dimensional chromatography to improve the separation and identification of the separable substances. (Stephenson)

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Arthropods, molluscs and pasture productivity. An experiment that will continue for several years was started to study the effects of pests on the productivity of pasture, a subject hitherto neglected. The slugs, snails, mites and insects of various classes were killed selectively with metaldehyde, chlorbenside, BHC and 'Phosdrin' in plots in a field sown 25 years ago with a mixture of rye-grass, cocksfoot, timothy and clover, but now containing other grasses and broad-leaved plants. The treatments did not change the botanical composition of the sward or its yield. (Henderson)

Staff and visiting workers

I. P. Woiwod and Janice Purchall were appointed to the staff, J. Bowden to a post financed by the Ministry of Overseas Development and Mr. C. J. Stafford of Shell Research Ltd., Woodstock and Mr. D. G. Gibbs joined as temporary workers. Monsieur M. Y. Robert of the Centre de Recherches Agronomiques de l'Oest, Rennes and Professor R. L. Giese of Purdue University, Indiana, were visiting workers. C. A. Edwards returned from Purdue University where he held a Senior Foreign National Science Foundation Scholarship. Judith Palmer left.

C. A. Edwards was the United Kingdom delegate in the Working Meeting on Temperate Forest Productivity at Gatlinburg, Tennessee. L. R. Taylor visited the East African Agriculture and Forestry Research Organisation, Maguga, Kenya and with R. A. French, visited Mr. Hille Ris Lambers' laboratory in Holland. A. J. Cockbain and Mrs. Margaret Jones attended the XIII International Congress of Entomology in Moscow.

Mr. W. E. Taylor, Mr. M. J. P. Shaw and Mr. A. R. Thompson gained the Ph.D. degree of London University.

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