ROTHAMSTED RESEARCH

Report for 1962

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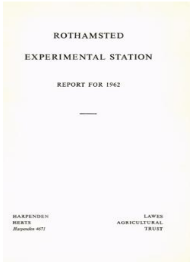
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Rothamsted Research

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ENTOMOLOGY DEPARTMENT

C. G. JOHNSON

D. S. Madge left to become Lecturer in Zoology at University College, Ibadan, Nigeria. Mr. P. F. Newell, a Ministry of Agriculture Scholar, joined the Department in October, and Mr. T. P. Sriharan of Osmania University, Hyderabad, India, and Mr. G. Hariri of the Ministry of Agriculture, Syria, in November.

F. Raw, C. A. T. Edwards, G. W. Heath, G. K. A. Buahin, J. R. Lofty and M. K. Arnold attended the colloquium on "Soil Fauna, Soil Microflora and their Relationships", held by the International Society of Soil Science at Oosterbeek, Holland, in September.

D. Calnaido and F. M. Smith were awarded the Ph.D. degree of London University.

Soil Fauna

The breakdown of vegetable matter in the soil by soil animals. Last year we described how the breakdown of leaf litter by soil animals (insects, other arthropods and worms) was being studied, and how earthworms began the process by pulling the litter into the soil. The increased leaf burial by *Lumbricus terrestris* with increased temperature, observed in Wisbech orchards, was studied further in Manor Wood, Rothamsted. One hundred apple leaves were placed on the ground beneath each of 30 wire mesh cages on 1 January. As the leaves disappeared they were replenished every week in half the cages so that the numbers on the surface remained fairly constant. The number of leaves buried was significantly and positively correlated with mean air temperature and with the temperature at 4 and 12 in. under the soil surface. These three variables accounted for 45, 33 and 22% of the variance respectively, in simple correlations; and of them, air temperature seems to have the greatest effect. The results also showed that more leaves were buried in periods immediately following cold weather than would have been expected otherwise.

Sixteen weeks after the experiment began, three times as many leaves had been buried under the replenished as under the other cages. This was not entirely because more leaves were present; more *L. terrestris* were subsequently found under the replenished cages than under the other cages, presumably because of immigration. (Raw and Lofty)

Other animals besides worms help in litter breakdown. The effects of different groups were studied by excluding them from, or allowing them access to, leaf disks in the soil, either by altering the composition of the fauna with aldrin or DDT or by enclosing the leaf disks in nylon bags of various meshes. In arable soil earthworms, Collembola and dipterous larvae were important in the initial fragmentation of the leaves; without worms the rate at which leaf tissue disappeared increased with increasing Collembola populations.

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Green oak-leaf disks inside the large-mesh bags, which allowed all animals of the meso- and micro-fauna and earthworms to enter, buried in recently ploughed-up pasture soil completely disappeared in 16 months; 10% of the beech disks remained.

Both oak and beech leaves disappeared about three times as fast when earthworms were present as when they were excluded. In bags of the finest mesh, which excluded all micro-arthropods, beech leaves were superficially intact after 12 months.

Where earthworms were excluded, disks in aldrin-treated plots disappeared at about half the rate of those in untreated plots; in the DDT-treated soil disks disappeared faster than in the untreated controls. These different rates of disappearance were positively correlated with the numbers of Collembola in the soil. Leaf disks disappeared faster in recently ploughed-up pasture soil than on the surface of mixed-oak woodland soil, possibly because those in pasture soil were constantly damp.

Another interesting feature is that some leaves, even from the same tree, sometimes broke down at different rates. Thus, although beech leaves picked from trees and buried in June all disappeared at about the same rate and about 80% of the leaf area had disappeared in 12 months, those picked and buried just before leaf-fall in September were of two kinds. One kind disappeared at the same rate as those picked in June, and the others remained intact for many more months. The intact leaves were thicker, tougher and browner than the others, although they were fairly green when first buried. After about 9 months they suddenly became even more acceptable than the residue of June leaves, both to worms and to other arthropods, and disappeared more quickly. Such leaves are thought to come from the outer parts of the tree, and the chemical differences between the two kinds and the changes from non-acceptability to acceptability are being investigated.

Breakdown of many different kinds of green leaf is being studied; kale, beet, bean and lettuce disappeared completely in two months. (Heath, Edwards and Arnold)

Breakdown of oak and beech leaves in woods depends on the depth they are buried in the litter layer. Most fragmentation goes on near the soil surface beneath the litter, and earthworms and dipterous larvae are mainly responsible; any decomposition which occurs before fragmentation scarcely affects the ash-free weight. This was shown in an experiment in which leaf disks were placed freely on the surface, in the middle and at the bottom of the litter layer, and samples were weighed and analysed periodically over a 10-month period. After 1 month beech leaves at the top had changed little, but those at the bottom had lost nearly half their ash-free weight. After 10 months all the bottom disks had disappeared and the top disks, which by then had reached the soil surface, were in about the same stages as the bottom disks had been after 1 month. In the oak wood much the same happened; but initial fragmentation was slower.

The hydrolysable carbohydrate content of the most-fragmented oak disks varied considerably in the first 5 months, and was as much as 300 mg/100 g of material in dry periods, when animals were least active.

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Beech leaves contained no hydrolysable carbohydrates after 5 months. (Heath and Arnold)

The side-effects of toxic chemicals in the soil on arthropods and worms. The long-term ecological effects of a single dose of DDT at 6, 20 and 60 lb a.i./acre and aldrin at 4 lb/acre are being studied in ploughed-up old pasture soil on Highfield with plots kept completely free of plants (*Rep. Rothamst. exp. Sta.* for 1961, p. 147). The plots were treated in May 1960 and sampled every week for the first year, and thereafter in alternate months.

Isotomid Collembola, which live near the surface, were more numerous in all the DDT-treated plots than in untreated controls, but they were almost eliminated by the aldrin. The onychiurid Collembola, however, which live in the deeper soil, were much more abundant than in the controls only in plots treated with DDT at 6 lb a.i./acre. The numbers in aldrin (4 lb) and DDT (60 lb) plots did not differ appreciably from the controls.

All doses of DDT decreased the numbers of mesostigmatid mites which prey on Collembola, but aldrin did not. This differential effect on predators is thought to be responsible for DDT treatments increasing isotomid Collembola and aldrin decreasing them. The numbers of oribatid mites, dipterous larvae and symphylids were decreased by fallowing and by DDT, but most by aldrin. All treatments except the smallest dose of DDT greatly decreased numbers of Pauropoda, Protura, Coleoptera, Hemiptera and Hymenoptera, but none affected nematodes, enchytraeids or earthworms.

The residues in the plots have been studied chemically by Jeffs, Insecticides Department. DDT disappeared very slowly; aldrin went more quickly, but its disappearance was accompanied by an increase of its oxidation product, dieldrin.

The effects on soil fauna of continued annual applications of aldrin is being studied in a crop rotation of sugar beet, barley, potatoes and winter wheat at Levington Research Station, by courtesy of Messrs. Fisons Fertilisers Ltd. Between 1 and 2 lb a.i./acre is applied to the soil, according to the particular crop, and the experiment is arranged in two series so that two different crops occur together. In 1962 soil samples were taken among sugar beet in spring and winter wheat in autumn: both series have had a total of 5 lb aldrin/acre since the experiment began in 1959 and the number of soil animals continues to fall in the aldrin-treated plots.

By courtesy of the Shell Chemical Co. the effects are being studied of aldrin and "Telodrin" applied every 6 months to four different soil types in Kent and Huntingdonshire carrying crops of potatoes, celery, sugar beet, carrots, cabbage and onions. Preliminary results indicate that aldrin is behaving as previously and that "Telodrin" is having similar effects but at much smaller doses in the two lighter soils. Effects on the soil fauna in the heavier soils, which contain much organic matter, have been slight. (Edwards and Arnold)

Preliminary tests made on small plots in a greenhouse with fumigants used to control nematodes and fungi, showed that 1 month after treatment

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with "D.D" at 400 lb/acre the top 6 in. of soil contained only 3% as many worms (excluding nematodes) and arthropods as untreated soil and the second 6 in. 15%. There was no sign of recolonisation after 4½ months.

A field experiment is now in progress. Sodium methyl dithiocarbamate at 600 lb a.i./acre and "D.D" at 800 lb/acre were injected in September 1962. Some of the plots were isolated from the surrounding soil by polythene sheet to a depth of 1 ft with 6 in. projecting above the surface. Two weeks after treatment no live micro-arthropods were found in the top 12 in. in the "D.D"-treated plots; the sodium methyl dithiocarbamate killed 99% in the top 6 in., but had little effect below this. The recolonisation of the plots from the side, above and beneath is being studied. Particularly interesting is the recolonisation from above by small wingless airborne arthropods. Water-tray traps placed at different heights up to 2 ft above soil level trapped between 10 and 4,000 soil micro-arthropods each week. Collembola formed between 70 and 90% of the catch. (Buahin and Edwards)

Soil pest control. In experiments on the chemical control of wireworms on Claycroft (with Insecticides Department) *gamma*-BHC, aldrin and dieldrin seed-dressings, *gamma*-BHC combine-drilled and aldrin spray treatments were applied to wheat drilled in autumn 1960 and spring 1961. After the experiments ended, the residual effects of the insecticide were measured by sowing plots in autumn 1961 with untreated wheat and assessing their yields and the amount of wireworm damage.

Plots treated in the spring of 1960 with aldrin, or where *gamma*-BHC or dieldrin seed-dressing (high rates) had been used, yielded significantly more (40·6, 37·4 and 39·8 cwt/acre respectively) than untreated plots (31·7 cwt/acre).

Treatment given in autumn 1960 showed no residual effects on spring wheat sown in 1962, but *gamma*-BHC (high rate) seed-dressing applied in the spring of 1961 increased the yield of untreated spring wheat sown in 1962 from 39 to 41 cwt/acre.

The effects of menazon on soil pests and on the general soil fauna are being studied at Newbury in collaboration with Imperial Chemical Industries. (Raw and Lofty)

Slugs are becoming increasingly important as pests, and there is no satisfactory method of controlling them in field crops. Promising molluscicides are being tested in conjunction with a study of the movements and habits of slugs and the places in the crop where they tend to collect (p. 158). The possibility is also being studied that herbicides may be used against slugs either to poison them directly or to deprive them of food. Tests have been made with ten herbicides used for controlling weeds in potato crops (where slugs do much damage) in conjunction with the Agricultural Research Council's Weed Research Organisation at Kidlington. Four triazines and one dinitrophenol were molluscicidal in laboratory tests, and the dinitrophenol was toxic to eggs of *Agriolimax reticulatus* in concentrations as little as 2 ppm aqueous solution. (Stephenson)

The slug-repellent properties of the dimethyl and dibutyl phthalates

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were reported last year (*Rep. Rothamst. exp. Sta.* for 1961, p. 149). Similar chemicals are used as plasticisers, which probably explains why dilute aqueous washings of some cellulose nitrate sheets have been found to be extremely toxic. The possibilities of using such solutions to control slugs are being studied. (Newell)

The effect of orchard management on the earthworm populations. The effect of orchard management on the earthworm population and the possible relevance of this to tree growth is being studied at Wisbech, where it has already been shown that *Lumbricus terrestris* is very important in burying leaf litter (*Rep. Rothamst. exp. Sta.* for 1961, p. 146).

An assessment of the earthworm populations in orchards with different types of management shows that organic manures (such as farm-yard manures and compost) and cultivation together have little effect on the abundance of *L. terrestris*. Organic manures alone greatly increased the numbers of *Allolobophora chlorotica*, *A. caliginosa* and *Eisenia rosea*, which all live near the soil surface, and cultivation alone greatly decreased them. Repeated sprayings with copper fungicides can almost eliminate the earthworm populations (*Rep. Rothamst. exp. Sta.* for 1961, p. 146), but the effects of other sprays cannot be estimated without special experiments beyond the scope of the present survey. In one orchard, with much copper (1,500–2,500 ppm) in the partially decomposed surface litter, some areas had been cultivated, others had not. The leaves on the apple trees were much darker in the cultivated than in the uncultivated areas, which may reflect the greater root-growth after the ploughing or the nitrogen released by the rotting of the grass, but as earthworms could be responsible, their effect is being further studied. (Raw and Lofty)

The biology of soil-inhabiting pests. Slugs are not randomly scattered in the soil under a crop; they discriminate in where they spend most of their time resting and where they lay their eggs. Thus when *Agriolimax reticulatus*, a common pest of winter wheat, was offered soil with particles ranging in size from less than 4 up to 20 mm, arranged in various patterns, it laid far more eggs in the finer soil, resting during the day beneath the larger particles. Not all slugs behave in this way: *Milax budapestensis*, a major potato pest, excavates cavities in large lumps of clay and lays eggs within them; *Arion hortensis* congregates mostly in the troughs between potato ridges, probably because it is dampest there. Another discovery of possible value in control is that *M. budapestensis* swallows soil, for this raises the possibility of using stomach poisons applied to soil.

Such information on slug behaviour is significant for deciding how to apply poisons and how to assess the results of tests. When to apply molluscicides, the effects of rolling to destroy habitable crevices and the choice of sampling sites in a crop are three factors now being studied at Rothamsted.

Slug activity and distribution in crops in relation to control are also being studied on the heavy clay at the Experimental Husbandry Farm, Terrington, Norfolk, in collaboration with the National Agricultural Advisory Service (Eastern District). (Stephenson)

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An improved method for extracting arthropods from the soil. Existing extraction methods leave much to be desired. The Tullgren funnel, which relies on gentle heat to drive the animals from soil, works with different degrees of efficiency with different animals and with different types of soil. In the modified Salt and Hollick apparatus the soil sample is broken by a water jet and washed through sieves: the animals and plant debris are then floated to the surface of magnesium sulphate solution, skimmed off, shaken with xylene and water and hand-picked from the upper xylene layer. Washing and sieving is slow, for samples are dealt with singly by hand, and removing animals from xylene is tedious, unpleasant and subject to personal errors. All this limits both the number and accuracy of estimations when the need for speed and accuracy is great.

An apparatus was therefore constructed which washes four samples simultaneously and mechanically. Each of the four units on the apparatus has a coarse wire-mesh cylinder to hold the soil sample, supported in a large polythene cylinder with a 150 mesh/in. sieve at the bottom. Both cylinders are rotated about a vertical axis, while two flat jets of water play on the sample and on the bottom sieve. Four samples can be washed in 10–30 minutes. Separation is being attempted in a special polythene separating funnel with zinc sulphate solution (specific gravity 1·4) and a solution of xylene and carbon tetrachloride (specific gravity 1·2), so that animals float to the top of the xylene–carbon tetrachloride solution, plant debris remains at the interface and soil sinks to the bottom. If this succeeds, hand picking will be unnecessary, for liquids, soil and debris will be run off from below. The fumes, however, are unpleasant and may be dangerous; hence the separation has to be done in a fume cupboard. Substitutes for the xylene–carbon tetrachloride solution are being sought. (Edwards and Heath)

Infestation and Loss of Yield

Gall midges. The work aimed to assess the effect of attack by swede midge (*Contarinia nasturtii*) on the yield of swedes. Three lots of swedes, sown consecutively at 2-weekly intervals, were caged, in a 6-ft cube, with nylon mesh as follows; artificially infested with midges reared in the insectary; kept completely free of midges, by caging and spraying with endrin; natural infestation allowed in an open-ended cage; uncaged controls. The caged plants were leafy and with fewer roots than those in the open; early sown plants yielded more than late sown, even though both had the same growing periods. Midge attack showed in different degrees, with corresponding symptoms to which the yields could be related as follows:

Symptom of attack	Percentage of attacked plants showing symptom			Mean yield in oz of attacked plants with symptom		
	1st sowing	2nd sowing	3rd sowing	1st sowing	2nd sowing	3rd sowing
All symptoms	100	100	100	12·8	6·6	6·1
Crumpled-leaf	83	100	100	14·1	6·6	6·1
Swollen-petiole	58	73	85	15·1	6·6	3·8
Many-neck	42	23	62	11·4	0·7	2·2
Cabbage-top	50	37	64	12·0	5·1	4·1
Unattacked	0	0	0	17·5	9·4	6·3

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Severely attacked crops produce a few very large and many small, unmarketable swedes. "Many-neck" and "cabbage-top" are associated with least yield. (Edwards, Arnold and Mrs. H. Bardner of Ministry of Agriculture, Plant Pathology Laboratory)

Insect Dispersal and Migration

The migratory flight of an individual insect begins with take-off from the place of birth, proceeds through one or more lengthy displacement flights and ends, when successful, in a new breeding site. Collectively, this results in the transference of population, during which the density of insects in the air changes at different places (including different levels in the air) or over a period at the same place. The process that can be studied in the individual as take-off flight and landing, can be measured in the population as flight periodicity, population displacement involving aerial density changes in time and space, and the reinfestation of habitats, especially crops. All these aspects, individually and collectively, are being studied.

Flight thresholds and flight periodicity. The study and measurement of temperature thresholds for take-off and flight by a range of insect species described in the last report (*Rep. Rothamst. exp. Sta.* for 1961, p. 150) was ended for the time being. The analysis of aerial populations of queen wasps (*Vespula germanica* Fabr.) *Aphis fabae* Scop., soldier beetle (*Rhagonycha fulva* Scop.), the noctuid moths *Agrochola lychnidis* (Schiff.), and *Amphipyra tragopoginis* (Linn.) showed that, once the air temperature that permits flight is attained, further rises in temperature do not affect numbers trapped, for these depend chiefly on the population size. Consequently, the size of the daily catch depends more on the period spent above the temperature threshold than on changes in mean daily temperature. Population changes can be eliminated in analysis by classifying daily catches as unity or zero, and the resulting graph (against daily temperature) indicates the threshold. Field data analysed in this way can be as accurate as laboratory measurements of thresholds. (Taylor)

The effect of light, temperature, relative humidity and wind speed on emergence and take-off of *Limothrips cerealium* Hal. from hibernation sites was analysed in this way. The mean temperature threshold for take-off, measured close to the insects, is about 18°, but ranges between 14° and 19°, depending on whether temperature is measured in the bark or some feet away in the air. This emphasises the need to specify the actual site for temperature measurement in such studies and the arbitrary value of many so-called threshold measurements. Before take-off can occur during the spring the adult thrips pass through a temperature-dependent development period at the very end of hibernation, in some ways similar to the teneral period of new adults. Most of the thrips emerged from hibernation beneath bark in sunlight and usually took off a few minutes later. Temperature was the most important single factor influencing the time and proportion of the population taking off, but low light intensity sometimes prevented some insects from taking off 1–2 hours before sunset, while the

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temperature was still high enough for flight. Effects of wind speed and relative humidity on take-off are relatively unimportant. (Lewis)

Individual take-off and flight is expressed collectively as daily flight periodicity, and the degrees of dispersal for populations of many species, especially in the upper air, are associated with times of flight in relation to wind. But the relation of flight periodicity to dispersal has not been developed because techniques for measuring periodicity have been inadequate. The disk-dropping suction trap now provides the method, and an atlas for flight periodicity of many species is being compiled. This will also provide material for threshold determinations.

For example, intense flight activity at midday occurred with Chrysomelidae and Thripidae, during the day with Tenthrediniidae and Muscidae, at dusk with Chironomidae, Mycetophylidae and Staphylinidae, at night with Chrysopidae, at dawn with Psocoptera and at dusk and dawn with Drosophilidae and some Mycetophididae, and after midnight with Cynipidae. Nematocera accounted for almost half the total catch: two more families in this suborder (*Rep. Rothamst. exp. Sta.* for 1961, p. 150), the Culicidae and the Psychodidae, divided clearly into darkly pigmented daytime fliers and pale evening and night fliers. The work is being extended to more habitats and species. (Lewis and Taylor)

Vertical distribution of insects at low altitudes. Much work has been done on the distribution of insects in the air up to several hundreds or thousands of feet, and something is known about the behaviour of vertical density-gradients during the day and season. Nearer to the ground, however, take-off and landing further complicate the changes in the gradient caused by atmospheric mixing. Moreover, it is within a few feet of the ground that aerial populations begin their build-up and the reverse process of crop infestation occurs. Gradients within a few feet of the ground have been studied a little by several workers, but mostly with techniques that do not permit a quantitative analysis in terms of aerial density; density measurements are essential to assess absolute numbers taking off or alighting and to fit density gradients at different altitudes into the same diffusion system.

Consequently, 15 suction traps measuring density directly were arranged at intervals from actual ground level to 32 m (105 ft) over grass and fallow; the vertical distribution of many different insect species was measured between May and October 1962 in relation to season and weather, especially the temperature gradient and the speed and direction of the wind. Operating the traps was a full-time job, and only preliminary results are yet known. These indicate a wide range of response to atmospheric movements by different species and great differences in their vertical distribution. Thus, tipulids remain remarkably close to the ground for most of the time, whereas different Lepidoptera are differently distributed. Honeybees and social wasps travel mainly between 0·5 and 5 m, and some small as well as large insects seem to fly mainly in inversion conditions at specific and very curious heights. For example, a species of chloropid flew mainly at 14 m and a bibionid at 5–9 m. Some species showed steep gradients even in the first few inches above the ground;

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others seemed prone to a more even distribution up to many feet. These differences are to some extent associated with times of flight, whose study is described in the previous section; but the tendency of a species to become generally involved in air currents or to fly at times and in a manner either to encounter or to avoid them should be shown by the full analysis. Changes in the gradient associated with deposition should also be revealed. (Taylor)

The physiology of aphid flight. One of the most interesting and generally significant facts about aphid flight is the relation of the duration of flight to the strength of the settling response and to host acceptance. Parturition, which follows, and the onset of flight-muscle autolysis also depends on a flight having been made. These matters are now being studied in as many aphid species as possible, for the relation of migratory flight to settling is important not only in aphid biology but also in virus transmission (see p. 163).

Two interesting species studied during the year were the root-feeding aphids *Rhopalosiphoninus staphyleae* (Koch) and *R. latysiphon* Davidson, which often occur in large numbers on clamped mangolds and potatoes respectively, but whose alatae are, for unknown reasons, rarely caught on flight traps except sometimes very close to the clamps. Little is known therefore about flight and the process of infestation by alatae. When colonies of *R. staphyleae* are kept on sugar-beet plants and *R. latysiphon* on sprouting potato tubers at 20° the alatae become flight mature within 24 hours of moulting. Like many other aphids, they do not settle, feed or reproduce until either they have flown a short time or fasted for several hours. Both species take-off and fly above 17° in the positively phototactic manner common to most aphids. When flight-mature alatae are kept in darkness, as they would be inside a clamp, they wander over the food plants for a day or two, probing and feeding before they finally settle; they then give birth to only slightly fewer nymphs in the first week of adult life than do flown alatae. Flight-muscle autolysis occurs in females of both species, but not so soon as in *A. fabae*, and some individuals that had flown and settled still had intact muscles after 10–12 days at 15°; autolysis then occurred, and although aphids kept on food plants in darkness retained the ability to fly longer than did flown ones, none was seen to fly after 10 days. The possibility that many of the aphids in clamps lose the ability to fly before they emerge into daylight is obvious and now has to be investigated.

Flight-muscle autolysis was observed for the first time also on viviparous species of *Hyalopterus pruni*, *Cavariella aegopodii* and *Aulacorthum solani*. (Cockbain)

Insect migration records. Most migrant Lepidoptera were uncommon in 1962. The earliest immigrants arrived late, possibly because of the late spring, and populations of many species remained very small. This was particularly true of *Colias crocea* Fourc. (the Clouded Yellow) and *Macroglossum stellatarum* L. (the Humming Bird Hawk-moth); *Vanessa atalanta* L. (the Red Admiral) did, at least partially, recover and *Vanessa cardui* L. (the Painted Lady) was seen more frequently than for some years.

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Plusia gamma L. (the Silver Y Moth) was not common until the end of the summer, and an immigration of *Herse convolvuli* L. (the Convolvulus Hawk-moth) probably occurred as late as September.

Among the rarer migrants *Laphygma exigua* Hübn (the Small Mottled Willow) was the only noteworthy species, with more records than ever before. It arrived quite suddenly, in unprecedented numbers, in south and south-east England on 6 May, probably in association with *Nomophila noctuella* Schiff. (the Rush Veneer), and bred successfully to give increased numbers later in the summer. This is the second year that one of the rare immigrants has arrived *en masse*; in 1961 it was *Utetheisa pulchella* L. (the Crimson Speckled). With the assistance of the Meteorological Office, it is hoped to demonstrate an association of these events with the meteorological conditions and wind trajectories, and to determine why the time of arrival is so clear-cut, and possibly the source of the immigrants. (French)

An insect flight chamber. Insects migrate particularly when the gonads, at least in females, are not fully developed; settling responses associated with host selection and oviposition are also bound up with internal physiological changes. A study of flight and the responses associated with it in relation to the physiological state of the insect has been hampered by the difficulties of flying insects freely under controlled conditions. Workers in other institutes have achieved this with aphids in specially constructed flight chambers, and the results are of great significance to migration studies generally. Aphids, however, are very slow fliers and are particularly suitable for this work; to induce more rapid fliers, such as moths or flies, to fly freely in a controlled air stream is more difficult, perhaps even impossible. Nevertheless, a new and more versatile type of flight chamber is being constructed in an attempt to achieve this. (Lewis)

Transmission of Viruses in Relation to the Behaviour and Physiology of Aphids

Factors affecting the transmission of non-persistent viruses by *Aphis fabae* and *Myzus persicae* continue to be studied in the laboratory. Alate *M. persicae* are generally better vectors of pea mosaic and sugar-beet mosaic viruses than are alate *A. fabae*, but this appears to be more associated with differences in their probing and settling behaviour than with differences in their intrinsic ability to transmit the viruses. Thus, new unflown alate *A. fabae*, unlike *M. persicae*, rarely probed when kept for short periods (*c.* 5 minutes) on infected broad beans or sugar-beet plants; therefore few, if any, acquired virus. However, after short periods of tethered flights *A. fabae* probed plants as readily as *M. persicae*, and there was then little difference in their infectivity.

Many alatae of *M. persicae*, but very few of *A. fabae*, transmitted pea-mosaic virus after flying from infected plants on which they had developed or became flight-mature. Alatae of neither species were infective when they withdrew their stylets after a long feed, but both probed briefly before flying, and it was then that the virus was acquired, but mostly by *M. persicae* and hardly at all by *A. fabae*. Separate observations showed that

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about twice as many *M. persicae* as *A. fabae* probed for 15–90 seconds (optimum time for virus acquisition); this may account for some of the difference in their infectivity.

After a short feed on infected plants the infectivity of flying (tethered) and fasting alatae, and also of fasting apterae, decreased at similar rates. The rate increased with increasing temperatures, and few aphids transmitted pea-mosaic virus after flying or fasting for 30 minutes at temperatures above 30°. By contrast, the persistence of sugar-beet yellows virus in fasting apterae of *M. persicae* was little affected by temperatures of between 1° and 30° during a fasting period of 30 minutes.

The species of host plant on which aphids were reared did not affect their ability to transmit viruses. Apterae of *A. fabae* from sugar beet transmitted pea-mosaic virus as efficiently as did aphids from broad beans, and apterae of *M. persicae* from broad beans transmitted sugar-beet mosaic virus as efficiently as did those from sugar beet. Flown alatae of both species were better vectors of these viruses than were fasted apterae, but apterae were the better vectors of henbane mosaic virus in tobacco. (Cockbain, with Gibbs and Heathcote, Plant Pathology Department)

Ecology and Dispersal of Frit Fly

The study of the relative abundance of *Oscinella frit* L. in grassland and oats for the three generations during the year and how the populations produced in grassland invade oats, and vice versa, was ended, at least temporarily. There are two aspects of this problem: the factors governing the size of the populations and those governing movement. The population levels have been measured, but most analysis has been of mechanisms of dispersal.

In 1961 three vertical profiles of aerial density over oats up to 8 m (27·5 ft) showed shallow profiles for the panicle generation indicating its proneness to high-altitude dispersal already demonstrated with catches up to 320 m (1,000 ft) (*Rep. Rothamst. exp. Sta.* for 1961, p. 155). The profiles for overwintering and tiller generations, however, were rather different. In 1962 the extensive series of traps up to 32 m (105 ft) over grass and fallow showed that during the same period as in 1961, and with very constant weather, the profiles above 2·5 m (8 ft) were not only remarkably constant and well defined but also of a shape indicating that, throughout the period May to October, frit fly of all generations become dispersed by atmospheric motion. (French)

With the panicle generation at least, daily changes in numbers in the air over an oat crop, mostly emigrants leaving the crop, are not significantly correlated with either daily temperature or rainfall, but very highly correlated with numbers emerging. Thus, as with aphids, these insects are not only adapted for high-altitude flight as a normal means of dispersal but, like them, the variation in numbers flying is more closely related to their production in the habitat than to any vagaries of behaviour caused by the weather. Indeed, moderately strong winds which might be thought to suppress flight did not do so effectively, for there was a *positive* correlation of numbers airborne with wind speed. (Calnaido)

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The Ecology of the Cabbage Whitefly (*Aleyrodes brassicae* Walk.)

The main aim of this work is to measure the population changes of this insect during the year and to relate them to its dispersal. For this the relation of speed of development to temperature changes must be determined; the process of dispersal depends not only on the numbers of insects produced (and they are increased when generations succeed each other quickly at high temperatures) but also on the rate at which adult females mature sexually, for this affects the powers of flight.

The period from egg to adult was measured at several temperatures between 14·5° and 27·5°; at these two extremes mean values were 48·8 and 18 days respectively. From these measurements the speed of development at various temperatures corresponding to those in the field were calculated. The estimated numbers of generations for 1960, 1961 and 1962 were 3, 4 and 3 respectively.

The rate of sexual maturation of the adult females is shown in the length of the preoviposition period: the mean values for this at 25°, 20°, 15° and 10° were 0·8, 1·4, 3·2 and 6·4 days respectively. Below 8·5° there was neither ovary development nor oviposition by insects collected from fields (as pupae) in August 1962.

Weather affects flight behaviour of autumn and summer populations differently. In summer a definite light threshold for flight occurs, so that flight ceases in the evening even when it is still warm enough for flying; autumn flights, however, are not so inhibited, and when temperatures are high enough some of the insects also fly at night.

Differences in sexual development between summer and autumn populations also affect flight. Suction traps caught most insects in autumn, and this was when dispersal was most widespread, which is not only because insects are more abundant but also because individuals appear to fly for a longer time. In autumn the preoviposition period is much longer than in summer, and 97% of newly emerging females were sexually immature. This evidently enables them to fly for a much longer time than the summer ones do before settling down to lay eggs, so accounting for the mass migrations commonly seen at this time of year; this is significant in insect migration generally, and is now being studied. (El Khidir)

Growth and Reproduction in *Aphis fabae* in Relation to the Amount of Plant Sap Ingested

The food requirements of aphids and the efficiency with which they use sap from plants partly determines both their success as species and the damage they do as their colonies grow. Yet the basic element in this, the amount of sap required by a growing and reproducing aphid, has only recently been assessed. The last report (*Rep. Rothamst. exp. Sta.* for 1961, p. 152) described how the amount of sap taken in, and the amount of excreta produced by *A. fabae*, fed on beans at 20°, were being measured. This has now been done from birth, through to adulthood and on during reproductive life till death. A balance sheet shows that the adult ingests about nine times more food during its life than the larva does as it grows,

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and that a single adult during its life extracts an average of 36 mg of sap from the plant. Only about 3 mg of this is used as food to produce new aphids, and the rest (91%) is excreted as honeydew.

This gives a baseline for further analysis of aphid growth and also for the loss of growth and yield of host plants in relation to feeding and increase of colony size. The values of different parts of plants and of different plants to the aphid will also be assessed against this. (Banks and Macaulay)

The Ecology of Insect Predators of Aphids and its Relation to Crop Growth

Insect predators of aphids feed not only on species that are pests of crops but also on many other kinds of aphids. Consequently, the number of predators is influenced by the general abundance of aphids, many of which live on weeds and in the woodland and hedgerows, which are also over-wintering quarters of predators. Many predators spend much of their lives in habitats other than agricultural crops, as, indeed, do many pest aphids. Both the aphids and the predators are highly mobile and can easily and quickly change their localities.

A study of the ecology of predators in habitats other than those of obvious importance to agricultural crops is therefore essential for an understanding of factors affecting their general abundance and their presence on crops. This was done with suction traps in copses and weed patches at different sites on the Rothamsted Farm from March to October 1962. The times of arrival and changes in abundance of aphids and their predators on a bean plot were also assessed. The results show in a striking way how apparently innocent insects can greatly influence yield of crops and how important it is to study not only the pest species but also the ecosystem of which they are a part. For example, the ant, *Lasius niger*, drives many predators away from the aphids it attends, and so protects them from attack. In a field experiment on bean plants infested with *A. fabae*, but without ants, predators established themselves earlier than on similar plants with ants; the aphids were less numerous and reached a maximum density later on ant-free than on ant-visited plants. Where ants attended, and so protected the aphids, the yield averaged 8 bean seeds/plant; without ants and where predators had free rein it was 17 bean seeds/plant, and on plants kept free from aphids, 50 bean seeds/plant. Both the presence of ants and the time of arrival and attack of aphid colonies by predators is very important. Predators appeared in the following order: Coccinellidae, Syrphidae, Chamaemyidae, Cecidomyidae, Chrysopidae and Anthocoridae. This is a nicely balanced system and must be studied as a whole. (Banks and Macaulay)

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