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Nematology Department

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flights, and most of the insects fly only from the old lower leaves on which they emerged to new, young leaves on the same crop, and often even on the same plant, where they settle and lay eggs.

In the late autumn, however, very large mass flights occur, which take clouds of insects away from the crop. These flights, which appear to be far larger than the number of newly emerged adults, are probably composed partly of adults prevented from laying a full complement of eggs by low temperatures which are not too low to stop flight. (Imam El Khidir.)

ECOLOGY OF THE FRIT FLY, (*OSGINELLA FRIT*, L.)

To check frit fly populations on oats, insecticide is applied to young plants in the tiller stage early in spring, so as to kill larvae hatched from eggs laid by adults then invading the crop. Early sowing also allows plants to grow beyond their most susceptible stage before this attack begins, but a second generation of adults from grassland and oat tillers in early July lays eggs in the developing oat panicles, and larvae from these eggs attack the grain.

Control by insecticides might be improved if more was known about the source of adults ovipositing in oat panicles, and this is being sought by studying the factors influencing sizes of populations on grassland, movement to oats, the build-up there and the return to grasses.

Trapping of frit fly over spring oats, begun in 1960, continued at the same site in 1961; peak catches of adults of the three generations during 1961 were on 13 May (11 June 1960) 5 July (4 July 1960) and 19 August (23 August 1960). The peaks for the second and third generations were at the same times in both years, but the important spring generation was a month earlier in 1961, and reasons for this were sought.

Far fewer frit fly adults attacked oat tillers in 1961 than in 1960, a difference attributable partly to a higher mortality of the overwintering generation on oats. Half of the larvae and three-quarters of the pupae of frit-infested winter oats died. However, the populations on grassland near the oats did not differ greatly in the two years, and the smaller attack on oat tillers in 1961 was partly attributable to cold weather depressing migration from the grasses.

Hourly suction-trap catches show that the threshold for take-off is about 16°, but the evening flight stops while temperatures are above 16° because light becomes the limiting factor. (Calnaido, French and Bull.)

Oats become infested in spring by frit flies migrating from grassland, but whether from near or far is uncertain. Also, adults which emerge from oat panicles in August return to grasses, but again flight habits and distances flown are unknown. Neither is it clear whether adults from oat tillers infest the panicles on the same crop or whether they come from elsewhere. Analysis of catches at Cardington up to 1,000 feet in the air go some way to show how frit fly migrate. In August the flies of the panicle generation reach a peak of aerial density in the morning, when turbulence and convection are greatest, and, swept up high into the sky, 50% of the aerial population occurs above 1,300 feet. The daily dispersal finishes by late

way, some aphids still transmitted the viruses to healthy plants after they had had tethered flights of 4 hours at 25°, but the number that transmitted decreased with increasing duration of flight. This suggests that even these non-persistent viruses may occasionally be transmitted after natural flights of many miles. However, this is much more likely with sugar-beet yellows virus, with which ability to transmit was unaffected by a 4-hour flight; the ability was lost before the wing muscles autolysed (3–6 days) by aphids fed on healthy plants between daily flights of 15 minutes each. (Cockbain, with Gibbs and Heathcote, Plant Pathology Department.)

THE ECOLOGY OF THE CABBAGE WHITEFLY (*ALEYRODES BRASSICAE* WALK.)

To find the relations between the whitefly populations developing on crops and the amount of movement, individually and collectively, within and beyond the crops by flight, adults were counted on the leaves of a kale crop, suction traps were operated above the crop, and the rate clean plants sited at different distances away from the crop became infested was measured. Temperature is a principal factor controlling the rate individuals mature, the rate the populations increases and their flight. The effects of temperature will be studied at different stages of the life history.

The shortest mean incubation period of eggs was 5.9 days at 27°, and the longest mean period was 18.2 days at 14.5°. Only 4% of eggs hatched at 10°, and they took at least 34 days, and this temperature is regarded as the development-hatching threshold. Between 14.5° and 28° about 90% hatched, but above 28° mortality increased.

Although there were winged whitefly on the crop between the end of November 1960 and April 1961, no new ones emerged, and low temperatures prevented flight. Aerial populations developed from April and reached a peak on the crop when the first generation of adults emerged at the end of May. In June, when the crop was old, leaves became dry on the plants and the number flying decreased. During this time there was a gradient of insects away from the crop, and clean plants put at distances up to about 50 feet away became colonised by flying adults. Trapping over a new crop began again in August, and populations were in the air until November, when temperatures below 10° again became limiting.

Hourly catches with the suction trap showed that there is always a peak of flight during the daytime, and sometimes also a considerable peak at night. To fly by day and night is very unusual with insects. Light is not a limiting factor in the flight of whitefly, as it is with aphids, and failure to fly by night is determined by low temperature. In summer and early autumn flight peaks are determined partly by rhythms of emergence and partly by temperature-controlled variations in the teneral period before flight. As with aphids, most adults emerge in the early morning and have a teneral period of 3–10 hours at normal daytime temperatures. The time of flight is governed by temperature and also by the condition of the leaves. All newly emerged adults left the leaves on which they were born in a matter of hours, and before they laid eggs. Migration, however, and the daily (and nightly) peaks, do not involve long

suction traps, and indeed with nets and sticky traps too, corrections have been applied to assess the amount of air sampled; and density estimates have often been made from the standardised catch on the assumption that the efficiency, at least for small insects (e.g. aphids), was close to 100%. This assumption was accepted and thought to involve a serious error only with large insects. Efficiency has now been measured for all types of suction trap developed in this department; it depends on insect size, trap size and wind speed. Tables are now being published from which the catch can be converted, with a known error, to density/unit volume of air, for any of the suction traps, catching insects of almost any size, in all wind speeds likely to be relevant. (Taylor.)

From new data and from Gregory's work on spore traps (*Rep. Rothamst. exp Sta.* for 1951), the aerodynamic efficiency of sticky traps for insects was also assessed; from Johnson's work on sticky traps and tow-nets, and from additional results with a whirligig trap, the efficiencies of all these traps was also calculated and tables prepared for converting their catches to aerial densities. Most of the efficiency of the sticky traps for small insects is explained in terms of the deposition of inert particles on cylindrical surfaces. (Taylor.)

Thus the programme on design, operation and standardisation of insect traps, especially suction traps, begun in 1946, has now been completed and the work brought to an end.

THE TRANSMISSION OF VIRUSES IN RELATION TO THE BEHAVIOUR AND PHYSIOLOGY OF ALATE APHIDS

A winged aphid will not remain on a host plant unless it has made a flight, and the duration of the flight partly determines how long the aphid will remain and feed on a plant. The profound changes in alate settling responses associated with differences in flight history may, therefore, affect the spread of viruses by winged aphids in the field, and winged aphids may differ from unwinged ones in the acquisition and transmission of viruses. Tethered winged *A. fabae* and *M. persicae*, previously bred, or merely fed, on both infected and uninfected plants, were flown for various lengths of time, and their subsequent powers of acquiring and transmitting the non-persistent pea and beet mosaic viruses were studied. The loss of infectivity during flights of different duration was also assessed.

A flight of only $\frac{1}{4}$ – $\frac{1}{2}$ hour is enough to induce either of the two aphid species to settle on a new host long enough to acquire either of these viruses, and longer flights rarely increased the number of aphids in a batch that became infective. However, *A. fabae* that had flown transmitted both viruses more readily than unflown ones which had been starved to induce them to feed (starvation periods shorter than 24 hours in the dark did not induce settling in the light). Starved *M. persicae* were more prone than starved *A. fabae* to probe before flight.

No *A. fabae* and only few *M. persicae* reared on infected plants transmitted virus to healthy plants when transferred to them before or after they had flown. After flying, a brief feeding period on an infected plant made both species infective. Made infective in this

and so to colonise different hosts. (Taylor, with Dr. V. Eastop of the British Museum (Natural History).)

Aphid feeding and excretion

The growth and reproduction of aphids depends on the efficiency with which they use the host plant as a source of food; an understanding of resistance and susceptibility of plants to aphid attack and the way in which viruses are acquired and transmitted also demands a knowledge of how food is ingested. The measurement of feeding rates and the factors which affect it are therefore significant in the general context of aphid biology as studied in this department. Such measurements can be made directly, using radioisotopes or (such is the speed at which food is taken and passed through the gut) by measuring the rates at which honeydew is secreted. These excretion rates are now being studied in *A. fabae*. The number of honeydew drops excreted by aphids from birth to death are counted by catching them on moving bands of indicator papers. Their volumes are measured from time to time, from the diameter of droplets collected in mineral oil. Thus the rate of imbibing food can be related to the growth and reproduction of the insects, and their efficiency in using the host can be assessed. (Banks.)

AGGREGATION IN INSECT POPULATIONS

A power law relating the variance to the mean, which gives an index measuring the degree of aggregation in different-sized populations, was described last year. Ideal material to test these degrees of aggregation (using this method) and the way in which they may be related to development, reproduction, behaviour and environmental factors is the long series of records of the numbers of wheat-midge larvae in wheat blossoms, collected for 35 years by the late H. F. Barnes. This material is now being analysed. An essential first stage in this, and indeed in the analysis of many samples, is the use of the appropriate transformation; power-law transformation tables for this purpose are being prepared. (Taylor, with Healy, Statistics Department.)

THE EFFICIENCY OF INSECT TRAPS

One of the major efforts of this department has been to rationalise and to standardise insect trapping. Before the suction trap, catches were rarely related to a spatial dimension of the environment; numbers caught from time to time were related only to themselves as a series. Suction traps relate the catch to a volume of air sampled and thus assess aerial density, which is an absolute measure related to a size dimension of the environment. There were three stages in this development: the empirical design of traps, the standardisation of the amount of air sampled in different wind speeds and the measurement of trap efficiency.

The most efficient trap is not the one which catches the most insects, but the trap which allows fewest insects to escape from the sample of air as it is taken in; it is therefore the trap with the smallest error in making the density estimate. Hitherto, with

when alighting in different circumstances, and on the subsequent movement of newly arrived migrants in the crop. (Taylor.)

Field experiments were also made to see whether the incidence of pea-leaf-roll virus in different bean varieties was associated with different degrees of infestation by the aphids, *A. fabae* and *A. pisum*. The degree of primary aphid infestation of seven bean varieties (Granta, Strubes, Tick 30b, Albyn Tick, Spring Tick, Minor and Metz Frey) did not differ greatly and was not related to the ultimate incidence of the virus. (Taylor with Gibbs, Plant Pathology Department.)

The physiology of aphid flight

Variation in flight thresholds and flight durations of *A. fabae* in relation to changes in temperature, humidity and fuel consumption, and the effects of prolonged flights on subsequent behaviour, reproduction and survival have already been closely studied (*Rep. Rothamst. exp. Sta.* for 1959, p. 139 and, 1960, p. 162). Similar work is now in progress with *Myzus persicae*. *M. persicae* can fly for up to 16 hours non-stop in a fixed position; the factors affecting flight prolongation are being analysed, together with their relation to settling behaviour and subsequent parturition and larval production. (Cockbain.)

Insect immigration records

Numbers of immigrant Lepidoptera were well below the average in 1961, except for six species. Very few migrants were seen in the first half of the year; the Painted Lady (*Vanessa cardui* L.), the Red Admiral (*Vanessa atalanta* L.) and the Clouded Yellow (*Colias crocea* F.) were scarce during the whole year. Increase in abundance of some species, especially the Silver Y (*Plusia gamma* L.), the Delicate (*Leucania vitellina* Hübn.), the White-point (*Leucania albipuncta* Schiff.), the Vestal (*Rhodometra sacraria* L.) and the Gem (*Nycterosea obstipata* Fab.) in September were presumably because of late immigration.

The outstanding immigrant of the year, the Crimson Speckled (*Utetheisa pulchella* L.), has been recorded at least twenty-nine times to date (12 January 1962) a number exceeded only once, in 1892 (forty-nine). (French.)

THE BIOLOGY OF APHIDS

Aphis fabae is a member of the "black aphid complex", which contains several closely related species and biological forms within species. Taxonomic characters and their variability have long been controversial issues and, even in one species, have not been fully studied biometrically. Bean aphids and others in this complex are now being reared on various hosts and at different temperatures, and it has been possible to change the proportions of the mouth parts of *A. fabae* by temperature treatments, so that they resemble those which distinguish *fabae* from the Tropeolum aphid (*Rep. Rothamst. exp. Sta.* for 1959, p. 138). This is not only significant taxonomically but is also related to the ability of aphids to feed successfully

Flight thresholds and flight periodicity

One of the most important factors affecting flight is its temperature threshold. Thresholds for both take-off and for sustained flight were obtained for *A. fabae* in the laboratory and field (*Rep. Rothamst. exp. Sta.* for 1959, p. 291, and 1960, p. 162). The main difficulty in estimating the flight threshold of a species from trap catches in the field has been to dissociate the variation in catch caused by behaviour, to which the threshold applies, from variation caused by changes in population level, to which it does not. For example, a zero catch could reflect a small population rather than a sub-threshold temperature.

A new method has now been developed for analysing trap catches so as to reveal flight threshold temperatures, and was applied to catches of queen wasps and species of aphids, beetles and moths; it remains to check these results against flight thresholds found experimentally in the laboratory. (Taylor.)

The degree of dispersal arising from the initial departure of insects on their migratory flights from breeding places depends largely on the time of day when most fly. When this is in the daytime the convection and turbulence of the atmosphere ensure maximum dispersal; daytime flight can be regarded as an evolved adaptation to this end, as with aphids. Crepuscular or nocturnal flight can be an adaptation to limit dispersal to times of minimum air movement. The flight periodicity of insects is, therefore, an essential part of migration studies, and is bound up with the process of crop infestation. Records of periodicity of the diffusion of insects through the upper air have already been obtained for many insect species at Cardington, and the factors controlling periodicity at the source of supply were analysed for *A. fabae* (*Rep. Rothamst. exp. Sta.* for 1956, p. 153). Other records have now been collected at eight different sites at ground level to establish typical patterns of flight periodicity for many insect groups throughout the year, and a comparative table of flight periodicities of many taxonomic groups is being made. This will illustrate factors controlling periodic flight and the likely methods of dispersal of many insects. It will be complementary to the more generalised dispersal periodicities in the upper air. A striking feature of the new results is the parallel division of at least three families of Diptera—Chironomidae, Mycetophilidae and Cecidomyidae—into two clearly defined groups of darkly pigmented daytime flyers and pale night-flying species. The Diptera is the only Order so far found which shows this evolved flexibility of periodicity. (Lewis and Taylor.)

Crop infestation by aphids

Aphids are borne on the wind to crops, but they probably alight on them only when wind-eddies carry them into shelter inside the crop. An experiment in 1961 was designed to test the mechanism of such alighting by arranging bean plants in certain patterns, with variation in spacing and plant size, in the field; the resulting patterns of infestation were studied in relation to wind speed and direction. In 1962 other experiments will supplement this work and should help in understanding the control exercised by the aphids

from counting slugs on the two halves, it is hoped to assess how populations of the three species increase by reproduction and by invasion from the margins. The effects of soil tilth on oviposition and movement of slugs are also being studied. (Stephenson.)

Soil pest control

Studies continue in collaboration with the Insecticides Department on the chemical control of wireworms by means of seed-dressings: γ -BHC, dieldrin, aldrin at standard and increased amounts were applied to winter wheat seed as liquid and spray (aldrin) and as dust combine-drilled with the seed (γ -BHC). Treatments were applied in spring 1960 soon after Claycroft was ploughed out of old grass. Counts in autumn 1960 showed that, except for liquid aldrin, all treatments had decreased the wireworm population. Effects on yield were not measured, because the unavoidably late sowing produced a poor crop. Residual effects from the insecticides applied in the spring of 1960 were detected on a crop of Cappelle wheat drilled in autumn 1960: when harvested in 1961, yields from all plots treated in spring 1960 were higher than from the untreated plots. Tests for further residual effects are being made.

Another experiment was begun to compare the effect on the wireworm population of the seed-dressings used with spring- and autumn-sown crops. Cappelle wheat treated as in the 1960 (spring) experiment was sown in November 1960; and Jufy wheat, treated with a high dose of γ -BHC and standard dieldrin, was sown in April 1961. Estimates on the autumn-sowing in the spring (1961) showed that all treatments had greatly decreased wireworm damage, although at harvest only high-dosage γ -BHC plots gave significantly higher yield than controls; however, the γ -BHC combine-drilled with the seed came close to this. There was little evidence of wireworm damage to the spring-sown wheat, but at harvest standard dieldrin-dressed seed gave significantly higher yields than the untreated. (Raw and Lofty, with Potter and Bardner, Insecticides Department.)

After last year's work on the repellent properties to slugs of dimethyl phthalate, dibutyl phthalate and of salicyl aldehyde (*Rep. Rothamst. exp. Sta.* for 1960, p. 159), further tests are being made with aldehydes of higher molecular weight, applied as seed-dressings to winter wheat.

INSECT DISPERSAL AND MIGRATION

Various aspects of the migration process, and of other forms of dispersal, with many insect species have been systematically studied for some years. With aphids, and particularly with *Aphis fabae*, the migration process was studied in its three parts, namely, the rhythms of emergence and of the post-teneral flight of the alatae; vertical and horizontal dispersal or the migration flight itself; the deposition of aerial populations and the infestation of new habitats, including crops. Various studies under these headings now proceed with many insects besides aphids.

relatively even temperatures and the unfavourable underlying layers, which were either sand or clay.

The life histories of some oribatid mites were also studied. There may be one generation annually, as in *Platynothrus peltifer* (Koch.), *Achipteria nitens* (Nic.) and *Fuscozetes fuscipes* (Koch.), two, as in *Tectocephus velatus* (Mich.) and *Nanhermannia nana* (Nic.), or possibly one generation in every 2 years in *Belba geniculosa* Oudms. (Madge).

Taxonomic work on the Symphyla continued, and specimens from India, Jamaica, Hawaii, Europe and the United Kingdom were studied. (Edwards.)

The biology of soil insect pests

Pests studied include lepidoptera, wireworms and slugs; and experiments on their behaviour, growth, development, fecundity and mortality in relation to environment, especially temperature, help in analysing the causes of outbreaks.

Laboratory and insectary studies of British cutworms aim to show how temperature affects the speed at which eggs and larvae develop and how different food plants affect growth of larvae of the Large Yellow Underwing (*Tryphaena pronuba* (L.)). The reactions of the larvae to light are particularly interesting. Like many other newly emerged insects, first instar larvae show strong positive phototaxis, a reaction which is reversed as the larvae enter later instars, when there is also a nocturnal feeding rhythm related to this, for larvae emerge from the soil only in the evening. The way these reactions are affected by temperature and humidity changes are also being studied. (Madge.)

Experiments continue on the effect of temperature on the speed of development of wireworms (Raw) and on the temperatures needed to complete the life histories of the Ghost Swift Moth (*Hepialus humuli* L.). Larvae of the Ghost Swift pupated when kept at 10°, 15° and out of doors; but those kept at 20° continued to grow and to moult. This indicates that the life cycle is usually completed in one season, but that sometimes it may be extended into the next. Adults of this insect and a related species, *H. lupulinus* (L.) (The Garden Swift Moth), were also caught in light traps as part of a general biological study of these insects. Fewer were caught and over a longer period than in 1960. Eventually larval and adult biology will, no doubt, be correlated. (Edwards.)

Slug biology

The movements of slugs, particularly the rate and manner in which they invade crops, are little understood, and an experiment is being made with three pest species (*Arion hortensis*, *Agrolimax reticulatus* and *Milax budapestensis*). A small garden plot with wide grass margins, on which the three species are prevalent, was cultivated and weeded all the spring and summer, so decreasing the slug population except on the grass margins, where it remained steady. Iron plates were driven 15 inches into the ground all round one-half of the plot on the inside of the grass margin, and the whole plot was planted with winter wheat. From the amount of slug damage and