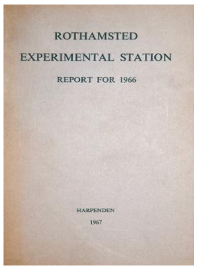
ROTHAMSTED RESEARCH

Rothamsted Report for 1966



Entomology Department

C. G. Johnson

C. G. Johnson (1967) *Entomology Department ;* Rothamsted Report For 1966, pp 188 - 207 **- DOI: https://doi.org/10.23637/ERADOC-1-14**

ENTOMOLOGY DEPARTMENT

C. G. JOHNSON

Margaret K. Arnold left and K. E. Fletcher and D. J. Cross were appointed, Cross to one of the supernumerary posts for work overseas. Mrs. Judith Palmer and P. J. Huston joined the department with Royal Society Grants in connection with the International Biological Programme. C. A. Edwards was awarded a Senior Foreign Scientist Research Fellowship by the National Science Foundation to work at Purdue University, Indiana for one year.

C. G. Johnson was a guest at the 75th Anniversary of the Netherlands Society of Plant Pathology and gave a paper at their International Symposium on Plant Diseases and Pests in Developing Europe. C. A. Edwards, K. E. Fletcher and R. Lofty attended a colloquium held by the International Society of Soil Science at Braunschweig. T. Lewis attended a conference in the Lebanon, sponsored by the International Society of Biometeorology and also visited the Centre de Recherche Agronomique de Sud-Est, Montfavet. Mrs. Judith Palmer visited the Bladliusonderzoek, T. N. O., Holland.

C. J. Banks and L. R. Taylor were awarded the D.Sc. degree and T. P. Sriharan the M.Phil. degree of London University.

The effect of pest attack on the growth and yield of plants and crops

Winter wheat and wheat-bulb fly. The experiment on Stackyard to study the effect of wheat-bulb fly attack on wheat sown at different dates (*Rothamsted Report* for 1965, p. 179) was repeated. In contrast to 1965, harvesting conditions were good and yields on infested and uninfested plots differed greatly. Sowing dates were 2 November 1965 and 8 January 1966, some plots were sprayed with hormone weedkiller and others not, and some were protected from egg-laying by covering with plastic sheets and others were not. The maximum larval population was 750,000/acre, about 35% more than in 1965, and gave a moderate to heavy attack.

Plots where egg-laying was prevented yielded an average of 48 cwt of grain/acre with no significant effect of sowing date. On plots attacked by wheat-bulb fly, yield from the November sowing was 47·4 cwt/acre, and from the January sowing 40·7 when sprayed with weedkiller and 37·5 when not; the effect of spraying was not statistically significant, although weeds were plentiful, especially in the thin places in the crop. Wheat-bulb fly attacked 40% of the shoots on all unprotected plots by 13 March, but those on plots sown early escaped serious damage because the plants had tillered when the attack started. The number of infested shoots was again greatly influenced by plant density, and more plants survived on plots with large plant populations. Surviving plants on severely attacked plots partly compensated for the losses by producing larger ears with heavier

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grains. Yield was seriously affected when there were fewer than $1\frac{1}{2}$ million shoots/acre by 11 May, as this limited the number of ears produced. Yield was also related to the amount of gapping.

The results from the two years allow the factors that affect yield of damaged crops, such as plant density, number of larvae, amount of gapping and amount of tillering, to be distinguished. (Bardner)

Plants with a well-developed second shoot survive the loss of the main shoot eaten by wheat-bulb fly. To find at what stage of growth this can happen, first shoots were killed artificially, with results described in the report of the Department of Insecticides and Fungicides. (Bardner, with Griffiths, Insecticides Department)

Patching of crop by wheat-bulb fly. A series of aerial photographs of fields damaged by wheat-bulb fly, taken by arrangement with Dr. G. H. Brenchley of the National Agricultural Advisory Service, Cambridge, showed two patterns of damage. In one, thin patches, usually more than one drill wide, were along the direction of drilling, and caused by the coulters going deeper than intended, so producing backward plants very susceptible to attack. In the second, the patches of injured plants were more irregular and longer, many as much as 50 yd across. Possible causes are either uneven distribution of fertilisers or other soil factors that influence the growth, and hence the susceptibility of the young plants to attack, or differences in the distribution of wheat-bulb fly eggs in the soil (see p. 205). To elucidate the reason, the fields will be examined again when under crops not attacked by wheat-bulb fly and when under wheat. (Bardner)

Effects of leaf-eating insects. How leaf-eating insects *Phaedon cochleariae* Fab. (Coleoptera, Chrysomelidae) and *Plutella maculipennis* Curtis (Lepidoptera, Plutellidae) affect the growth and yield of cruciferous plants (turnip var. early Milan and radish var. French breakfast) was studied to develop methods for studying the relation between damage and the food requirements and the growth of the insects.

Larvae of both insects ate more food when feeding on plants 8 weeks old than on younger plants, although larvae developed faster on the younger plants. The semi-fluid faeces of *P. cochlaeriae* larvae could not be collected to estimate the digestibility of the food or the amount excreted. However, the efficiency with which the food eaten by *P. maculipennis* was converted into larval tissue (percentage conversion = dry weight of insect × 100/dry weight of food consumed) was estimated at 41·3% and did not differ significantly with different varieties or ages of plants. The coefficient of use (i.e. (dry weight of food consumed — dry weight of faeces/dry weight of food consumed) × 100) measures digestibility, and larvae of *P. maculipennis* feeding on turnip plants 4, 6 and 8 weeks old used 55·6, 48·1 and 27·1% respectively; on radishes of similar age the use was 54·6, 53·4 and 47·3%. Both insects damaged a greater area of radish than of turnip leaf, perhaps because the dry-weight/area ratio of turnip increased with age, though it was almost constant for radish. *P. maculipennis* larvae and adults much preferred turnip to radish, irrespective of

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the plants on which they had been reared, and chemical and nutritional factors possibly affected the amount of leaf eaten or damaged. Growth analysis was used to assess the response of the plants to injury by the insects. (W. E. Taylor and Bardner)

Damage in the field by flea beetles (*Phyllotreta* spp.) is easily recorded by the number of feeding holes/unit area of leaf, but it is difficult to assess the population of flea beetles responsible, because the insects are very mobile. Damage done by known numbers is therefore being studied with caged beetles on radish out of doors and in a constant temperature of 20° C. Out of doors in August and September 1966 beetles consumed 0·045 mg dry/matter/day, and made between 0·5 and 2·7 holes/day. Assuming that a beetle makes one feeding hole/day, damage in the field by the late summer generation was estimated to have been caused by beetles at a mean density of 5 beetles/sq ft of plot. In 1963, on a site where beetles were seriously lessening yield, the population was estimated at about 10 beetles/sq ft. (Bardner and W. E. Taylor)

Cereal leaf-miner. Damage by leaf-miner to cereals, and particularly to the flag leaves, has increased at Rothamsted during the last 2 years. It shows as a conspicuous blistering and yellowing at the distal end of the leaves, most commonly on wheat, but sometimes on barley and rye. The identity of the responsible species is uncertain. It was known as *Agromyza* (or *Domomyza*) *ambigua* (Fall.), though it now seems likely to be *A. nigrociliata* Hendel (Diptera).

Past reports by the National Agricultural Advisory Service from eastern England indicate that the last periods of prevalence were 1953–55 and 1941–44. Before 1955 and 1963 attacks were few enough to escape notice, but since 1963 extensive attacks have been reported in different parts of the country.

Our work started too late to observe the egg and early larval stages of the insect, and was restricted to measuring the effects on yield of the flag-leaf attack in the field by comparing yields of attacked and unattacked plants. In 1966 the average number of wheat plants attacked ranged between 10 and 20% of the total at Rothamsted and Woburn. The area of flag leaf destroyed was between 15 and 20%, and some plants lost 50%. Fewer than 2% of barley plants were attacked and less area was destroyed than on wheat. No obvious differences in attack were seen on different varieties of wheat at Rothamsted. The total leaf area, the area of leaf destroyed and the weight of grain produced was measured on many attacked wheat plants (var. Cappelle). Comparison with unattacked plants showed that loss in yield was small. Losses of approximately 3–8% in the weight of grain/attacked plant, or 1–1·5% for the total crop, seemed a likely average in 1966.

Because of the late start, the number of eggs laid/leaf and the subsequent survival, both of which would influence the effect on yield, were not measured. Soil-sampling for pupae after harvest indicated a population of 900,000/acre on Great Knott 1; assuming 1·5 million plants/acre, this gives an average of two larvae/mine. (Cross)

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The effect of frit fly (*Oscinella frit* L.) and brown rats on the yield of sweet corn. A small field experiment with sweet corn (var. Kelvedon Experiment 152) assessed the loss of yield caused by frit fly, using three different methods based on comparing sets of injured and uninjured plants. All gave similar results. Sixty-eight per cent of plants were attacked by frit fly; whether uninjured plants near to injured ones grew better than they otherwise would, and so compensated for some loss could not be measured in this small trial. However, many plants were destroyed at the two-to-three-leaf stage by brown rats (*Rattus norvegicus* Berk.), and this allowed compensatory growth by uninjured sweet corn to be assessed (Table 1). Although 28% of plants were killed by rats, yield losses were less and ranged from 8 to 19% according to the method of assessment. (Judenko)

TABLE 1

The effect of brown rats on the yield of sweet corn

(Data per 0·03 acre, average of three methods)

	Rat attack		
	Yield losses	Yield in absence of rats	% loss
Number of marketable cobs*	39	274	14
Current value of marketable cobs*	4*s*. 6*d*.	£2 15*s*. 0*d*.	8
Total green weight of whole plants, cwt	1·23	6·59	19
Weight of all cobs, cwt	0·45	2·99	15

* These two factors were kindly assessed by Messrs. Ridley & Houlding Ltd., Fruit Brokers & Commission Agents, Covent Garden, London.

The effect of *Aphis fabae* on beans. Effects of *Aphis fabae* on yield of beans could not be measured because the infestation was exceptionally small. However, this gave an opportunity to measure whether the insecticides "Rogor E" and "Metasystox N.F" affect yield directly. Neither insecticide sprayed once on crops of Maris Bead tick bean with stem-densities of about 50,000/acre at amounts between 2·4 and 4·2 a.i./acre affected the quantity, germination, crude protein content or valuation of the beans for seed. (Judenko)

Aphids and virus diseases of lucerne, and their effects on yield. The effects of bean leaf-roll virus on yield of four varieties of lucerne grown in pots under glass were further studied. The differences in yield (dry weight, total of four cuts in 1 year) of uninfected and infected plants of Chartainvilliers, du Puits, Provence and Rhizoma lucerne were 12, 18*, 20* and 29*% respectively (*$P < 0{\cdot}05$). Factors that may affect yield in the field, e.g. susceptibility of infected plants to frost damage and failure of infected plants to recover after dormancy, are also being studied.

A field experiment was started to study the effects of aphid infestation and virus infection on the yield of lucerne, in pure stands and mixed with cocksfoot, to see whether the spread of virus-infective aphids from lucerne can be lessened by periodic spraying with a suitable systemic insecticide. There are four treatments, lucerne sprayed and unsprayed, lucerne and cocksfoot sprayed and unsprayed; each treatment is replicated four times. The experiment is to continue for 3 years. Aphids were counted on all plots five times during the year. On average, 12 times as many aphids were

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found on unsprayed as on plots sprayed three times with "Metasystox", and 1·2 times as many on lucerne as on lucerne and cocksfoot plots. Eighty-nine per cent of all aphids were *Acyrthosiphon pisum*; others were mainly *Brachycaudus helichrysi* and *Myzus persicae*. Aphids were most abundant in early October, when there was a mean of 237 *A. pisum*/5-ft row of unsprayed lucerne. The incidence of lucerne mosaic virus in early September was 0·6% in sprayed and 0% in unsprayed plots. The incidence of bean leaf roll virus in early October was 0·6% in sprayed and 1·9% in unsprayed plots.

The plots were cut twice, and yields were taken from the second cut in late October. Yields from lucerne and cocksfoot plots were greater than from lucerne plots (mean of 25·2 and 22·5 cwt dry matter/acre respectively, $P < 0{\cdot}05$), but there was no significant difference between yields from sprayed and unsprayed plots (24·3 and 23·4 cwt/acre), probably because aphids were not numerous until autumn.

Observations in February and March 1966 indicated that eggs of *A. pisum* on lucerne are killed when lucerne is sprayed with paraquat, possibly because the dormant shoots carrying the eggs die. This suggests a method, other than by the use of insecticides, that might lessen the early spread of virus-infective aphids from lucerne, and might be useful to growers in areas where annual legume crops are grown near lucerne, but this awaits more detailed study. (Cockbain, with Etheridge, Insecticides Department, and Gibbs, Plant Pathology Department)

The aggregation of pests

The effect of shelter on the distribution of insects in the air and on crops. In the air of the sheltered zone to leeward of 3-ft-tall wooden-lath fences, insects were much more abundant than in exposed places near by, and the more open the windbreak, the fewer insects accumulated in the air behind it. Increases in numbers in the zone 7 times the height (7*H*) to leeward of the fence had a range of 1–900%, depending on the type of insect and permeability of the fence. The more open the fence, the farther to leeward most insects accumulated. Comparing the profiles of insect aerial density and the wind-speed profiles behind fences with 0, 25, 45 and 70% open space showed the aerial density greatest in places where shelter was greatest, namely at 1, 2, 3 and 4 times the height of the respective fences and to leeward of them.

The components of the wind that produced these effects were wind-speed, turbulence and the mean angle of the wind to the fence. Relative accumulation (i.e. the number of insects in a sheltered zone compared with numbers in an exposed zone) of Cecidomyiidae, Mycetophilidae and Aphididae depended mostly on the angle of the incident wind to the fence, and both increased together. The relative accumulation of mycetophilids and cecids diminished as turbulence increased, and the faster the wind, the farther to leeward was the zone of greatest density.

Many artificial windbreaks and belts of trees and hedges are taller than 3 ft, so in 1966 aerial density profiles near to 8-ft fences were studied. The shape of the profiles to leeward of these and of the 3-ft fences did not

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differ significantly, and the relationships described above for 3-ft fences possibly apply to taller ones. Two series of traps at different heights above the ground up to twice the height of an 8-ft fence, one in the sheltered zone and the other exposed, showed that the fence increased the aerial density to the leeward up to about 16 ft above the ground. The horizontal and vertical profiles were combined to produce a two-dimensional pattern of insect distribution near a windbreak.

Differences in the density of insects in the air above the crop were sometimes reflected in numbers of insects and virus infection on the plants. In 1965 a natural infection of a turnip crop with turnip mild yellows virus was greatest in a narrow zone parallel to, and 2–6*H* to leeward of, a 45%-permeable fence. The wind had been across the fence during the early summer flights of *Myzus persicae*. In the same crop, later in the season, there were also more larvae of *Scaptomyza apicalis* Hardy (Diptera), a turnip leaf-miner, in plants near to the windbreak than elsewhere, perhaps because shelter affected the distribution of ovipositing adults. (Lewis)

Aggregation by the Heteroptera. The Cotton Stainer, *Dysdercus intermedius* Distant is among many Heteroptera that aggregate on plants or in soil. Aggregation by *D. intermedius* in the laboratory was affected by the smell of their food (cotton seeds), moisture, temperature, light, the roughness of the substrate and the physiological state of the insects (*Rothamsted Report* for 1965, p. 183). The smell of the secretion from the scent glands also seemed to affect aggregation. There are three dorsal abdominal scent glands in the larvae and two metathoracic scent glands in the adult. When disturbed, e.g. by pinching with forceps, the insects secrete a yellowish liquid from the scent glands and excrete a large drop of watery brown liquid from the anus. The secretion from the scent glands spreads on the cuticle and evaporates within a few seconds, and gas chromatography indicates that it has four components. The anal excretion is more complex.

D. intermedius responded to increased crowding in various ways. Moulting was synchronised when larvae were reared in dense crowds; more second-instar larvae died than of other stages, especially when reared singly; adults reared from crowded larvae weighed less and were smaller than those reared uncrowded. Ovaries developed faster when females were crowded. (Youdeowei)

Insect migration and dispersal and a continuous census of pests

Migration and dispersal studies are bound up with aerial trapping, and a logical development of dispersal studies is to use aerial traps for a continuous census of some insects, with a view to forecasting pest attacks. Methods are being developed for this and consist of sampling the most numerous insects, such as aphids, with traps sucking in air at an altitude of 40 ft (so avoiding an excess of local populations) and by light traps that sample the less-abundant night-flying insects.

Six large 40-ft suction traps have now been established over 400 miles on the south-east side of England and Scotland from Dundee to Wye in

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Kent. Preliminary analysis of catches in 1965 shows a very strong correlation between daily catches by pairs of traps over distances up to 100 miles. Correlations for the single species *Oscinella frit* resemble those for the whole family Aphididae and for the whole order Thysanoptera, but differ from those for Lepidoptera. This suggests that one trap indicates the size and quality of the population of small, numerous insects over a very large area indeed. The catches for 1966 from the United Kingdom and the Central States of the United States (see *Rothamsted Report* for 1964) should show the minimum number of traps needed to record daily population changes on a regional scale, and it seems likely to be small. In 1967 one trap is to operate at Silwood Park, Berkshire, run by Dr. T. R. E. Southwood of the Imperial College, and it is hoped also to operate another at Wageningen in Holland, as part of an investigation into the cost and efficiency of pest surveys currently operated in the United Kingdom and Europe in connection with the International Biological Programme.

Analysis of trap catches differs from usual sampling practice, because there are no sample units in the accepted sense. Each catch is part of a continuous series of insects and wind that flows past the trap during the sampling period. To relate such samples to the spatial distribution of insects, 13 suction traps were randomly distributed in a cereal crop, operated simultaneously during July and August and catches are being analysed. (Taylor and French)

Light trap survey. Light traps were established at 29 new sites in co-operation with the N.A.A.S., the Forestry Service, schools, University Departments, the Field Studies Council, local Museums and Natural Science Societies, Horticultural Research Stations and private individuals; ten more will be added this year.

For the first time the survey should be wide enough to indicate the distribution of some pest species and the major regions covered by the arrival of immigrant insects into Britain. An attempt will be made to relate the immigration of easily tracked Lepidoptera to those of ubiquitous pests, such as aphids, whose source is not easy to discover. (Taylor and French)

With the co-operation of the National Institute of Oceanography a 12-in. suction trap was installed on the Royal Research Ship *Discovery* while cruising in the Atlantic Ocean near the Azores (Madeira) and Canary Islands. It is hoped that the catches in this trap, which will indicate the densities of insects over sea, can be related to the immigration of insects from the Azores and neighbouring areas that are already recorded regularly. (French)

Long-distance migration of Lepidoptera and synoptic meteorology. When all records are available and assessed, 1966 will probably prove to be a very good year for many of the commoner species of migrant Lepidoptera, though the reasons are not obvious. Four species of moths were recorded in several localities throughout southern England at the end of January and beginning of February; their detection was partly from the light traps used for the survey work that operated throughout the year. The arrival of these moths, *Agrotis ypsilon*, *Plusia gamma*, *Laphygma exigua* and

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Nomophila noctuella, was closely correlated with a wind that provided transport from either south-west Portugal or Morocco. This wind from the coast of Morocco on the evening of 26 January passed west of Portugal over the Atlantic and around a high-pressure area centred over Spain, before coming inshore over south-west England in the early morning of 29 January ahead of a cold front.

Many of the immigrant butterflies were particularly abundant in 1966; *Vanessa cardui* had the best season for many years, being recorded as common in much of southern England and Wales at the end of May as a result of recently arrived immigrants. These large numbers continued throughout the summer, and especially in September. *Vanessa atalanta* was plentiful, but probably not as abundant as *V. cardui*. *Plusia gamma* was very common, with evidence of a big migration in June as far north as Caithness, and another in September. *Agrotis ypsilon* was also unusually common with signs of a spring and autumn immigration into south-west England. Other rarer immigrant moths were also widespread, but their commonness cannot be assessed at this stage.

The migration records for 1964 were considered as a whole in relation to synoptic meteorology. The scarcity of migrants was reflected in the scarcity of winds suitable for transporting the insects from areas south of the British Isles. No suitable back track to North Africa and few from Spain were obtained. The most satisfactory track applied to the moth *Eurois occulta* shown clearly to be wind-borne from Scandinavia to various parts of England and Scotland during August. (French)

An automatic machine for sorting and counting insects. Work to develop an apparatus to sort and count trapped insects continues. A sorting apparatus was made by which a large catch can be separated semi-automatically into seven groups of differently sized insects in 20 minutes, but more clearly defined separation is required. Work on automatically counting the separated catch suggests more clearly defined fractions may be obtained while counting.

A continuous flow system that combines separation and counting shows some promise, but its success will depend largely on the efficiency of the electronic counting unit being built. (Arnold, Insecticides Department)

Soil fauna

Effects of insecticides on soil fauna. Effects on soil invertebrates of the organophosphorus insecticides thionazin ("Zinophos", "Nemafos"), carbaryl ("Sevin"), sumithion, parathion, diazinon, disulfoton, phorate ("Thimet") and trichlorphon ("Dipterex") were further studied at Woodstock, Kent, where soil was sampled for residues and microfauna each month. Some of the microfauna are commonly increased by organophosphorus insecticides, possibly because the parasitic and predatory mites are killed.

Thionazin was moderately toxic to earthworms, carbaryl more so and phorate was very toxic, even at 4 lb a.i./acre. Trichlorphon and sumithion had little, and disulfoton and carbaryl some, effect on wireworms. At 4 lb

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a.i./acre diazinon brought populations to about one-third those in untreated soil, parathion to one-seventh and phorate to less than a tenth. These kills were reflected in the less damage done to potatoes and cereals by the pest. (Edwards and Arnold)

Numbers of entomobryid and onychiurid Collembola and of oribatid mites increased after treating soil with chlorfenvinphos ("Birlane"), and this increase coincided with a decrease in parasitic mites. Other groups of animals were affected only slightly. Chlorfenvinphos did not kill earthworms in other tests or seem to accumulate in their tissues, but field populations were diminished, although few of the results were statistically significant. (Edwards and Thompson)

Work on the leaching of insecticides from soil continued in laboratory and field. In the laboratory dieldrin was applied at the equivalent of 20 lb a.i./acre to soil columns, 14 in. high and 12 in. wide, which were leached with 18 in./sq in. of water. The amount of dieldrin washed through the column varied inversely to the amount of organic matter in the soil.

Dieldrin was applied at 20 lb a.i./acre to the land bordering three ponds. Dieldrin never exceeded 0·001 ppm in any of the samples taken from the pond during the next 9 months, although analyses of the soil 5 yards from the treated section of the field indicated some movement of dieldrin through the soil towards the pond. (Edwards and Thompson)

Standardisation of methods for extracting invertebrates from soil. The efficiency of various methods of extracting animals from soil was compared and the factors that affect the efficiency of Tullgren funnels studied in detailed work financed by the Royal Society in connection with the International Biological Programme. Soil samples can be stored for up to a month at 5° C without seriously affecting the extraction of the animals; intact samples yield more animals than broken ones, and inverted samples more than upright ones; picric acid is the best collecting fluid; efficiency of extraction decreases with increasing thickness of the soil sample; animals were trapped in very wet soils; the diameter of the sample, different temperature and humidity gradients and heating cycles all affect the efficiency of extraction. The animals remaining in the soil were later extracted by flotation, and counted.

The types of apparatus compared include simple Tullgrens, Macfadyen high-gradient Tullgrens, "Oxford" infra-red extraction (Kempson) and a grease film extractor (Aucamp). (Edwards and Fletcher)

Sterilisation of soil by gamma-radiation. The effects of the soil fauna on the growth of crops are difficult to assess because the animals cannot be eliminated without also changing the soil in other ways. An attempt was therefore made to kill all the soil animals in a quantity of soil with gamma-radiation. Little is known about the susceptibility of arthropods to irradiation except for some stored-product pests, cockroaches and a few pests where control has been attempted by releasing "sterile males". To find lethal doses, soil and cultures of soil animals were therefore exposed to doses ranging from 5 to 200 Krads, and the animals were extracted from irradiated and unirradiated soils at weekly intervals in Tullgren funnels.

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All soil animals were killed within 6 weeks by 200 Krads; the smallest dose needed to do this has not yet been found. Soil microflora recovered from a dose of 100 Krads in 2–3 weeks. Preliminary results indicate that the most active animals are the most easily killed, and the most resistant are the relatively inactive oribatid mites and onychiurid Collembola. (Edwards with Mr. P. A. Cawse, Atomic Energy Research Establishment, Wantage)

Litter breakdown. To establish better the chain of animals responsible for breaking down plant debris in soil, work began in order to find a tracer that would label the plant material and be incorporated into the tissue of soil invertebrates. Neutron bombardment of whole leaves, labelling with cobalt, silver or carbon are being tested. (Edwards)

The effects of "slit-seeding" on pests and soil fertility. The use of weed-killers instead of traditional cultivations may create new pest problems and increase the importance of the soil fauna in maintaining good soil conditions. In the second year of the experiment at Rothamsted with wheat "slit-seeded" in land sprayed with paraquat some plots were treated with a mixture of diazinon, "Zinophos", chlordane and DDT designed to eradicate as many soil animals as possible. Unfortunately the paraquat failed to kill weeds adequately and the "slit-seeded" plots yielded less grain than the ploughed ones. A more complex experiment was studied at Woburn with spring wheat comparing drilling on ploughed land with "slit-seeding" into land sprayed with paraquat. Some plots were sown with insecticide-dressed seed and some not. Half of each plot was treated with an insecticidal mixture as at Rothamsted. Yields were the same on paraquat-treated and ploughed plots, and were significantly increased by the insecticide mixture. Tillering was more on the "slit-seeded" than on the ploughed plots. Parasitic nematodes (counted by Corbett, Nematology Department) were much more numerous in the ploughed than in the "slit-seeded" plots, but the ploughed land was treated with aminotriazole in autumn 1965. (Edwards)

Slugs

The molluscicidal properties of ioxynil. Ioxynil (3,5-di-iodo-4-hydroxy-benzonitrile) kills slugs readily when applied to them in the laboratory, and its use to control slugs in the field was studied. When *Agriolimax reticulatus* Müll. were allowed to choose filter-paper moistened either with a 0·05% aqueous suspension of ioxynil or with water alone mucous trails made visible with fluorescein showed that ioxynil was strongly repellant. Seed boxes containing soil with a surface cover of Shepherd's purse (*Capsella bursapastoris* L.) and Chickweed (*Stellaria media* L.) were sprayed with an aqueous suspension of ioxynil at the rate of 2¼ lb a.i./acre. None of the vegetation was eaten during the next 3 days, and no more slugs died in the ioxynil-treated than in the untreated boxes. Baits composed of bran and ioxynil or of bran, ioxynil and metaldehyde containing 0·5% ioxynil did not kill slugs. It seems that ioxynil is ineffective as a contact and stomach poison on baits in the field, largely because it repels slugs.

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Ioxynil is a stomach poison, and the lethal dose administered into the stomach in 2·0% agar jelly was approximately 50 μg for *A. reticulatus* ranging in weight from 300 to 600 mg. Attempts are being made to formulate the compound to eliminate its repellent effect and exploit its "oral toxicity". (Stephenson)

Resistance of potato varieties to slug attack. Different varieties of potato differ in their susceptibility to attack by slugs, and a laboratory technique was developed to assess this susceptibility. Adult *Arion hortensis* Fér. prefer soil in which potatoes have been grown to otherwise similar soil. Soil from pots in which Ulster Chief and Kerr's Pink had grown accumulated significantly more slugs than soil in which King Edward had grown, whereas soil from pots growing Dunbar Standard accumulated significantly fewer. Soluble components of potato tubers were examined for either their attractiveness or acceptability to slugs. Undiluted juice from the skin and cortex of King Edward, Majestic and Pentland Dell tubers after exposure to air for 48 hours at 10° C killed adult *A. hortensis* which walked over it, in 20–40 hours at 10° C, but diluted/10 it did not even in 68 hours. Filter-paper moistened with the dilute extracts was bitten more often by slugs than filter-paper moistened with distilled water. Most bites were with extract of King Edward, which is very susceptible to attack by slugs. (Stephenson)

Aphid studies

Overwintering sources of the pea aphid and bean viruses. The pea aphid (*Acyrthosiphon pisum*) is the main vector of bean leaf-roll virus (BLRV) and pea enation mosaic virus (PEMV), and the main overwintering hosts common to the aphid and the viruses are being sought. Of the common pasture and fodder legumes, birdsfoot-trefoil (*Lotus corniculatus*) and lucerne (*Medicago sativa*) are preferred winter hosts of *A. pisum* (Table 2), but only lucerne is a host of BLRV. A few apterous aphids collected from red and white clover crops were infective with BLRV, but clover is less important than lucerne as a winter host of the aphid; aphids from sainfoin were not infective. None of the other legumes listed in Table 2 and none of the previously recorded winter hosts of *A. pisum* were susceptible to BLRV in glasshouse tests, e.g. bush vetch (*Vicia sepium*), tufted vetch (*V. cracca*), everlasting pea (*Lathyrus latifolius*) and meadow vetchling (*L.*

TABLE 2

Overwintering of A. pisum *on different legumes*

	Mean No. of eggs*		Mean No. of fundatrices*
	December 1965	February 1966	April 1966
Birdsfoot trefoil	306	80	10
Lucerne	63	28	3
Hop trefoil	18	7	0
Alsike	9	2	0·03
Sweet clover	6	2	0·05
Red clover	5	0·3	0
White clover	2	0·7	0

* per $1\frac{1}{2}$ sq ft of plot; mean of 3 replicates.

https://doi.org/10.23637/ERADOC-1-14

pratensis). Observations on the overwintering sources of *A. pisum* continue, but the results indicate that lucerne is the main source of BLRV-infective aphids.

None of the apterous *A. pisum* collected from perennial legumes in the field in 1966 were infective with PEMV (8,500 aphids tested), and no biennial or perennial legumes tested in the glasshouse proved susceptible to PEMV (30 species or varieties, including eight varieties of lucerne, were tested). Some annual vetches, e.g. *Vicia sativa* and *V. hirsuta*, may germinate late in the year and survive the winter; these plants are hosts of PEMV, and the possibility that they are the main overwintering sources of the virus is being studied. (Cockbain)

Incidence of bean leaf-roll virus in lucerne. BLRV does not cause distinct symptoms in lucerne, so its incidence in lucerne crops was estimated by testing the ability of apterae of *A. pisum* that developed on them to infect *Trifolium incarnatum*. Aphids were collected from 46 crops and from eight variety or experimental trials. Some aphids from all crops were infective with BLRV, indicating that all crops were infected, but the proportion infective had a range of 1–86%. Infective aphids were not abundant on crops in eastern and south-eastern counties where most lucerne is grown, and more abundant on old crops than on young (Table 3); there was little difference between varieties (12 sampled), between pure stands and lucerne–grass mixtures or between crops grazed and those harvested by cutting. Assuming that the aphids were from different plants, that all plants were infested (probably true for most crops) and that only 63% of aphids that develop on infected plants transmit BLRV (see p. 200), the incidence of virus in crops was estimated as shown in Table 3. The validity of the conversion, from percentage infective aphids to percentage infected plants, will be tested next year. BLRV seems more common than *Verticillium* wilt in lucerne crops in this country, although wilt is reputed to be the main disease.

TABLE 3

Estimated incidence of bean leaf-roll virus in lucerne

	Year sown				
	1966	1965	1964	1963	<1963
No. of crops sampled	4	10	15	8	9
Estimated % of infective aphids	8	34	35	46	41
Estimated % of infected plants	13	54	56	73	65

Of all crops examined in 1966, only a few plants of Etoile du Nord lucerne in a variety trial in Yorkshire showed the brilliant vein-yellowing symptoms previously reported as symptoms of BLRV in lucerne. These are probably caused by another aphid-transmitted virus. (Cockbain, with Gibbs, Plant Pathology Department)

Vector relations of bean leaf-roll and pea enation mosaic viruses. The minimum time for transmission of BLRV and PEMV by pea aphids that had developed on infected field beans was studied in the glasshouse. No aphid transmitted BLRV during a 1-hour feed on *Trifolium incarnatum* test plants, but 10% transmitted during 2 hours; maximum transmission

https://doi.org/10.23637/ERADOC-1-14

(67%) was obtained in 4 days. Thirty-seven per cent of aphids transmitted PEMV in ½ hour, the shortest time tested, and maximum transmission (90%) was obtained in 1 day.

The vector efficiency of eight clones of pea aphids from five species of legumes in the field was compared. Apterae that had developed on field beans infected with BLRV or PEMV were tested for infectivity by allowing them to feed for 4 days on *T. incarnatum* seedlings, one aphid per seedling. Transmission of BLRV by aphids from the eight different clones had a range of 35–80% (mean, 63·3%). Significantly fewer aphids from two of the clones transmitted virus than aphids from three of the clones. Aphids from the remaining three clones were not significantly more efficient than those from the other five clones. Efficiency was not associated with the species of host plant from which the clones were originally selected, for both the least and most efficient clones were from lucerne.

Transmission of PEMV had a range of 83–100% (mean, 97·1%), and all aphids tested from six clones transmitted on each of three occasions. Significantly fewer from one of the clones transmitted virus than from six of the others. Efficiency as vectors of PEMV was not associated with efficiency as vectors of BLRV, for the poorest vector of PEMV was a clone from hop trefoil (*Medicago lupulina*), which was one of the most efficient vectors of BLRV. (Cockbain and Costa)

The flight behaviour of alate *Aphis fabae*. There has been a tendency to suppose that winged aphids must first make a long migratory flight before they can accept a host and settle down to reproduce or make short flights. The extent to which flight follows such a pattern is doubtful and is being tested with alate alienicolae of *Aphis fabae*. Fourth-instar pre-winged nymphs from cultures on bean plants or from natural infestations in the field were placed on young bean seedlings and allowed to moult. The adult winged aphids they produced divide into three classes according to the way they behaved before flight. Many flew before they deposited nymphs, and their behaviour conformed closely with the conventional idea of migrants described above. A second category of aphids ("flyers") took off some time after they were presumed to be able to fly and had deposited up to 17 nymphs before their initial take-off. These may therefore lack some, at least, of the "migratory drive". Other alate aphids never flew at all, and though they deposited nymphs, some did not move from where they moulted.

The proportion of each class in the population differed greatly. The proportion of "migrants" had a range of 8–32% in the laboratory stock and from 40 to nearly 90% in the field. The proportion of aphids that deposited nymphs before flight ("flyers") had a range of 43–70% in the laboratory and 7–46% in the field; and there were 7–39% of non-flyers in the laboratory and 2–14% in the field.

In the laboratory (20° C, 15½ hours day length) greater proportions of "flyers" and "non-flyers" were among the first alatae formed in a colony, although they were large, robust and seemed well equipped to fly. They also occurred among the last alatae produced just before the infestation overwhelmed the host plant. Alatae produced during the intervening

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period, though smaller than those produced earlier, had the largest percentage of migrants. Many alatae produced towards the end of the life of a colony were incapable of flight, possibly from nutritional deficiencies, because they were small, often with deformed wings and lacked sclerotisation in the dorsal–abdominal region. Results from field and laboratory were similar in that the early alatae were large, though relatively few were "migrants".

Parasitic fungi caused the premature end of the aphid infestation on the experimental plot of field beans this year, so that a stage equivalent to that obtained in a culture colony before the host plant collapsed could not be studied. The complex inter-relationships between size, behaviour, population growth and environmental conditions are being studied both in the laboratory and field. A lack of migratory vigour among many alatae, particularly early in the season, may be very important in spreading aphid-borne plant viruses over short distances. (Shaw)

Comparison of water traps, sticky traps and suction traps for assessing aphid migration. Different workers use different methods of assessing aphid migration. This often makes comparison of their results difficult. Even water traps, now widely used, give variable results. To compare methods suction traps, yellow water traps and yellow sticky cylinders were used to catch aphids flying over fallow and grass. The results demonstrated the difficulties of estimating aphid populations from different trapping methods. For example, yellow water traps gave different estimates of relative density for total aphids, *Myzus persicae* and *Cavariella aegopodii* over fallow and grass, though suction traps showed the aerial densities to be similar. The water traps either overestimated density over fallow or underestimated it over grass. Over fallow the proportions of different species of aphids differed in these three kinds of trap; of all aphids caught in suction and sticky traps 20% were *Brachycaudus* spp. but in water traps they constituted only 4% of the catch. *Cavariella aegopodii* represented 10% of the catch in water and suction traps, but 30% in sticky traps. Moreover, the proportions of the different species taken on each type of trap changed in sunny and cloudy weather. Flight of *Brachycaudus* spp. seemed less inhibited by dull weather than flights of many other species.

Water traps of different sizes were exposed on fallow, and although larger traps caught more aphids, the numbers trapped/unit surface area of trap decreased with increasing trap size, and more aphids would be caught by a larger number of small traps than by fewer larger traps of the same total surface area. The size and composition of catches differ in differently coloured water traps. Yellow traps caught more aphids than those of other colours; green and black caught $\frac{1}{3}$ as many as yellow, and blue, red and white approximately $\frac{1}{25}$ as many. Catches in yellow and green traps usually contained similar proportions of each species (though not the proportions flying), except *Phorodon humili*, which was more common in green traps. (Costa and Lewis)

https://doi.org/10.23637/ERADOC-1-14

Diseases, parasites and predators of insects

Insect pathology. In the search for pathogens of the wheat-bulb fly (*Leptohylemyia coarctata*), 1,000 eggs from wild adults were buried in the Stackyard field in August 1965. The eggs were protected from predators and macroparasites and were examined at intervals during autumn and winter; 79% hatched in January and February, and 7·2% were apparently infertile; 12·4% of embryos died with no obvious symptoms of disease, although a few contained Gram-negative bacteria (probably *Pseudomonas* spp.), 0·3% died infected with a fungus (*Phialophora* sp.) and 0·2% died infected with spherical bacteria. The same number of eggs was buried in August 1966, and abnormal eggs were removed and examined in late October; 5·5% were infected with *Phialophora* sp. 0·7% were dead and contained no obvious micro-organism and 0·4% contained bacteria.

Attempts to infect eggs with *Phialophora*, by immersing them in spore suspensions and by feeding spores to gravid females, failed; infection of larvae was not achieved. The fungus is probably a pathogen, and its mode of transmission needs further study. Spores remain viable in eggs for at least a year at 2–4° C, and the fungus can be cultured on yeast–glucose–phosphate agar at 18° C.

Many embryos that died without obvious signs of microbial infection became brown and gelatinous. Spherical particles, about 50 mμ diameter, occurred in such embryos in January 1966, but similar though fewer particles also occurred in apparently normal embryos; such particles were not seen in abnormal eggs in November 1966 (material examined by Woods, Plant Pathology Department) and the cause of death remains unknown.

Over 1,000 1st–3rd instar larvae were dissected from wheat plants collected from three sites in late winter and spring; 86·5% were alive, 12·9% were dead and 0·6% were moribund. The only micro-organism found in dead larvae were Pseudomonad-like bacteria (isolated from 41 out of 42 larvae from the three sites); however, similar bacteria, but fewer colonies, were obtained from 22 out of 30 apparently normal larvae. Tests in which larvae were immersed in suspensions of the bacteria, or were fed on agar containing the bacteria, produced no pathological effects.

Thirty five per cent of dead larvae, and 5% of living larvae, had brownish necrotic spots or patches on the body surface. Their position, number and shape differed in different larvae, and whereas some were irregular in outline, many were circular (<0·05–0·9 mm diameter). Only 57% of 2nd–3rd instar larvae with these spots pupated, and only 48% emerged as adults; corresponding results for normal larvae were 100 and 95% respectively. The abnormality seems not to be associated with bacteria, for though bacteria were isolated from two dead larvae, they were not found in two living larvae in this condition. Some spherical virus-like particles, 50–60 mμ diameter, were found in seven dead larvae and in one of two living larvae with necrotic spots, but not in seven apparently normal larvae. However, attempts to extract and concentrate the particles (by Gibbs, Plant Pathology Department), and to reproduce the condition by treating normal larvae with material from dead larvae, failed.

https://doi.org/10.23637/ERADOC-1-14

Immersing the larvae in aqueous suspensions of *Bacillus thuringiensis* (Biotrol BTB 25 w) at concentrations of 5×10^7 to 5×10^9 spores/ml, or in purified *Tipula* iridescent virus (supplied by Dr. C. F. Rivers, ARC Virus Research Unit, Cambridge) at 5×10^{10} particles per ml 0·85% NaCl, had no obvious effects.

Several hundred pupae were collected from five sites in June; 80% emerged, 10% were parasitised by Coleoptera and 0·6% by Hymenoptera. Most of the remaining pupae that became abnormal or failed to emerge contained micro-organisms, but it is not known whether any were primary pathogens. *Aspergillus niger* was isolated from some that became dry and shrunken (2·9% of all pupae), and two types of Pseudomonad-like bacteria, also found in normal pupae, were isolated from many that decomposed within the puparium (5·3%).

Several hundred adult female flies were collected from one site in July and August: 47% of those that died within 20 days of sampling contained no obvious micro-organisms in the body fluid outside the gut; 36% contained only bacteria (Pseudomonad-types were isolated from many); 3·3% contained bacteria and yeast-like organisms; 0·9% contained bacteria and microsporidia; 0·5% contained bacteria, yeast-like organisms and flagellate protozoans; 11·7% were infected with *Entomophthora muscae* (4·7% died of this infection within 5 days of sampling) and 0·9% were infected with a fungus causing an abdominal cyst.

Infection with microsporidia did not seem to affect survival, for the mean longevity, after capture, of infected adults was 23 days, and the mean for all adults was 22 days. Eggs from infected adults, and from adults fed on microsporidia, are still to be examined.

These results indicate that the incidence of disease in field populations of the wheat-bulb fly is small. No micro-organism was found that offers the possibility of use to control the pest, but the survey will be continued. (Cockbain, with Bailey, Bee Department)

Predators of frit fly. In 1964 and 1965 DDT barriers were used to prevent ground predators gaining access to experimental plots of oats infested with frit fly, but in 1965 weather was unfavourable for oviposition of frit fly and for movement of predators and therefore for the experiments. In 1966 plots of two different sizes (1×1 yd and 2×2 yd) were surrounded by DDT barriers. Some of the smaller ones were laid out at the end of June to protect the emerging frit. All plots were unsprayed. There were approximately 1·7 times more eggs and larvae on the 2×2 yd and 1×1 yd protected plots than on unprotected plots, and more frit fly were trapped in emergence cages over the protected oats at the end of June than from unprotected plots. Until 12 July the number of frit fly from cages over the late-protected plots and unprotected plots were similar (290 : 288); after this, excessively wet weather caused DDT to seep from the barrier into the soil, killing soil insects and some emerging frit.

Pitfall traps placed among the oat plants caught ground predators, many of which were tested in the laboratory for their willingness to eat eggs and larvae of frit fly. The commonest carabid in June was *Agonum dorsale* (51% total catch), which eats larvae but not eggs. *Bembidion lampros*, a

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known predator of eggs, formed 6·3% of the catch. Carabids and staphylinids were tested, up to four at a time, in a dish with soil; the eggs were placed on black filter-paper on the soil surface or where they were laid on the coleoptile of the oat plant. The two main egg predators in June, *Bembidion lampros* and *Tachyporus* spp., ate 94% and 75% of eggs at the soil surface and 5% and 28% of eggs from the coleoptile. In September–October *B. lampros* ate no eggs, but *Trechus quadristriatus* removed 71·4% from the soil surface and 67% from the coleoptile. A mite, *Pergamasus longicornis*, was common in the autumn and also ate the eggs (42% surface and 72·3% coleoptile). The larvae in the shoot of the oat plant were protected and were eaten only when removed from the plant. The predatory bug *Anthocoris nemorum* was common between the glumes of the oat panicles and was seen to feed on all stages of frit fly, including the adults, in the field.

Adult frit flies of all generations were eaten by general dipterous predators. Empidids (*Tachydromia* spp.) emerged from grass and from oats at the same time as adult frit and caught and ate the frit, as did a species of *Scatophaga*. Spiders' webs, present in the vegetation at all times, caught adult frit flies.

Adult carabids running over the surface of the ground when the female frits were laying eggs disturbed the insects, which flew away without laying the full complement of eggs. This disturbance, which was greater with *A. dorsale* and *Notiophilus biguttatus* than with *Nebria brevicollis* or *Harpalus rufipes*, sometimes almost halved the number of eggs laid on a given number of plants in a given time. Parasitism of the immature stages of the panicle generation was small; 28 *Cyrtogaster vulgaris* (Hymenoptera) emerged from 10 sq yd of oat panicle, but from 631 frit-infested grain kept singly in tubes no parasites emerged.

The weight of grain from 1 sq yd of oats from protected and unprotected plots was similar, although approximately one-third of the grain from unprotected plots was infested with frit-fly larvae. (Jones)

Predation of wheat-bulb fly. The pitfall traps used to estimate the activity of predators were improved to prevent rain drowning the catch and eroding the soil around the lip. An experiment in Stackyard in May and June showed that the new traps caught significantly more arthropods than the old ones.

Straw barriers drenched in DDT were placed around 40 plots, each 1 yd square, to measure the effect of predators on numbers of wheat-bulb fly eggs in the fallow. Half of these plots and of 40 plots without barriers, were covered with netting to prevent female flies from laying eggs. The surviving population of eggs was sampled by taking 16 soil cores (2½ in. diameter) from each plot. There was no significant difference between plots with and without DDT barriers, suggesting that eggs were not eaten by predators from July till the end of September.

Pitfall trapping continued during and after this experiment, and the total catch of 161 carabids from 50 traps, from November until the end of February, was less than that for one week in August, indicating that there was little predation in those months. Traps in the hedgerow and along the

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edge of a wheat crop caught more carabids than those in the fallow field.

Populations of wheat-bulb fly eggs were sampled, in autumn when most eggs had been laid, and later in spring before they hatched, to find the number killed by predators. The egg populations in autumn and spring did not differ significantly, further evidence that predators do not kill many eggs in Rothamsted soil. Sterile eggs were 9, 14, 6 and 3% of the populations studied. No parasites of eggs were found.

Serological tests, by the gel-diffusion method, were tried as a method of identifying predators that had eaten pupae, but few of the many tests made were positive, perhaps because pupae fed to different carabids were not detectable 12 hours after they were eaten. The precipitin ring test, which is more sentive but less specific, gave inconclusive results.

Pupae from different areas were reared individually to study their parasites. Two hundred and four pupae from Rothamsted produced 1 parasite, a hymenopteron; 50 from Woburn produced 1, 102 from Thorney, near Peterborough, produced 4, all staphylinids. The prevalence of staphylinid parasites in the fens was also noted last year.

The effect of predators on wheat-bulb fly larvae was studied by excluding predators from 20 plots with barriers of polythene sheeting fixed to a timber framework. A greater proportion of arthropods was excluded in April and May than in other months, but lessening the number of carabids by 85% had no effect on numbers of wheat-bulb fly surviving. Nevertheless, a large proportion of newly hatched larvae died, and their movement to the host is an important factor in causing death. Tracks made by larvae showed that they preferred agar cubes in which wheat was grown to untreated agar and that they found treated agar first by moving apparently at random rather than by movement directed to the cube in which wheat had grown.

About 65% of larvae feeding in wheat-shoots also died. Sampling populations of larvae showed that their numbers on successive occasions were significantly correlated with numbers of plants, demonstrating that mortality depended on food supply. Further analysis showed that the number of larvae surviving was related to the number of larvae/unit area and to the numbers of shoots/unit area when invasion was accomplished. This relationship accounts for nearly all of the variation in survival; one component, larval density, suggests a density-dependent relationship, whereas the other, shoot-density, suggests a density-independent relationship, because of the number of shoots is greatly influenced by weather. (Ryan)

Biology of the wheat-bulb fly

Population studies. Numbers of eggs, larvae, pupae and adults were again estimated on the permanent reference plots in Great Harpenden field and on the $\frac{1}{2}$-acre plot of wheat alongside a $\frac{1}{2}$-acre plot of fallow in Stackyard field. As in 1965, a large proportion of the eggs in the reference plots were infertile from an unknown cause, and the wheat-bulb fly population there is now extremely small. This is partly from the infertile eggs, and possibly because the alternating wheat and fallow plots are long and

https://doi.org/10.23637/ERADOC-1-14

narrow, and so are less attractive for ovipositing females than larger blocks of fallow, such as on Broadbalk and on Stackyard. If long-term population studies are to continue on the reference plots it might be better to have fewer but larger blocks of wheat and fallow.

Adults were studied in Stackyard field mainly to assess dispersal from the wheat crop and to investigate methods for sampling adult populations, particularly with sticky traps and water traps. Rows of sticky traps were placed 1 yd and 30 yd inside the wheat crop, and in the fallow 30 yd and 60 yd from the edge of the wheat. The traps in the wheat were 3 ft and 6 ft above ground level; those in the fallow were at ground level and 1½, 3 and 6 ft above ground level. Groups of water traps, shallow water-filled trays painted white, green and brown, were placed in rows in the fallow, 30 and 60 yd from the wheat crop.

The trap catches are being analysed, but the sticky traps caught 9 times as many males as females and the water traps caught 2·5 times as many females as males, although emergence cages showed that equal numbers of males and females emerged. The trap catches are thus selective. Table 4 shows the percentage of males and females caught in traps of different colour. (Raw and Lofty)

Catches from a 40-ft trap at Rothamsted during June and August 1964 and 1965 were examined, but no wheat-bulb fly was found. Catches from a suction trap at 8 ft at the same site for the same months in 1964 produced only one male and two females. A 1-ft-high suction trap, also at the same site, was examined for catches in June, July and August 1962, but no wheat-bulb fly was found. Hence over the land surface in districts where the fly is common adult flies in the air are few, although they are locally abundant in restricted sites. Though adults must disperse from wheat-fields to oviposition sites, suction traps probably cannot be used to collect information about this or about any longer-range dispersal. There are reports that the fly is occasionally caught in light traps. (Bardner and L. R. Taylor)

TABLE 4

Wheat-bulb fly—percentage of males and females caught in water traps of different colour

	White	Green	Brown
Males	80	15	5
Females	40	34	26

Food of the adult wheat-bulb fly. The ovaries of the wheat-bulb fly mature after the females emerge and wheat-bulb flies reared on diets lacking or deficient in protein lay few, if any, eggs (*Rothamsted Report* for 1959, p. 222). It is important, therefore, to know the feeding habits of adults. Flies have been observed with the proboscis extended on umbelliferous flowers, dead flies, bird droppings, and they probe water droplets on wheat plants, but the actual diet, and particularly the sources of protein, are unknown. Smears of the crop content of females, collected from different sites and at different times after emergence, suggest that fungal spores may be an important protein source and that the females feed fairly selectively on the fruiting bodies of specific fungi. For many crops were

https://doi.org/10.23637/ERADOC-1-14

filled with spores of a fungus that has not yet been identified; its identity, occurrence and distribution may provide clues to the behaviour of wheat-bulb fly females. Some crop smears also contained bacteria and a few spores of different species, such as *Cladosporium* and *Ustilago*, and some contained many basidiospores of *Coprinus radiatus*. (Raw, with Gregory, Plant Pathology Department)

Tests for resistant varieties. Field tests for resistance of wheat plants to wheat-bulb fly can be upset by the uneven germination of the varieties being tested, and by uneven distribution of wheat-bulb fly eggs in the soil. To avoid these difficulties and to give more precise assessment, seven wheat species, five bread wheats and four rye varieties were tested for resistance by growing them in separate boxes of soil containing known numbers of wheat-bulb fly eggs. The plants were examined periodically to assess growth and damage, and larvae and pupae were counted. The pupae were kept until adults emerged. In general, the results confirmed those of field tests reported in 1965. None of the varieties resisted attack or were unsuitable as hosts for wheat-bulb fly. Both the amount of infestation and the average weight of pupae were correlated with the tillering capacity of the varieties, confirming that the varieties that have most tillers favour the survival of wheat-bulb fly larvae. (Raw and Lofty)

https://doi.org/10.23637/ERADOC-1-14