Rothamsted Report for 1967

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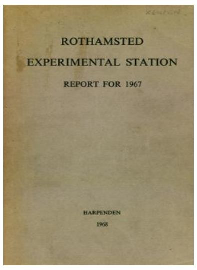

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ENTOMOLOGY DEPARTMENT

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Aphid studies

Overwintering sources of the pea aphid and bean viruses. Further work on overwintering hosts common to the pea aphid (*Acyrthosiphon pisum*) and two aphid-transmitted legume viruses, bean leaf-roll (BLRV) and pea enation mosaic (PEMV), confirmed that lucerne is the main source of BLRV-infective aphids (Table 1). Almost a third of the fundatrices and fundatrigeniae taken from small plots of lucerne at Rothamsted in April 1967 were infective; no aphids from small plots of the other legumes listed in Table 1 were infective.

TABLE 1

Overwintering of A. pisum *on different legumes*

	Eggs* Dec. 1966	Eggs* Feb. 1967	Fundatrices† April 1967	Fundatrigeniae† April 1967
Lucerne	61	19	1	3
Sainfoin	17	1	0·1	0·3
Hop trefoil	15	11	0·4	3
Alsike	9	1	0	0
Red clover	5	0	0·2	0·4
White clover	1	2	0	0
Birdsfoot trefoil	271‡	170‡	17‡	77‡

* Per 4½ sq. ft of plot (3 replicates of 1½ sq. ft each).
† Per 4½ sq. ft of plot (from 3 replicates of 30 sq. ft each).
‡ All aphids, and probably most eggs, were *Acyrthosiphon loti*.

Seedlings of kidney vetch (*Anthyllis vulneraria*) were infected with PEMV when inoculated manually in the glasshouse, but attempts to infect them using *A. pisum* failed, and although eggs of *A. pisum* were found on kidney vetch during the winter, PEMV-infected plants were not found in the field. No other biennial or perennial legumes tested in the glasshouse proved susceptible to PEMV. So far, therefore, such legumes have not been implicated as reservoirs of PEMV in the United Kingdom. Annual vetches that persist through the winter may be the main source of PEMV in spring; nevertheless, none of the aphids tested from three crops of winter tares (*Vicia sativa*) in Suffolk in spring was infective; nor were aphids from overwintering populations on annual vetches in the hedgerows at five sites in Hertfordshire. Thus, how PEMV overwinters remains unknown. (Cockbain)

Aphids and virus diseases of peas. Infestation by *Acyrthosiphon pisum* of peas growing at different distances from lucerne was studied at five sites in Lincolnshire and Essex. Numbers of aphids ranged from 0·3 to 1·7 million/acre in the lucerne and from 0·03 to 0·5 million/acre in the peas at the time of sampling, but there was no significant decrease in the amount of infestation within the pea crops at distances up to 1000 yd from the nearest lucerne. Possibly distances were too small to reveal a gradient, or

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the amount of infestation from a single neighbouring source was small compared with that from other more numerous and distant sources.

Bean leaf roll virus (BLRV) was found in commercial crops of Gregory's Surprise and Emblem growing near lucerne, but not in crops of Dark Skin Perfection, Big Ben, Trident and Maro. Pea enation mosaic virus was isolated from some plants of all these varieties.

An experiment was done to assess the susceptibility of different pea varieties to BLRV ("pea top yellows"). Eighteen of the more commonly grown vining, dry harvesting and dwarf garden varieties were sown in late March, and some plants of each variety were inoculated with different isolates of the virus from lucerne in late May. Inoculated and uninoculated control plants were sprayed with "Metasystox" several days after the inoculation. Symptoms were recorded and sample shoots tested for BLRV in early July, and the plants were harvested in July and August.

Six of the varieties (Gregory's Surprise, Laxton Superb, Jade, Elwy, Honey and Meteor) proved very susceptible to BLRV. At least 95% of the inoculated plants, and about 15% of the uninoculated ones became infected. The mean yield of the inoculated plants ranged from 15 to 33% of the uninoculated ones for the different varieties. It is obviously inadvisable to grow these varieties near established lucerne, the main source of BLRV-infective aphids. Although only about 10% of the inoculated plants of var. Pauli developed symptoms, there was a significant difference of 18% in yield between inoculated and uninoculated plants.

Eleven of the varieties (Dark Skin Perfection, Kelvedon Wonder, Feltham First, Peter Pan, Big Ben, Onward, Nuwonder, Topcrop, Lincoln, Rondo and Maro) were not susceptible; they did not develop symptoms, BLRV was not recovered from them and the inoculated plants did not yield differently from uninoculated ones.

Of two American pea varieties now grown in this country that were tested for susceptibility to one isolate of BLRV in the glasshouse, Freezer 69 was very susceptible and Scout apparently not. (Cockbain)

Aphids and virus diseases of lucerne. The experiment started in 1966, on the effects of aphid infestation and virus infection on the yield of lucerne, in pure stands and with cocksfoot showed that in January unsprayed plots had four times as many eggs of *Acyrthosiphon pisum* as plots sprayed with "Metasystox" in mid-November 1966, when some eggs were already present. The numbers of eggs/unit length of row of lucerne was the same on plots of lucerne only as on lucerne/cocksfoot plots.

Some plots were sprayed with "Metasystox" four times between mid-April and mid-October, and aphid populations were assessed six times. A third of all aphids sampled were *A. pisum*, the rest were mainly alatae and young nymphs of *Brachycaudus helichrysi*, *Aphis fabae* and *Myzus persicae*, but these did not survive long on the crop. *A. pisum* were few throughout the year, with most aphids in mid-May and late October, when there were 14 aphids/5 ft row of unsprayed lucerne. On average, *A. pisum* was 7 times as abundant on unsprayed as on sprayed plots, and 1·6 times on lucerne in pure stands as on lucerne mixed with cocksfoot.

A. pisum were fewer on the control plots at Rothamsted that had been

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kept unsprayed than on commercial crops! For example, during July there were 850 times as many on the crops examined in Essex, and during October eleven times as many on crops in Norfolk as on the control plots at Rothamsted. The difference was mainly because the plots at Rothamsted were accidentally contaminated with "Metasystox" when nearby field beans were sprayed from the air in July. "Metasystox" was found in plants taken from the control plots ten days after the aerial spraying. The resident aphid population was killed, and few alatae of *A. pisum* came into the crop until September.

The incidence of lucerne mosaic virus in the plots at Rothamsted in late September was 2·6% in those sprayed and 3·3% in the controls. The incidence of bean leaf-roll virus was 5% in sprayed and 33% in control plots. There was little difference in the incidence of virus between lucerne and lucerne/cocksfoot plots. Plots were cut three times, and yields were taken from each cut. The total yields from lucerne/cocksfoot plots were greater than from lucerne plots (mean of 118·5 and 109·8 cwt dry matter/acre respectively, $P = 0{\cdot}01$). There was no significant difference between yields from sprayed and control plots (112·0 and 116·2 cwt/acre), probably because there were few aphids on the crop during the year, and the difference in virus incidence in sprayed and control plots is still relatively small.

In a separate experiment observations confirmed earlier results that spraying lucerne with paraquat during winter, as recommended to control weeds in established crops, diminishes the numbers of *A. pisum* developing on the crop. On average there were 2·4 and 12 times as many fundatrices and fundatrigeniae in April on the unsprayed plots of 4th- and 2nd-year crops respectively as on plots sprayed with paraquat in early February. This is probably because most leaves on the dormant shoots, where the eggs are laid and the fundatrices feed, die within a few days of spraying. (Cockbain, with Etheridge, Insecticides Department)

Incidence of bean leaf-roll virus in lucerne. The incidence of BLRV in lucerne crops was again estimated by testing the ability of apterae of *Acyrthosiphon pisum* that developed on the crops to infect *Trifolium*

TABLE 2

Incidence of bean leaf-roll virus in lucerne

	Year sown		
	1967	1966	1965
% infective aphids*	1	61	68
% infected plants†	3	61	78

* 80 aphids per crop.
† 40 plants per crop.

incarnatum seedlings. Twenty-four crops, totalling 600 acres, in areas not surveyed in 1966, were sampled. Some aphids from all crops were infective; the range was 1–75% and the mean 34%. Infective aphids again tended to be more abundant in eastern than in western counties and more abundant on old than young crops. However, young crops in areas where much lucerne is grown are often heavily infected, and the percentage of

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infective aphids on two 1st-year crops, undersown in cereals in north Norfolk in 1967, was 15% (2·7 million *A. pisum*/acre) and 31% (1·9 million/acre) respectively in early October.

The validity of the conversion, from percentage infective aphids to percentage infected plants (*Rothamsted Report* for 1966, p. 199), was tested by taking samples of aphids and shoots at random from three crops, sown in different years, and testing both for infectivity. Table 2 shows good agreement between the proportions of infective aphids and shoots in the different crops, and indicates that most aphids that develop on infected lucerne can transmit BLRV.

No plant examined in lucerne crops in 1967 showed the vein-yellowing symptoms previously reported as symptoms of BLRV, and no lucerne seedlings developed these symptoms when infested with aphids from lucerne in the field, although many seedlings became infected with BLRV. Attempts to separate BLRV and lucerne vein-yellowing virus (LVYV), by transferring aphids from infected lucerne to several different species of legumes, failed, for the few species susceptible to LVYV were also susceptible to BLRV. Field beans (var. Herz Freya), infested with aphids from BLRV-infected lucerne showing vein-yellowing, developed symptoms of BLRV-infection, but whereas BLRV was recovered from all bean plants up to the time they senesced (18 weeks), LVYV was recovered from only a few after 6 weeks, and from none after 12 weeks. (Cockbain)

The flight behaviour and wing polymorphism of alate *Aphis fabae*. Individuals of *Aphis fabae* can become either wingless (apterous) or winged (alate) adults according to the conditions in which they are reared. Conclusive evidence that progeny of apterous mothers are influenced before birth to become apterae has not yet been obtained. However, some form of pre-natal change seems to control the wing development in early progeny within young alate parents because all attempts to prevent offspring becoming apterae by crowding the parents and the offspring have failed, whereas crowding progeny from older alatae has prevented them from becoming apterae.

To prevent aphids becoming apterae, nymphs of apterous parents and the later progeny of winged parents have had to be maintained in crowds in leaf cages or by making many individuals feed in only a small area. Isolation of individuals, up to as late as the 3rd instar, has produced large proportions of apterae, interforms and "non-flyers" (see *Rothamsted Report* for 1966 p. 200 for definition of "migrants" and "non-flyers").

Isolating the 2nd instar produced apterae, and there is evidence that crowding during the development of the 3rd instar may be particularly important in influencing the flight behaviour of the alate adult. When nymphs in the early 3rd instar were isolated only 40% of the adults produced flew and 40% were interforms, whereas when isolated in the late 3rd instar 53% of adults flew and only 9% were interforms. Isolating at the late 4th instar stage produced 91% of adults which flew and 1% of interforms. Crowding increased the proportions of alatae and "migrants" and diminished those of apterae and interforms.

Daughters of young alatae, and progeny of solitary apterae that were

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reared in isolation from birth, were without wax markings on the abdomen, whereas apterae reared in crowds, interforms and 4th instar pre-winged nymphs usually had pronounced markings. The cause of function of the wax is not known, but the marks may indicate progress towards the aphid becoming alate rather than apterous.

Dissections indicate that the wing-muscles of interforms autolyse prematurely. Many but not all "non-flyers", 4–5 days after moulting, had autolised wing muscles. "Non-flyers" could not use their wings when dropped through the air, though a few could open them. (Shaw)

Field studies on flight behaviour. Samples of about 100 4th-instar *A. fabae* from field beans (var. Maris bead), broad beans (var. Aquadulce Claudia) and second-year sugar beet (var. Sharpe's Klein E) were removed at approximately 3-day intervals from the time when 4th instar pre-winged nymphs were first observed on the crops until none was found. Each nymph was placed on a young seedling of the same type as the plant from which it came and left in the glasshouse to moult. The adults were then segregated according to whether they failed to fly, and whether they deposited nymphs before flight.

The proportion of "migrants" among the early alatae from either variety of bean was small, about 30% from field beans and 22% from broad beans. It increased as the population on the plants and catches in traps in the crops increased; reached a peak of 75% from field beans and 70% from broad beans, and then diminished to 12% from field beans and 14% from broad beans. The proportion on "non-flyers" changed in the opposite way, starting at about 52% from field beans and 72% from broad beans, declining to about 19 and 22% at the population peak, and then increasing to about 75%. The proportion of "flyers" remained fairly constant at about 15% from field beans and 12% from broad beans. Parasitic fungi (*Entomophthora planchoniana*, *E. aphidis* and *E. fresenii*) again greatly diminished the infestation, particularly on field beans, and the infestation ended at an early stage on both crops.

Results from sugar beet were less consistent. Winged aphids appeared on the sugar beet much sooner than on the beans, possibly in the second generation after infestation by the spring migrants. Many more of the aphids from sugar beet were classified as "flyers", some depositing as many as 20 nymphs each before their initial take-off, which was as late as the fourth day after moulting. The proportion of "migrants" in the samples started at about 15%, slowly increased to about 60% at the population peak and then declined to about 30%. The proportion of "flyers" started at about 60%, decreased to 19% at the population peak and then increased to about 30%. The proportion of "non-flyers" remained fairly constant at about 30%. (Shaw)

Morphological examination of aphids from the field. The mean wing length and hind tibia length of *A. fabae* in nine samples removed at 4-day intervals from field beans (var. Garton's Pedigree Tick) between 26 June and 30 July 1966 decreased during the sampling period from $3{\cdot}41 \pm 0{\cdot}019$ mm and $1{\cdot}22 \pm 0{\cdot}008$ mm respectively to $3{\cdot}21 \pm 0{\cdot}024$ mm and $1{\cdot}10 \pm$

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countrywide survey will then be known, and several European countries may have become involved. The possibility of working in conjunction with the series of suction traps from Texas in the U.S.A. to Alberta in Canada (*Rothamsted Report* for 1965, p. 184) depends upon the continuance of the project in the North Central States (Regional Project NC-67). We now have daily samples of most aphid taxa from all traps. Direct comparison requires that the NC-67 traps should also produce results regularly.

Analysis of data from Kansas State University, Manhattan, Kansas, in collaboration with Drs. R. Berry, the late W. W. Dry and L. A. Halgren, showed that more aphids migrate at night at high altitudes in the warmer continental climate of North America than in the cool maritime climate of Britain. This affects the approach to the study of long-distance movements of aphids.

The total aphids caught per month over three years now begins to show a regional pattern that will be increasingly useful, at least in retrospect, as a general index of aphid abundance (Table 3). Only the aphids have been separated from the catches during 1967, and these have been identified to 70 small taxa, mostly species; surprisingly, identification takes little more time than the original sorting of aphids from other insects, i.e. 1–3 hours per 1000 insects. This now provides material for a full-scale correlation that will decide, when replicated, the maximum interval between traps needed for assessing populations of aphids over wide areas. The species identified during 1967 include the pests: *Aphis fabae; Brevicoryne brassicae; Hyperomyzus lactucae; Macrosiphum euphorbiae; Myzus persicae; Phorodon humuli; Rhopalosiphum* spp. Table 3 shows that there are occasional flights of aphids during the winter. The origin of these aphids is unknown.

It is proposed that during 1968 catches from the traps will be sent in twice a week and that sorting and identifying aphids immediately will provide a tentative monitor service for those National Agricultural Advisory Service officers who are interested. This will also enable the labour necessary for any particular speed of service to be assessed. However, a catch for any single day may be 4000–5000 aphids, which is the result of inefficient over-sampling. Now that it is known that a monitor service does not require too many traps, we propose to re-assess the original choice of trap and to try to adjust the volumetric samples to the season, so as to increase the size in winter, spring and autumn and lessen them in mid-summer. This will help to spread the labour of dealing with catches. We also propose to increase the efficiency of the trap by adjusting the dimensions of inlet and fan, and perhaps to redesign the trap using new non-corrosive materials. (L. R. Taylor and French)

Comparison of aphid warning systems. There are many kinds of local warning systems; for example, there are 10 in England, including the extensive scheme of the Sugar Beet Corporation, and at least 12 extensive schemes in western Europe. It is difficult to compare the efficiency of these schemes for lack of a measured standard of efficiency. The scheme of the Sugar Beet Corporation in England is therefore being taken as a model, and its efficiency in detecting the earliest date of the year that aphids arrive on crops is being compared with that of four other methods,

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population diversity in relation to different kinds of land-use is being analysed at Rothamsted.

Trapping all the year round also provides regular, standardised information about the arrival of the immigrants when information from casual observers is lacking. It has detected the arrival in January and February in some years of migrants previously considered to be spring immigrants, and it allows their arrival to be related with the large-scale meteorological situation, especially wind. It is hoped that other insects, especially aphids, also coming from a distance early in the year may also be detected by the suction traps operating throughout the year.

The light traps are regarded as part of a general survey system, but the prospect for using the migrant Lepidoptera as indicator species for aphid movement remains speculative until more light traps are working every day of the year and suction traps are working from Cornwall to Norfolk, when the light-trap system is established in every vice-county.

The sampling principle of the light trap has never been clearly understood. It seems reasonable to suppose there is an area of influence around the trap, which, when insects fly into it, increases their prospect of being caught. An attempt was made to assess the size of this area by operating trios of traps in triangles with sides ranging from 5 yds to 100 yds, but the catches have yet to be analysed. (L. R. Taylor and French)

Suction-trap survey. At present there are seven traps roughly along the line of the east coast of Great Britain from Ashford in Kent to Dundee. They sample continuously at 40 ft above the ground level. During 1967 counting and identifying the aphids in these traps has been the main task. The prime difficulty is still the mechanical one of sorting and counting the many thousands of insects trapped. The southernmost traps in this system at Rothamsted, Broom's Barn (Suffolk) and Wye (Kent) will operate throughout the winter with the aim of detecting the earliest date when different species of aphids fly.

The 40-ft trap was designed to monitor current aerial populations of small insects, such as aphids, and their movements, to provide information needed to warn of changes that might affect crops, and to show the pattern of movement into and about the country. The height of 40 ft was chosen to sample the generally dispersing populations rather than the local ones. The correlation of catches from pairs of traps at distances up to 100 km apart is remarkably good, and ceases to be statistically significant only at distances approaching 1000 km. Thus it seems that only a few traps will provide information applicable to a large area and that both abundance and movement of aphids can be studied on a national scale.

The first transect of five traps from Dundee to Wye in Kent has now operated for three years, and aphid species caught have been identified for one year.

Traps at Wageningen and Silwood Park will begin to operate in spring 1968 as part of a second transect at right angles to the first down to the tip of Cornwall as we get traps and sites. Within the period 1968–1973 it is hoped that a reporting service will be operating and that computer storage and retrieval will facilitate manipulation of data. The cost of a

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differences, in addition to differences in the percentage permeability, may affect the airflow over and through the barrier and the numbers and distribution of insects near by. To test this possibility the insect density in the leeward sheltered zone behind two commercial windbreak materials, (1) plastic "Netlon" with very small holes and (2) coir netting with medium-sized holes, was compared with density behind lath fences of equivalent percentage permeability. The results of these shelter experiments and others which included natural living windbreaks and measurements of aerial density profiles of insects to leeward of a hawthorn hedge, itself a source of insects, are being analysed. (Lewis)

A continuous census of flying insects

Light traps and suction traps are being used in a national census of flying insects. The aim is to provide continuous information on abundance and distribution of pests and other insects in different regions throughout the year, year after year. It is hoped that the census will eventually lead to warning systems forecasting the likelihood of pest outbreaks. The efficiency of different kinds of aphid-warning systems is being compared by Judith Palmer in connection with the International Biological Programme, but it will take several years to test the practicability of trapping systems for the purpose of forecasting and warning, especially with other insects. Nevertheless, the results are promising and a relatively few aerial traps seem likely to indicate the population of small flying insects over a wide area.

The system at present consists of many light traps 3 ft above the ground and a few suction traps that sample different kinds of insects 40 ft above the ground. The results from both kinds of trap will be related to each other, to the weather and to the use of the land around them.

Light-trap survey. The light-trap catches are used to record immigrant moths, to study long-term changes in the abundance and diversity of night-flying moths and to compare with catches of small insects in the suction traps.

Twenty-four new trap sites were added in 1967, bringing the total from Cornwall to the Shetland Isles to 53, but there are still areas in Wales, East Midlands and the Scottish border counties without traps. As the survey grows, more people offer their services in operating a trap and identifying the catch.

Agrotis c-nigrum and *A. exclamationis* were the moths caught in the greatest numbers where they occur, but *Orthosia gothica* and *Xanthorhoe fluctuata*, although caught only in small numbers, were the only species caught in every trap. The catch is not restricted to Lepidoptera; the Trichoptera are being studied by Dr. M. I. Crichton, Zoology Department, The University, Reading, and other insects are available when better arrangements can be made for sorting. The records of Lepidoptera are sent to the Biological Records Centre, Monk's Wood Experimental Station, for their scheme to map the distribution of insects in the British Isles;

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0·008 mm. The wing length/hind tibia length ratio increased from 2·803 ± 0·0154 to 2·913 ± 0·0159, and the number of rhinaria on the third antennal segment increased from 14·5 ± 0·52 to 16·7 ± 0·43, and both factors were negatively correlated with day length ($r = 0{\cdot}718$, $P < 0{\cdot}02$ and $r = -0{\cdot}925$, $P < 0{\cdot}001$ respectively). During the same period the proportion of "migrants" in each sample increased from 40 to 50%, "flyers" decreased from 46 to 7% and "non-flyers" from 14 to 2%.

The pooled measurements from all samples showed that wing length and tibia length were correlated ($r = 0{\cdot}673$, $P < 0{\cdot}001$) and that the number of rhinaria on the third antennal segment was more closely correlated with wing length ($r = 0{\cdot}238$) than with tibia length ($r = 0{\cdot}199$, 752 d.f.); the mean wing length was 3·20 ± 0·008 mm, hind tibia length of 1·15 ± 0·002 mm and there were an average 15·05 ± 0·097 rhinaria on the third antennal segment. *A. fabae* caught in the two 40-ft suction traps at Rothamsted (approximately 0·9 mile apart) during the same period had a mean wing length of 3·28 ± 0·021 mm, hind tibia length of 1·17 ± 0·009 mm and had 17·39 ± 0·371 rhinaria on the third antennal segment. Either the aphids from the experimental field-bean plot were not representative of the general aphid population at the time or only the longer-winged aphids with more rhinaria were reaching the traps.

Of the aphids collected in 1967 only those from the samples taken from field beans at 3-day intervals between 27 June to 30 July 1967 have so far been examined. The mean wing length and hind tibia length again decreased during the sampling period from 3·39 ± 0·22 mm and 1·25 ± 0·008 mm to 2·88 ± 0·46 mm and 1·02 ± 0·025 mm respectively. The increase in wing length/tibia length ratio from 2·754 ± 0·0166 to 2·836 ± 0·0256 was again negatively correlated with day length ($r = -0{\cdot}732$, $P < 0{\cdot}02$). There was no detectable change in the mean number of rhinaria on the third antennal segment (*c.* 14). The mean dry weight of "migrant" aphids decreased during the sampling period from 178·96 ± 5·606 to 91·80 ± 2·589 μg, and was usually more closely correlated with tibia length than wing length. A wing-loading factor calculated for "migrants" as aphid dry weight/area of forewing, where area was estimated by (wing length)^2/4, declined from 63·73 ± 1·441 μg/mm^2 to 43·71 ± 1·009 μg/mm^2.

As the population on the crop and the proportion of "migrants" in the alate population increased, alatae were smaller, but their wing loading also decreased, and these would need less energy for take-off and to maintain flight than larger alatae. Studies on the inter-relationship of population density and behaviour of alatae are continuing with particular attention to fuel reserves and morphology. (Shaw)

Shelter effects

The height and permeability of windbreaks affects the size and distribution of aerial populations near by (*Rothamsted Report* for 1966), but windbreaks may have the same amount of open space, though the size and number of spaces in them may differ. For example, there can be few large gaps as with lath fences or many small holes as with netting, and these

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TABLE 3

Rothamsted insect survey aphid samples

Trap	Dundee	Newcastle	High Mowthorpe	Broom's Barn	Rothamsted (Tower)	Rothamsted (Farm)	Wye	Total	Mean
Year				Total aphids per year					
1965	31886	12042	—	14214	12929	14242	—	—	17062
1966	16730	10325	11523	15332	15528	14818	—	—	14042
1967	10083	12581	15114	23734	21760	23387	19462	—	18017
Mean p.y.	19566	11649	13318	17760	16739	17482	19462	—	16428
Month				Mean per month of all years					
January	0	0	0	1	0	0	0	1	0·1
February	0	0	0	0	1	0	0	1	0·1
March	1	0	0	0	0	1	0	2	0·3
April	1	2	4	4	11	22	12	56	8·0
May	91	22	64	321	670	559	666	2393	341·9
June	502	642	1432	3545	5241	5802	9630	26794	3827·7
July	961	906	6035	7905	4829	5259	5936	31831	4547·3
August	2647	1167	803	1422	1117	1142	734	9032	1290·3
September	11619	6184	3232	1992	1929	2137	1409	28502	4071·7
October	3714	2719	1715	2515	2868	2517	1063	17111	2444·4
November	31	3	58	52	74	48	12	278	39·7
December	0	0	2	2	2	1	0	7	1·0
Mean p.m.	1631	970	1112	1480	1395	1457	1622	9667	1381·0

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namely the 40-ft suction trap, yellow sticky traps, yellow trays and inspection of crops for aphids. In 1968 Mr. Hille Ris Lambers' warning system of potato aphids in Holland will be compared with the results obtained from a 40-ft suction trap. (L. R. Taylor and Judith Palmer)

Mechanical sorting and counting of trap catches. A prototype apparatus for sorting insects mechanically into several size-groups was made and is being used. Its main value so far has been in speeding the extractions of the many thrips in the catches, in cleaning dirty catches and in splitting the catch into more easily identifiable groups than was possible before. The separation into the different groups, however, is still not well enough defined. Further work on counting insects automatically was postponed until insects of different sizes can be better separated. (Arnold, Insecticides Department)

Soil fauna

Effects of insecticides on the soil fauna. The effects of the organophosphorus insecticides parathion, diazinon, chlorfenvinphos, disulfoton and phorate on populations of the invertebrate animals in the soil was further studied. The rates at which the insecticides disappeared after adding 4–8 lb a.i./acre were also measured. In previous trials Collembola became more abundant after soil was treated with DDT but not after any other chlorinated hydrocarbon insecticide. Numbers of Collembola also increased after applying all the organophosphorus insecticides listed above except phorate, and trombidiform and oribatid mites also increased in most experiments, an effect not reported previously. All these increases are thought to follow the destruction of predators, particularly the gamasid mites. In some experiments the numbers increased so much that the total biomass of soil invertebrates was greater in the treated than in the untreated soil, and in no experiment did the biomass or numbers of animals become less than half of that in untreated soil. These effects of the organophosphorus insecticides seldom lasted more than a year, and 95% of the residues had disappeared in six weeks to nine months. The order from greatest to least persistence was chlorfenvinphos, phorate, disulfoton, parathion and diazinon. (Edwards and Thompson)

The leaching of insecticides from soil. Leaching of insecticides from soil was measured in the field and laboratory. Dieldrin was applied to the surface of clay/loam, peat and to silt/sand soil columns 14 in. high and 12 in. wide, and water equivalent in amount to 18 in. of rain was leached through each column. The soil was either broken and sieved before packing into the columns or was taken undisturbed from the field. Much more dieldrin leached through the columns of undisturbed soil than through those with sieved soil; most (2% of that applied) passed through the intact clay/loam column; only 0·2% of the amount applied passed through the other columns.

Dieldrin was applied at 20 lb a.i./acre to soil at the edge of one pond and the same dose of chlorfenvinphos at the edge of another. The amounts

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of insecticides that drained into the ponds are still being assessed, but so far only small amounts of dieldrin, which reached the pond by surface run-off rather than in drainage water, have been detected. (Edwards and Thompson)

Sterilisation of soil with gamma-radiation. In studying whether the fauna of soil affects soil fertility, it would be advantageous to kill all the animals without damaging the soil flora, and without applying chemicals. Attempts were therefore made to eliminate the invertebrate animals in soil with gamma-radiation. That this can be done within 6 weeks of a dose of 200 K.rads was reported last year, and further work shows that all the animals die within 5 months after a dose of 100 K.rads. The mortality–time curves are not linear, even on a probit scale, but have an initial steep part reflecting a rapid kill during 5 days and a subsequent shallow curve. Animals in culture on plaster of Paris were killed sooner than those in intact cores of soil, and 5 K.rads killed parasitic mites sooner than some species of Collembola, thus causing the Collembola to increase in number.

Gamma-radiation affects *Allolobophora chlorotica*, a common earthworm of arable and pasture land, similarly to smaller soil invertebrates, and 200 K.rads killed all worms within 24 hours. Fifty per cent of worms were dead 11 weeks after a dose of 100 K.rads, 15 weeks after 50 and 25 K.rads, and more than 21 weeks after 10 K.rads. (Edwards and Lofty with Mr. P. A. Cawse, Atomic Energy Research Establishment, Wantage)

A comparison of methods used in extracting invertebrate animals from soil. Many methods are currently used to extract invertebrate animals from soil, but their relative efficiencies are not known accurately, so the numbers extracted by several methods from different kinds of soils were compared, to be able to recommend methods for use in the International Biological Programme.

Work on factors that affect the efficiency of Tullgren funnels (*Rothamsted Report* for 1966, p. 196) was supplemented by a study of eight dynamic methods using Tullgren-type funnels and four flotation methods. Samples of one soil type from fallowed arable land, pasture and woodland were used, and a funnel and a flotation method were compared using samples from several different types of soil.

In general, dynamic methods, that is those that rely on the animals moving away from the soil, extracted more micro- and meso-arthropods than flotation methods, though the two kinds of method did not differ greatly in the efficiency with which they extracted the larger arthropods. The air-conditioned "high-gradient" Tullgren funnel described by McFadyen, in which steep gradients of temperature and humidity are maintained in the soil, extracted more of most kinds of arthropods than the other methods. Flotation methods extracted more animals from the soil of arable land than from pasture and least from woodland soil, indicating that the efficiency of extraction is affected by the organic matter in the soil. The funnel method was more efficient than the flotation method for extracting micro- and meso-arthropods from loam and sandy soils, but flotation extracted more Insecta.

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Numbers of animals extracted usually increased in soil samples that were stored at 5° and 20° C for 28–56 days before being extracted, although the difference after storage at 5° C was not often significant. However, fewer Sminthuridae and Symphyla were extracted after 56 days at 20° C than before storage.

The collecting fluid placed beneath large-diameter Tullgren funnels also affected the number of animals extracted. Fewer were recovered over distilled water than over alcohol or a solution of picric acid, and numbers extracted over distilled water increased when alcohol was placed in a side-arm beneath the funnel. After extraction in funnels some samples were again subjected to extraction by flotation, which again showed that more animals remained in the samples kept above distilled water than above alcohol, proving that the collecting fluids affected the extraction of the animals from the sample and not their behaviour once they have emerged into the funnel beneath the sample. (Fletcher and Edwards)

Wireworms. The organophosphorus insecticides "Dursban", phorate and N 2790 (O-ethyl S-phenyl ethyl phosphonodithioate) were compared with the organochlorine aldrin for their effects on wireworms. Two sites cropped with winter wheat and sugar beet were sampled before and after treatment, reported by Insecticides and Fungicides Department. (Lofty, with Griffiths and Scott of Insecticides Department)

Slugs

Control of damage by slugs to sugar beet. The effectiveness of metaldehyde bran pellets in controlling the damage done to sugar-beet seedlings by slugs was tested by applying pellets to wheat stubble at 28 lb/acre (13·5 oz a.i./acre) at two sites in the autumn and in the spring immediately after drilling or after the seedlings emerged. On a third site a 20% aqueous suspension of metaldehyde was applied at $1\frac{1}{4}$ gal/acre to bare soil in autumn after drilling in spring or at the two-leaf stage; for comparison pellets were applied at the same time. Damage from slugs was assessed by counting the proportions of seedlings attacked in sections of row 4 × 15 ft long. Pellets were significantly better applied in spring than in autumn, when they had little effect.

Few dead slugs were seen on the surface of the soil during the 3 days after applying the pellets at two sites, but at the third the numbers, mainly of *Agriolimax reticulatus* (Muller), found in three quadrats each 1 yd square indicated that approximately 49000 slugs/acre were killed. Only two dead slugs were found on the plots sprayed with the suspension of metaldehyde. Periods of heavy rain over several days after the treatment in spring broke down the pellets and beat some into the soil, and damage might have been better controlled had the pellets remained intact until the plants were big enough to resist attack. Up to the stage of singling, 30% of plants could be damaged without apparent effect on the number that became established after singling. Further trials will be made with improved pellet formulations. (Stephenson and Dunning, Broom's Barn Experimental Station)

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The susceptibility of different varieties of potato to attack by slugs. A susceptible variety, King Edward, and a resistant one, Pentland Falcon, were grown in sand culture. At leaf-fall intact tubers were not harvested. Instead they were immersed for 5 days in a beaker of distilled water while they were still attached to the plant *in situ* in the sand. The effect of this liquid on *Arion hortensis* was then tested by offering slugs a choice between filter-papers moistened with the test liquid or distilled water. After 24 hours in the dark at 10° C the mucus tracks on the papers were made visible by dusting with powdered fluorescein and counted; the papers moistened with water that had contained King Edward tubers had more tracks than papers with distilled water alone, which had the same number as papers moistened with water that had contained Pentland Falcon tubers. This suggests that a water-soluble substance in the growing tuber diffuses into the soil water, where it is detected by slugs, and this possibility is being investigated. Filter-papers moistened with solutions of alanine, phenylalanine, arginine and glycine, amino acids that are all present in mature tubers, were tested using the filter-paper technique. *A. hortensis* crawled more on those moistened with a 0·1% solution but not with a 1% solution, than on papers with distilled water alone.

The sucrose and dextrose content of the tubers of some varieties diminishes during the growth and maturation of the tuber, the sucrose content changing the most. The feeding of *A. hortensis* on filter-paper moistened with aqueous solutions of sucrose or dextrose was measured by weighing the faecal pellets produced in 88 hours under standard conditions. The amount eaten increased as the sucrose concentration approached 1·0% and then diminished as the concentration was further increased. Changes in dextrose concentration produced little change in the amount of feeding. Slugs cause damage, mainly to mature tubers, and the possibility that the concentration of sucrose in mature tubers differs in different varieties and is related to palatability to slugs is being investigated.

Slugs and minimal cultivation. On the plots at Woburn that were planted with winter wheat by slit-seeding after treatment with paraquat much debris remained on the surface, especially patches of straw and husks from the previous wheat crop. Many *A. reticulatus* occurred under the debris and severely damaged the young wheat. There were few slugs and little damage on the ploughed plots; indeed, *A. reticulatus* is usually rare on sandy soils as at Woburn. Although only half as many plants remained in the slit-seeded plots as in the ploughed plots, they produced only about 25% fewer tillers; the grain yield on the slit-seeded plots was less than on the ploughed plots by a provisional figure of 28%. The reason for the sudden increase in slugs on the paraquat-treated plots is unknown, but could be from migration to the debris, increased breeding under it or fewer losses by predation. On the heavier soils at Rothamsted *A. reticulatus* was equally common on the ploughed as on the paraquat-treated plots. As in 1966, the paraquat failed to kill weeds adequately at Rothamsted, and the yield was much less on the slit-seeded than on the ploughed plots. (Whiting and Lofty)

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Biology of the wheat-bulb fly

Population studies. Numbers of eggs, larvae and pupae were again estimated on the permanent reference plots in Great Harpenden. Populations were very small, and followed the trend of a steady decline in numbers over the last four years, namely from 1 300 000 eggs/acre in 1964 to 38000/acre this year. This decline may be caused by the shape and size of the alternate wheat and fallow plots (each plot is 14 ft × 263 ft, covering less than $\frac{1}{10}$ acre), but may also reflect the general decrease observed in this pest elsewhere. It is hoped that changes now made in the size and configuration of the plots will show whether the wheat-bulb fly populations are affected by the size and shape of oviposition sites and whether the decline of the last few years was caused by other factors.

A $\frac{1}{2}$-acre site in Stackyard, fallowed the previous summer, had an egg population of about 1 million/acre, and plots of winter wheat were sown there by standard drilling or broadcast at 1 and 3 bushels/acre, to test the effects of the two methods of seeding on infestation and plant damage. Harrowing after sowing tended to drag the broadcast seed into rows, so there was little difference between the appearance of the two crops. This treatment possibly accounted for no differences being noted in wheat-bulb fly attack. However, there were more damaged plants and larvae at the larger seed rate, confirming earlier observations that a thick stand favours the survival of the larvae. (Lofty)

Feeding and ovary development. Now that more is known about the food of the adult wheat-bulb fly (*Rothamsted Report* for 1966, p. 206) the relation between feeding and ovary development is being studied. When wheat-bulb flies emerge their crops are small, undistended and with 3–5 lobes; the ovaries are small and undeveloped. After feeding, the crop expands and can occupy up to two-thirds of the abdominal space.

The crops of the first flies of both sexes that were caught in emergence cages and by sweeping in Stackyard from 19 June onwards, were lobed or contained fluid with bacteria, yeast cells and a few fungal spores, probably from the honey dew on the wheat leaves from which they fed. On 3 July the crop of one female was repleted with spores of the fungus *Septomyxa affinis* (Sherb.) Wr. Thereafter an increasing number of females and males were found to have fed on *Septomyxa* spores, and on 17 and 19 July crops from flies caught in emergence cages contained only *Septomyxa* spores. A careful examination of all fungi present under the cages showed dense spore-bearing mycelia of *Septomyxa* on dead *Poa annua* and on the dead, lower leaves of wheat at the soil surface. Flies, of both sexes, collected from various localities all contained spores of *Septomyxa* in their crops and intestines, but these did not always completely fill the crop as they had in flies from Stackyard. Flies were not found with their crops filled with basidiospores of *Coprinus radiatus* as they were in 1966, but a few spores of fungi such as *Ustilago*, *Cladosporium*, *Erysiphe*, and *Penicillium* were found in some, also yeasts, bacteria, crystals and lepidopterous scales. Several other Anthomyiid flies caught while sweeping wheat and in water traps on fallow were dissected. The crops of more than half contained *Septomyxa* spores.

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As early as 11 July one female wheat-bulb fly from Stackyard contained mature eggs in the ovarioles, but it was only from 22 July onwards that most ovaries were enlarging, and by 27 July most females contained mature eggs. The amount of fat body in the abdomen in July ranged from very little to filling most of the abdomen; the fat body diminished in August when the eggs matured. The first eggs were laid in breeding cages on 26 July. The peak period of wheat-bulb fly emergence in Stackyard was 1–4 July, and the last were caught on 28 July. (Jones)

TABLE 4

Source and date of wheat-bulb flies with crops containing spores of Septomyxa *sp. 1967*

Date	Locality	Spores of *Septomyxa* present
19 June–2 July	Stackyard, Rothamsted	—
3 July–28 August	Stackyard, Rothamsted	***
12 July–27 July	Broadbalk, Rothamsted	*
18 July	Finchingfield, Essex	***
18 July	Great Bardfield, Essex	**
20 July	Hynes, Beds.	*
22 July	Dunton, Cambs.	**
25 July and 1 August	Whittlesey, Cambs.	*
25 July	Great Pelham, Herts.	***
26 July	Elford, Tamworth, Staffs.	***
3 August	Colney Heath, Herts.	***

*** Crops filled exclusively with spores of *Septomyxa*
** Crops filled mainly with spores of *Septomyxa*
* Crops with some spores of *Septomyxa*

Pathology of the wheat-bulb fly. Eggs and larvae of the wheat-bulb fly were again examined in the search for pathogens. Seventy per cent of eggs buried in the soil in the field in August 1966 hatched in January or February; 5·3% seemed to be infertile; 11·4% of embryos died infected with *Phialophora* sp. (at least 21% of these also contained other micro-organisms or nematodes), and 7·9% contained bacteria, actinomycetes or other fungi; 5·2% of embryos died without obvious signs of microbial infection.

Eggs infected with *Phialophora* were more common than in 1965–66, but the proportion of eggs infected with this fungus differed greatly in different samples. Thus, for 7000 eggs kept in groups of 500 in soil in an insectary from August 1966 to January 1967 the infection rate ranged from 0·2 to 16·6%. Eggs seem to be already infected when laid, and it was not possible to infect eggs with *Phialophora* after they were laid. There were more infected eggs during the early period of egg laying, but the reasons for this are not known. Female flies that lay infected eggs live as long as those that lay uninfected ones, and both infected and apparently uninfected eggs can be produced by the same female.

Several hundred 1st–3rd-instar larvae were dissected from wheat plants from Stackyard field in late winter and spring; 86·8% were alive, 11·2% dead and 1·9% moribund. At least six different bacteria were isolated from the dead larvae, but symptoms were not consistent, and the bacteria were probably sacrophytes. Three per cent of dead larvae and 2% of living

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larvae had necrotic lesions on the body surface, but its cause remains unknown. (Cockbain, with Wilding, Bee Department)

Effects of *Bacillus thuringiensis* on wheat-bulb fly. Two commercial spore preparations of *B. thuringiensis* were tested as seed-dressings to see whether they prevented wheat-bulb fly larvae attacking wheat in seed-boxes in the insectary.

"Biotrol" wettable powder was applied to the seeds at 5 rates between 0 and 1·0% viable spores/weight of seed, and the seeds sown and grown for 60 days in soil infested with larvae. There was a significant and negative linear relation both between log weight of seed dressing and number of shoots attacked, and between log weight of dressing and number of adult wheat-bulb flies that emerged from the soil. However, a seed dressing of 0·7% a.i. by weight of seed was necessary to lessen the number of attacked shoots by 20% and a dressing of 0·25% to lessen the number of adults emerging by 25%. To halve the number of attacked shoots, or number of adults emerging, would need more than ten times the weight of these dressings.

"Thuricide" aqueous spore suspension, at 5 rates between 0 and 0·66% a.i. by weight of seed, had no effect on the number of attacked shoots.

A preparation of the heat-stable exotoxins produced in culture by *B. thuringiensis*, supplied by Dr. C. M. Ignoffo, International Minerals and Chemical Corporation, California, was also tested by dipping wheat seedlings in aqueous solutions of the exotoxins, partially drying them and then allowing larvae to feed on them. More newly emerged larvae were killed by feeding on these seedlings than by feeding on untreated seedlings (Table 5); 82% of treated larvae died outside the seedlings, but at least 67% fed inside the centre shoots before they died.

TABLE 5

Wheat-bulb fly larvae killed by feeding on wheat seedlings treated with B. thuringiensis *exotoxins*

	Exotoxin conc. (μg/ml)				
	0	1	10	100	1000
% dead after 9 days	10	37	40	53	93
% ,, 27 days	50	77	77	97	100

Mean of 2 replicates, 75 larvae/replicate.

Ingesting the toxins periodically increased mortality, but not significantly so. Thus, when larvae fed for a limited time on the surface of seedlings treated with 10 μg/ml of toxins 77% died within 30 days, whereas 87% died when given four similar opportunities to feed.

Many larvae that survived after ingesting the exotoxins became malformed pupae that died. Thus 47, 47, 33, 13 and 0% of larvae survived to become adult after feeding during the 3rd instar on seedlings treated with 0, 1, 10, 10^2 and 10^3 μg/ml exotoxin respectively.

The effectiveness of the dried exotoxins as a seed dressing was tested in replicated experiments in seed-boxes. On average, 31% fewer shoots were attacked when seed was treated with exotoxins (1·5% by weight of

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seed) than when not (difference not significant, $P = 0{\cdot}10$), and 86% fewer adults emerged from soil containing seed-treated plants. (Cockbain)

The movement and dispersal of adult wheat-bulb flies. Little is known about the movement of adult flies from fields in which they emerge, or how far and in what concentrations they fly to bare soil to oviposit. Flies that emerge from a wheat field do not reproduce another generation of adults that season, so if they stay close to their emergence site they reproduce a generation next year only when wheat is sown near by. Therefore, if winter wheat were eliminated for one year over a considerable area, it might also be possible to lessen or even eliminate wheat-bulb fly from the area, at least for a period until the area became generally reinfested.

With this in mind, National Agricultural Advisory Service officers persuaded farmers at Whittlesey not to sow winter wheat in 1966/67 in an area about 2 sq. miles that is usually heavily infested. Larvae that hatched in spring from eggs previously laid in the soil would therefore starve, and any flies in the area would have come from a source beyond it. The area was surrounded on three sides by farms growing wheat, but there was an urban area to the north-east. Nine traps, in the form of white-painted baking tins filled with water, were placed in a line 2 miles long across the area from west to east and another 6 in a transect of about the same length from north to south. All the traps were at the edges of potato fields and where adults also normally laid eggs.

During the season 95 males and 199 females were caught of which 90% were caught in the eight traps in the western and southern parts of the area, that is within about half a mile downwind from winter wheat, which was the most likely source. The seven traps on the north-east transect caught only 10% of the total.

Most of the insects caught were in traps closest to wheat; but this does not necessarily mean that many did not disperse beyond these traps. However, other information suggests that many of the flies remained close to where they emerged. For example, of all the insects caught apparently coming from the near-by wheat 58% were caught soon after the emergence period (11 July–8 August) and 42% later in the year (9 August–6 September); this alone does not distinguish between little dispersal from near-by wheat or so much dispersal as to give a more or less uniform distribution of insects over the whole area, but the former is much more likely because of the gradient across the wheat-free area, and because populations of eggs, estimated by Mr. F. E. Maskell of N.A.A.S., were positively correlated with the numbers of females as indicated by the traps ($r = 0{\cdot}59$, $P > 0{\cdot}05$). Nevertheless, these results must be interpreted with care, for such gradients do not necessarily indicate the ability of the insects to disperse. Many of the insects probably fly far beyond the limits of the detected gradient.

Flies were also trapped at Rothamsted over the same period at various distances from emergence sites in Broadbalk, Stackyard and Great Harpenden fields, all close together. Eighteen traps, in two lines, intersected on Broadbalk: one line, 2 miles long, ran east to west, and the other, 1 mile long, from north to south: of the 39 females and 7 males caught, 32

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of the females were within a quarter mile from the emergence sites. Thus the population of adults tended to remain fairly close to emergence areas throughout the egg-laying period, supporting the idea that a year without winter wheat in an area of a few square miles might control wheat-bulb fly. (Bardner, Lofty and Huston)

Biology of the frit fly

Frit flies and ground predators. During late May and early June, when female frit flies were laying their eggs, pitfall traps were placed between the rows of oats in crops sown on 17 April in the Garden Plots and on 8 March in Highfield. The commonest carabid among the late-sown oats in the Garden Plots was *Bembidion lampros* (2·1 beetles/trap/week), but on Highfield it was less common (0·43 and 0·03 beetles/trap/week in two areas). *Notiophilus biguttatus* was also commoner among late-sown oats (0·55/trap/week) than on Highfield (0·1 and 0·2/trap/week). *Agonum dorsale*, very common in 1966, was rare as was *Nebria brevicollis*. In the autumn, pitfall traps placed in the Garden Plots after oats, where the surface of the ground was hard and also after rotovating on a plot that had grown peas, caught also *Trechus quadristriatus*. In the freshly rotovated soil 1·7 beetles/trap/week were caught, but not from soil whose surface was hard, where the main carabid was *N. brevicollis* (1·0/trap/week). The ratio of all ground predators in the two plots was 1·5 (rotovated soil) : 1·0 (hardened surface).

The commonest predators caught were *B. lampros* and *T. quadristriatus*, which prey on dipterous eggs and larvae, and the effect of these and others on the infestation of plants by frit-fly larvae was tested in the laboratory. Frit flies lay on the coleoptiles of oat seedlings in the 2–4-leaf stage, but some eggs may fall to the ground, where they are vulnerable to predators, which also attack the larvae as they move from one shoot to another. When eggs, 5 per pot, were placed on soil at 5–10 mm from an oat seedling 44–33% of the larvae produced penetrated the seedling, whereas few or none did when carabid ground predators were present. Counting eggs on random samples of oat seedlings in the field in May and June, therefore, better indicates the potential larvae and damage to shoots than the cumbersome method of extracting the eggs from soil by the Webley grab often used for sampling, because with carabids active in the oat crop many eggs and larvae in the soil would be eaten. Predators also affected the ability of frit-fly larvae to move from a plant infested with several larvae to uninfested plants 3 cm away. Without predators, 22% of the larvae that emerged from eggs laid on the coleoptile of one plant infested near-by plants, whereas with predators there, only 2% did. Even *N. brevicollis*, a carabid that usually feeds on larger insects, decreased the number that spread to near-by plants to 5%. (Jones)

Mortality of frit-fly larvae. When six or more eggs were laid on the coleoptile of one 2–4-leaf oat seedling by a fly most of the resulting larvae failed to establish themselves in the plant. After 10 days one shoot usually contained only two or three larvae (although a shoot may have six), and

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rarely were there more than two pupae; the larvae that failed to invade the shoot where the eggs hatched either died or moved to another tiller or plant; when many eggs were laid on one shoot as many as 80% of the resulting larvae died within 14 days. (Jones)

Parasitism of the panicle generation. Panicles cut from 5 separate sq yds of oats yielded no chalcid parasites; nor did 575 fritted grains kept singly in tubes. This may have been because bad weather in May and June retarded the development of the parasites, and adults emerged too late to attack the immature stages of frit fly in the grain. (Jones)

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

Winter wheat and wheat-bulb fly. The experiment on Stackyard field comparing the yields of wheat sown on three different dates in plots exposed to and protected from wheat-bulb fly attack was repeated. Results in 1965 and 1966 showed that attack by wheat-bulb fly mainly caused loss of yield by decreasing the number of potential ear-bearing shoots/acre, and that even the surviving plants and shoots could not compensate fully for lost shoots because they were unevenly distributed. The distribution of damaged shoots and the growth of individual plants was therefore carefully studied in protected and unprotected plots. Plants were marked and numbered during the attack in lengths of row 1 yd long, and plants in each inch were counted, together with those in the adjacent rows. At harvest the ears from each plant were labelled, and these will be individually threshed to find the weight and number of grains from each plant. Results are not yet analysed.

At the end of the attack the presence or absence of plants from each 6-in. section of row was recorded to give a complete record of the distribution of damage. Plants removed from the plot showed that the attack was about half that in 1965 and 1966; nevertheless, the attack destroyed between half and one-fifth of the plants, depending on the date of sowing. (Bardner and Huston)

Effect of gaps on yield. Plants damaged by wheat-bulb fly and other cereal pests are often aggregated, so that the crop consists of dense stands of plants interspersed with patches where most of the plants have died; the graduation between the two is often sharp. To measure how the distribution of damaged plants affects compensatory growth, plots were sown with the same amounts of wheat (except in the control) distributed in rows arranged differently. The control plot, with all rows present, had 30 rows; and the other plots only 22, but with the 8 missing rows arranged either evenly or in groups of 2, 4 or 8.

Treatment	0	1	2	4	8	
Yield, cwt/acre at 85% d.m.	47·6	44·2	41·9	38·0	37·3	S.E. of mean $\pm$ 0·59

From the yield of the ungapped plot the expected yield of the gapped plots without any compensatory growth would be 34·9 cwt/acre, whereas all exceeded this. However, the amount of compensatory growth depended greatly on the distribution of the rows, and was much less when the gap exceeded 4 rows wide (28 in.). Rows adjacent to 8-row gaps had 37% more straws than other rows and next to a 1-row gap 17% more. The work will be extended to include the effects of irregular-sized gaps more characteristic of pest attack. (Bardner and Huston)

The effect of leaf-eating insects on the growth of plants. Different numbers of *Phaedon cochleariae* Fab. (Col., Chrysomelidae) and *Plutella maculipennis* Curtis (Lep. Plutellidae) were fed on radish (var. French Breakfast) and turnip (var. Early Milan White) and the yield of the roots related to the damage done to the vegetative parts. The loss in the area of leaf and dry matter in the root, that is to say the yield, of radish plants defoliated by larvae of either insect was proportional to the number of insects eating the leaves. The later loss in leaf area and root yield attributable to each larva of *P. maculipennis* was 4% (10 cm^2) and 5·2% (0·14 g) respectively, and from each larva of *P. cochleariae* 4·5% (12·3 cm^2) and 4·9% (0·17 g) in leaf area and root yield respectively.

Increasing the numbers of *P. maculipennis* larvae on turnip did not affect the subsequent yield and leaf area because the plants recovered from the injury. The amount of compensatory growth increased with the number of *P. maculipennis* larvae that injured the plant. By contrast, turnip plants injured by larvae of *P. cochleariae* did not recover, and the subsequent loss in the leaf area and the root yield was proportional to the number of insects. The loss in leaf area and root yield caused by each *P. cochleariae* larva was 2·9% (10 cm^2) and 2·6% (0·6 g) respectively.

Two insects have different effect because they feed differently. *P. maculipennis* tended to wander and become evenly distributed on all the leaves present at the time, thus damaging especially the small area of young leaves, but *P. cochleariae* tended to stay in one place, thus damaging the older leaves most. This produced a different pattern of injury, and the different methods of feeding may have accounted for turnip reacting differently to the two kinds of injury. Both insects damaged radish more than turnip, confirming earlier observations that they injured a greater area of radish than of turnip leaf.

The effect of simulating insect damage to growth and yield of both plants was comparable to the effect of direct defoliation by the insects. This work will show how the age of the leaves destroyed is related to the distribution of dry matter in the plant. (W. E. Taylor and Bardner)

Frit-fly shoot attack on oats. Among 1716 ringed plants growing in 140 segments of row with 10 in. between plants in an area of approximately $\frac{1}{7}$ acre, 9% of the plants were attacked both in main stems and tillers. Plants attacked both in main stems and tillers yielded an average of 63% less than unattacked plants, whereas plants attacked in tillers only did not yield significantly less than unattacked plants.

Unattacked plants growing between the two nearest plants of which one or both were attacked in the main stem and tiller yielded an average 2·04 g, whereas unattacked plants between two unattacked plants yielded 2·12 g.

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This indicates that unattacked plants adjacent to attacked did not compensate for losses in the attacked ones. (Judenko)

Methods of assessing losses caused by frit fly and phorate to the yield of sweet corn (*Zea mays L.*). An area of about $\frac{1}{4}$ acre was planted with sweet corn (var. Early King), and of all hills that were planted 47% failed to produce plants. Phorate, applied as granules in the furrows at sowing at 1·5 lb a.i./acre, with a Gandy granule applicator, significantly lessened attack by frit fly on shoots from 41·2 to 17·7%. It also decreased numbers of plants by 10%, though this difference was not statistically significant. In spite of lessening attack, it not only failed to increase yield but probably decreased it.

The following seven kinds of yield of sweet corn were examined: total green weight, total weight of all cobs, number of marketable cobs assessed according to the grading recommended by Ministry of Agriculture, Fisheries and Food (a total of three yield factors), and the number and current value of marketable cobs assessed by the current commercial standards. The yield of control and treated areas was assessed from samples taken at random.

Yields of all kinds were smaller on plots with than without phorate, although the differences were not significant statistically. Unattacked plants from plots with phorate gave less of five kinds of yield than those from plots without phorate, but only one kind of yield was significantly less; the other two kinds of yield were greater from plots with than without phorate, although not significantly so.

Unattacked plants growing between two plants of which one or both were attacked yielded more on average than unattacked plants between two unattacked ones, but the differences were not significant, so sweet corn seems not to compensate for frit-fly attack.

The average yields of individual plants from treated and untreated plots were examined, but results have yet to be analysed. However, the results illustrate two important points; (1) that it may be dangerous to assess the value of an insecticide merely from its effect on infestation; (2) the fact that an insecticide does not increase yield is not necessarily evidence that the insect against which it was applied is negligible as a pest. (Judenko)

Staff and visiting workers

F. Raw, who left to become Professor of Entomology at the University of Queensland, Australia, died suddenly at Brisbane in October. He leaves many saddened friends at Rothamsted.

D. J. Cross was seconded to the Cocoa Research Institute of Ghana, and P. J. Huston left. I. F. Henderson was appointed.

C. G. Johnson lectured to the European Plant Protection Organisation in Paris, visited laboratories in Poland as guest of the Polish Academy of Science and, with Mrs. J. Palmer, visited Mr. D. Hille Ris Lambers' laboratory in Wageningen. Papers were read by R. Bardner and E. Judenko at the F.A.O. Symposium in Rome on crop losses and by C. A.

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Edwards and K. Fletcher at the IBP/UNESCO Symposium in Paris on Methods of Soil Ecology.

A. Youdeowei and M. F. Ryan were awarded the degree of Ph.D. of the University of London. Dr. L. V. Knutson of Cornell University and Dr. Sein-Toe of the Department of Agriculture, Burma, spent some time working in the department.

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