ROTHAMSTED RESEARCH

Rothamsted Report for 1936

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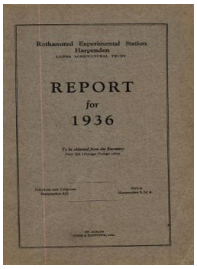

Entomological Department, 1915-1936

Rothamsted Research

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low vapour pressure, and that ammonia vapour although useful for deinfesting utensils was highly toxic to fungi. Pyridine above certain concentrations was toxic to cultures of fungi (*Aspergillus niger*) and this could not be explained by an alteration in *p*H value of the culture medium. The effect however was purely inhibitory and on neutralising the free pyridine with acid, the growth of the cultures proceeded normally. Pyridine seemed to have a specific toxic effect to the mites *Tyroglyphus longior* and *Aleurobius farinae.*

Miscellaneous investigations. The immunity to wart disease of certain varieties of potatoes led Roach(48) to explore this field by means of a delicate grafting technique developed by him. All the eight possible types of plants were built up by grafting together root, shoot and tuber systems from either immune or susceptible plants. In none of the experiments was the reaction of the tubers to wart disease changed. The field was thus narrowed since immunity or susceptibility could not be referred to a factor capable of being translocated and Roach suggested that the examination of the proteins by immuno-chemical methods presented a hopeful line of attack. An attempt to follow up this suggestion led to the elaboration of an anaerobic wet grinding apparatus(49) by which means a labile blue compound occurring in certain varieties of potato was observed for the first time.(50) The apparatus presented a number of possibilities; besides the examination of the plant constituents unstable in air, separation of cell-wall material for chemical examination and the estimation of starch content of potato tubers by mechanical means seem feasible by its means.

Roach's technique was applied by him to the grafting of plants upon foreign root-stocks,(51) thus when woody nightshade, (*Solanum Dulcamara*) was grafted on potato (*S. tuberosum*), growth was stimulated and the nightshade attained twice the weight it did on its own roots. Lupin grafted on broad bean was of greater girth and height than when grown on its own roots. In reciprocal grafts the root stock was dwarfing in its effect.

THE WORK OF THE ENTOMOLOGICAL DEPARTMENT AT ROTHAMSTED 1915-1936

By C. B. Williams and Staff

This report is divided into the following sections :—Introductory, Soil insects, Parasites and biological control, Aphid problems, Chemical relationship between insects and plants, Tropic reactions, Relation of insects to climate, Population studies, Studies on Cecidomyidae, Studies on species of economic importance, Migrations and aggregations of insects, Insect morphology, Miscellaneous activities.

At the end of each section a bibliography is given.

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(49) W. A. Roach. Biochem. Journ., (1925), XIX, 783.
(50) W. A. Roach. Annals of Botany, (1925), XXXIX, 883.
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Introductory

The first Entomological work at Rothamsted started during the Great War when in 1915 H. Eltringham made investigations on the prevalence of the larvae of the common House fly (*Musca domestica*) in farm manure heaps (Publication No. 161). The next problem of an entomological nature, also arising out of the war situation, was that of wireworms in recently ploughed land, and early in 1916 A. W. Rymer Roberts was appointed by the Ministry of Agriculture to work in the " Protozoological " Department at Rothamsted on this question.

In 1918 Dr. A. D. Imms was appointed in charge of the new Entomological department and later J. Davidson (1920-1928) and H. M. Morris (1920-1927) were appointed as assistant entomologists. When Morris left H. F. Barnes was appointed in his place ; and when Davidson left Barnes was promoted and H. C. F. Newton (1929-1935) was appointed to the junior position.

In 1932 Imms, who had recently been elected a Fellow of the Royal Society, left to take up an appointment at Cambridge and in 1933 he was replaced by Dr. C. B. Williams. Newton left in January 1935 and was followed by A. C. Evans.

During the period covered by this report a large number of temporary visitors, research students, Ministry of Agriculture Scholars, and men working on special grants, have studied in the department and these will be referred to in the sections dealing with their work.

The Beekeeping research is part of the Entomological Department, but a separate report on the work on this subject was issued in the last Rothamsted Annual Report for 1935 (pp. 60-66).

Up till 1924 the Department was housed in a room in the old building, but in that year the new laboratory was completed and the Department took over its present accommodation.

Soil Insects

The beginning of the Entomological Department at Rothamsted was largely due to the demand for an increased knowledge of soil insects, and particularly of wireworms, following on the ploughing up of large areas of grassland during the war.

The earliest work was done by A. W. Rymer Roberts who in 1916 studied the biology of *Agriotes obscurus* and made morphological observations on the larvae of *Agriotes sputator* and *Athous haemorrhoidalis*. In collaboration with Dr. Tattersfield, Head of the Department of Insecticides, the toxicity of a number of compounds to wireworms was tested.

Morris in 1921 devised an apparatus for separating the insects and other fauna from the soil. It consisted of a series of sieves of diminishing mesh through which the soil was washed by a strong stream of water. The residue in each sieve had to be examined for insects, but most of them were retained by the bottom sieve which had 50 meshes to the inch. From his examinations Morris calculated that there were in the " dunged " plot on Broadbalk about 15.1 million invertebrates (arthropods and millipedes, etc., not, of course, protozoa) per acre, of which 7.72 million were insects. On

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the untreated plots the figures were 4.95 million total, of which 2.4 million were insects. He found that the bulk of the total were in the top three inches of the soil, but the greatest number of the wireworms (Elaterid larvae) were found at a depth of from 5 to 7 inches. Artificial manures were found to have very little effect on the soil fauna, but dung increased both the number of individuals and the number of species.

Little more was done on soil insects after the departure of Morris until the arrival of W. R. S. Ladell in 1935. Ladell developed a much more efficient technique for separating the insects, etc., from the soil by a modified " flotation " process. A sample of 4 to 8 lbs. of soil is stirred up in a container in a strong solution of magnesium sulphate (s.g.1.11) through which a fine stream of air bubbles is continually rising to the top. The insects, which are all lighter than the solution, rise to the top and are slid off on the froth into a settling chamber and then on to a filter paper. The magnesium sulphate is cheap, flocculates any clay in the soil, and is so little toxic that insects removed in the egg stage by this method can be hatched out and bred.

The figures obtained by this technique are very much larger than those found by Morris' method. For example, the Broadbalk plots previously mentioned give the following figures in millions per acre by Ladell's apparatus :

	Total Invertebrates	Insects only.
Manured	84.6	69.3
Unmanured	38.2	33.5

These figures are nearly ten times Morris' values.

Using Ladell's method K. D. Baweja has examined 300 samples of soils in 14 months and the maximum number obtained indicated a population of 486 millions soil animals per acre, including 475 million insects, of which the majority are Collembola.

Baweja has been following the return of the fauna to soil completely sterilised by heating to 212°F. He used plots 9 x 9 feet and took the samples from an inner square of 7 x 7 feet. Four plots were sterilised to the depth of 12 inches in February and four in May. Two of each lot were isolated by a barrier to a depth of 12 inches from the surrounding ground, so that recolonisation was only possible from above and below.

His results briefly stated are :

(1) that the time taken for the sterilised plots to build up a population equal to the control averaged seven months in the case of the unenclosed plots and five months in the case of the enclosed, for both times of sterilisation.

(2) The return of the insects was more rapid than that of any other group.

(3) Collembola and Diptera predominated, with Coleoptera and Hemiptera next in importance.

(4) Both sterilised and control plots showed a peak of population in late autumn (October and November).

Ladell has carried out a series of field experiments on the effect of insecticides on wireworms and has shown that modern lay-out of plots and statistical analysis can be applied to this type of work and

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that the sampling error and experimental error can be reduced sufficiently to detect real differences between the effect of the fumigants on the wireworm population.

Ladell has also extended his plot technique to include a study of the oat eelworm (*Heterodera schachtii*) and has found that by a proper system of sampling it is possible to get an adequate indication of the effective infestation of the soil by eelworms. He has also shown a definite relation between the soil infestation and previous and subsequent plant injury, and has demonstrated significant differences between the cyst population of the soil before and after insecticide treatment.

Barnes, as a preliminary to including *Tipula paludosa* in his population studies (see p. 110), has found a simple method for breeding these insects from the egg to the third larval instar. Arising from this work Miss C. B. J. Lovibond has been appointed by the Bingley Research Station to work at Rothamsted on leather-jackets.

Soil Insects

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Parasites and Biological Control

Shortly after the war investigations were started at Rothamsted, at the request of the Imperial Bureau of Entomology, on parasites of Earwigs, with a view to shipping them to New Zealand where the earwig had become a great plague. The early work was carried out by A. M. Altson who in 1924-25 studied two Tachinid parasites *Digonochaeta setipennis* and *Racodineura antiqua*, solved their curious life histories and learned how to breed them in some numbers.

Consignments of *Digonochaeta setipennis* were shipped to New Zealand and also a smaller number to Hawaii, which country was visited in 1925 by Dr. Imms on a special mission to study the methods of biological control used so successfully in these islands.

In 1927 the work at Rothamsted was extended, by means of a grant from the Empire Marketing Board, to a study of the insect enemies of certain weeds. This investigation was carried out in co-operation with the New Zealand Government, and in January

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W. M. Davies was appointed in charge of the work under the direction of Dr. Imms at Rothamsted, in conjunction with Dr. Tillyard of the Cawthron Institute in New Zealand.

In the autumn of 1927 Davies resigned on his appointment as advisory entomologist in the North Wales province and H.C.F. Newton was appointed in his place. Newton continued this work until 1929 when it was transferred to Farnham Royal.

A long list of weeds, considered dangerous in New Zealand, was submitted, including Gorse, Ragwort, Blackberry, Foxglove, Convolvulus, Bracken, Dock, Nettle, etc. Attention was directed to the first three in particular. In the case of gorse the prevention of spread rather than eradication was the first aim and a weevil *Apion ulicis*, which prevents seed formation, was chosen. On the other hand in the blackberry total eradication was hoped for and experiments were made with a Buprestid beetle, *Coraebus rubi*, which kills the whole plant by burrowing in the base of the stem.

The chief insects feeding on Ragwort in this country are the larvae of *Tyria jacobaeae* (Lepid : Arctiidae), of *Homeosoma* spp. (Lepid: Phycitidae), flea beetles of the genus *Longitarsus* and the fly *Phorbia senecionella*. *Homeosoma* and the *Longitarsus* beetle were studied but the major part of the work concerned *Tyria*. The breeding of this moth was at first carried out in the insectary, but a sudden request for 100,000 pupae in the summer of 1928 necessitated other methods being found. Ovipositing females and eggs were collected in large numbers, but this also proved insufficient, so in the late summer an attempt was made to collect pupae from the actual breeding ground in the Brecklands district of S.W. Norfolk. This method was soon found to be a practical way of obtaining large numbers and in a short time 30,000 were obtained. Many of them were parasitised and since they could not be sorted out before shipment special precautions had to be taken on receipt of the pupae in New Zealand.

As these parasites were of great economic interest they were sent to the late Dr. Waterston at the Natural History Museum who identified them as follows :

1. *Apanteles popularis* Hal.	Larval parasite.
2. *Hemiteles* sp.	Hyperparasites of 1.
3. *Dibrachys cavus* Wlk.	
4. *Mesochorus facialis* Bridg.	
5. *Melanichneumon perscrutator* Wesm.	Pupal parasites.
6. *Psycophagus omnivorus* Walk.	
7. *Coleopisthus vitripennis* Thoms.	

M. perscrutator and *C. vitripennis* had not previously been bred or recorded from this host.

The blackberry problem presented greater difficulties owing to the close relation of the blackberry to many cultivated plants. In fact the insect finally chosen was a serious pest of roses in the South of France, but in spite of this it was considered sufficiently hopeful to justify the risk. Several journeys were made by Newton to the Riviera to collect larvae in the affected Rose stems and these were brought back to Rothamsted under special permit from the Ministry of Agriculture. As difficulty was experienced with this

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insect in New Zealand arrangements were finally made to ship living infected brambles. Great assistance in this part of the work was received from the staff of the " Station de Zoologique Agricole " first at Mentone and later at Antibes.

In the case of the gorse, the weevil *Apion ulicis* was collected from many parts of Great Britain and in some cases as high as 90 per cent. of the seed was found to be destroyed. Tests were made with this insect but it could not be found to attack any of the cultivated species of Leguminosae.

Nearly forty-six thousand weevils were shipped to New Zealand in cool storage (34-38°F) chiefly in damp sterilised sphagnum.

Of the other species discussed the shipments were :

Tyria jacobaeae 17,000 pupae and 20,000 eggs
Coraebus rubi 11 boxes
and smaller consignments of *Vanessa urticae*, and *Chrysophanus phloeas*.

In the spring of 1929 this Biological Control work was handed over to the Imperial Institute of Entomology, who had by now started their own parasite breeding laboratories at Farnham Royal.

During this period investigations had also been carried out on parasites of Frit Fly by Imms, and on a Phorid parasite of Bibionid flies by Morris. Imms also published several papers on general problems of biological control.

In 1933 U. S. Sharga in a short visit to Rothamsted found the Thysanopteron *Aptinothrips rufus* to be common on most of the experimental plots of grass in " Park Plots," and to be infected by an internal parasitic nematode *Anguillulina aptini*. He noted that the percentage of parasitism by the nematode was very much higher on some plots than on others, and in particular that parasitism was very high on a limed plot and very low on the corresponding unlimed plot, which apart from this difference had had identical manurial treatment.

Miss A. M. Lysaght investigated the problem more thoroughly (1934-36) and found that, while the difference in parasitism in the above mentioned plots was confirmed, in other plots intermediate figures were found and that the lime relation alone was insufficient to account for the difference. It seems more likely that the difference is due to the composition of the vegetation and is possibly associated with the amount of *Holcus lanatus* (Yorkshire Fog).

PARASITES AND BIOLOGICAL CONTROL

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Aphid Problems

In 1920 Davidson commenced a series of studies on the biology of *Aphis rumicis*, the bean Aphis. He made a detailed description of the several types of individual, both sexual and parthenogenetic. This species over-winters in the egg stage on the Spindle Tree, and the eggs hatch in spring, developing into " fundatrices " which give rise parthenogenetically to either winged and wingless forms or to the latter only. The winged forms fly to the summer host plant (of which 85 species are mentioned by Davidson in his " List of British Aphides ") and then give rise either to apterous forms which stay on that plant or to winged forms which may fly to other summer hosts. At the end of summer certain winged forms, morphologically indistinguishable from the ordinary winged forms but physiologically specialised, return to the winter host and then produce apterous sexual females. At the same time winged males appear on the summer host plant, fly to the winter host and fertilise the females. Several overwintering eggs are then produced by the sexual females. During mild winters it is possible for the agamic forms to survive. The appearance of the sexual forms appears to be caused by climatic factors and especially by the shortening days.

The rate of reproduction on different hosts was shown to be widely different. Broad beans, mangolds and beet permitted rapid reproduction ; the spindle tree, dock and poppy were not very suitable ; while on dwarf french-beans the rate of reproduction only about balanced the death rate.

Some evidence was produced that the rate of reproduction on a new host plant might be affected by the previous host plant of an individual.

The rate of reproduction was studied on eighteen varieties of *Vicia faba* and on *V. narbonensis*. It was found that the hosts could be divided into seven classes on a basis of susceptibility. Taking the variety which gave a maximum rate of reproduction as 100 the following degrees were found : 100 : 98 : 71 : 55 : 39 : 27 and 3.

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The latter figure applied to *V. narbonensis* which most nearly represents the wild prototype of the modern varieties.

Conditions of growth of the host plant also affected the rate of reproduction, as did the age of the plant, the manurial value of the soil, the soil acidity and aeration.

It was found that, in general, the rate of reproduction was higher on beans grown in sand than in soil. Increased potash and magnesium sulphate caused an increase in the rate of reproduction. Plants six weeks older than controls gave a marked decrease.

The source of food supply was studied and it was found to be chiefly in the phloem, although the cortex mesophyll cells may be tapped in cases of heavy infestation.

C. T. Gimingham studied the "egg burster" of several species of aphids. This organ is a heavily chitinised sawlike ridge on the head of the nymph which is left behind on hatching.

Aphid Problems

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Chemical Relationship between Insects and Plants

Arising out of Davidson's previous work on the bean Aphis, Davidson and Henson studied the effect on aphis infestation produced by injecting bean plants, or watering the sand in which the plants grow, with various substances. The effect of pyridine in particular was studied and it was shown that a plant could take up enough of this chemical to get rid of the aphis infestation, without itself being killed. The pyridine however affected the roots of the plant and

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interfered with its rate of growth. The mean weight of the treated plants was only 60 per cent. of the controls. No clear cut limits were found when the pyridine was lethal to the aphids but harmless to the plants.

More recently Evans has published an essay dealing with the various physiological relationships existing between plants and insects, and is now studying the relation between the chemical constitution of cabbage plants grown under various conditions and the cabbage aphis and the cabbage white butterfly. He hopes to be able eventually to interpret Davidson's results from a physiological and biochemical point of view.

CHEMICAL RELATIONSHIPS BETWEEN INSECTS AND PLANTS

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TROPIC REACTIONS OF INSECTS.

Imms and Husain carried out extensive trials with many aromatic substances in a preliminary attempt to discover the influence of various constituents in the baits extensively used by economic entomologists. Chiefly Diptera were attracted and the most successful baits were beer and molasses or a mixture of the two. Ethyl alcohol showed little or no attraction but with the addition of small amounts of butyric, valerianic or acetic acid it exercised a powerful stimulus. Aqueous solutions of the above acids were not attractive so probably the respective ethyl esters were the attractive agents.

Newton described the development and structure of the companiform sensillae occurring on the wing bases of the adult worker bee. His results did not support the conclusion of McIndoo who claimed that the actual termination of the nerve fibre is exposed to the outside air.

The function of the contact chemo-receptors in the antennae and fore-tarsi of honey bees was studied by J. T. Marshall who found that a bee responds to stimulus by extending its proboscis when the antennae comes into contact with a saccharose solution of M/12 concentration, while a concentration of M/1 is required to elicit a response from the fore-tarsus. Amputation of the antennae did not impair the normality of the bee in respect of its gustatory reactions but does result in a complete loss of olfactory recognition of the smell of comb. It was concluded that the antennae are the seat of all olfactory organs which perceive mild odours.

Marshall also published a review of literature on the location of olfactory receptors in insects.

Work is now going on in the department on the temperature and humidity preferences of insects by J. Deal, and on the chemotropic responses of soil insects by W. R. S. Ladell.

TROPIC REACTIONS OF INSECTS

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The Relation of Insects to Climate Studied by Means of Continuous Trapping.

In 1932 C. B. Williams started a series of investigations into the use of traps as a means of sampling the population of active flying insects in a given area ; and on the interpretation of the results so obtained in relation to variation in climate and weather conditions.

The investigation was carried on with the help of several workers, including G. A. Emery, P. S. Milne, J. A. Freeman, Miss J. Anderson and Mrs. K. J. Grant.

Three types of traps have been designed and tested. The first, using light as the attraction, has been in use for four years continuously. It is fitted with a mechanism that separates the catches at different periods of the night so that the time that any insect enters the trap can be found.

A second type of trap in which the insects are swept into moving nets by electric fans was tested for one summer and found to be of considerable use for the smaller insects and particularly for Aphidae. No attractive agent was used in this trap.

A third type of trap, using a bait as an attractant and killing the insects as they approach the bait by means of a 1,000 volt electric circuit, has been tested during 1936. It was found to have distinct possibilities for future work. The description of this trap is not yet published.

In connection with the examination of the large numbers of insects captured in these traps, Milne has devised a rapid method of dealing with the counting by means of a large rotating stage under a binocular microscope

On the meteorological side of the investigation two instruments have been designed, one to record the duration of bright moonlight at night, and the second (adapted from a Greenwich instrument) to record the amount of night cloud. These instruments were found necessary as both moonlight and cloud have a distinct effect on the numbers of insects caught in the trap.

The following are some of the results obtained in the analysis of the results of the four years' observations with the light trap.

(1) Two of the most important single factors in determining the size of the catch are the minimum temperature of the night and the wind.

(2) In general a rise of minimum temperature of about 4°F doubles the number of insects caught.

(3) Insects are most abundant (other factors being equal) on dead calm nights. A wind with average maximum velocity 2-5 miles per hour reduces the catch by 50%, a wind of 20 miles an hour reduces it by over 90%. These figures apply to " all insects " taken together. The larger insects alone are less sensitive.

(4) In general the catches are reduced by the presence of moonlight. The family Noctuidae of the Lepidoptera are particularly affected and in this group the catch at no moon is on an average

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three times that at full moon. No lunar effect is found in the insects which fly at dusk and dawn.

(5) The catches are higher on cloudy nights than on clear nights, but as cloudy nights have a higher minimum temperature much of the difference is due to this associated factor.

(6) Nearly all groups and species of insects have special times of night during which they are most active. In tests over four years of about sixty species of Lepidoptera, approximately 75% gave a closely similar period of maximum activity in each of the four years.

(7) In a few species investigated the two sexes have different times of flight. In the Lepidoptera the females usually appear in the trap earlier in the night than the males.

(8) The insects tend to reach their maximum activity later in the night when they are abundant than when they are scarce.

(9) In the family Noctuidae, the percentage of females is distinctly lower on an average in the common species than in the rare ones. Also within the common species this percentage is much lower on nights when the insect is common than when it is rare.

(10) In the Noctuidae a trap at a height of 3½ feet from the ground catches only a small proportion of females. On the other hand a trap at a height of about 35 feet from the ground caught a much higher proportion.

(11) It has been found essential in analytical work to deal with the geometric means of captures rather than their arithmetic mean. The simplest way of getting this result is to convert all catch values into logarithms.

(12) In the course of four years continuous use of the trap individuals of 256 species of Macro-Lepidoptera have been captured, which is 34% of all the species of these families known to have occurred in Great Britain. Similarly in the family Capsidae 57 species have been trapped, which is 32% of the known British fauna.

Relation of insects to climate

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Population Studies

A series of population studies was initiated in 1927 by Barnes. These are essentially field studies supported by insectary rearings and have their foundations on an accurate knowledge of the biologies of the insects in question. They were intended to collect information regarding the fluctuations in degree of infestation of the crop, the extent of parasitism and the dates of emergence, as well as in numbers from year to year of various insect pests. Their design has been such as to enable them to become routine studies which could be continued over decades by technical assistants.

In the first instance six gall midges were studied, each for a period of about five years: two wheat blossom midges occurring on Broadbalk wheat; one of the meadow foxtail grass species at Aberdeen; the button top midge of basket willows at Syston, Leicestershire; the Arabis midge at Harpenden; and lastly the leaf curling pear midge occurring in Devon.

Many interesting results of general importance have been obtained from these studies of variation in insect numbers. It has been shown conclusively that the weather plays an overwhelming part in the occurrence of epidemic outbreaks. In the first instance, the weather acts directly on the insect by affecting the sex ratio, the dates of emergence and the size of generations, particularly the over-wintering ones. In 1936 an exceptional downpour of rain on one day in June, followed by warm weather which resulted in the caking of the soil, prevented the successful emergence of the wheat midges. The numbers of one species were reduced to one-half, those of the other species to one-sixth. Secondly, the weather affects the insects by its influence on the host plants. The close interrelationships of the flowering period of wheat and the egg-laying period of the wheat blossom midges was demonstrated in 1933 when a lack of adjustment, due to the early spring having a differential effect on the rates of development of the plant and midges, resulted in a great decrease in numbers of larvae subsequently found on the wheat. Again a drought in the late summer of 1929 so affected the growth of willows at Syston near Leicester that both the midges and their parasites were reduced by two-thirds. In this case three years elapsed before the insect population and the yearly growth of the willows regained their normal proportions. Thirdly, the weather acts differentially on the host insect and its parasites and thus upsets the normal adjustment in the relative times of emergence of the adult insects. Twice in the course of these investigations this lack of normality has resulted in an outbreak of injurious midges, once the button top midge and once one of the meadow foxtail midges.

After the initial periods of study, the question arose of the usefulness of continuing the investigations on certain species. It was decided to allow the work on the foxtail midge, the Arabis midge and the leaf curling pear midge to lapse, but to continue those on the wheat blossom midges and the button-top midge of basket willows. These two studies are now in their 11th and 10th consecutive year respectively and unique sets of data have been

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obtained. The following table shows the numbers of larvae of the wheat blossom midges present on Broadbalk from 1927-36.

Numbers of larvae of Contarinia tritici (*A*) *and* Sitodiplosis mosellana (*B*) *present in 500 ears of wheat on Broadbalk, 1927-1936.*

	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936
A	1,780	2,195	19,265	18,595	19,273	7,356	1,511	3,381	4,289	708
B	715	2,043	587	3,748	6,027	3,114	319	572	4,221	2,869

In 1936 after preliminary biological studies had been made, similar fluctuation studies were started on the carrot fly in Lincolnshire and the common cranefly (*T. paludosa*) at Harpenden.

Population Studies

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Studies on Cecidomyidae

Since 1927 many investigations on this important group of flies have been undertaken. Barnes, who came to the Station after being trained for specialist work in this field under Dr. E. P. Felt in the U.S.A., has been in charge. The gall midge family of flies includes many species which are injurious to crops. Besides these forms there are beneficial species which are predacious on other insects such as aphids, coccids, psyllids and thrips as well as other forms which feed on mites and fungi, rusts and mildews. The investigations are restricted to gall midges of economic importance, but include midges from all over the world.

Among the injurious gall midges which have been studied are those attacking grasses grown for seed. The gall midges of meadow foxtail grass were the first to receive attention and a detailed survey revealed that the most injurious species had not previously been described. A simple method was found for controlling the extent

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of damage by delaying the flowering of the grass until after the peak of emergence of the midges. Miss M. E. Metcalfe assisted in the work on the grass seed gall midges and studied those affecting seed production in cocksfoot and rye grass. D. P. Jones has from time to time worked in the department in this connection also, but most of his work has been done at Aberystwyth.

The clover seed midge also received the attention of Miss Metcalfe who showed that the form of this midge occurring in Great Britain was the same as that occurring in the U.S.A. and Canada. The sainfoin midge is at present under investigation.

The gall midges causing damage to the willow basket making industry have been investigated in some detail. *R. heterobia*, the button-top midge, was the first to receive attention and this led to an investigation into the resistance of basket willows to attacks by this midge. It was found that all varieties of *Salix triandra* were susceptible but that varieties of other species including *S. viminalis*, *S. purpurea* and *S. alba* were immune. *R. terminalis*, the bat willow gall midge, was next investigated and it was found to be restricted to *S. alba* and *S. caerulea*, but preferred the latter. The so-called "shot hole" gall midges (*Rhabdophaga* spp.) of willows were subsequently studied and each species of willow was found to be attacked by a distinct species of gall midge.

Among the gall midges injurious to fruit, biological studies have been made on the leaf curling pear midge, the red bud borer of budded fruit and rose trees, the black currant gall midge, and the raspberry cane midge.

Gall midges of importance to the horticulturalist have also been studied. Among these can be enumerated the chrysanthemum midge, the arabis midge and the violet midge which is still under investigation.

Arising from the above studies, which have been mainly biological and from an economic aspect, several lines of more academical and broader interest have been pursued. Anatomical and morphological studies on the clover seed midge have been carried out by Miss Metcalfe and similar ones on the olearia bud gall midges have been made by Miss Anderson. Barnes has shown that the phenomenon of unisexual families has been found to occur in 7 species of gall midges. Instead of families in which both sexes are evenly distributed, these gall midges produce all male families or all female families. Normal mating occurs but owing to a complex chromosome mechanism in the egg these families of one sex arise. Miss Metcalfe carried on a cytological study of this problem after leaving Rothamsted on a Commonwealth Fund Fellowship to work under Dr. C. W. Metz at the Carnegie Institution and the Johns Hopkins University in Washington, U.S.A.

A preliminary study of the factors governing the emergence of gall midges was made and the effect of light on the time of day of emergence and the effect of accumulated temperature on the dates of emergence was indicated. This line of investigation is temporarily in abeyance.

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A study of the variation in the segmentation of the antennae revealed the interesting fact that the quality and quantity of food given to the larvae affected not only the general size of the resultant adult midges but also the number of the antennal segments.

In addition to such investigations compilations of the research work dealing with particular aspects of gall midges have been made. These include world lists of grass seed-eating forms, of aphid-eating gall midges, those eating coccids and allied forms, mite-eaters and fungus-eating midges. These compilations have proved of great value to workers all over the world.

As a direct result of all this work on gall midges Barnes is now recognised as one of the foremost world specialists in the group. It is pleasing and yet disconcerting to find that he is consulted by economic entomologists whenever gall midges are in question. This involves the spending a considerable part of his time identifying midges from practically every country in the world. He has amassed an outstanding collection of such forms.

Studies on Cecidomyidae

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Studies on Species of Economic Importance

In the course of the work at Rothamsted a number of shorter studies on special insects of economic importance have been made. The principle of these are outlined below.

The gout fly of barley (*Chlorops taeniopus*) was one of the first insects of direct economic importance to receive attention. J. G. H. Frew studied the life history of this pest and found the type of distortion caused to the host plant depends on the stage of growth of the plant when attacked, and the degree of distortion of the plant depends upon the rate of growth at the time of attack. Certain manures (particularly superphosphate) were shown to have a beneficial effect in reducing the infestation of summer barley. This result was shown to be entirely due to their stimulating effect upon the maturing of the ear and the growth of the ear-bearing internode. The larval anatomy and morphology of the head-capsule and mouth parts of the fly were described.

Other Dipterous pests of cereals and grasses which have been studied include the frit fly, concerning which A. Steel described the immature stages in great detail; the wheat bulb fly of which H. M. Morris described the eggs which were found in the soil of a permanent mangold field (Barnfield) at Rothamsted; and lastly the timothy grass flies.

Collembola of economic importance were worked on by W. Maldwyn Davies who was later to become a recognised specialist in this group. In 1926 Barnfield was severely infested by *Bourletiella hortensis* and Davies devised a machine for collecting this spring-tail. The insects were caused to spring into the air and were caught on a box and sacking which had previously been smeared with tar. *Sminthurus viridis* was proved by this same investigator to do serious damage to clovers and grasses. An investigation into the effect of variation in relative humidity on different species in this order showed that those Collembola which are devoid of a tracheal system as a rule were very susceptible to dry conditions. On the other hand *Sminthurus viridis* which possesses a tracheal system and well developed ventral tube is much less susceptible to atmospheric dryness.

Among beetles of economic importance H. C. F. Newton discovered and described for the first time the egg and first instar larva of the pigmy mangold beetle (*Atomaria linearis*). He also investigated the biology of the flea beetle *Psylliodes hyoscyami* which attacks henbane, a medicinal herb, and of which a severe outbreak occurred in 1930. He also described in detail the larval stages.

Unusual types of damage by the caterpillars of two moths have been put on record. In the first instance climbing rose stems were noted by Barnes as having been scarred by a caterpillar of the Peppered moth. In the second Barnes and Professor S. P. Mercer of the Belfast Seed Testing Station drew attention to the caterpillars of *Apamea secalis* damaging the panicles of meadow foxtail grass. The caterpillars of this moth usually destroy the stems. An account by Barnes of the biology and British distribution of the

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hollyhock seed moth (*Platyedra malvella*) which is closely allied to the pink bollworm of cotton (*P. gossypiella*) is in the press.

Two biological studies have been made on Agromyzid flies by Barnes. The first was a newly discovered species, *Dizygomyza barnesi* Hendel, whose larvae feed and make tunnels in the cambium layers of certain basket willows. The second was the asparagus miner, *Melanagromyza simplex* H. Loew. Only a preliminary note on this latter fly in co-operation with Dr. C. L. Walton of the Long Ashton Research Station has yet appeared, but a full account is in the press.

The physiology of the sheep blow-fly, *Lucilia sericata*, had been studied in detail by A. C. Evans before he joined the Rothamsted staff. Since then he has made a critical review of the relevant literature.

STUDIES ON SPECIES OF ECONOMIC IMPORTANCE

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Migrations and Aggregations of Insects

Since 1932 considerable work has been done in the department on the migrations of insects other than locusts, and particularly on the migration of Lepidoptera.

As it is impossible to make personal observations on migrant insects, except perhaps at long intervals, much of the work has been in the nature of organisation and propaganda and a number of popular articles have been written asking for information. Broadcasting has also been used for this purpose.

A large group of amateur entomologists organised under the Insect Immigration Committee of the South Eastern Union of Scientific Societies (of which Committee C. B. Williams is the Chairman) observes the dates of arrival and the variation in numbers from day to day of the principal British immigrant butterflies and moths. These are recorded on standard record cards and forwarded by the Secretary, Captain T. Dannreuther, to Rothamsted for study and analysis.

The Insect Immigration Committee is also in touch with the residents on a number of lightships and lighthouses all round the coasts of the British Isles, and most valuable information is being obtained.

In addition Rothamsted has co-operated with the Natural History Museum in London in the preparation of two booklets with coloured illustrations, the first on " British Immigrant Butterflies and Moths," of which over 1,000 copies have been sold by the Museum, and the second (in the press) on " Butterfly Migrations in the Tropics."

As a result of this and other propaganda work a very large number of records of movements of insects in Britain and a smaller number of records from other parts of the world are continually coming in.

In this work C. B. Williams and Mrs. K. J. Grant have co-operated. Briefly the results are as follows :—

(*a*) A very large increase has been made in our knowledge of the facts of insect migration all over the world, and particularly in Britain and Western Europe.

(*b*) There is a considerable increase in evidence supporting the idea of a return flight to the south in the autumn of several of our British Immigrants which arrive from the south in the spring. This is particularly the case in the " Red Admiral " butterfly and the "Clouded Yellow," and to a lesser extent in the "Painted Lady."

(*c*) We have a very full account of a great immigration into England in 1936 of the " Silver Y " moth, *Plusia gamma*. This pest has been known for many years to be a migrant but previous records have been very incomplete and scattered. The southward autumn flight of this species seems also to be established.

(*d*) By collecting the past history of the outbreaks of the migrant moth *Celerio livornica* both in Europe and in U.S.A. for the past century Mrs. Grant has shown that the outbreaks of the moth tend to occur simultaneously in both continents. This discovery is of fundamental importance in the study of the causes of migration.

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The problem of gregariousness or aggregations of insects, which is partly related to that of mass migration, has been under consideration and advantage has been taken of opportunities to study two cases at Rothamsted. One in the Diptera has been reported on by Barnes, and a case of gregarious hibernation of a ladybird, by Evans.

MIGRATIONS AND AGGREGATIONS OF INSECTS

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INSECT MORPHOLOGY

From time to time in the history of the department certain aspects of pure entomological interest have arisen. For example Imms dealt briefly with the head and mouth-parts of Diptera in the light of Petersons' researches published in 1916. Later he discussed the position of the Grylloblattidae and, after considering Walker's view that they are nearest allied to the Blattidae of the Orthoptera Cursoria and Crampton's view that they should be placed along with the Orthoptera Saltatoria, maintained that the Grylloblattidae should be included in the group Cursoria. Imms also commented upon recent research on the wing venation of insects.

The morphology of the larva of the Lucanid beetle, *Dorcus parallelopipedus*, was studied by E. E. Edwards, while J. G. H. Frew described the larval and pupal stages of the Chironomid fly, *Forcipomyia piceus* Winn.

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Similar studies of academic interest have been carried out on various insect pests: such as one by W. Maldwyn Davies on the tracheal system of Collembola, especially *Sminthurus viridis* the Lucerne Flea; several others by Miss Metcalfe and Miss Anderson on gall midges (*see* section on Cecidomyidae); on the morphology of the head capsule and mouth parts of the Gout fly by J. G. H. Frew (*see* section on Species of Economic Importance).

Insect morphology

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Miscellaneous Activities of the Department

Imms, while head of the department, produced his "Text Book of Entomology" which has become the standard work both in England and North America and has done much to raise the level of entomological education. He followed it up by a supplementary volume entitled "Recent Advances in Entomology."

From 1922-24 Imms also contributed the series of reports entitled "Recent advances in Entomology" to Science Progress. From 1925-28 this was carried on by Davidson and from 1929 to date by Barnes.

Imms also produced a small book on "Social Behaviour in Insects" and a useful paper on technique for entomological students.

The Entomological Section, has kept a regular watch on insect outbreaks on the farm at Rothamsted and short reports by Newton and Evans on this subject have appeared in the Rothamsted Annual Report.

Miscellaneous

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INSECT PESTS AT ROTHAMSTED AND WOBURN, 1936

A. C. Evans

General

This year was notable for an infestation of the wheat plots on the Long Period Cultivation Experiment by the Wheat Mud-beetle which attacked the young plants so severely that resowing with spring wheat was necessary. Wheat Bulb-fly attacked the wheat after fallow on Broadbalk and Hoos field. Pigmy Mangold-beetle was not seen at all on the farm, a contrast to last year when so much damage was done on Barnfield.

Wheat

During February the wheat plots of the Long Period Cultivation Experiment were found to be very severely damaged all over by *Helophorus nubilus* F., the Wheat Mud-beetle. This insect is a comparatively new pest owing to a change in food plant in recent years and appears to be of increasing importance. It was considered advisable to resow the plots with spring wheat; this germinated well and was not attacked. Soil samples from the wheat and barley plots were examined at the end of September and no signs of the beetle was found. No attack was noted on the plots up to December. A general survey of the farm was conducted and one small infested patch was found on Great Knott and a few very small scattered patches in Winter Oats Variety Trial and Three Course Rotation Experiment. The remaining cereal areas were found to be free. The steady increase of the Wheat Blossom Midges (*Sitodiplosis mosellana* Géhin and *Contarinia tritici* Kirby) shown for the last three years was severely checked this year.

Number of Larvae per 500 *ears*

	1935	1936
C. tritici	4,289	708
S. mosellana	4,221	2,869

The relative parasitism this year was low, 12-13 per cent for both species and so a further increase was expected. Dr. Barnes attributes the fall to climatic factors occurring just before the peak of emergence; a day of violent thunderstorms followed by three to five hot days caked the clay-flint soil of Broadbalk and this caking brought about a high mortality.

A bad attack of Wheat Bulb-fly began to develop in March on that section of Broadbalk fallowed the previous year and by the end of

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